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Optimization of Foam Mat Drying Conditions of Black Plum (*Vitex doniana*) for Improved Amino acid Composition

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Abstract

Black plum (*Vitex doniana*) is a sweet, edible perennial shrub widely distributed in tropical West Africa and are nutritional rich. Foam mat drying is a technique whereby foam is incorporated into food material by addition of a foaming agent before subjecting it to drying. Optimization of foam mat drying of black plum pulp to powder using response surface methodology for amino acid determination was studied. The fruits were processed to powder through foam mat drying using glycerol monostearate (5 to 15%) as foaming agents, carboxymethyl cellulose (3 to 5%) as foam stabilizer at temperature of 50ºC to 70ºC and 90ºC for non-foam dried sample till moisture content of less than 10% was achieved. The samples were analyzed for and amino acid composition using standard analytical methods. The values recorded for the essential amino acid was in the range of, threonine, 0.19 mg/100 to 0.35 mg/100g, histidine, 0.11 mg/100g to 0.23 mg/100g, 0.16 mg/100g to 0.27 mg/100g, isoleucine, 0.09 mg/100g to 01.8 mg/100g, tryptophan, 0.20 mg/100g to 0.34 mg/100g, methionine, 0.12 mg/100g to 0.24 mg/100g, valine, 0.11 mg/100g to 0.23 mg/100g, lysine, 0.05 mg/100g to 0.15, mg/100g, phenylalanine 0.12 mg/100g to 0.21 mg/100g. Amino acids varied significantly ($P \leq 0.05$). Foam mat dried samples and samples with higher concentration of foaming agent recorded the highest values. The study shows that foam mat drying minimize the loss of amino acid composition and thus, improvement in the nutritional quality of the fruit powder.

Keywords: Black plum, foam mat drying, foaming agent, amino acid

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1. Introduction

Black plum (*Vitex doniana*) is a sweet, edible perennial shrub widely distributed in tropical West Africa, the fruit is green when matured and changes to dark brown when fully ripened (Adejumo *et al*., 2013). The fruit is known as "*Uchakiri*" in Eastern part of Nigeria, *Ori-nla* in Western part of Nigeria and *Dinyar* in Hausa speaking area of Northern Nigeria (Amah and Okogeri, 2019). In Nigeria, various parts of the plant are used by traditional medicine practitioners in the management and treatment of several disorders which include cancer, hypertension, rheumatism, and other inflammatory diseases (Dadjo *et al*., 2012). Black plum fruit is usually eaten as snack either as fresh or processed into compotes, jams, marmalades, prunes, juices or alcohol beverages and have a sweet prune-like taste with velvet-like texture (Uchenna and Otu, 2019). The fruits are good source of micronutrients including iron, calcium, phosphorus, magnesium, manganese, fluorine, sulfur, potassium, vitamins A, B1, B2, E and C as well as phytochemicals with good antioxidant capacity (Uchenna and Otu, 2019).

Black plum has the potentials to increase the levels of adiponectin (a hormone that plays vital role in regulating blood sugar) thereby helps in lowering blood sugar level (Hassan and Shamsudeen, 2019). Hassan and Shamsudeen (2019) reported that black plum syrup is like honey and the physicochemical and sensory results showed that it can be substituted for other syrups as a nutritive sweetener. Hassan and Shamsudeen (2019) reported the uses of black plum tree stem bark extract for the control of hypertension and its anti-hepatotoxic effect as well as in the treatment of stomachache, pains, disorders, and indigestion. In Ghana it is used for treatment of colds and cough in children and its bark in the treatment of sterility. In Sierra Leone, black plum fruits are regarded as a remedy for A and B avitaminosis (Adejumo *et al*., 2013).

Drying is an important food processing operation that preserves raw food materials (Solchansani and Jayas, 2020). Drying process occurs when water vapor is removed from food materials surface into the surrounding space, resulting in a dried product with an extended shelf life and reduced water activity (Adeyeye *et al*., 2022). During drying processes, the moisture content can be reduced to a level ranging from 1 to 10%, and this prevent or slow down the activity of microorganism and undesirable enzymatic action that could lead to deterioration and eventual spoilage (Adeyeye *et al*., 2022). In addition to substantial reduction in weight and volume of the food product been dried, drying minimizes packaging requirements, storage and transportation costs of food product (Bag *et al*., 2011). As drying operation progresses, it creates a new microstructure, and the spatial distribution of the microstructure characteristics is important in texture perception of the resultant product (Bag *et al*., 2011). The most critical aspect in drying of food materials is to minimize the loss of its quality, keeping in view its nutritional, physical, chemical, microbial properties and sensory attributes (Figiel and Michalska, 2016).

Foam mat drying is a technique in which liquid or semisolid food materials are converted into foam by incorporating air into it through whipping with the addition of an edible foaming agent and stabilizing the emulsion with a foam stabilizer (Franco *et al*., 2016). The process is simple, economical and time efficient in comparison to other drying processes (Hardy and Jideani, 2017). Foam formation also increases the surface area which increases the overall mass transfer, thus reducing the drying time, minimizing nutritional loss and the organoleptic properties of the resultant food product as well as a reduction in energy need of the entire drying process is achieved (Falade and Okocha, 2010). Shaari *et al.* (2018) reported a high mineral content for foam mat dried papaya powder with a better reconstitution property than papaya dried using other drying methods. Hossain *et al*. (2021) also reported stability in the vitamin C content and antioxidant composition of foam mat dried mango powder.

Nutritional attributes of food are sometimes lost during the drying process. For instance, Hossain and Brunton (2010) reported a reduction in the antioxidant properties of vacuum oven-dried *Lamiaceae* herbs. To preserved antioxidant potentials and other nutritional properties of black plum fruit, a drying method with minimal loss to product quality like foam mat drying method need to be adopted for the drying of the fruit. Hence, optimization of the foam mat drying parameters would preserve the antioxidant capacity and the nutritional composition of the resultant black plum powder.

2. Materials and Methods

Fresh black plum fruits were obtained from local farmers in Adu village, Ajaokuta Local government area, Kogi State, Nigeria. Glycerol monostearate (foaming agent) and carboxyl methyl cellulose (stabilizing agent) a product of Sim Company, Pulau Pinnang, Malaysia was sourced from Mekang Chemicals vendor, Ojota, Lagos State.
Box-Behnken of the design expert was used to generated the runs as shown in the experimental design (Table 1).

2.1 Sample preparation

Foam mat dried black plum powder was prepared according to the method described by Hossain *et al*. (2021). Fresh black plum fruits were thoroughly washed with distilled water to remove foreign matters and subjected to sorting process to removed bad unripen ones. The edible portions of the plum were removed manually with a clean kitchen knife and the pulp collected was subjected to foaming process using glycerol monostearate as foaming agents and carboxymethyl cellulose as foam stabilizer at different concentrations as shown in Table 1. Two hundred grammes (200g) of the black plum pulp were mixed and whipped with the foaming and stabilizing using a kitchen mixer for 30 min. Thereafter, the foamed mixture was spread on an aluminum tray and placed in a cabinet dryer for the drying process at different temperature. Fig 1.

2.2 Sample analysis

2.2.1 Determination of Amino acid composition

The amino acid profile was determined using amino acid analyser as described by Onwuka, (2018). The sample was dried to constant weight, defatted using soxhlet extractor and hydrolyzed in a sealed glass ampoule at 105˚C ± 5˚C for 22 h using 7ml of 6MHCl. The hydrolysate was evaporated in a rotary evaporator and loaded into the Technicon Sequential Multi sample Amino acid Analyser (TSM, Taryton, USA.).

2.3 Statistical Analysis

All experiments were carried out in triplicate and data obtained were subjected to analysis of variance (ANOVA) and the means were separated by lowest standard deviation test (SPSS version 16). Significant level was accepted at 5%. All the experimental data were analyzed using multiple regression analysis and the correlation between the independent variables and dependent variables were developed from the model generated using RSM of design expert. The optimized values were statistically obtained at a confidence level of 5% using the numerical tools and the desirability function of the design expert.

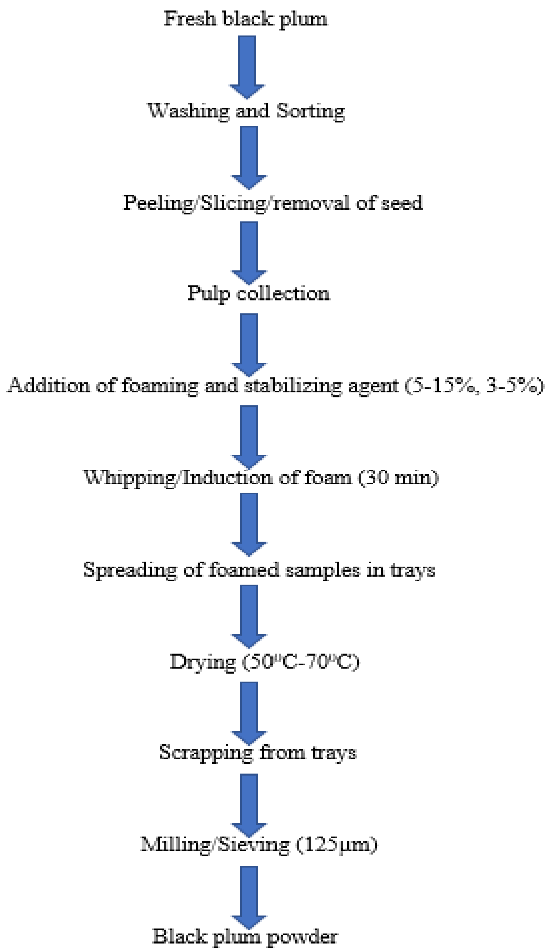

Figure 1: Flow chart for the production of foam mat dried black plum powder.
Source: (Hossain *et al*., 2021).

Plate 1. Fresh black plum

Plate 2. Foam mat dried black plum powder

Table 1: Experimental Design using Box-Behnken of design expert

Runs	Temperature (^{0}C)	Foaming agent (%)	Stabilizing agent (%)
1	70	15	4
2	50	5	4
3	60	5	5
4	50	10	3
5	50	15	4
6	70	10	3
7	60	15	5
8	50	10	5
9	70	10	5
10	60	15	3
11	70	5	4
12	60	5	3
Control	90	0	0

3. Results and Discussion

3.1 Amino acid composition of foam mat dried black plum powder

Amino acid composition of foam mat dried black plum powder is presented in Table 2. The values recorded for the essential amino acid was in the range of, threonine, 0.19 mg/100 to 0.35 mg/100g, histidine, 0.11 mg/100g to 0.23 mg/100g, 0.16 mg/100g to 0.27 mg/100g, isoleucine, 0.09 mg/100g to 01.8 mg/100g, tryptophan, 0.20 mg/100g to 0.34 mg/100g, methionine, 0.12 mg/100g to 0.24 mg/100g, valine, 0.11 mg/100g to 0.23 mg/100g, lysine, 0.05 mg/100g to 0.15 mg/100g, phenylalanine 0.12 mg/100g to 0.21 mg/100g. The results showed that foam mat drying had a significant ($p \leq 0.05$) effect on the amino acid composition of the black plum powder. All the sample foam mat dried recorded a significantly ($p \leq 0.05$) higher values than the sample that was not foam mat dried. The results also indicated that the amino acid composition increases with an increase in the concentration of foaming and stabilizing agent. Likewise, sample foam dried at a considerably higher temperature recorded a lower amino acid composition than foam mat dried sample at a lower temperature. High composition of amino acid recorded in foam-mat dried samples could be attributed to the low-temperature of drying and short-time exposure of the samples to heat which minimizes heat-induced protein denaturation, proteolysis and the degradation of amino acids (Mishra *et al*., 2014). It could due to the Maillard reaction that may have occurred during drying, forming complex structures of sugar–amino acids (Manditsera *et al*., 2019). Darniadi *et al*. (2017) reported an increase in the amino acid composition of foam mat dried bluberry powder. Krasaekoopt and Bhatia (2012) also reported increase in the amino of composition of yogurt subjected to foam mat drying process. Also, the porous structure of the foam matrix also protects sensitive components like the amino acid composition from oxidation and heat However, the specific impact on amino acids depends on the drying temperature, drying duration, and the presence of foaming agent and stabilizers, which may interact with and affect the amino acids or proteins (Lima *et al*., 2019). The quality of the protein in a material is determined by the level of amino acids contained in the material. Amino acids, when viewed from a nutritional perspective, consist of two groups, namely essential and non-essential amino acids.

Table 2: Amino acid composition of foam mat dried black plum powder (mg/100g)

Samples/EAA	Threonine	Histidine	Leucine	Isoleucine	Tryptophan	Methionine	Valine	Lysine	Phenylalanine	TEAA
NFDS	$0.19^{k}\pm0.01$	$0.11^{j}\pm0.02$	$0.16^{j}\pm0.01$	$0.09^{h}\pm0.01$	$0.20^{i}\pm0.01$	$0.12^{i}\pm0.01$	$0.11^{j}\pm0.01$	$0.05^{i}\pm0.01$	$0.12^{i}\pm0.01$	1.15
$T_{70}F_{15}S_4$	$0.33^{c}\pm0.02$	$0.23^{a}\pm0.02$	$0.26^{b}\pm0.01$	$0.18^{a}\pm0.01$	$0.33^{b}\pm0.01$	$0.24^{a}\pm0.01$	$0.22^{b}\pm0.01$	$0.14^{b}\pm0.01$	$0.21^{a}\pm0.02$	2.14
T50F5S_4	$0.25^{h}\pm0.01$	$0.15^{g}\pm0.02$	$0.19^{h}\pm0.05$	$0.12^{f}\pm0.01$	$0.23^{gh}\pm0.01$	$0.16^{g}\pm0.01$	$0.14^{h}\pm0.01$	$0.07^{g}\pm0.01$	$0.15^{fg}\pm0.01$	1.46
$T_{60}F_5S_5$	$0.26^{g}\pm0.01$	$0.16^{f}\pm0.02$	$0.21^{g}\pm0.01$	$0.12^{f}\pm0.01$	$0.24^{g}\pm0.01$	$0.18^{f}\pm0.01$	$0.17^{f}\pm0.01$	$0.09^{e}\pm0.01$	$0.16^{ef}\pm0.05$	1.59
$T_{50}F_{10}S_3$	$0.29^{e}\pm0.05$	$0.19^{d}\pm0.02$	$0.24^{d}\pm0.01$	$0.14^{d}\pm0.01$	$0.28^{e}\pm0.06$	$0.19^{e}\pm0.01$	$0.18^{e}\pm0.02$	$0.09^{e}\pm0.02$	$0.18^{bcd}\pm0.01$	1.78
$T_{50}F_{15}S_4$	$0.34^{b}\pm0.03$	$0.22^{b}\pm0.02$	$0.25^{c}\pm0.01$	$0.17^{b}\pm0.01$	$0.33^{b}\pm0.01$	$0.24^{a}\pm0.01$	$0.23^{a}\pm0.01$	$0.15^{a}\pm0.0$	$0.21^{a}\pm0.01$	2.14
$T_{70}F_{10}S_3$	$0.28^{f}\pm0.01$	$0.18^{e}\pm0.02$	$0.22^{f}\pm0.01$	$0.13^{e}\pm0.01$	$0.26^{f}\pm0.02$	$0.19^{e}\pm0.01$	$0.16^{g}\pm0.06$	$0.08^{f}\pm0.01$	$0.17^{de}\pm0.01$	1.67
$T_{60}F_{15}S_5$	$0.35^{a}\pm0.02$	$0.23^{a}\pm0.02$	$0.26^{b}\pm0.01$	$0.18^{a}\pm0.01$	$0.34^{a}\pm0.02$	$0.24^{a}\pm0.01$	$0.23^{a}\pm0.02$	$0.13^{c}\pm0.01$	$0.21^{a}\pm0.01$	2.17
$T_{50}F_{10}S_5$	$0.32^{d}\pm0.02$	$0.21^{c}\pm0.02$	$0.24^{d}\pm0.01$	$0.17^{b}\pm0.02$	$0.31^{c}\pm0.02$	$0.22^{c}\pm0.01$	$0.21^{c}\pm0.01$	$0.11^{d}\pm0.01$	$0.18^{bc}\pm0.01$	1.97
$T_{70}F_{10}S_5$	$0.32^{d}\pm0.02$	$0.21^{c}\pm0.01$	$0.23^{e}\pm0.01$	$0.16^{c}\pm0.01$	$0.29^{d}\pm0.01$	$0.21^{d}\pm0.01$	$0.19^{d}\pm0.01$	$0.11^{d}\pm0.01$	$0.17^{cd}\pm0.01$	1.89
$T_{60}F_{15}S_3$	$0.35^{a}\pm0.02$	$0.22^{b}\pm0.01$	$0.27^{a}\pm0.01$	$0.18^{a}\pm0.01$	$0.32^{b}\pm0.01$	$0.23^{b}\pm0.01$	$0.22^{b}\pm0.01$	$0.14^{b}\pm0.01$	$0.19^{b}\pm0.01$	2.12
$T_{70}F_5S_4$	$0.23^{i}\pm0.02$	$0.12^{i}\pm0.01$	$0.18^{i}\pm0.04$	$0.90^{i}\pm0.21$	$0.21^{i}\pm0.01$	$0.15^{h}\pm0.01$	$0.13^{i}\pm0.01$	$0.06^{h}\pm0.01$	$0.15^{gh}\pm0.01$	2.13
$T_{60}F_5S_3$	$0.22^{j}\pm0.03$	$0.13^{h}\pm0.01$	$0.18^{i}\pm0.02$	$0.11^{g}\pm0.04$	$0.22^{h}\pm0.01$	$0.16^{g}\pm0.01$	$0.14^{h}\pm0.01$	$0.06^{j}\pm0.01$	$0.14^{h}\pm0.02$	1.36
RDA (EU recommended)										5-10

Values are mean ± standard deviation of triplicate determinations. Means in the same row with different superscript are significantly different ($p<0.05$).

Keys: T= Temperature (°C); F= Foaming agent Conc (%); S= Stabilizing agent Conc (%), NFMD = None foam mat dried sample, EAA= Essential amino acid, NEAA= Non-essential amino acid, TEAA= Total essential amino acid, TNEAA= Total non-essential amino acid.

Essential amino acids are amino acids that cannot be produced by the body itself and must be obtained from food sources of protein (Cisse *et al*., 2013). Meanwhile, non-essential amino acids are amino acids that can be produced by the human body (Cisse *et al*., 2013). Histidine is an important amino acid for proper functioning of immune system and neurotransmitter synthesis. Leucine is essential in the synthesis and repair of muscle protein while isoleucine is involved in production of energy and muscle metabolism. Lysine is known to play an important role in hormone regulation and calcium absorption, methionine plays an important role in antioxidant defenses and detoxification.

3.2 Response surface analysis for amino acid composition

All analyses were conducted in triplicates. 3-Dimensional response surfaces were used to illustrate the correlation between the dependent and independent variables. Effect of the independent variables (Temperature of drying, foaming agent and stabilizing agent concentration) on the responses or dependent variables (amino acid composition) were predicted using regression models. The *p*-values generated for the amino acid composition were significant with a *p*-value ≤0.05 as shown in table 3 which implies a significant model. A *p-value* larger than 0.05 means the model or factor is not significant. The R^2 values also show the level of significance of the model, the closer the R^2 values to one (1), the better the model. An average R^2 of 0.96 was recorded. Adequate precision value which is desirable measure of signal to noise ratio showed the amino acid composition had values greater than 4.0 which is an indication of adequate signal as shown in Table 3. The contour plots for the amino acid composition as shown in figures 2 and 3 indicates that the independent variables have a significant effect on the amino acid composition as it showed a significant increase as the percentage concentration of foaming and stabilizing agent increases with a reduction in drying temperature. The following regression equation (Equations 1-9) for amino acids were developed in terms of coded units, taking into account the effects of individual independent components and their significant interactions.

Threonine (mg/100g) = 0.2950-0.0050A + 0.0513B + 0.0137C + 0.0025AB + 0.0025AC + 0.0100BC (1)

Histidine (mg/100g) = 0.1875-0.0037A + 0.0425B + 0.0112C + 0.0100AB + 0.0025AC + 0.0050BC (2)

Leucine (mg100g) = 0.2275 0.0037A + 0.0350B + 0.0037C + 0.0050AB + 0.0025AC - 0.0100BC (3)

Isoleucine (mg/100g) = 0.1458 + 0.0050A + 0.0338B + 0.0087C + 0.0100AB + 0.0000AC - 0.0025BC (4)

Tryptophan (mg/100g) = 0.2808 - 0.0062A + 0.0525B + 0.0137C + 0.0050AB + 0.0025AC + 0.0000BC (5)

Methionine (mg/100g) = 0.2008-0.0025A + 0.0375B + 0.0100C + 0.0025AB - 0.0025AC - 0.0025BC (6)

Valine (mg/100g) = 0.1850-0.0075A + 0.0400B + 0.0125C + 0.0000AB + 0.0000AC - 0.0050BC (7)

Lysine (mg/100g) = 0.1017-0.0037A + 0.0363B + 0.0100C + 0.0000AB + 0.0025AC - 0.0125BC (8)

Phenylalanine (mg/100g) = 0.1767-0.0025A + 0.00275B + 0.0050C + 0.0000AB + 0.0000AC + 0.0000BC (9)

Table 3: Analysis of variance for antioxidant capacity and amino acid

Responses	Model	F-Value	P-Value	R^2	Adjusted R^2	Predicted R^2	Adeq. Precision
Threonine	2FI	26.64	0.0012	0.96	0.93	0.82	14.13
Histidine	2FI	18.51	0.0029	0.95	0.90	0.75	11.68
Leucine	2FI	18.51	0.0029	0.95	0.90	0.75	12.08
Isoleucine	2FI	15.92	0.0040	0.95	0.89	0.71	11.16
Tryptophan	2FI	40.68	0.0004	0.97	0.95	0.88	17.49
Methionine	2FI	32.04	0.0008	0.97	0.94	0.85	15.62
Valine	2FI	24.33	0.0015	0.96	0.92	0.80	13.74
Lysine	2FI	34.50	0.0007	0.97	0.94	0.86	16.92
Phenylalanine	2FI	14.32	0.0052	0.94	0.87	0.68	9.93

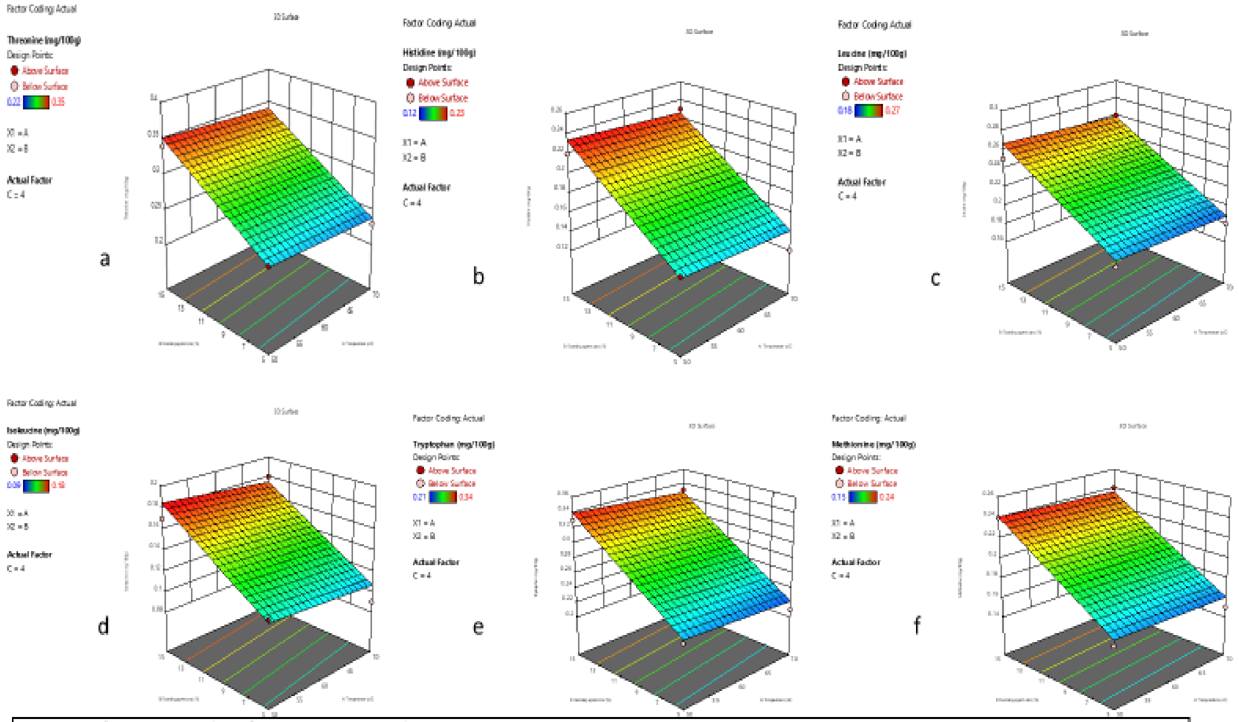

Fig 2. Contour plot for amino acid composition
a= Threonine, b = Histidine, c = Leucine, d = Isoleucine, e = Tryptophan, f = Methionine

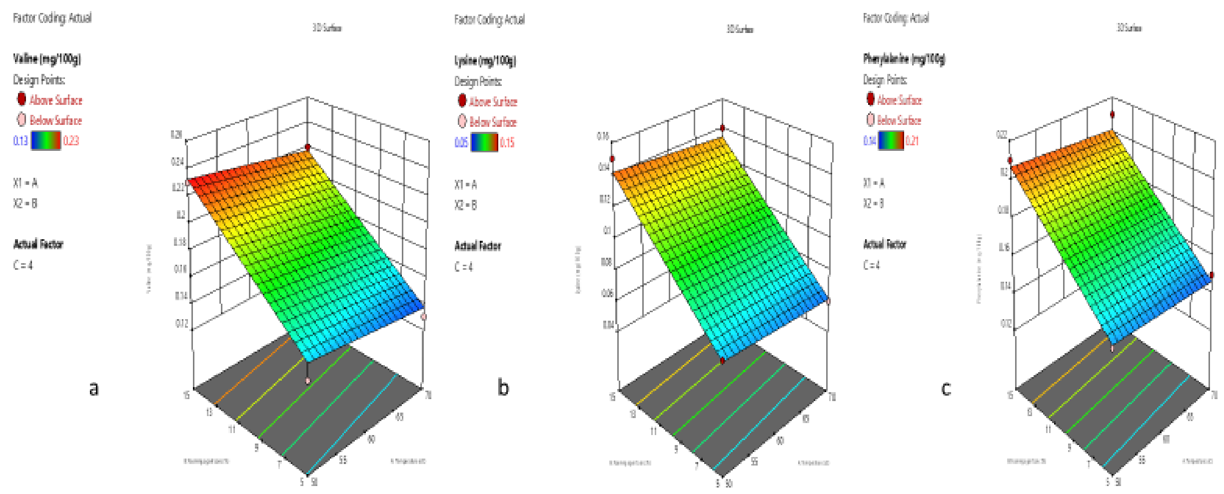

Fig 3. Contour plot for amino acid composition
a= Valine, b = Lysine, c = Phenylalanine

3.3 Determination and validation of the optimal parameters

The independent variables were optimized by response surface methodology using Design-Expert version 13 software. The optimal conditions were obtained on the basis of desirability using the desirability function of Design-Expert's numerical optimization program. The fitness of the model equations was determined under the predicted conditions and experiments were conducted using the optimal parameters to confirm the validity of the optimized condition. The results are tabulated in Table 4**.** The relative standard error (RSE) percentages were calculated to determine the accuracy of the models for prediction and expressed in percentage. Relative standard error are useful measures that provide an indication of the relative size of the error likely to have occurred due to sampling. RSE is calculated by dividing the predicted values by the standard error of the predicted values multiply by 100. Low RSE is an indication that the model can make accurate prediction, while high RSE indicates less confidence that predicted value is close to experimental value. The obtained relative standard error values for foam-mat dried black plum powder as regards the amino acid showed that the models can be used for adequate predictions. The results as shown in Table 4 demonstrated no consequential disparities between the predicted values and the experimental values, which also confirms the adequacy of the prediction using the models. Also, the closer the desirability function to 1, the better the model for prediction.

Table 4: Summary of the validation under the optimal condition for and amino acids composition

Responses (mg/100g)	Target	Predicted Value	Experimental Value	RSE	Desirability Level
Amino acid composition					0.97
Threonine	Maximum	0.35	0.41±0.01	3.4	
Histidine	Maximum	0.23	0.30±0.01	5.2	
Leucine	Maximum	0.26	0.34±0.01	4.3	
Isoleucine	Maximum	0.18	0.29±0.01	7.1	
Tryptophan	Maximum	0.34	0.43±0.01	3.6	
Methionine	Maximum	0.25	0.37±0.01	5.0	
Valine	Maximum	0.23	0.38±0.01	5.5	
Lysine	Maximum	0.15	0.24±0.01	10.0	
Phenylalanine	Maximum	0.21	0.29±0.01	5.5	
Optimal condition					
Foaming agent (%)		15			
Stabilizing agent (%)		4.48			
Temperature of drying (°C)		55.90			

Experimental values are mean ± standard deviation of triplicate determinations; RES: Relative standard error

4. Conclusion

The study investigated the foam mat drying of black plum pulp at different temperature, foaming and stabilizing agent concentration. Generally, the findings indicate that the independent variables significantly (p=0.05) have influence on the amino acids' composition of the black plum powder. The ANOVA showed that the average generated models for the amino acids composition had an average R^2 value greater than 90%, significant model F-values (p=0.05), non-significant 'lack of fit,' and an adequate precision value greater than 4. The optimal parameters for amino acid of 15% foaming agent, 4.48% stabilizer, 55.90°C drying temperature was predicted and the values was verified to be in good agreement with the experimental values as the difference between them were minimal. The study's findings demonstrate black plum potentials as an ideal fruit for fruit powder due to its nutritional composition.

References

Adejumo, A.A., Alaye, S.A., Ajagbe, R.O., Abi, E.A. and Adedokun, F.T. (2013). Nutritional and Anti-nutritional Composition of Black plum (vitex doniana). *Journal of Natural Sciences Research*, 3(12): 144-148

Adeyeye, S. A. O., Ashaolu, T. J., and Babu, A. S. (2022). Food drying: A review. *Agricultural*

Amah, U. J., and Okogeri, O. (2019). Nutritional and phytochemical properties of Wild Black and Sinsin, B. (2012). Uses and management of black plum (*Vitex doniana* Sweet) in

AOAC. (2016). Appendix F: Guidelines for Standard Method Performance Requirements. AOAC Official Methods of Analysis, 1–17.

Bag, S.K., Srivastav, P.P., and Mishra, H.N. (2011). Optimization of process parameters for foaming of Bael (*Aegle marmelos L.*) fruit pulp. Food Bioprocess Technol 4:1450–1458. https://doi.org/10.1007/ s11947-009-0243-6

Cisse, M., Zoue, L.T., Soro, Y.R., Megnanou, R.-M. and Niamke, S. (2013). Physicochemical and Functional Properties of Starches of Two quality Protein Maize (QPM) Grown in Côte d'Ivoire. Journal of Applied Biosciences, 66, 5130 doi.org/10.4314/jab.v66i0.95010

Dadjo, C., Assogbadjo, A. E., Fandohan, B., Kakaï, R. G., Chakeredza, S., Houehanou, T. D., ...

Darniadi, S. (2017). *Optimisation of foam-mat freeze-drying conditions for blueberry powder and evaluation of powder properties* (Doctoral dissertation, University of Leeds).

Falade, K.O., and Okocha, J.O. (2010). Foam-mat drying of plantain and cooking banana (Musa spp.). Journal of Food and Bioprocess Technology, doi: 10.1007/s11947-010-0354-0

Figiel, A., and Michalska, A. (2016). Overall quality of fruits and vegetables products affected

Franco, T.S., Perussello, C.A., Ellendersen, L.N., and Masson, M.L. (2016) Effects of foam mat drying on physicochemical and microstructural properties of yacon juice powder. LWT- Food Science and Technology. 66: 503-513

Hardy, Z. and Jideani, V.A. (2017). Effect of spray drying compartment and maltodextrin concentration on the functional, physical, thermal, and nutritional characteristics of Bambara groundnut milk powder. *Journal of food processing and preservation. 46(11): 178-189*

Hassan, A. and Shamsudeen, A.J. (2019). Cottage Processing of Black Plum (Vitex doniana) into Juice in Katsina State, NorthWestern Part of Nigeria. *Umoru Journal of Microbiology Research (UJMR)*. 4(2):88-95

Hossain, M. B., Barry-Ryan, C., Martin-Diana, A. B., & Brunton, N. P. (2010). Effect of drying method on the antioxidant capacity of six Lamiaceae herbs. *Food Chemistry*, *123*(1), 85-91.

Hossain, M. B., Barry-Ryan, C., Martin-Diana, A. B., & Brunton, N. P. (2010). Effect of drying method on the antioxidant capacity of six Lamiaceae herbs. *Food Chemistry*, *123*(1), 85-91.

Hossain, M.A., Mitra, S., Belal, M., and Zaman, W. (2021). Effect of foaming agent concentration and drying temperature on biochemical properties of foam mat dried tomato powder. Food Research. 5: 291-297.

Krasaekoopt, W. and Bhatia, S. (2012). Production of Yoghurt Powder Using Foam-Mat Drying. AU Journal of Technology, 15(3), 166, 167, 168.

Lima, R.S., Ferreira, S.R.S., Vitali, L., and Block, J.M. (2019). May the superfruit red guava and its processing waste be a potential ingredient in functional foods? Food Res. Int. 2019, 115, 451–459.

Manditsera, F.A., Luning, P.A., Fogliano, V., and Lakemond, C.M.M. (2019). Effect of domestic cooking methods on protein digestibility and mineral bioaccessibility of wild harvested adult edible insects. Food Res. Int. 2019, 121, 404–411.

Mishra, H.N., Jacob, J.K. and Srinivasan, N. (2002). Preparation of apple powder and evaluation of its shelf life. Beverage and Food World, 29(1), 49–52 Morgan, A.I., Graham, R.P., Ginnette, L.F

Onwuka, G. I., (2018). Food Analysis and Instrumentation under-exploited legumes Cassia laevigata W. and (Theory and practice). Second edition *Naphthali Tamarindus indica L.*. Journal of Food Composition Prints, Lagos, Nigeria, pp. 343, 353-359, 373

Solchansanj, S., and Jayas, D. S. (2020). Drying of foodstuffs. In *Handbook of industrial*
Southern Benin. *Fruits*, *67*(4), 239-248.

Uchenna, J.A and Otu, O. (2019). Nutritional and Phytochemical Properties of Wild Black Plum (Vitex doniana) Seed from Ebonyi State. *International journal of Horticulture, Agriculture and Food science (IJHAF)*. 3(1): 32-36.