

Extrusion Cooking and its Impact on the Overall Acceptability of Snacks Produced from Aerial Yam and Soybean Composite Flour

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Abstract

This study evaluated the impact of extrusion cooking on the overall acceptability of snacks produced from aerial yam and soybean composite flour. Design Expert (version 11.0.1) was used in the experimental design, with a three factor experimental set up at five levels each. The aerial yam and soybean composite flour was formulated in the ratio of 1:3, and extruded using laboratory scale single-screw extruder. Twenty runs were carried out to produce twenty samples for the sensory test. Response Surface Methodology was adopted in analyzing the effect of the independent variables on the dependent factors. Results of sensory evaluation showed that the overall acceptability scores ranged from 4.20 to 7.10. The least score of 4.20 for overall acceptability was recorded for snacks produced at 100 °C barrel temperature, 100 rpm screw speed and 33% feed moisture, while the highest score (7.10) for overall acceptability was obtained from snacks produced at 110 °C barrel temperature, 100 rpm screw speed and 37% feed moisture. Response surface analysis revealed that increase in barrel temperature, screw speed and feed moisture resulted in an increase in the 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 the overall acceptability. The interaction of the extrusion cooking parameters had significant ($p < 0.05$) effect on the overall acceptability of the snacks. The acceptability scores ranged from 4.20 to 7.10, indicating moderate to high acceptance by sensory panelists.

Keywords: Extrusion Cooking, Snacks, Single-Screw Extruder, Aerial Yam Flour, Soybean Composite Flour, Sensory Evaluation.

Introduction

Extrusion cooking is preferred over other food processing techniques because it is a continuous, highly productive process that results in significant nutrient retention because of the high temperature and short time required. Extrusion also offers excellent opportunity to modify hydration properties and to improve paste stability and functionality of food matrices, by tailoring the processing conditions (Terefe *et al.*, 2022).

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 (Sebio and Chang, 2000; Pardeshi and Chattopadhyay, 2014; Pawar *et al.*, 2014; Navale *et al.*, 2015; Umoh and Ekanem, 2024).

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 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 (Nikmaram *et al.*, 2015; Umoh and Ekanem, 2024).

Establishing a trustworthy dataset that can tell processors, vendors, and customers about their preferences depends heavily on the sensory qualities of food (Edet *et al.*, 2024). According to Umoh *et al.* (2024), 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.* (2013) 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 of 5.2 to 7.5, per 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 (Kothakota *et al.*, 2013). Upadhyay *et al.* (2008) also observed similar findings.

The barrel temperature and their interactions, screw speed and feed moisture have been reported to have significant effect on the overall acceptability of the extrudate (Alemayehu *et al.*, 2019)

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 out 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 climber 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 (Umoh *et al.*, 2021).

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* (Ogbuagu, 2008; Umoh *et al.*, 2021; Umoh and Abasiokong, 2024).

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; Umoh and Iwe, 2023).

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 (Iwe, 2003). 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 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 usage (Iwe, 2003; Umoh and Abasiokong, 2024).

Problem Statement

Over the years, the production of extruded snacks or ready-to-eat (RTE) foods with desirable quality characteristics, using extrusion processing technology has been of great concern to food manufacturers or processors. This resulted in the need for appropriate selection of extrusion process variables regimes that could guarantee the production of acceptable extruded snacks.

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 (Umoh and Abasiokong, 2024). 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 (Umoh and Iwe, 2022).

This study is relevant to food science and agricultural processing, particularly in developing new extruded food products.

Research Gap

Extrusion cooking is still a complex process that has to be optimized for specific applications based on the nature of raw materials and desired final product, despite the increased utilization of the process. The need to select appropriate extrusion conditions that will produce wholesome ready-to-eat foods, and investigate the impact of these extrusion cooking conditions on the overall acceptability of the extruded snacks becomes absolutely

necessary. This current research attempts to bridge the gap and conceptualize an approach towards producing acceptable extruded snacks with desired sensory characteristics.

This study is aimed at evaluating the impact of extrusion cooking on the overall acceptability of snacks produced from aerial yam and soybean composite flour, using Response surface analysis.

Materials and Methods

Procurement 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

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

Preparation of Aerial Yam Flour

In accordance with the procedure outlined by Umoh *et al.* (2021), 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, then 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 polyethene bag for later use.

Preparation of Soybean Flour

The process outlined by Umoh and Ekanem (2024) 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 polyethene bag at room temperature for later use.

Preparation of Composite Flour Sample

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

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 guarantee

uniform hydration of the raw material. The extruder was turned on, and the barrel temperatures and screw speeds were adjusted appropriately. 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 (Fig. 1), and then placed in airtight zip-lock polyethylene bags for additional laboratory analysis (Umoh and Ekanem, 2024). Twenty (20) runs were carried out, according to the experimental design/layout.



Fig.1: Sample of Aerial yam and soybean composite flour extruded snacks

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) (Umoh and Abasiokong, 2024). A ten-man semi trained panel evaluated the twenty (20) samples, and accordingly, scored for the overall acceptability of the snacks.

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 (BT), screw speed (SS) and feed moisture levels (FM) as the independent factors was adopted. Response Surface

Methodology (RSM) was used to analyze the effects of the independent factors or variables on the dependent variable (the response). According to Nkesiga *et al.* (2021), Response Surface Methodology (RSM) is an important statistical method for experimental design, model construction, analysis of factors and optimal search for conditions. Response surface methodology has the benefit of concurrently varying independent variables to have a useful model of overall variations in response.

Analysis of Variance was carried out at 5% significance level, to evaluate the impact of the extrusion cooking conditions (the independent variables) on the overall acceptability of the extruded snacks (the response).

Results and Discussions

The results of the overall acceptability of snacks produced from aerial yam and soybean composite flour 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 displays 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 (Alemayehu *et al.*, 2019) but higher than 4.00 to 6.44 previously reported for sorghum-based extrudates supplemented with defatted soy meal flour by Tadesse *et al.* (2019).

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 previously reported by Kothakota *et al.* (2013); 5.94 to 7.02 for selected aerial yam cultivars and African breadfruit extruded snacks (Olatoye and Arueya, 2021).

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 high range of scores recorded for the snacks indicates that the extruded aerial yam and soybean composite flour was well accepted generally by the panelists.

Impacts of Extrusion Process on Overall Acceptability

The effects of the extrusion process parameters (barrel temperature, screw speed and feed moisture) on the overall acceptability of the aerial yam and soybean composite flour extruded snacks are shown by the Response surface plot presented in Fig. 2 to 4.

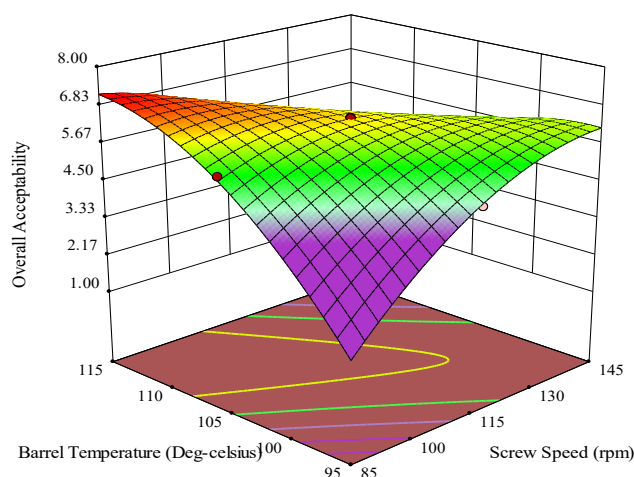


Fig. 2: Response surface plot showing the impact of Barrel temperature and Screw speed on Overall acceptability

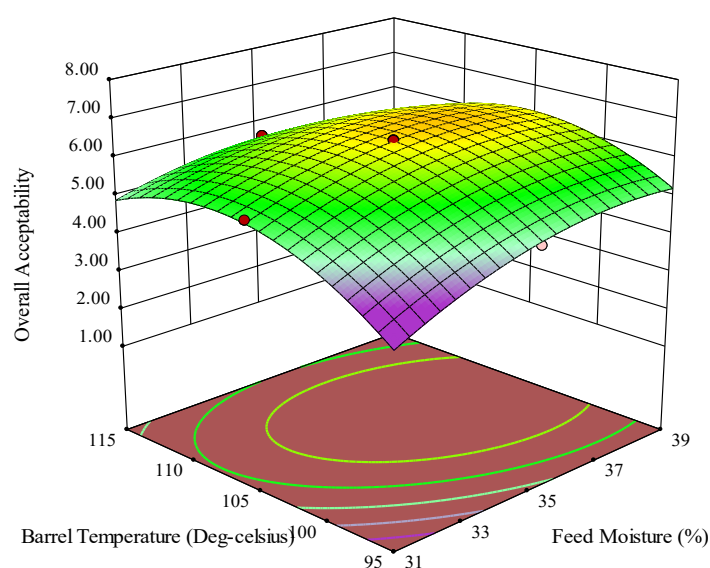


Fig. 3: Response surface plot showing the impact of Barrel temperature and Feed moisture on Overall acceptability

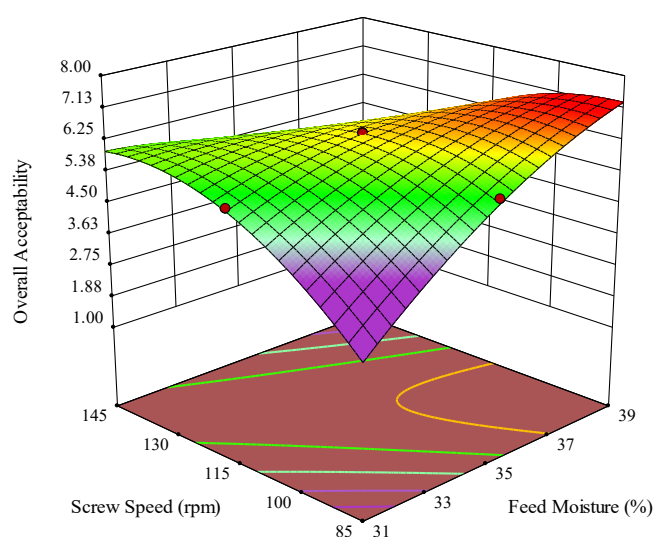


Fig. 4: Response surface plot showing the impact of Screw speed and Feed moisture on Overall acceptability

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 Fig. 2. The findings of Kothakota *et al.* (2013) 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 Fig. 3. 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 Kothakota *et al.* (2013)'s earlier report.

Consistent with the findings of Kothakota *et al.* (2013), the Response surface plot on the effect of screw speed and feed moisture on overall acceptability in Fig. 4 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 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			

Analysis of variance (ANOVA) at 5% significance level, for the effect of extrusion cooking parameters on the overall acceptability score of the aerial yam and soybean composite flour extruded snacks showed that barrel temperature, screw speed and feed moisture recorded a *p*-value of 0.0255, 0.338 and 0.0474 respectively (Table 2). This implies that barrel temperature and feed moisture significantly ($p < 0.05$) affected the overall acceptability of the snacks, while screw speed insignificantly ($p > 0.05$) affected the overall acceptability. The "Test of between-subjects effects" of the extrusion process parameters on the overall acceptability indicated that the extrusion process parameters and their interactions had significant ($p < 0.05$) effect on the overall acceptability of the snacks.

Conclusion

This study has demonstrated that extrusion parameters significantly influence the acceptability of aerial yam-soybean snacks, with barrel temperature and feed moisture playing dominant roles. 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.

Findings, from this study, suggest that it is practically possible for food manufacturers or processors to develop acceptable food products from aerial yam (one of the under-utilized food crops), and its composites, using extrusion cooking technology.

Recommendations

Based on the findings, the following actionable recommendations are highlighted for food scientists, manufacturers, or future research:

- Other necessary food ingredients/spices should be incorporated into the feed to further boost or improve the quality characteristics of the extruded snacks.
- One limitation of this study is the relatively small sensory panel size, which may limit generalizability. Future studies could involve larger, more diverse panels.
- It is pertinent to recommend that more research should be done in the area of investigating the impact of other extrusion process conditions or parameters, especially, feed ratio or percentage feed composition and residence time on the extrusion processing.
- Physical, chemical and nutritional properties, as well as engineering properties should be investigated. This is to ensure optimal exploration of the potential applications of aerial yam and its composites in food products development/extrusion technology
- In view of the difficulty encountered in sourcing for aerial yam bulbils in the course of carrying out this research, it is recommended that individuals, corporate organizations and government, at all levels should as a matter of exigency, venture into large scale cultivation of aerial yam. This is to ensure that aerial yam, as a food crop, does not go into extinction, and that the food crop is readily available and affordable for its potential food uses/applications.

Conflict of Interest

The authors hereby declare that no conflict of interests exists.

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