

Impact of Barrel Temperature, Screw Speed and Feed Moisture on the Phytate and Tannin Contents of Extruded Snacks from Aerial Yam and Soybean Flour Mixture

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Abstract

This study investigated the impact of barrel temperature, screw speed and feed moisture, as extrusion process parameters, on the phytates and tannins contents of extruded snacks produced from aerial yam and soybean flour mixture, using Response surface methodology. Design Expert (version 11.0.1) was used in the experimental design. A three factor experimental set up at five levels each, with barrel temperature, ($X_1 = 95, 100, 105, 110, \text{ and } 115^\circ\text{C}$), screw speed ($X_2 = 85, 100, 115, 130, \text{ and } 145 \text{ rpm}$) and feed moisture levels ($X_3 = 31, 33, 35, 37, \text{ and } 39\%$) as the independent factors was adopted. Coded values for the independent variables used were -2, -1, 0, 1, 2, where -2 represents the lowest, 0 represents the medium (mid-point), and 2 represents highest levels, respectively. The extruded snacks were produced using a Laboratory scale single-screw food extruder, and twenty (20) runs were carried out in the course of the extrusion process. The extruded snacks were subjected to laboratory analysis, using standard equipment and methods. Results of the laboratory analysis for the determination of phytates and tannins contents of the extruded snacks showed that phytates ranged from 12.48 to 32.86 mg/100g, and tannins varied between 0.93 and 5.46 mg/100g sample. Analysis of variance indicated that barrel temperature, screw speed and feed moisture had significant effect ($p < 0.05$) on the phytates and tannins contents of the extruded snacks. The results obtained for the phytates and tannins contents of the snacks can attest to the fact that it is possible to obtain expanded or ready-to-eat (RTE) products from aerial yam and soybean flour mixture through extrusion processing technology, that possess minimal levels of anti-nutrients/toxicity.

Keywords: Antinutrients, Extrusion Processing, Phytates and Tannins, Extruded Snacks, Response Surface, Aerial Yam, Soybean Flour.

Introduction

Phytates occur naturally in several vegetable products. Seeds, grains, nuts and legumes store phosphorus as phytic acid in husks in the form of phytin or phytate salt. Their presence may affect bioavailability of minerals, solubility, functionality and digestibility of proteins and carbohydrates (Umoh *et al.*, 2021; Popova and Mihaylova, 2019). They are sometimes

considered antinutrients. Among the anti-nutritional compounds of most significant importance to be mapped in complementary foods are phytate (or phytic acid). Phytate [inositol hexaphosphate (IP6)] is widely present in plant-based foods. It is well-documented that even small amounts of phytate in the diet will significantly reduce iron absorption. The bioavailability of mineral elements for absorption is affected when phytates in grains bind to the minerals and form indigestible complexes (Daguma *et al.*, 2021)

Tannins are polyphenolic compounds that give a bitter or astringent taste to some foods. They exhibit anti-nutritional properties by impairing the digestion of various nutrients and preventing them from being absorbed by the body. Tannin can also bind and shrink proteins. Tannin-protein complex may result in digestive enzymes inactivation and protein digestibility reduction caused by protein substrate and ionisable iron interaction (Pismag *et al.*, 2024; Popova and Mihaylova, 2019). Tannins, categorized as phenolic compounds and recognized as ANFs, are present in the structure of various plant-based raw materials. Their consumption interferes with protein and mineral digestion as tannins form complexes with carbonyl groups in dietary proteins or enzymes (Daguma *et al.*, 2021; Pismag *et al.*, 2024).

Aerial yam (*Dioscorea bulbifera*) is a vigorous climber plant native of West Africa, cultivated for their bulbils which are consumed once cooked like potatoes in water with oil or roasted with local sauce (a combination of palm oil and other local spices). About 50-60 species of yam (*Dioscorea* spp.) are found in Nigeria but only 5 or 6 species are important as food. Unfortunately, some of these food crops have been under-exploited for their food values, for example, *Dioscorea bulbifera* (Umoh and Abasiokong, 2024)). *Dioscorea bulbifera* is native to Africa and Asia and is commonly known as "air potato".

Soybean (*Glycin max*), a large oil seed in the *Leguminosae* family, is primarily grown as a food crop. The seeds 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.

The extrusion process is an efficient, continuous process, which uniquely combines several unit operations, namely: mixing, shearing, heating, pumping, forming, and sizing. Extrusion cooking technology, a high-temperature-short-time (HTST) process, is increasingly used in the food industries for the development of new cereal based snacks, including high dietary fibre foods, baby foods, breakfast cereals and modified starch from cereals (Sarka *et al.*, 2021; Umoh and Ekanem, 2024).

Ali *et al.* (2024) reported that when the feed moisture content is increased (14 to 22%) during extrusion, significant variations in anti-nutritional factor levels may occur. The reduction of phytate, tannin, and polyphenol in lentils has been found to be more pronounced in feed materials with increased moisture content compared with feeds with lower moisture content. Furthermore, the best processing conditions for lowering the phytate level of wheat bran involve high feed moisture content (20%) combined with a moderate extrusion cooking temperature (115°C).

According to Arun kumar *et al.* (2018), extrusion process reduced the phytic acid content of sorghum-soya blends up to 57.48% as reflected by its lower content in the final product,

compared to that in the feed material. The researchers inferred that the reduction in phytic acid content followed by extrusion might be due to the hydrolyzation of inositol into lower molecular weight forms like penta-, tetra and triphosphates.

Extrusion cooking generally reduces phytates and tannins content in food products. The specific reduction depends on extrusion conditions like barrel temperature, moisture content and screw speed. These conditions affect thermal and mechanical forces applied to the food, impacting the structure of starches and proteins, and leading to the breakdown of anti-nutritional factors like phytates and tannins (Daguma *et al.*, 2021).

Barrel temperature and the proportion of defatted soy meal flour have been reported to have significant effect on phytic acid content of the extrudate, whereas feed moisture has no significant effect. These observations are made after a study carried out by Tadesse *et al.* (2019) on the extrusion of sorghum supplemented with defatted soy meal flour. Furthermore, increasing the level of addition of soy meal flour from 0 to 20% causes a significant increase in phytic acid content of the extrudate from 323.47 to 428.33mg/100g. Extruding sorghum and soy meal flour at 135, 150 and 165°C, at same soy meal level and feed moisture content, causes a significant reduction in phytic acid content of raw sorghum flour (553.28mg/100g) by about 24, 35 and 45% respectively.

It has been reported that though extrusion processing could not completely eliminate tannin, a considerable reduction is observed depending upon the process variables (Arun kumar *et al.*, 2018). Available literature has it that minimum reduction is observed when the feed consists of 20% soybean with 16% feed moisture, extruded at 110 °C barrel temperature with a screw speed of 350rpm, while the highest reduction in tannin content is noticed when the blend containing 20% soybean and 16% feed moisture is extruded at 150 °C and 350 rpm.

Negative influence of extrusion on tannin content has been reported to be attributed to the thermal degradation of molecules, changes in their chemical reactivity or the formation of insoluble complexes during the course of extrusion (Umoh and Ukwo, 2024). The role of extrusion in declining the tannin content of sorghum-soya blends has been confirmed by Arun kumar *et al.* (2018). Barrel temperature has been reported to have a significant influence in reducing the tannin content of sorghum-soya mixture. Rahul and Uday (2016) reported that increasing extrusion temperature considerably reduces the tannin content in lentil splits.

More so, increase in screw speed has been reported to bring about a slight decrease in tannin content of sorghum-soya blends, but further increase in screw speed leads to increase in tannin content of extruded sorghum-soya blends. Maximum reduction in tannin content can be achieved at high barrel temperature and medium screw speed (Arun kumar *et al.*, 2018). Omosebi *et al.* (2018) also reported that extrusion cooking had no significant effect on the tannin content of extruded complementary diet from quality protein maize and soybean protein concentrate.

According to reports by Tadesse *et al.* (2019) and Umoh *et al.* (2021), the tannin content of the extrudates was significantly affected by feed moisture and barrel temperature. The

report further indicated that extrusion of sorghum and soy meal flour blend at 15, 18 and 21% feed moisture significantly reduced the tannin content of the extrudates by 76.45, 72.96 and 71.41% respectively, from raw sorghum flour (303.75 mg/100 g). Lower reduction of tannin content at maximum feed moisture resulted from the short residence time of the dough in the extruder barrel due to the high lubricating effect of the high feed moisture content (Tadesse *et al.*, 2019). Also, barrel temperature has been reported to have a significant effect on tannin content of extrudates. Tadesse *et al.* (2019) observed that extruding sorghum and soy meal flour blend at 135, 150 and 165 °C, at the same level of soy meal flour, brings about a significant reduction in tannin content of the raw sorghum flour (303.75mg/100g) by about 61, 76 and 86% respectively. This is due to the destruction of tannin at high temperature.

Problem Statement

The production of extruded snacks or ready-to-eat (RTE) foods with desirable quality characteristics, over the years, from underutilized/lesser known food crops using extrusion processing technology has been of great concern to food processors. This resulted in the need for appropriate selection of extrusion process variables regimes that could guarantee the production of acceptable extruded snacks with minimal levels of antinutrients/toxicity. This current research attempts to bridge the gap and conceptualize an approach towards producing acceptable extruded snacks with desired quality characteristics. This study is relevant to food science and agricultural processing, particularly in developing new extruded food products.

This study is therefore aimed at investigating the impact of barrel temperature, screw speed and feed moisture, as extrusion process parameters, on the phytates and tannins contents of extruded snacks from aerial yam and soybean flour mixture, using Response surface methodology.

Specific Objectives

Specific objectives of this study are:

- To produce extruded snacks from aerial yam and soybean flour mixture.
- To determine the phytate and tannin contents of the extruded snacks produced from aerial yam and soybean flour mixture.
- To evaluate the impact or effect of the extrusion process parameters, namely; barrel temperature, screw speed and feed moisture content, on the phytate and tannin contents of the extruded snacks.

Materials and Methods

Procurement of Aerial yam bulbs and Soybean seeds

The aerial yam bulbs and the soybean seeds used in this study were purchased in an urban market in Uyo, Akwa Ibom State, Nigeria.

Preparation of Aerial yam flour

Aerial yam flour was prepared according to the method described by Umoh and Abasiokong (2024). The aerial yam bulbs were cleaned and sorted to remove unwanted materials, before peeling with knife, washed with clean water and sliced to 10 mm thickness using kitchen knife. The slices (chips) were then dried, using a laboratory oven at a temperature of 60 °C for 12 h. The dried slices (chips) were then milled using MF120 Hammer mill made in Italy, and sieved with laboratory sieve of 600µm aperture size. The flour obtained was packaged in a polyethene bag for subsequent use.

Preparation of Soybean flour

Soybean flour was prepared according to the method described by Umoh *et al.* (2021). Seeds were screened to remove foreign materials, splits, and damaged beans. This was followed by washing and roll boiling at 100 °C for 30 minutes. It was then oven -dried at a temperature of 70 °C for 12h, and milled in a disc attrition mill. The milled full-fat soybean was sieved using a 100-mesh standard sieve. The flour obtained was then stored in air- tight polyethene bag at room temperature for further use.

Extrusion processing

This was done according to the method described by Umoh and Iwe (2022), using a single-screw laboratory scale extruder. Two hundred grams (200g) of the flour mixture (25% aerial yam flour, 75% soybean flour) was precisely estimated and preconditioned by the ideal moisture levels, permitted to remain for around two minutes (2min) to guarantee uniform hydration of the natural substance. The extruder was turned on, and the barrel temperatures and the screw speeds of the extruder were set accordingly. The natural substance was taken care of, through the container, into the extruder. The extrudates were gathered as they exit through the die, dried, and packaged in impenetrable zip lock polyethylene sacks for further laboratory analysis.

Determination of Phytic Acid (Phytate) content

This was determined according to the method of Mecance and Widdowson as described by Umoh and Ukwo (2024). Two and half grams (2.5 g) of the sample was extracted with 50 ml 3% TCA for 30 minutes, centrifuged and transferred into a 40 ml conical flask. Four millilitres (4 ml) of FeCl₃ solution was added, heated in a boiling water bath for 45 minutes, centrifuged and carefully decanted. The precipitate was washed with 20 ml 3% TCA, heated and centrifuged. Then dispersed in a few ml of water and 3 ml of 1.5 M NaOH added with mixing. The volume was brought to 30 ml with water, heated for 30 minutes, centrifuged and carefully decanted. The precipitate was washed again with hot water, re-centrifuged and decanted. Then dissolved with hot 40 ml 3.2 M HNO₃, and transferred into a 100 ml standard flask, cooled to room temperature and diluted to volume with distilled water. The iron (Fe) of the solution was determined, with an assumed 4:6 iron-phosphorus molecular ratio.

Calculation:

Determined Fe in the sample = Xmg

Convert Xmg to $mmole$ $X = 5mmole = 55.85(mol\ Fe)$

Therefore, phosphorus, $P = \frac{6}{4} \times X = 4mmole$ of P

Phytic acid, $P.A = 660.80 \times Y = Zmmole\ P.A$

Where: 660.80 is the molar weight of P. A, Y is $6 \times \text{molecular mass of P}$

$\therefore mg\ P.A = Z \times 660.80$, i.e.,

Phytic acid ($mg/100g$) = $Zmmole \times \text{molecular weight of P.A}$

Determination of tannin content

The Folin-Dennis spectrophotometric method as described by Umoh and Ukwo (2024) was adopted in the determination of tannins. One gram (1g) of the sample was dispersed in 10 ml distilled water, agitated and allowed to stand for 30 minutes at room temperature, then centrifuged. Two and half millilitres (2.5 ml) of the supernatant, 2.5ml of tannic acid solution were dispersed into a 50 ml flask respectively. One millilitre (1 ml) of Folin Dennis reagent was added to each flask, followed by 2.5 ml of saturated Na_2CO_3 solution. The mixture was then diluted to 50 ml mark, and incubated for 90 minutes at room temperature. The absorbance was measured at 250 nm in a BENWAY Model 6000 electronic spectrophotometer. The tannin content was calculated using equation 1.

$$\text{Tannin (\%)} = \frac{A_n}{A_s} \times C \times \frac{100}{W} \times \frac{V_f}{V_a} \quad [1]$$

Where:

A_n = Absorbance of test sample

A_s = Absorbance of standard solution

C = concentration of standard solution

W = weight of Sample

V_f = total volume of extract

V_a = volume of extract analyzed

Experimental Design/Statistical Analysis

Design Expert (version 11.0.1) was used in the experimental design. A three factor experimental set up at five levels each, with barrel temperature, ($X_1 = 95, 100, 105, 110$, and $115^\circ C$), screw speed ($X_2 = 85, 100, 115, 130$, and $145\ rpm$) and feed moisture levels ($X_3 = 31, 33, 35, 37$, and 39%) as the independent factors was adopted. Coded values for the independent variables used were -2, -1, 0, 1, 2, where -2 represents the lowest, 0 represents the medium (mid-point), and 2 represents highest levels, respectively. Response Surface Methodology (RSM) was used to analyze the effects of the independent factors or variables on the dependent variables (the responses).

Results and Discussions

The results of the phytates and tannins contents of the extruded snacks produced from aerial yam and soybean flour mixture are presented in Table 1.

Table 1: Phytate and tannin contents of extruded snacks from aerial yam and soybean flour mixture

S/N	Barrel temp(°C)	Screw speed(rpm)	Feed moisture (%)	Phytate (mg/100g)	Tannin (mg/100g)
1	105	115	31	17.48±0.018	2.63±0.025
2	105	115	35	12.73±0.025	3.70±0.017
3	105	115	35	12.81±0.025	3.72±0.017
4	105	85	35	27.62±0.019	2.48±0.008
5	100	130	33	16.37±0.013	4.00±0.001
6	110	100	37	26.78±0.015	5.46±0.009
7	100	100	37	24.49±0.020	0.93±0.026
8	110	130	33	25.39±0.025	1.81±0.016
9	105	115	35	12.48±0.025	3.71±0.017
10	115	115	35	32.86±0.032	4.75±0.021
11	95	115	35	20.34±0.021	2.54±0.009
12	105	115	39	23.97±0.046	1.19±0.014
13	105	115	35	12.60±0.025	3.72±0.017
14	100	100	33	19.21±0.031	2.83±0.017
15	110	130	37	24.95±0.017	3.71±0.030
16	110	100	33	25.55±0.026	3.50±0.008
17	105	145	35	30.34±0.011	2.01±0.112
18	100	130	37	25.74±0.008	1.21±0.341
19	105	115	35	12.87±0.025	3.74±0.017
20	105	115	35	12.71±0.025	3.71±0.017

Note: Values are mean ± standard deviation of triplicate determination

Phytate

The results of the phytate content of the extruded aerial yam-soybean flour blends are presented in Table 1. The phytate content ranged between 12.48 and 32.86mg/100g of sample. The observed range of values for phytates in the extruded snacks is lower than 158.93 to 191.33 mg/100g for extruded oat-soybean-linseed flour blends, earlier reported by Daguma *et al.* (2021); 177.53 to 311.83 mg/100g for extruded sorghum-soya blends (Arun kumar *et al.*, 2018); and 247.32 to 485.69 mg/100g for sorghum-based extruded product supplemented with defatted soy meal flour (Tadesse *et al.*, 2019). High temperature during extrusion can cause thermal degradation of phytates, breaking them down into less harmful forms.

Phytates occur in several vegetable products. Seeds, grains, nuts and legumes store phosphorus as phytic acid in husks in the form of phytin or phytate salt. Their presence may affect bioavailability of minerals, solubility, functionality and digestibility of proteins and carbohydrates (Umoh *et al.*, 2021; Popova and Mihaylova, 2019).

Tannin

The results of the tannin contents of the extruded snacks are presented in Table 1. The tannin contents of the snacks varied between 0.93 and 5.46mg/100g (Table 1). This range of values is higher than 0.03 and 0.04% for extruded meals of quality protein maize, soybean concentrate and cassava starch (Omosebi *et al.*, 2018); 0.1942 to 0.4643 % tannic acid for extruded sorghum-soya blends (Arun kumar *et al.*, 2018); 0.28 to 0.81mg GA/g – dry matter, for soybean hull (Tabibloghmanyet *al.*, 2020), but much more lower compared to 35.50 and 130.17mg/100g for sorghum-based extruded product supplemented with defatted soy meal flour (Tadesse *et al.*, 2019); 8.4 to 22.89 mg/100g for extruded oat-soybean-linseed flour blends, earlier reported by Daguma *et al.* (2021).

The mechanical shearing force of the extruder, together with heat can breakdown tannin structures, resulting in the reduction of tannin level in the extrudate.

Tannins exhibit anti-nutritional properties by impairing the digestion of various nutrients and preventing them from being absorbed by the body. Tannin can also bind and shrink proteins. Tannin-protein complex may result in digestive enzymes inactivation and protein digestibility reduction caused by protein substrate and ionisable iron interaction (Popova and Mihaylova, 2019). The extrusion cooking operations (mixing, shearing force, and high-temperature heating) involved could contribute to a reduction of phytate and condensed tannin content of composite flour (Daguma *et al.*, 2021).

Impact of extrusion process parameters on phytate

The effects of extrusion process parameters (barrel temperature, screw speed and feed moisture) are presented below.

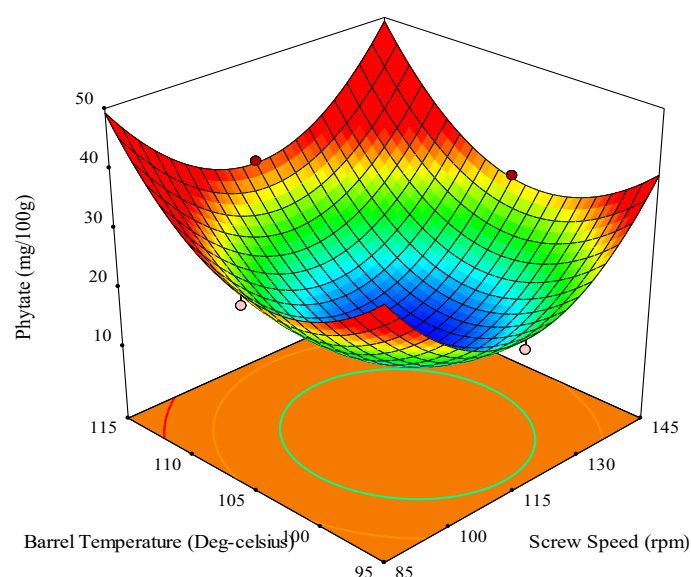


Fig. 1: Response surface plots showing the impact of barrel temperature and screw speed on phytate.

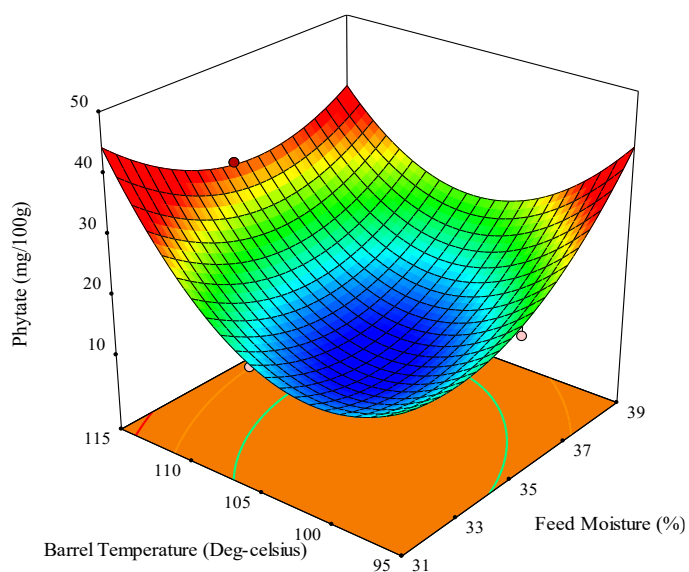


Fig. 2: Response surface plot showing the impact of barrel temperature and feed moisture on phytate

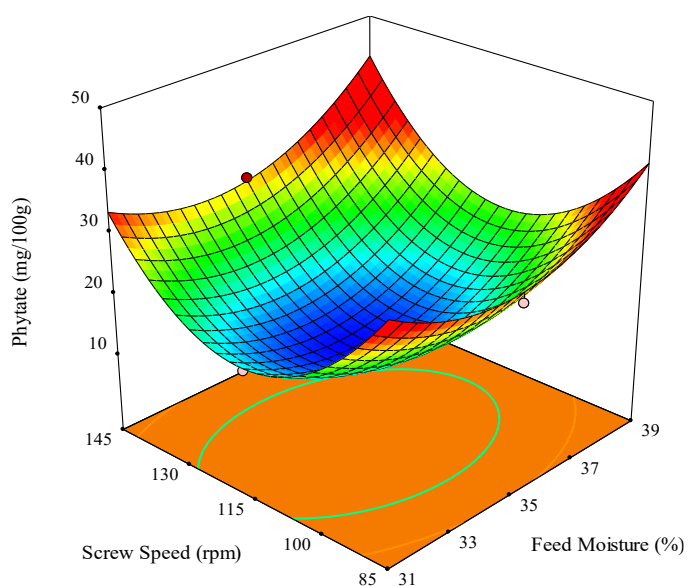


Fig. 3: Response surface plot showing the impact of screw speed and feed moisture on phytate

In Fig. 1, it was observed that increase in both the barrel temperature and screw speed of the extruder resulted in quadratic increase in phytate levels in the extrudates. This observation is in agreement with that of Arun kumar *et al.* (2018) and Umoh *et al.* (2021). In Fig 2, the contour and response surface plots for the effect of barrel temperature and feed moisture on phytate, indicated that increase in barrel temperature of the extruder led to quadratic increase in phytate content of the snacks. Also, increase in feed moisture resulted in quadratic increase in the phytate levels in the extruded snacks. This observation is in agreement with the earlier report by Arun kumar *et al.* (2018).

The Response surface plot for the impact of screw speed and feed moisture on phytate is presented in Fig 3. Increase in both the screw speed of the extruder and feed moisture resulted in increase in the phytate content of the snacks.

All the three extrusion process parameters (barrel temperature, screw speed and feed moisture) had significant effect ($p < 0.05$) on the phytates content of the extruded snacks (Table 2).

High temperature during extrusion can cause thermal degradation of phytates, breaking them down into less harmful forms.

Table 2: Analysis of variance for phytate (mg/100g) at 5% significance level

Source	Sum of Squares	df	Mean Square	F-value	p-value
Barrel Temp	403.723	3	134.574	41.747	0.0001
Screw Speed	402.859	3	134.286	41.658	0.0001
Feed Moisture	147.460	3	49.153	15.248	0.001
Error	29.012	11	3.224		
Total	9561.261	20			

The result of the “Test of between-subjects effect” of the extrusion process parameters on phytate (Table 3) showed that all the three process parameters and their interactions had significant effect ($p < 0.05$) on phytate, except $BT \times SS$, which showed non-significant effect ($p > 0.05$) on the phytate content of the extruded snacks.

Table 3: Tests of Between-subjects effects of extrusion process parameters on phytate

Source	Sum of Squares	df	Mean Square	F-value	Sig.
Corrected Model	854.613 ^a	14	61.044	3040.031	0.0001
Intercept	7008.950	1	7008.950	349051.298	0.0001
BT	403.723	3	134.574	6701.903	0.0001
SS	402.859	3	134.286	6687.564	0.0001
FM	147.460	3	49.153	2447.878	0.0001
$BT \times SS$	0.020	1	0.020	0.996	0.364
$BT \times FM$	24.012	1	24.012	1195.839	0.0001
$SS \times FM$	0.732	1	0.732	36.457	0.002
$BT \times SS \times FM$	4.147	1	4.147	206.534	0.0001
Error	0.100	5	0.020		
Total	9561.261	20			
Corrected Total	854.714	19			

Note: BT = Barrel temperature, SS = screw speed, FM = feed moisture

Impact of extrusion process parameters on tannin

The impact of extrusion process parameters on tannin are shown by the Response surface plots in Fig. 4 to Fig. 6.

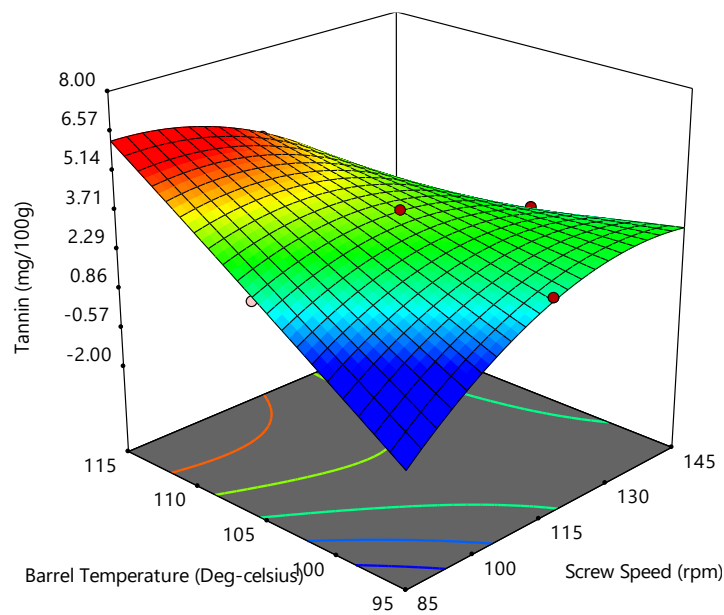


Fig. 4: Response surface plot showing the impact of barrel temperature and screw speed on tannin

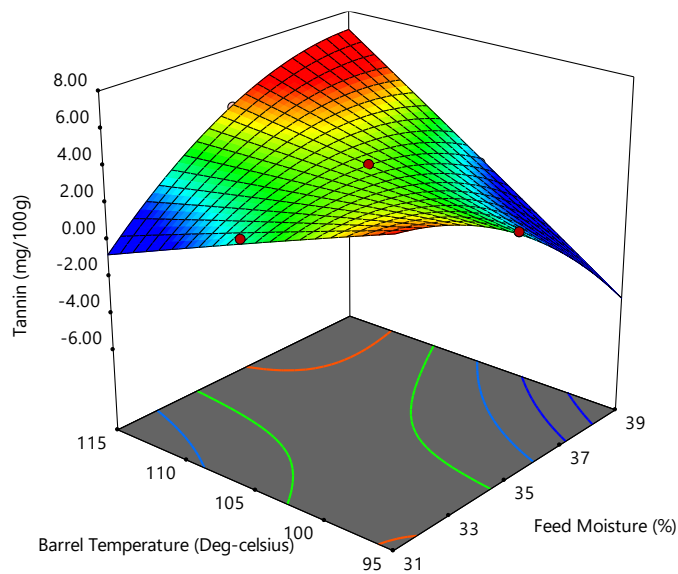


Fig. 5: Response surface plot showing the impact of barrel temperature and feed moisture on tannin

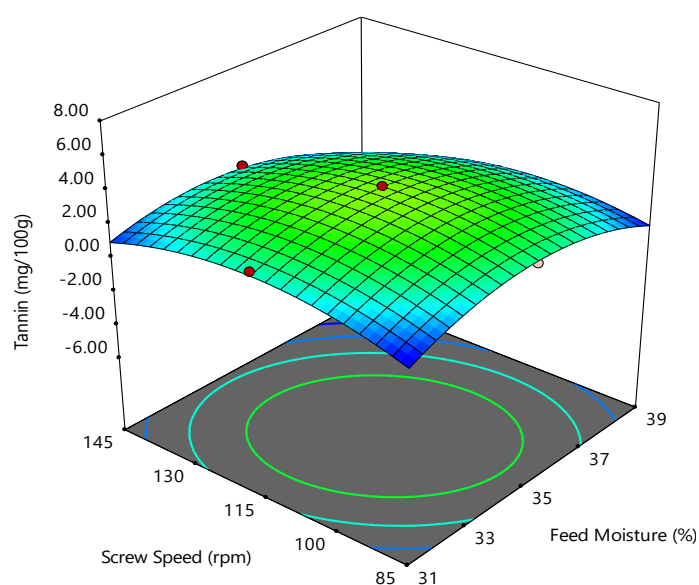


Fig. 6: Response surface plots showing the impact of Screw speed and feed moisture on tannin

The generated Response surface plot for the impact of barrel temperature and screw speed on tannin showed that increase in barrel temperature resulted in increased level of tannin, while increase in screw speed up to 115rpm increased the level of tannins initially. Increasing the screw speed beyond 115rpm resulted in decreased tannin contents of the extruded snacks (Fig. 4).

Increasing the barrel temperature and feed moisture did not result in corresponding increase in tannin contents of the extrudates (Fig. 5). This observation is in agreement with that of Arun kumar *et al.* (2018) and Umoh *et al.* (2021). Rather, the tannin level was observed to decrease as the feed moisture increased. Increase in barrel temperature showed little or no impact on the tannin content of the snacks.

From the Response surface plot showing the impact of screw speed and feed moisture on tannin (Fig 6), increase in both screw speed and feed moisture up to 115rpm and 35%, respectively, resulted in initial increase in tannin. Further increase in both the screw speed and feed moisture resulted in decreased tannin contents of the extruded snacks, which is in agreement with the earlier findings of Arun kumar *et al.* (2018), and Tabibloghmany *et al.* (2020).

The mechanical shearing force of the extruder, together with heat can breakdown tannin structures, resulting in the reduction of tannin level in the extrudate.

Table 4: Analysis of variance for tannin (mg/100g) at 5% significance level

Source	Sum of Squares	df	Mean Square	F-value	p-value
Barrel Temp	6.245	3	2.082	1.520	0.0275
Screw Speed	3.854	3	1.285	0.938	0.0462
Feed Moisture	6.019	3	2.006	1.465	0.0288
Error	12.327	11	1.370		
Total	215.860	20			

Analysis of variance (ANOVA) at 5% significance level showed that all the three extrusion process parameters (barrel temperature, screw speed and feed moisture) had significant effect ($p < 0.05$) on the tannin content of the extruded snacks (Table 4).

Table 5: Test of Between-subjects effects of extrusion process parameters on tannin

Source	Sum of Squares	df	Mean Square	F-value	Sig.
Corrected Model	27.668 ^a	14	1.976	10587.184	0.0001
Intercept	73.258	1	73.258	392453.028	0.0001
BT	6.245	3	2.082	11151.369	0.0001
SS	3.854	3	1.285	6882.440	0.0001
FM	6.019	3	2.006	10748.177	0.0001
BT×SS	2.989	1	2.989	16012.567	0.0001
BT×FM	9.138	1	9.138	48952.567	0.0001
SS×FM	.113	1	.113	604.353	0.0001
BT×SS×FM	.086	1	.086	461.317	0.0001
Error	.001	5	.000		
Total	215.860	20			
Corrected Total	27.669	19			

Note: BT = Barrel temperature, SS = screw speed, FM = feed moisture

Also, all the three extrusion process parameters: barrel temperature; screw speed; and feed moisture, and even their interactions showed significant effect ($p < 0.05$) on the tannin content of the snacks (Table 5).

Conclusions

This study has shown that the three extrusion process parameters; barrel temperature, screw speed, and feed moisture have significant impact on phytates and tannins content of the extruded snacks produced from aerial yam and soybean flour mixture. The interactions of the process parameters also have significant effect on phytates, except the interaction of barrel temperature and screw speed, which shows no significant impact on the phytates content of the extruded snacks.

Barrel temperature of 105 °C, screw speed of 115 rpm and feed moisture content of 35% produce extrudates with the lowest phytate content, while 100 °C barrel temperature; 100 rpm screw speed; 37% feed moisture content produce extrudates with the lowest tannin content.

It is possible to obtain expanded or ready-to-eat (RTE) products from aerial yam and soybean flour mixture through extrusion processing technology, that possess minimal levels of anti-nutrients/toxicity.

However, it is pertinent to recommend that further study should be carried out to investigate the impact of other extrusion process parameters especially, feed ratio, die diameter and residence time on the phytate and tannin content of the extrudate.

Conflict of Interest

The authors hereby declare that no conflicts of interest exist.

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