Vol. 17(6) pp. 111-121, June 2023
DOI: 10.5897/AJFS2022.2180
Article Number: 3DA9DAD70831
ISSN: 1996-0794

http://www.academicjournals.org/AJFS

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African Journal of Food Science

Full Length Research Paper

Influence of extrusion process conditions on bulk density, water absorption capacity and oil absorption capacity of extruded aerial yam-soybean flour mixture

Enobong Okon Umoh[1*] and Madu Ofo Iwe[2]

[1]Department of Agricultural Engineering, Akwa Ibom State University, Ikot Akpaden, P.M.B., 1167, Uyo, Nigeria.
[2]Department of Food Science and Technology, Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria.

Received 17 February, 2022; Accepted 18 June, 2022

The influence of extrusion factors on bulk density, water absorption capacity, and oil absorption capacity of aerial yam-soybean flour mixture was examined utilizing a research facility scale single-screw extruder with the flour blending proportion of 25% aerial yam: 75% soybean. Response surface strategy in light of Box-Behken plan at three factors, five levels of barrel temperature (95, 100, 105, 110, and115℃), screw speed (85, 100, 115, 130, and145 rpm) and feed moisture (31, 33, 35, 37, and 39%) were utilized in 20 runs. The results showed that bulk density ranged from 0.4779±0.003 to 0.7211±0.003 g/cm^3; water absorption capacity from 2.52±0.032 to 3.89±0.007 g/g; while oil absorption capacity ranged from 1.12±0.028 to 2.88±0.007 g/g. The best extrusion condition combinations were 110°C barrel temperature, 130 rpm screw speed and 33% feed dampness for bulk density; 105°C barrel temperature, 115 rpm screw speed and 35% feed dampness for water absorption capacity; and 110°C barrel temperature, 130 rpm screw speed and 37% feed dampness for oil absorption capacity. Analysis of variance showed that barrel temperature, screw speed, and feed dampness significantly ($p<0.05$) affected the bulk density, water absorption capacity, and oil absorption capacity of the extrudates.

Key words: Optimization, functional properties, extrusion, aerial yam, response surface.

INTRODUCTION

Airborne sweet potato (*Dioscorea bulbifera*) is an arrangement of sweet potato filled in specific region of the planet. This bulbils-bearing sweet potato has a place with the solicitation Dioscoreal, Family Dioscoreaceae, and Genus *Dioscorea*, and is detested by animals among the satisfactory sweet potato species. It is native to Southeast Asia, West Africa, and South and Central America. Furthermore, wild species are predominant in both Asia and Africa (Nwosu, 2014).

Flying sweet potato (*D. bulbifera*) is recorded to be an unsavory sweet potato among the palatable sweet potato species which unlike the conventional sweet potato produces elevated bulbils that appear to be potatoes thus the name elevated/air potatoes (Ojinnaka et al., 2017).

*Corresponding author. E-mail: enoumoh2003@yahoo.com. Tel: +2348035408924.

This kind of sweet potato is consumed by couple of organizations and is generally underutilized both at asset and business levels because of multiple factors (Igyor et al., 2004). These incorporate, having a decently terrible following sensation dissimilar to other sweet potato species, being dark to a significant number of people, and much work has not been completed on it to propose usages to which it will generally be put to. Anyway, there are numerous applications for flying sweet potato, including the use of its wholesome and utilitarian properties to convey grouped current items, as well as its monetary value (Sanful and Engmann, 2016).

D. bulbifera has been for the most part used in the Chinese clinical system as a significant zest during the time spent redoing and staying aware of kidney work (Ahmed et al., 2009). In Asia, this flavor has been enthusiastically proposed for treating diabetes. It has been customarily used to cut down glycemic levels, giving a more upheld sort of energy and better insurance against heftiness and diabetes; regardless, this property has not yet been consistently illustrated (Brand-Miller et al., 2003).

Flying yam (*D. bulbifera*), as a less well-known food crop, has not been financially well-managed. It is only a small portion of the harvest that is processed into second sweet potato flour, which is especially noticeable in Yoruba-speaking areas of West Africa and less so in other parts of the continent (Orkwor et al., 1998). Processing aerial sweet potato to flour can help reduce our reliance on wheat flour for warmed foods and post-harvest adversities (Prince-will and Ezembaukwu, 2015).

Soybean (*Glycine max*), a large oil seed in the Leguminosae family, is primarily grown as a food crop. Soybean processing and use as food dates back to the 11th century B.C. in ancient China. It was then filled in various parts of the world only in the twentieth century. The major transporting nations are the United States, Brazil, China, and Argentina (Iwe, 2003). Soybean is primarily grown for its seeds, which are used for human food and animal feed, as well as for oil extraction. Soy food sources are likely the fastest developing arrangements in the food industry, with things ranging from conventional soy food assortments to protein trimmings and from dairy and meat alternatives to various kinds of Western and traditional food assortments progressed with soybean flour and its parts (Iwe, 2003).

As a food crop, the flying sweet potato has yet to gain global recognition. Handling it into a stable flour/blend and then expulsion handling to make pasta will increase the detectable quality of the gather in the food trade, highlighting its potential food uses/values to the food business (Princewill-Ogbonna and Ezembaukwu, 2015).

Furthermore, the extension of well-known food-handling systems, for example, expulsion cooking, and the use of *D. bulbifera* beyond the pharmacological viewpoint could mean introducing new techniques and food items, thereby offering choice to customers.

This research also highlights the impact of expulsion process limits or factors on the utilitarian properties of an aeronautical sweet potato soybean flour combination using response surface methodology.

MATERIALS AND METHODS

Collection of soybean seeds and aerial yam bulbs

Soybean seeds and aerial yam bulbs used in this study were purchased from Uyo Urban market in Uyo Local Government Area, Akwa Ibom State, Nigeria.

Sample preparation

The flour samples used in this research were prepared in the Food Processing Laboratory, Department of Food Science and Technology, University of Uyo, Uyo, Akwa Ibom State, Nigeria.

Preparation of aerial yam Flour

This was done as shown by the methodology depicted by Olurin et al. (2006). The Aerial sweet potato bulbs were cleaned and organized to kill bothersome materials, before stripping with sharp edge, washed with clean water and sliced to 10 mm thickness using sharp edge. The cuts (chips) were then dried using an oven at a temperature of 60°C for 12 h. The dried cuts (chips) were then handled using utilizing CAST IRON 1A 2A grinding machine and sieved with lab sifter of 600 µm opening size. The flour was packaged in a polyethene pack for following use.

Preparation of soybean flour

This was finished by the method portrayed by Iwe (2003). Seeds were screened to dispense with new materials, parts, and hurt beans, trailed by washing and roll bubbling at 100°C for 30 min. It was then grill-dried at a temperature of 70°C for 12 h and processed, utilizing CAST IRON 1A 2A grinding machine. The handled full-fat soybean was sieved using a 100 µm network standard sifter. The flour was then taken care of in fixed shut polyethene sack at room temperature for additional usage.

Arrangement of sample blend

The aerial sweet potato-soybean flour blend was prepared in the ratio of 25:75, conveyed in proportions of 25% flying sweet potato flour and 75% soybean flour.

Extrusion cooking

Expulsion cooking was done using a privately created single-screw research center scale extruder in the Department of Food Science and Technology Laboratory, Federal University of Agriculture, Abeokuta, Ogun State, Nigeria. 200 g of the flour blend (25% airborne sweet potato flour, 75% soybean flour) was definitively assessed and preconditioned by the ideal clamminess levels, allowed to stay for two 2 min to ensure uniform hydration of the raw substance. This was to ensure that any dry community was cleared out (Strahm, 2000). The privately created extruder was turned on, and the barrel temperatures (95 to 115°C) and the screw speeds (in upset each moment rpm) of the extruder were set by the preliminary arrangement. The normal substance was dealt with through the compartment into the extruder. The extrudates were collected as they exit through the die; grill dried, and packaged in impervious zip lock polyethylene sacks for additional laboratory examination. Twenty runs were done by and large, during the expulsion cycle, according to the preliminary arrangement.

Determination of functional properties

The following functional properties of the extruded aerial yam-soybean flour mixture were determined.

Bulk density

The flour test was filled in a 10 ml dried estimating chamber and the lower part of the chamber tapped a few times on the research center table until there could have been no further lessening of the sample level subsequent to filling to the 10 ml mark.

$$\text{The bulk density (g/cm}^3\text{)} = \frac{weight\ of\ sample\ (g)}{volume\ of\ sample\ (cm^3)}$$

Water absorption capacity

Water absorption capacity of the extrudate was determined according to the methods described by Onwuka (2005). Ten milliliters (10 ml) of refined water was blended in with one gram (1 g) of test in a blender and homogenized for 30 s, kept at room temperature for 30 min, and centrifuged at 5000 rpm for 30 min. The volume of the supernatant (free water) in a graduated chamber was noted. The amount of water ingested (all out short free) was increased by its density for transformation to grams. Density of water was thought to be 1 g/ml.

$$Water\ absorption\ capacity = \frac{V_1 - V_2}{W} \times density\ of\ water$$

Where: v_1 = initial volume of water (10 ml); v_2 = final volume after centrifugation; w = weight of sample (1 g)

Oil absorption capacity

The oil absorption capacity of the extrudate was determined according to the methods described by Onwuka (2005). Precisely one gram (1 g) of flour mix test was blended in with 10 ml of vegetable oil. The oil and the sample were homogenized for 30 s and allowed to stand for 30 min at room temperature, and afterward centrifuged at 5,000 rpm for 30 min. The volume of free oil (supernatant) was noted straightforwardly from the graduated rotator tube. The amount of oil ingested (total minus free) was then multiplied by its density to convert into grams. Density of oil was taken to be 0.88 g/ml for faded palm oil.

$$Oil\ absorption\ capacity = \frac{V_{1} - V_2}{w} \times density\ of\ oil$$

Where: V_1 = Initial volume of oil; V_2 = Final volume after centrifugation; w = Weight of sample.

Experimental design/ statistical analysis

Design expert (variant 11.0.1), a Statistical Computer Application Software Package was used in the preliminary arrangement. Focal composite randomized design (CCRD) was used with a three variable preliminary set up at five levels each, with barrel temperature (X1), screw speed (X2), and feed dampness levels (X3) as the free factors (Table 1).

Reaction surface methodology (RSM) was used to examine the effects of the independent components or variables on the reliant elements (the reactions). Coded values for the autonomous elements used were - 2, - 1, 0, 1, 2, where - 2 tends to the least, 0 tends to the medium (mid-point), and 2 tends to most critical levels independently.

RESULTS AND DISCUSSION

Functional properties of extruded aerial yam-soybean flour mixture

The results of the effects of extrusion process conditions on the functional properties of extruded aerial yam-soybean flour mixture are presented in Table 2.

Bulk density

The mass thickness of the extrudates increased in the range of 0.4779 ± 0.003 and 0.7211 ± 0.003 g/cm^3, as shown in Table 2. This range of mass thickness values is greater than 0.24 ± 0.05 to 0.36 ± 0.03 for sorghum-based expelled thing upgraded with soy supper flour (Tadesse et al., 2019); 0.0202 to 0.3503 g/cm^3 for expelled rice flour-pineapple waste squash powder-red gram powder (Anjineyulu et al., 2013); and 0.19 to 0.31 g/cm^3 for fish-maize (Omohimi et al., 2014).

Mass thickness is a measure of puffing and is clearly related to the outer layer of the possible outcome of expanded starch-based extrudate. It is not completely established by the combination of advancement and resulting shrinkage or breakdown of water rage ascends in extrudates and by the effect of kick the can broadening because of the adaptable property of the broken down matrix (Tadesse et al., 2019). Light thickness suggests a sensitive plan, which is appealing in this type of situation.

Water absorption capacity

The eventual outcomes of water absorption capacity of the expelled flying sweet potato soybean flour combination are presented in Table 2. The recorded characteristics ranged from 2.52 ± 0.032 to 3.89 ± 0.007 g/g. This extent of values is imperceptibly higher than 2.5 to 3.56 g/g for cassava/soybean extrudates (Olusegun et al., 2016); 1.667 to 2.320 g/g for meat straightforward from mucuna bean seed flour (Omohimi et al., 2014), yet lower than 3.918 to 5.997 g/g for pineapple waste squash rice flour-red gram powder based extrudates (Anjineyulu et al., 2013); 4.92 to 6.07 g/g for fish-maize based expelled snacks (Nkubana et al., 2020), and 3.922 ± 0.079 to 6.017 ± 0.018 g/g for arranged to-eat beat based snacks (Alemayehu et al., 2019).

Water retention limit provides information about the

Table 1. Coded and actual values of different experimental variables.

Factor	Units	Code	Level					Interval of variation
			-2	-1	0	1	2	
Barrel temp.	℃	X_1	95	100	105	110	115	5.0
Screw speed	rpm	X_2	85	100	115	130	145	15.0
Feed moisture	%	X_3	31	33	35	37	39	2.0

Source: Author

Table 2. Effects of extrusion conditions on functional properties of extruded aerial yam-soybean flour mixture.

S/N	BT (℃)	SS (rpm)	FM (%)	Bulk Density (g/cm^3)	Water Absorption Capacity (g/g)	Oil Absorption Capacity(g/g)
1	105	115	31	0.6969±0.004	2.60±0.003	1.72±0.028
2	105	115	35	0.4885±0.003	3.89±0.007	1.94±0.007
3	105	115	35	0.4790±0.003	3.81±0.007	1.98±0.007
4	105	85	35	0.6708±0.002	2.91±0.014	1.69±0.021
5	100	130	33	0.6712±0.002	3.06±0.004	1.63±0.002
6	110	100	37	0.6249±0.002	2.94±0.014	1.95±0.014
7	100	100	37	0.6175±0.003	2.88±0.021	1.76±0.007
8	110	130	33	0.7211±0.003	2.69±0.014	2.64±0.021
9	105	115	35	0.4787±0.003	3.83±0.007	1.91±0.007
10	115	115	35	0.6933±0.003	2.69±0.003	2.80±0.021
11	95	115	35	0.7167±0.003	2.58±0.141	1.12±0.028
12	105	115	39	0.6755±0.001	2.57±0.007	2.62±0.014
13	105	115	35	0.4779±0.003	3.82±0.007	1.90±0.007
14	100	100	33	0.6598±0.002	2.71±0.014	1.34±0.014
15	110	130	37	0.6043±0.002	2.80±0.007	2.88±0.007
16	110	100	33	0.6985±0.004	2.95±0.071	1.92±0.014
17	105	145	35	0.6982±0.005	2.52±0.032	1.62±0.004
18	100	130	37	0.7011±0.002	2.68±0.022	2.31±0.001
19	105	115	35	0.4788±0.003	3.81±0.007	1.98±0.007
20	105	115	35	0.4784±0.003	3.80±0.007	1.92±0.007

Values are mean ± standard deviation of triplicate determination, BT= Barrel temperature, SS= Screw speed, FM= Feed moisture.
Source: Author

level of gelatinization of starch in feed trimmings in general by assessing how much water is polished off by starch granules as a result of the thing's initial overflow of water (Olusegun et al., 2016). Water retention properties depend on the openness of hydrophilic social affairs which bind water particles and the gel-outlining limit of the macromolecules being referred to.

Oil absorption capacity

In Table 2, the eventual outcomes of the effects of expulsion conditions on the down to earth properties of expelled flying sweet potato-soybean flour combination showed that oil absorption capacity of the extrudates increased from 1.12 ± 0.028 to 2.88 ± 0.007g/g. This recorded extent of values is within the extent of 1.761 to 2.389 g/g for meat basic from mucuna bean seed flour (Omohimi et al., 2014). Oil retention limit can be used as a document of the hydrophobicity of an expelled thing (Tabibloghmany et al., 2020). The results of regression analysis/ANOVA of the models for the responses: functional properties of extruded aerial yam-soybean flour mixture are presented in Table 3.

Model selection/equation for optimization of extrusion process parameters for bulk density

The final regression model for bulk density is given in Equation 1.

$$B_D = 36.44 - 0.3947BT - 0.04170SS - 0.7262FM - 0.00016BTSS + 0.0023BTFM + 0.00012SSFM + 0.00233BT^2 + 0.00024SS^2 - 0.0134FM^2 \quad (1)$$

Table 3. Coefficient of Regression/ANOVA for Functional properties.

	Bulk density		Water absorption capacity		Oil absorption capacity	
	Coeff.	**p-values**	**Coeff.**	**p-values**	**Coeff.**	**p-values**
X_O	36.44		-250.14		-10.11	
Linear						
X_1	-0.394	0.6366	2.55	0.5611	0.0714	< 0.0001
X_2	-0.04170	0.1513	0.4482	0.0448	0.0097	0.0355
X_3	-0.7262	0.0307	5.39	0.7130	0.0991	0.0069
Interaction						
X_1X_2	-0.00016	0.2079	-0.00092	0.1140		
X_1X_3	0.0023	0.0276	0.00388	0.3520		
X_2X_3	0.00012	0.6835	-0.001792	0.2055		
Quadratic						
${X_1}^2$	0.000233	< 0.0001	-0.0123	< 0.0001		
${X_2}^2$	0.00024	< 0.0001	-0.00128	< 0.0001		
${X_3}^2$	-0.0134	< 0.0001	-0.0799	< 0.0001		
Test for model adequacy						
R^2	0.9663		0.9757		0.7418	
Pred. R^2	0.7415		0.8240		0.5159	
Model F-value	31.85		44.63		15.32	
Lack of fit	70.80		164.46		77.84	

X_o = intercept, X_1 = Barrel temperature (BT), X_2 = Screw speed (SS), X_3 = Feed moisture (FM), Significance at p< 0.005.
Source: Author

Where, B_D = Bulk density (g/cm^3), *BT* = Barrel Temperature (°C), *SS* = Screw Speed (rpm), *FM* = Feed moisture (%)

In Equation 1, the positive terms suggest direct association between the expulsion cycle limits (BT, SS and FM), and their correspondences (straight and quadratic) with mass thickness, while the negative terms show a converse association between them. It was seen that all the three expulsion process limits (BT, SS and FM) have switch relationship with the response, mass thickness (BD), construing that mass thickness decreased with development in the expulsion cycle limits. The results of regression analysis/ANOVA of the models for viable properties in 3 show a model F-worth of 31.85 for mass thickness, which is exactly what the model recommends. Potential gains of "prob>F" under 0.0500 gathers that the model terms are basic, beside BT, SS, BT×SS and SS×FM with p-potential gains of 0.6366, 0.1513, 0.2079, and 0.6835 independently (Table 3).

The "Shortfall of fit F-value" of 70.80 for mass thickness recommends that the "Shortfall of fit" is not basically similar with the pure slip-up. This model can subsequently be used to investigate the arrangement space. The model was tremendous with a decent coefficient of confirmation, R^2 of 0.9663 (Table 3). The high coefficient of confirmation showed astonishing connection between the free factors (barrel temperature, screw speed and feed clamminess) and the response, and this implies that the response (mass thickness) model is adequate, and can figure out 96% of the total irregularity in the response.

Model selection/equation for optimization of extrusion process parameters for water absorption capacity

The final regression model for water absorption capacity is given in Equation 2.

$$W_{AC} = -250.14 + 2.55BT + 0.4482SS + 5.39FM - 0.00092BTSS + 0.00388BTFM - 0.001792SSFM - 0.0123BT^2 - 0.00128SS^2 - 0.0799FM^2 \quad (2)$$

Where, W_{AC} = Water absorption capacity (g/g), *BT*= Barrel Temperature (^{0}C), *SS* = Screw Speed (rpm), *FM* = Feed moisture (%)

In Equation 2, the positive terms suggest direct association between the expulsion cycle limits and their participations with the levels of water retention limit, however, the negative terms show a retrogressive association between them. For this present circumstance, it was seen that all the three expulsion process limits (BT, SS and FM) have direct relationship with the response (water ingestion limit). This proposes that water retention limit (WAC) showed a straight addition with development in the expulsion cycle limits.

Table 4. Output for numerical optimization of extrusion process parameters for functional properties.

Extrusion criteria	Unit	Lower limit	Upper limit	Optimization goal	Relative importance	Output
Barrel temperature	℃	95.00	115.00	Maximize	3	112.85
Screw Speed	rpm	85.00	145.00	Maximize	3	144.99
Feed Moisture	%	31.00	39.00	Range	3	35.12
Bulk Density	g/cm^3	0.4779	0.7211	Range	3	0.8165
WAC	g/g	2.52	3.89	Range	3	1.58
OAC	g/g	1.12	2.88	Range	3	2.85
Desirability						0.972

WAC = Water absorption capacity, OAC = Oil absorption capacity.
Source: Author

The model F-value of 44.63 induces that the model is basic. Potential gains of "prob>F" under 0.0500 surmises that the model terms are basic, beside BT, FM, BT×SS, BT×FM and SS×FM, with p-potential gains of 0.5611, 0.7130, 0.1140, 0.3520 and 0.2055 exclusively (Table 3).

The "Shortfall of it F-value" of 164.46 for water assimilation limit in Table 3 indicates that the "Shortfall of fit" isn't fundamentally similar to the pure bungle. As a result, this model could be used to investigate the arrangement space at any time. The model was massive, with a satisfying coefficient of confirmation, R^2 of 0.9750 (Table 3). This implies that the response (water retention limit) model is adequate and can account for 97% of the response's total variance.

Model selection/equation for optimization of extrusion process parameters for oil absorption capacity

The final regression model for oil absorption capacity is given in Equation 3.

$$O_{AC} = -10.11 + 0.0714BT + 0.0097SS + 0.0991FM \quad (3)$$

Where, O_{AC} = Oil absorption capacity (g/g), BT= Barrel Temperature (°C), SS = Screw Speed (rpm), FM = Feed moisture (%)

In Equation 3, the positive terms suggest direct association between the expulsion cycle limits and the level of oil assimilation limit. All the expulsion interaction limits (BT, SS and FM), apparently had direct relationship with the response (OAC). This suggests that oil retention limit (OAC) of the extrudates extended with extension in barrel temperature (BT), screw speed (SS), as well as feed soddenness (FM).

From the outcomes of regression assessment/ANOVA in Table 3, the model F-value of 15.32 shows that the picked model is gigantic, and potential gains of "prob>F" under 0.0500 deduces that the model terms are basic. Here, the model straight terms; BT, SS, and FM recorded p-potential gains of < 0.0001, 0.0355, and 0.0069 independently, showing that they are basic (p< 0.05) (Table 3).

The "Shortfall of fit F-value" of 77.84 for oil assimilation in Table 3 recommends that the "Shortfall of it" is not colossal similar with the pure bumble. This model can subsequently be used to investigate the arrangement space. The high coefficient of confirmation, R^2 worth of 0.7418 (Table 3), showed a fair connection between the independent elements (barrel temperature, screw speed and feed moistness) and the response, showing that the model is adequate, and can figure out 74% of the total capriciousness in the response.

Mathematical optimization of extrusion process parameters for functional properties

The most extreme conceivable barrel temperature and screw speed, followed by the reach for feed moisture, were the fundamental rules for imperatives advancement of the expulsion interaction boundaries. The enhancement objective for the reactions was the reach. The ideal enhancement objectives and result for every expulsion cycle boundary and reaction is introduced in Table 4.

The ideal extrusion process boundaries were 112.85°C for barrel temperature, 149.99 rpm for screw speed, and 35.12% for feed dampness. Likewise, the ideal practical properties were 0.8165 g/cm^3 for bulk density, 1.58 g/g for water absorption capacity, and 2.85 g/g for oil absorption capacity, with an attractiveness of 0.972%. In the interim, the advancement results got for the objective of upgrading the reach for the reactions were 0.4779 to 0.721 g/cm^3 for bulk density, 2.52 to 3.89 g/g for water absorption capacity, and 1.12 to 2.88 g/g for oil absorption capacity.

Response surface plots for the functional properties of aerial yam-soybean flour mixture

Effects of extrusion process parameters on bulk density

Figures 1 to 3 depict the response surface plot showing

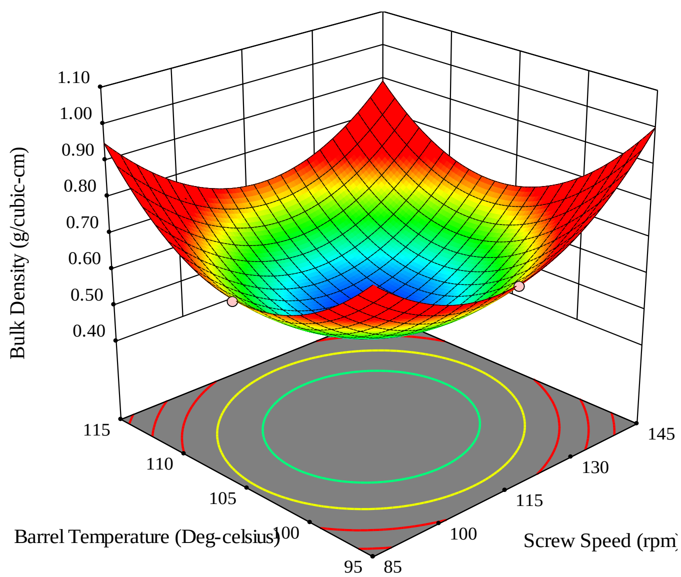

Figure 1. Response surface plot showing the influence of barrel temperature and screw speed on bulk density.
Source: Author

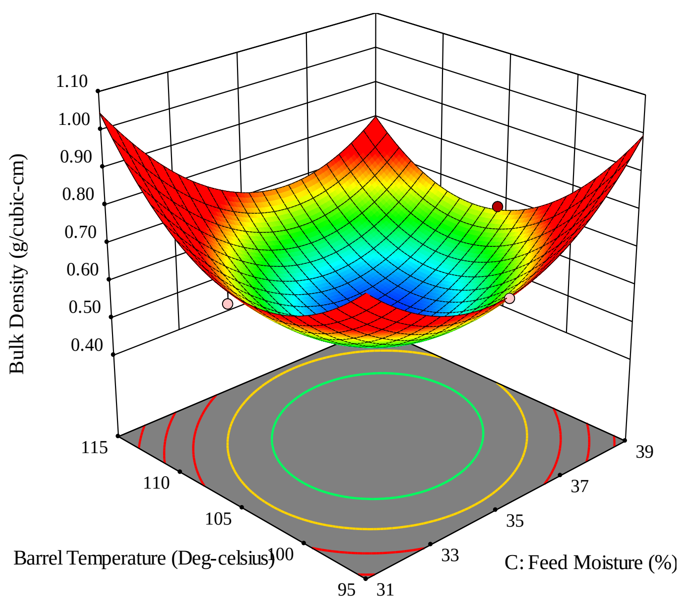

Figure 2. Response surface plot showing the influence of barrel temperature and feed moisture on bulk density
Source: Author

the impact of barrel temperature and screw speed; impact of barrel temperature and feed clamminess; impact of screw speed and feed soddenness on mass thickness of expelled ethereal sweet potato soybean flour combination.

Figure 1 shows the response surface plot for impact of barrel temperature and screw speed of the extruder on mass thickness of the extrudates. It was seen from the

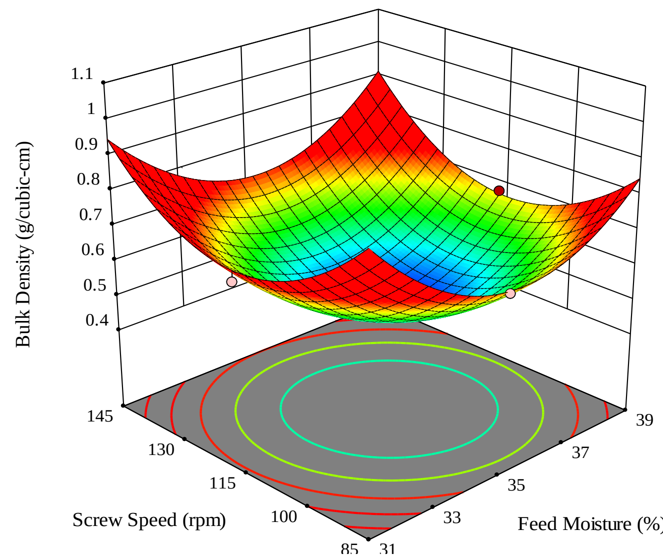

Figure 3. Response surface plot showing the influence of screw speed and feed moisture on bulk density.
Source: Author

plot that, development in barrel temperature and screw speed achieved quadratic extension in mass thickness of the extrudates. This insight is at distinction with that of Omohimi et al. (2014); Alemayehu et al. (2019), and simultaneously with that of Anjineyulu et al. (2013).

Moreover, the response surface plot showing the effects of barrel temperature and feed moisture on mass thickness (Figure 2) showed that extension in both barrel temperature and feed sogginess achieved quadratic development in mass thickness of the extrudates. The discernment that development in feed moisture extended the mass thickness is in agreement with that of Peluola-Adyemi and Idowu (2014); Tiwari and Jha (2017), and despite a past report by Guldiken et al. (2019) for desi chickpea-grain extrudates. Extension in mass thickness with extension in feed soddenness may be attributed to diminished flexibility of combination and lower improvement (Anjineyulu et al., 2013; Tiwari and Jha, 2017).

In Figure 3, the response surface plot showing the effects of screw speed and feed clamminess on mass thickness exhibited that increasing the screw speed and feed sogginess achieved quadratic development in mass thickness of the extrudates. This discernment that accelerates results in extended mass thickness of the extrudates is in agreement with that of Omohimi et al. (2014), but disregarding that of Tiwari and Jha (2017). The extension in mass thickness as screw speed additions might be a direct result of heightened effect of temperature on extrudate mellow under extended shear environment, which could construct the level of gelatinization process subsequently gave extrudates with higher mass thickness (Omohimi et al., 2014).

Examination of vacillation (ANOVA) at 5% significance

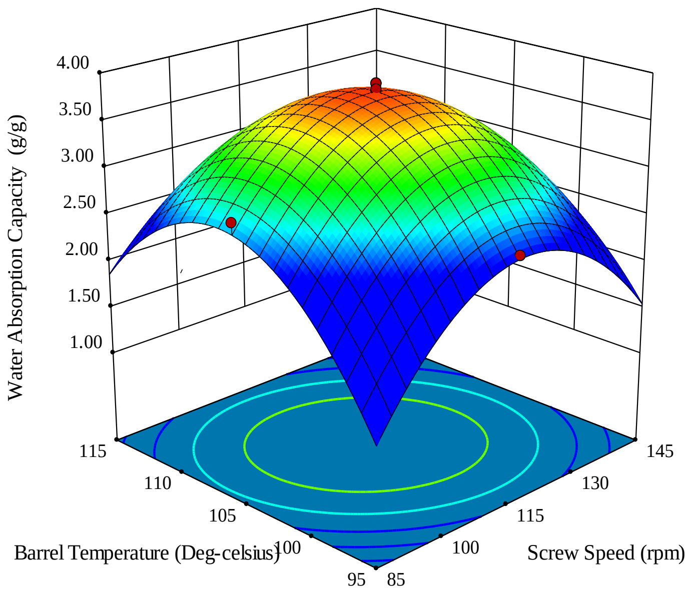

Figure 4. Response surface plot showing the influence of barrel temperature and screw speed on Water absorption Capacity.
Source: Author

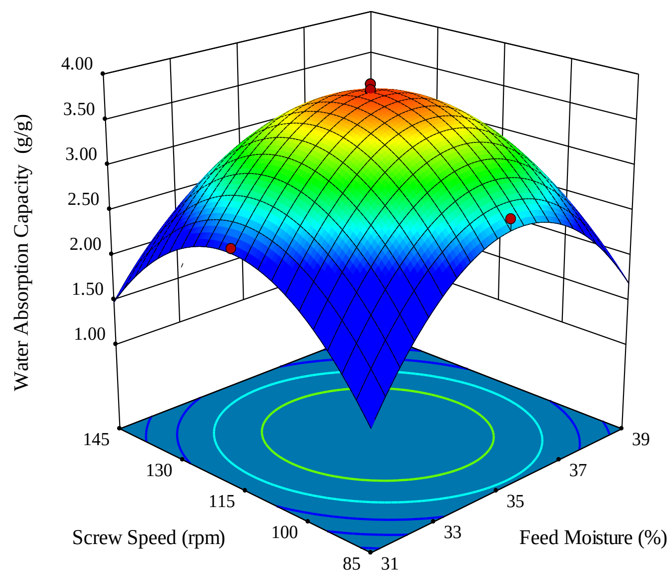

Figure 6. Response surface plot showing the impact of screw speed and feed dampness on Water Absorption Capacity.
Source: Author

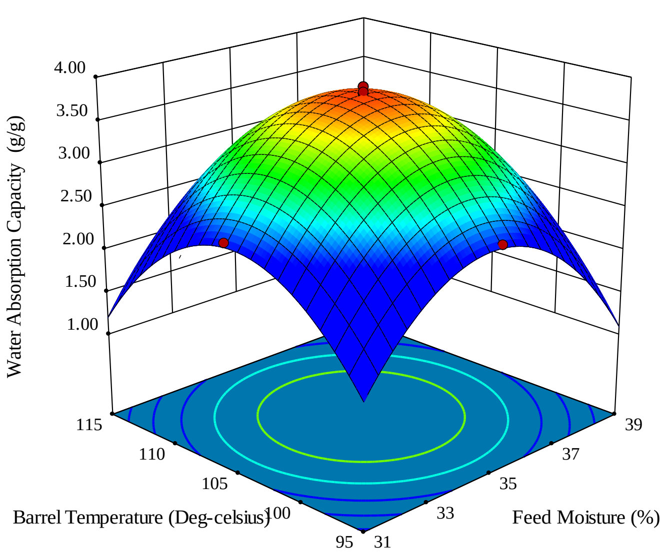

Figure 5. Response surface plot showing the influence of barrel temperature and feed moisture on Water Absorption Capacity
Source: Author

level, for the effect of barrel temperature, screw speed and feed moistness on mass thickness of the expelled flying sweet potato soybean flour combination showed that the expulsion interaction conditions (Barrel temperature, Screw speed and Feed moisture) had colossal effect ($p< 0.05$) on mass thickness of the extrudates.

The "Preliminary of between-subjects" effects of the expulsion interaction conditions on mass thickness showed that the cycle limits, including their associations, similarly had gigantic effect ($p < 0.05$) on mass thickness of the extrudates, except for SS×FM, which showed non-basic ($p > 0.05$) influence on mass thickness.

Effect of extrusion process parameters on water absorption capacity

Figures 4 to 6 show response surface plot for the impacts of barrel temperature, screw speed and feed dampness on water retention limit of the extrudates. In Figure 4, the response surface plot for the effect of barrel temperature and screw speed on water assimilation limit exhibited that extension in barrel temperature and screw speed achieved quadratic diminishing in water retention limit of the extrudates. This validation is like that of Omohimi et al. (2014), yet contrary to that of Anjineyulu et al. (2013).

Basically, Figure 5, which shows the response surface plot for effect of barrel temperature and feed clamminess, exhibited that climbing the barrel temperature of the extruder and feed sogginess provoked a quadratic decreasing in water retention limit of the extrudates. This affirmation is in any case, contrary to that of Lin et al. (2000); Lazou and Krokida (2010).

In Figure 6, the response surface plot showing the effect of screw speed and feed soddenness exhibited that accelerating the extruder up to 115 rpm and increasing feed moistness up to 35% caused development in water assimilation limit. These insights confirm the past revelations by Peluola-Adeyemi and Idowu (2014) and Tabibloghmany et al. (2020). Further increase in the screw speed beyond 115 rpm and feed sogginess above

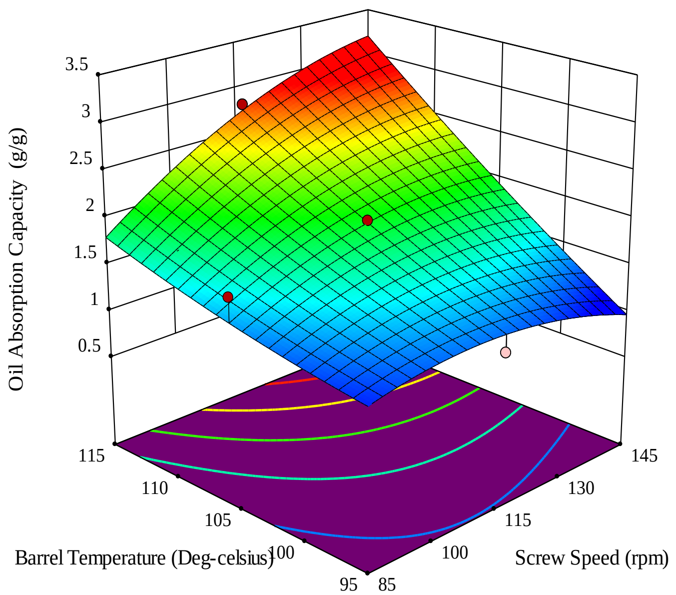

Figure 7. Response surface plot showing the effect of barrel temperature and screw speed on Oil Absorption Capacity.
Source: Author

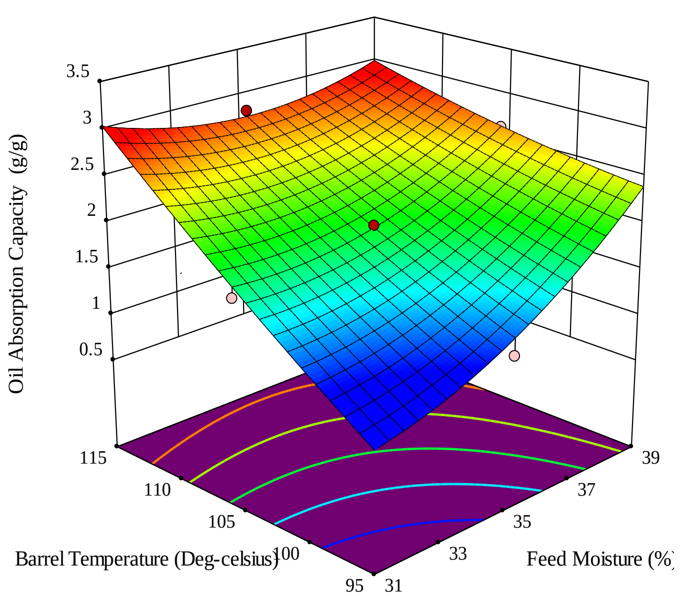

Figure 8. Response surface plot showing the effect of barrel temperature and feed moisture on Oil Absorption Capacity.
Source: Author

35%, achieved a slight decrease in water retention limit of the extrudates.

Water retention limit or record gives information about the level of gelatinization of starch in the feed fixing generally by assessing how much water is polished off by starch granules following expansion in excess water at first present in the thing (Altan et al., 2008). Gelatinization,

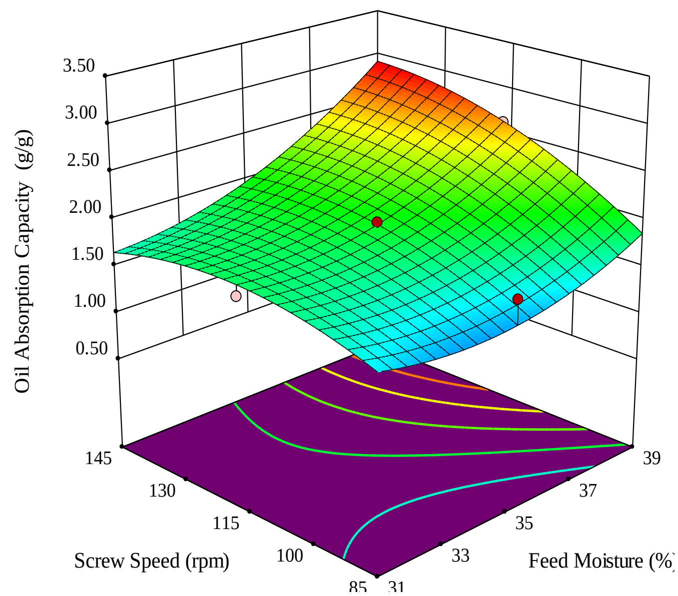

Figure 9. Response surface plot showing the effect of screw speedand feed moisture on Oil Absorption Capacity.
Source: Author

the change of unrefined starch to a cooked and eatable material by the utilization of hotness and water, is one of the huge effects of expulsion of the starch portions of food sources (Ding et al., 2006).

Along these lines, the decrease in water retention limit of the extrudates may be credited to the weakening or defilement of starch. Examination of vacillation (ANOVA) at 5% significance level, for the effect of barrel temperature, screw speed, and feed sogginess on water assimilation limit of the extrudates showed that the expulsion interaction conditions (barrel temperature, screw speed and feed clamminess) had enormous effect ($p< 0.05$) on water ingestion limit of the extrudates. The "preliminary of between-subject effect" of the expulsion interaction limits on water assimilation limit showed that the expulsion cycle limits, including their correspondences, had immense effect ($p< 0.05$) on the water retention limit of the extrudates.

Effect of extrusion process parameters on oil absorption capacity

Figures 7 to 9 present the response surface plot for the effect of barrel temperature and screw speed on oil retention limit; effect of barrel temperature and feed clamminess on oil limit; effect of screw speed and feed moistness on oil assimilation limit.

Oil ingestion limit is the limit of a thing to absorb oil, and this deal with the flavor and augmentation mouth feel of a food material. In Figure 7, the response surface plot exhibited that development in barrel temperature provoked an immediate extension in oil retention limit, while acceleration achieved a decrease in oil assimilation limit of the extrudates. This discernment agrees with the earlier revelations by Omohimi et al. (2014). The extension in oil assimilation limit may be credited to increased level of starch defilement in the extrudates due to high commitment of atomic power (Omohimi et al., 2014).

The response surface plot showing the effect of barrel temperature and feed moistness on oil assimilation limit is presented in Figure 8. It was seen from the plots that extension in both barrel temperature and feed sogginess achieved a sharp development in oil retention limit of the extrudates. In Figure 9, the response surface plot showing the effect of screw speed and feed moisture exhibited that acceleration was achieved early on extension in oil assimilation limit. Further acceleration achieved decrease in oil retention, while development in feed clamminess provoked extension in oil assimilation limit of the extrudates. These discernments are in agreement with the earlier disclosures of Tabibloghmany et al. (2020).

Examination of distinction (ANOVA) at 5% significance level, for the effect of barrel temperature, screw speed and feed soddenness on oil ingestion limit showed that the expulsion cycle limits: barrel temperature (BT); screw speed (SS); feed moistness (FM) generally ($p < 0.05$) influenced the oil assimilation limit of the extrudates.

The "Preliminary of between-subject effect" of expulsion process conditions on oil assimilation limit showed that the expulsion cycle conditions and their associations, beside BT×SS×FM, had tremendous effect ($p < 0.05$) on oil ingestion limit of the extrudates.

Conclusion

This study has shown that extrusion process conditions: barrel temperature; screw speed; feed dampness, and their interactions have both positive and adverse impact on bulk density, water absorption capacity, and oil absorption capacity of the extruded aerial yam-soybean flour mixture. The bulk density of the extrudates was altogether impacted by all the extrusion process conditions. With the exception of the connection of screw speed and feed dampness, which significantly affected the bulk density of the extrudates, the associations of the extrusion conditions also had a meaningful effect on bulk density. The extrusion boundaries and their co-operations significantly affected the water absorption capacity of the extrudates. Oil absorption capacity of the extrudates was altogether impacted by the three extrusion conditions. The co-operations of the process conditions likewise affected oil absorption capacity, with the exception of the connection of barrel temperature, screw speed, and feed dampness. The best extrusion condition blends were 110°C barrel temperature, 130 rpm screw speed and 33% feed dampness for bulk density; 105°C barrel temperature, 115 rpm screw speed and 35% feed dampness for water absorption capacity; and 110°C barrel temperature, 130 rpm screw speed and 37% feed dampness for oil absorption capacity.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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