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Effect of extrusion process parameters on the overall acceptability of snacks produced from aerial yam and soybean flour mixture

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Abstract

This study was conducted to evaluate the effect of extrusion cooking parameters on the overall acceptability of the snacks produced from aerial yam and soybean flour mixture. Design Expert (version 11.0.1) was used in the experimental design, with a three-factor experimental setup at five levels each. The aerial yam and soybean flour mixture was formulated in the ratio of 1:3 and extruded using a laboratory-scale single-screw extruder. Response Surface Methodology was adopted in analyzing the effect of the independent variables on the dependent variable. Results showed that the overall acceptability scores ranged from 4.20 to 7.10. Response surface analysis revealed that an increase in barrel temperature, screw speed, and feed moisture resulted in an increase in overall acceptability. The overall acceptability of the snacks was significantly ($p < 0.05$) affected by barrel temperature and feed moisture, while the screw speed had no significant ($p > 0.05$) effect on overall acceptability. The interaction of the extrusion cooking parameters had a significant ($p < 0.05$) effect on the overall acceptability of the snacks. The high range of scores recorded for the snacks indicates that the aerial yam and soybean composite flour extruded snacks were generally well accepted by the panelists.

Keywords: Aerial yam flour, Extrusion cooking, Overall acceptability, Response surface, Single-screw extruder, Soybean flour, Snacks.

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Contents

Contribution of this paper to the literature
This paper presents an empirical study on the effect of extrusion process parameters (barrel temperature, screw speed, feed moisture) on the acceptability of snacks derived from aerial yam and soybean flour mixtures. The study is relevant to food science and agricultural processing, particularly in formulating/developing new extruded food products.

1. Introduction

Mixing, shearing, heating, pumping, shaping, and sizing are just a few of the unit operations that are uniquely combined in the efficient, continuous extrusion process. A high-temperature-short-time (HTST) process called extrusion cooking technology is being used more and more in the food industry to create new cereal-based snacks, such as breakfast cereals, baby foods, high-dietary-fiber foods, and modified starch from cereals [1-5].

Extrusion cooking, like other methods of heating food, can affect nutritional content in both positive and negative ways. Benefits include minimizing lipid oxidation and contaminating microbes, increasing soluble dietary fibers, gelatinizing starch, destroying anti-nutritional elements, and preserving the food's natural colors and flavors. Notwithstanding these benefits, the process's drawbacks include the loss of heat-labile vitamins and the occurrence of the Maillard reaction, which lowers the protein's nutritional value. For an extruded product to be nutritionally balanced, production factors must be controlled [5, 6].

Establishing a trustworthy dataset that can tell processors, vendors, and customers about their preferences depends heavily on the sensory qualities of food [7]. According to Umoh et al. [8], sensory qualities that are perceptible to the human senses, such as appearance, flavor, texture, scent, taste, and general acceptability of foods, are commonly used to evaluate the quality of food.

Kothakota et al. [9] investigated how the extrusion procedure affected the extrudates' overall acceptability. The extruded product, comprising broken rice flour, dehydrated pineapple waste pulp powder, and red grain powder, has an overall acceptance rating of 5.2 to 7.5, according to the investigations. The total acceptability value of the extrudates made from rice flour, red grain powder, and pineapple waste pulp powder was also found to rise quadratically as screw speed and barrel temperature increased, before falling linearly as these parameters decreased. As the feed moisture content rose, so did the total acceptance value, according to Kothakota et al. [9]. Upadhyay et al. [10] also observed similar findings. The barrel temperature and their interactions, screw speed, and feed moisture have been reported to have a significant effect on the overall acceptability of the extrudates [11].

A perennial, semi-wild food crop, the aerial yam (*Dioscorea bulbifera*) is a member of the *Dioscoreaceae* family of yams and grows on vines that ascend to poles and trees. After cooking, the hard back of the bulb is peeled off and consumed. Among its many common names are bitter yam, aerial yam, potato yam, air yam, and air potato. Originating in West Africa, *Dioscorea bulbifera* is a hardy climbing plant that is grown for its bulbils, which are eaten after being cooked like potatoes in oily water or roasted with a local sauce made of palm oil and additional spices [12].

Aerial tubers or bulbils are harvested by manual plucking from the vine. They are included in the roots and tubers, which are widely distributed throughout the tropics, with only a few in the temperate regions of the world [13].

There are roughly 50–60 species of yams (*Dioscorea spp.*) in Nigeria, but only 5–6 of them are significant food crops. Regrettably, some of these food crops, like *Dioscorea bulbifera*, have been underutilized for their nutritional value [12, 14, 15].

Soybeans are cultivated mainly for their seeds, which are used to produce oil and as food for humans and animals. In the food industry, soy food sources are probably the ones that are developing the fastest. Products range from traditional soy food assortments to protein trimmings, dairy and meat substitutes, and various Western and traditional food assortments that have advanced with soybean flour and its components [16, 17]

Soybeans are nutrient-dense and have a distinct chemical makeup on an average dry matter basis; they have the highest protein concentration of any legume, with roughly 40% protein and 20% oil [16]. Soybeans have high levels of both quantity and quality in their protein and oil components. Because soy oil has a high percentage of unsaturated fatty acids, including linolenic and linoleic acids, it is considered a healthy oil. Furthermore, soybeans contain a variety of trace chemicals called phytochemicals that have been demonstrated to have special health advantages. The greatest amount of protein obtained comes from soy meals because of their high protein content and high protein utilization [15, 16].

Additionally, the use of aerial yam (*Dioscorea bulbifera*) in conjunction with known food processing techniques, such as extrusion cooking, would introduce new food processing technology and food products, providing consumers with variety [15]. The potential application of aerial yam and soybean blending and/or extrusion cooking of the blend in food product formulation has not been sufficiently studied [18].

This study aims to evaluate the impact of extrusion cooking on the overall acceptability of snacks produced from aerial yam and soybean composite flour, using response surface analysis.

2. Materials and Methods

2.1. Procurement of Soybean Seeds and Aerial Yam Bulbs

The aerial yam bulbs and soybean seeds were acquired from the Uyo Urban Market in the Uyo Local Government Area of Akwa Ibom State, Nigeria.

2.2. Sample Preparation

In this study, flour samples were made at the Department of Agricultural Engineering's Crop Processing Laboratory at Akwa Ibom State University, Ikot Akpaden, Akwa Ibom State, Nigeria.

2.3. Preparation of Aerial Yam Flour

In accordance with the procedure outlined by Umoh et al. [12], aerial yam flour was made by cleaning and sorting the bulbs to remove any unwanted materials, then peeling them with a knife, washing them with clean water, and cutting them into chips that were 10 mm thick. The chips were then dried in a laboratory oven set at 60°C for 12 hours, after which they were milled using an Italian-made MF120 Hammer mill and sieved through a laboratory sieve with an aperture size of 600 µm. The flour that was produced was then sealed in a polyethylene bag for later use.

2.4. Preparation of Soybean Flour

The process outlined by Umoh and Ekanem [5] was used to prepare the soybean flour. After screening the seeds to remove splits, foreign materials, and damaged beans, they were cleaned and roll-boiled at 100°C for 30 minutes, oven-dried at 70°C for 12 hours, and then ground in a disc attrition mill. The milled full-fat soybean was then sieved using a 100-mesh standard sieve, and the flour was sealed in an airtight polyethylene bag at room temperature for later use.

2.5. Preparation of Flour Mixture Sample

Aerial yam and soybean flour mixture was made in a 1:3 ratio, which consists of 25% aerial yam flour and 75% soybean flour.

2.6. Preparation of the Extruded Snacks

A laboratory-scale single-screw extruder was used for this purpose. Two hundred grams (200 g) of the composite flour sample were precisely measured, preconditioned to the appropriate moisture levels, and left for approximately two minutes (2 min) to ensure uniform hydration of the raw material. The extruder was turned on, and the barrel temperatures and screw speeds were adjusted accordingly. The raw material was fed into the extruder through the hopper, and the extruded snacks were collected as they came out of the die, oven-dried, and then placed in airtight zip-lock polyethylene bags for further laboratory analysis [5].

2.7. Determination of Overall Acceptability

The overall acceptability (sensory quality attribute) of the aerial yam and soybean composite flour extruded snacks was determined using a 9-point Hedonic scale ranging from 1 (extremely dislike), 5 (neither like nor dislike), to 9 (extremely liked) [15]. A ten-member semi-trained panel evaluated the samples and accordingly scored the overall acceptability of the snacks.

2.8. Experimental Design/Statistical Analysis

The experimental design was created using Design Expert (version 11.0.1). Barrel temperature (BT), screw speed (SS), and feed moisture levels (FM) were chosen as the independent factors in a three-factor experiment that had five levels each. The impact of the independent variables or factors on the dependent variable (the response) was examined using Response Surface Methodology (RSM).

3. Results and Discussions

The results of the overall acceptability of snacks produced from aerial yam and soybean flour mixture are presented in Table 1.

Table 1. Overall acceptability of aerial yam and soybean composite flour snacks.

S/N	BT (°C)	SS (rpm)	FM (%)	Overall acceptability
1	105	115	31	5.51 ± 0.011
2	105	115	35	6.43 ± 0.031
3	105	115	35	6.39 ± 0.031
4	105	85	35	5.76 ± 0.111
5	100	130	33	6.42 ± 0.008
6	110	100	37	7.10 ± 0.006
7	100	100	37	6.00 ± 0.021
8	110	130	33	5.45 ± 0.008
9	105	115	35	6.45 ± 0.031
10	115	115	35	5.60 ± 0.001
11	95	115	35	4.89 ± 0.021
12	105	115	39	6.17 ± 0.043
13	105	115	35	6.47 ± 0.031
14	100	100	33	4.20 ± 0.002
15	110	130	37	5.13 ± 0.002
16	110	100	33	5.98 ± 0.021
17	105	145	35	4.99 ± 0.006
18	100	130	37	6.11 ± 0.011
19	105	115	35	6.41 ± 0.031
20	105	115	35	6.44 ± 0.031

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

Table 1 depicts the overall acceptability results of the snacks made with a composite flour of aerial yam and soybean. According to the recorded ratings, the snacks' overall acceptability ranged from 4.20 to 7.10. This range of values is lower than 7.22 to 8.33 for pulse-based snacks [11] but higher than 4.00 to 6.44 previously reported for sorghum-based extrudates supplemented with defatted soy meal flour by Tadesse et al. [19].

However, the range of values for overall acceptability for the extruded snacks made from aerial yam and soybean composite flour falls between 5.2 and 7.5 for rice flour-pineapple waste pulp powder-red grain powder extrudates those previously reported by Kothakota et al. [9] and those reported to be 5.94 to 7.02 for selected aerial yam cultivars and African breadfruit extruded snacks by Olatoye and Arueya [20].

The snacks produced at 100°C barrel temperature, 100 rpm screw speed, and 33% feed moisture had the lowest overall acceptability score of 4.20, while the snacks made at 110°C barrel temperature, 100 rpm screw speed, and 37% feed moisture yielded the highest score (7.10). The wide range of scores recorded for the snacks indicates that the extruded aerial yam and soybean composite flour was generally well accepted by the panelists.

3.1. Effect of Extrusion Process on Overall Acceptability

The response surface plot displayed in Figures 1 through 3 illustrates how the extrusion process factors (barrel temperature, screw speed, and feed moisture) affect the overall acceptability of the aerial yam and soybean composite flour extruded snacks.

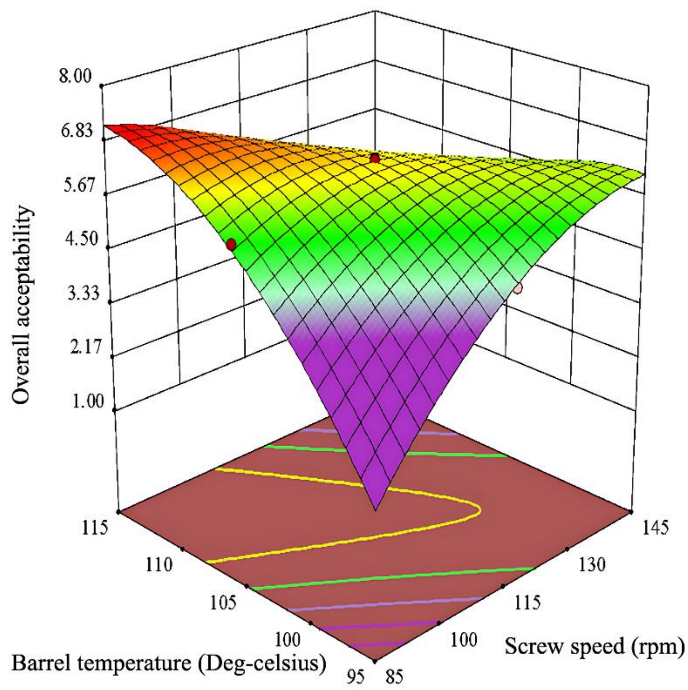

Figure 1. Response surface plot showing the impact of barrel temperature and screw speed on overall acceptability.

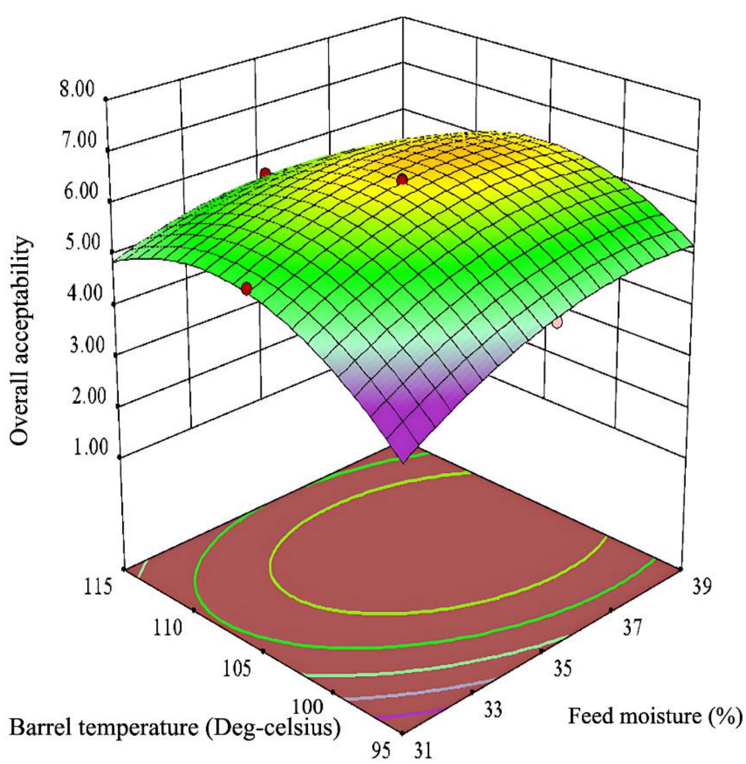

Figure 2. Response surface plot showing the impact of barrel temperature and feed moisture on overall acceptability.

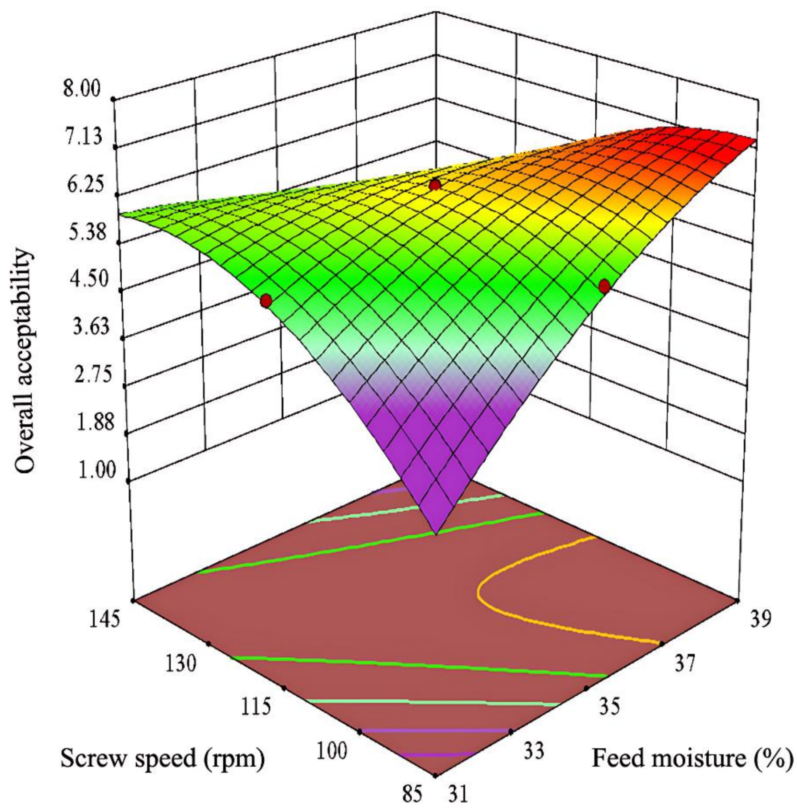

Figure 3. Response surface plot showing the impact of screw speed and feed moisture on overall acceptability.

The overall acceptance score of the snacks increased when both the barrel temperature and the extruder's screw speed increased, according to the response surface plot for the effects of both variables on the extrudates' overall acceptability in Figure1. The findings of Kothakota et al. [9] are comparable to this discovery.

The response surface plot for the impact of feed moisture and barrel temperature on the snacks' overall acceptability score is displayed in Figure 2. The overall acceptability increased when the extruder's barrel temperature was raised. In the meantime, the overall acceptability of the snacks increased in tandem with an increase in feed moisture. This claim supports the earlier report of Kothakota et al. [9].

Consistent with the findings of Kothakota et al. [9] the response surface plot on the effect of screw speed and feed moisture on overall acceptability in Figure 3 showed that an increase in both factors led to a corresponding increase in the overall acceptability of the snacks.

Table 2. Analysis of variance for overall acceptability at a 5% significance level.

Source	Sum of squares	df	Mean square	F-value	p-value
Barrel temp	2.472	3	0.824	1.609	0.0255
Screw speed	1.975	3	0.658	1.285	0.338
Feed moisture	1.398	3	0.466	0.910	0.0474
Error	4.611	9	0.512		
Total	704.359	20			
Corrected total	9.339	19			

Barrel temperature, screw speed, and feed moisture all had p-values of 0.0255, 0.338, and 0.0474, respectively, according to an analysis of variance (ANOVA) at the 5% significance level (Table 2). This suggests that screw speed had an insignificant ($p > 0.05$) impact on the snacks' overall acceptability, whereas barrel temperature and feed moisture had a significant ($p < 0.05$) impact. The overall acceptability of the snacks was shown to be significantly ($p < 0.05$) impacted by the extrusion process parameters and their interactions, according to the "test of between-subjects effects" of the parameters.

4. Conclusion

This study has demonstrated that the extrusion process parameters—barrel temperature, screw speed, and feed moisture—as well as how they interact, affect the snacks' quality features in both positive and negative ways. The overall acceptability of the aerial yam and soybean composite flour extruded snacks increased as a result of increases in barrel temperature, screw speed, and feed moisture. While screw speed had no discernible impact on overall acceptance, barrel temperature and feed moisture had a considerable impact on the snacks' overall appeal. The overall acceptance of the snacks was significantly impacted by the interactions of the extrusion parameters.

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