

Effects of Barrel Temperature, Screw Speed and Feed Moisture Content on the Organoleptic Properties of Aerial Yam-Soybean Flour Extruded Snacks

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Abstract

The effects of barrel temperature, screw speed and feed moisture content, as extrusion process parameters, on the organoleptic properties of aerial yam-soybean flour extruded snacks were investigated, using Response surface Analysis. The extruded snacks were produced using a Laboratory scale single-screw food extruder. Results of the determination of organoleptic properties of the extruded snacks showed that: texture; taste; colour; and aroma ranged from 4.38 to 6.02; 4.68 to 6.78; 4.58 to 6.97; and 4.45 to 7.00, respectively. Response surface Analysis indicated that barrel temperature and screw speed had significant effect ($p < 0.05$) on texture, while feed moisture had no significant effect ($p > 0.05$) on the texture of the snacks. All the extrusion parameters had significant effect ($p < 0.05$) on the taste of the snacks. Barrel temperature and feed moisture had significant effect ($p < 0.05$) on colour, while screw speed showed non-significant effect ($p > 0.05$) on the colour of the snacks. Barrel temperature had significant effect ($p < 0.05$) on aroma, while screw speed and feed moisture had no significant effect ($p > 0.05$) on the aroma of the snacks. The results obtained for the organoleptic properties of the snacks can attest to the fact that it is possible to obtain expanded or ready-to-eat (RTE) products from aerial yam-soybean flour blends by extrusion processing technology, that possess desirable organoleptic properties.

Keywords: Organoleptic Properties, Extruded Snacks, Aerial Yam, Response Surface, Barrel Temperature.

Introduction

Despite the increased use of extrusion process, it is still a complex process that has to be optimized for specific applications based on the nature of raw materials and desired final product. Even within a given extrusion process, small variations in processing conditions affect process variables as well as product quality (Desrumaux *et al.*, 1999). In addition to the usual benefits of these processes, extrusion offers the possibility of modifying the functional properties of food ingredients and/or texturizing them. The process has found numerous applications, including increasing numbers of ready-to-eat (RTE) cereals; salty and sweet snacks; co-extruded snacks; indirect expanded products; croutons for soups and salads; an expanding array of dry pet foods and fish foods; textured meat-like materials

from defatted high-protein flours; nutritious precooked food mixtures for infants feeding; and confectionery products (Umoh and Ukwo, 2024). Like other processes for heat treatment of food, extrusion cooking may have both beneficial and undesirable effects on nutritional value. Beneficial effects include gelatinization of starch, destruction of anti-nutritional factors, increased soluble dietary fibres, reducing lipid oxidation and contaminating microorganisms and retaining of natural colours and flavours of foods. Despite these advantages, occurrence of Maillard reaction that reduces the nutritional value of the protein and loss of heat-labile vitamins are the disadvantages of this process. Control of process parameters is essential to obtain a nutritionally balanced extruded product (Nikmaram *et al.*, 2015).

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

The effect of temperature, feed moisture and residence time on the aroma volatiles generated during extrusion of maize flour has been investigated by Bredie *et al.* (1998). The results showed that low temperature and high feed moisture contents favour the production of volatiles associated with lipid degradation. Increasing both the temperature and residence time, along with a reduction in moisture content, has been reported to increase the production of compounds derived from the Maillard reaction, whilst reducing the levels of those compounds associated with lipid degradation.

Using a trained sensory panel to study the aroma profile of extrudate produced from wheat flour and wheat starch fortified with mixtures of cysteine, glucose and xylose, a vocabulary of twenty-four (24) odour attributes has been developed (Bradie *et al.*, 1998). The results indicated that extrusion of the wheat flour alone resulted in an extrudate aroma characterized by the terms biscuity, cornflakes, sweet and cooked milk. Addition of cysteine and glucose resulted in major differences in aroma, with the cereal terms, popcorn, nutty/roasted and puffed wheat predominating.

The high-temperature-short-time (HTST) conditions in extrusion cooking have only minor effects on the natural colour and flavour of foods. However, available literature has it that, in many foods, the colour of the product is determined by the synthetic pigments added to the feed material as water- or oil-soluble powders, emulsions or lakes. Fading of colour due to product expansion, excessive heat or reactions with proteins, reducing sugars or metal ions may be a problem in some extruded foods.

Alemayehu *et al.* (2019) had reported that decreasing barrel temperature and feed moisture led to an increase in Appearance, while increasing the screw speed led to a corresponding increase in the appearance of the extrudate.

According to a report by Tadesse *et al.* (2019), extrudate prepared from 10% soy meal flour proportion and at process conditions of 165 °C barrel temperature and 15% feed moisture was the most preferred (6.68) in terms of colour, while extrudate prepared from 0% soy meal flour proportion (sorghum flour alone) at 150°C barrel temperature and 18% feed moisture was rated lowest (2.96) for colour. The relative higher colour score at high barrel temperature and lower feed moisture was however, attributed to Maillard and caramelization reactions, high expansion of extrudate and starch dextrinization (Tadesse *et al.*, 2019).

Tadesse *et al.* (2019) reported that the highest crispness score of 4.66 and 4.48 have been recorded at 0% soy meal flour, 165°C barrel temperature and 15% feed moisture content; and 10% soy meal flour, 165°C barrel temperature and 15% feed moisture content respectively. The report also has it that, extrudate produced from 20% soy meal flour proportion at 150°C and 18% feed moisture content had the least crispness score of 1.96. Increasing temperature progressively resulted in greater porosity of extrudates due to formation of large number of large sizes air pockets, resulting in an increase in crispness (Shi *et al.*, 2011; Garg and Singh, 2010).

Hardness of rice flour pulse powder, pineapple pomace extrudate has been reported to vary between 8.94 and 16.52N (Kathakota *et al.*, 2013). It has also been reported that hardness increases with increase in feed moisture content, which may be due to increased expansion with increase in moisture content. The increase in hardness with increase in temperature may be due to higher expansion at elevated temperature and with decreased melt viscosity, but it also increases the vapour pressure of water. This ultimately favours the growth of bubble which is the driving force for expansion that produces low density products and thus increases hardness of the extrudates. Also, hardness of the extrudates decreases with increase in screw speed of the extruder (Kothakota *et al.*, 2013; Ding *et al.*, 2006).

Tadesse *et al.* (2019) reported that soy meal flour proportion, barrel temperature and feed moisture have been found to have a significant influence on the hardness of the resulting extrudate samples. An increase in soy meal flour level, results in a significant increase in hardness of the extrudates. Also, a significant increase in hardness from 93.14 to 103.61N results from increase in feed moisture content from 15 to 18%. Further increase in feed moisture to 21% also results in a significant increase in hardness to 114.278N (Tadesse *et al.*, 2019).

Other studies have also revealed that the hardness of extrudate increases as the feed moisture content increases (Brncic *et al.*, 2006). When the moisture content of the composite flour is high enough, it may impede rapid gelatinization of starch granules in the extrudates. The incomplete gelatinization eventually leads to incomplete expansion of the extrudates and consequently increases the hardness of the extrudates. Tadesse *et al.* (2019) also reported that increasing the barrel temperature from 135 to 165 °C reduces the hardness of the extrudate significantly. This is due to the decrease in bulk density and/or increase in expansion caused by low feed moisture content or high barrel temperature of the extruder.

More so, it has been reported that an increase in feed moisture content causes an increase in the hardness of the extrudates, while increase in screw speed and barrel temperature results in a decrease in hardness of the extrudates (Peluola-Adeyemi and Idowu, 2014; Nkubana *et al.*, 2020). Increase in hardness of the extrudates with an increase feed moisture content, probably, is due to decrease in expansion which results in increase in moisture content. Increase in temperature causes decrease in hardness which may be due to reduction in melting viscosity favouring bubble growth, increasing expansion and lowering the density, thereby giving a softer extrudate. An increase in screw speed lowers the melting viscosity of the mix, resulting in a less dense and softer extrudates (Peluola-Adeyemi and Idowu, 2014).

Production of characteristics textures is one of the main features of extrusion technology. The extent of changes to starch determined by the operating conditions and feed materials produce the wide range of product textures that can be achieved. Texture of the extrudate decreases with increase in barrel temperature and feed moisture (Alemayehu *et al.*, 2019). Tadesse *et al.* (2019) observed that extrudate from 10% soy meal flour extruded at 165 °C barrel temperature and 15% feed moisture resulted in higher flavour score of 6.80, while 4.88 flavour score was for extrudate prepared from 0% soy meal flour (sorghum flour alone) at 150 °C barrel temperature and 18% feed moisture. The higher flavour score at higher temperature and lower feed moisture was attributed to the increase in volatile compounds and flavour intensity because of high degree of Maillard and caramelization reaction (Tadesse *et al.*, 2019).

Statement of the Problem

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 processors. This resulted in the need for appropriate selection of extrusion process variables regimes that could guarantee the production of acceptable extruded snacks with optimum organoleptic properties.

This study aims at investigating the effect of some of the extrusion process variables, like barrel temperature, screw speed and feed moisture content on the organoleptic properties of aerial yam-soybean extruded snacks, with emphasis on ascertaining the appropriate extrusion process variables that could produce wholesome ready-to-eat foods with desirable quality characteristics.

Research Gap

Extrusion 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 effects of these extrusion conditions on the quality characteristics of the extruded snacks becomes absolutely necessary. This

current research attempts to bridge the gap and conceptualize an approach towards producing extruded snacks with desirable sensory characteristics.

Aim/Objective of the Study

The aim of this study is to investigate the effects of barrel temperature, screw speed and feed moisture content, as extrusion process parameters, on the organoleptic properties of aerial yam-soybean flour extruded snacks, using Response surface analysis.

Materials and Methods

Collection of Soybean Seeds and Aerial Yam Bulbs

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

Sample Preparation

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

Preparation of Aerial Yam Flour

Aerial yam flour was prepared according to the method described by Umoh and Iwe (2022). 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 knife. The slices (chips) were then dried, using an 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 and Abasiokong (2024). 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 12 h, and milled in a disc attrition mill. The milled full-fat soybean was sieved using a 100-mesh standard sieve. The flour obtained (Plate 4) was then stored in air- tight polyethene bag at room temperature (about 22 °C) for further use.

Preparation of Sample Blends

The Aerial yam–Soybean flour blend was prepared in the ratio of 25:75, expressed in percentage as 25% aerial yam flour and 75% soybean flour.

Preparation of the Extruded Snacks

This was carried out using a single-screw laboratory scale extruder. Two hundred grams (200g) of the flour blend (25% aerial yam flour, 75% soybean flour) was accurately measured and preconditioned according to the desired moisture levels, allowed to stay for about two minutes (2min) in order to ensure uniform hydration of the raw material. The extruder was switched-on, and the barrel temperatures and the screw speeds of the extruder were set accordingly. The raw material was fed, through the hopper, into the extruder. The extruded snacks were collected as they exit through the die, oven-dried, and packaged in air tight zip lock polyethylene bags for further laboratory analysis (Umoh and Abasiokong, 2024).

Determination of Organoleptic Properties

Sensory quality attributes of the aerial yam-soybean flour blend extruded snacks were 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 samples, and accordingly, scored for texture, taste, colour and aroma 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 variables (the responses).

Results and Discussions

Organoleptic Properties

The results of the organoleptic properties (texture, taste, colour and aroma) of aerial yam-soybean flour blend extruded snacks are presented in Table 3.1.

Note: Values are mean $\pm$ standard deviation of triplicate determination.

Table 3.1: Organoleptic properties Aerial yam - Soybean flour blend Extruded Snacks.

S/N	BT (°C)	SS (rpm)	FM (%)	Texture	Taste	Colour	Aroma
1	105.00	115.00	31.00	5.72±0.021	5.66±0.003	6.11±0.003	6.30±0.034
2	105.00	115.00	35.00	5.91±0.042	6.73±0.004	6.85±0.001	6.95±0.111
3	105.00	115.00	35.00	5.96±0.042	6.78±0.004	6.81±0.001	6.90±0.111
4	105.00	85.00	35.00	4.79±0.003	5.13±0.003	5.15±0.001	6.00±0.001
5	100.00	130.00	33.00	5.79±0.124	6.35±0.011	6.97±0.033	6.00±0.421
6	110.00	100.00	37.00	5.55±0.004	5.86±0.005	6.86±0.011	7.00±0.011
7	100.00	100.00	37.00	5.88±0.014	6.67±0.122	6.44±0.022	6.30±0.004
8	110.00	130.00	33.00	5.86±0.002	5.98±0.002	6.05±0.002	5.90±0.006
9	105.00	115.00	35.00	5.90±0.042	6.72±0.004	6.86±0.001	6.83±0.111
10	115.00	115.00	35.00	4.98±0.007	4.90±0.002	5.71±0.044	5.00±0.021
11	95.00	115.00	35.00	5.57±0.011	5.11±0.002	4.58±0.002	4.45±0.011
12	105.00	115.00	39.00	5.89±0.044	6.58±0.005	6.60±0.004	6.20±0.001
13	105.00	115.00	35.00	5.95±0.042	6.74±0.004	6.88±0.001	6.89±0.111
14	100.00	100.00	33.00	5.47±0.004	4.88±0.001	5.02±0.022	4.76±0.006
15	110.00	130.00	37.00	6.02±0.001	5.21±0.003	5.77±0.231	5.01±0.001
16	110.00	100.00	33.00	4.38±0.004	5.19±0.011	5.14±0.011	6.01±0.312
17	105.00	145.00	35.00	4.89±0.002	4.68±0.006	4.99±0.009	5.02±0.006
18	100.00	130.00	37.00	5.10±0.004	6.00±0.003	5.36±0.034	5.85±0.001
19	105.00	115.00	35.00	5.93±0.042	6.70±0.004	6.83±0.001	6.93±0.111
20	105.00	115.00	35.00	5.99±0.042	6.72±0.004	6.84±0.001	6.91±0.111

Note: Values are mean ± standard deviation of triplicate determination.

BT=Barrel temperature, SS= Screw speed, FM= Feed moisture

Texture

The recorded scores for texture varied between 4.38 and 6.02 (Table 3.1). This range of values is higher than 1.96 and 4.64 for sorghum-based extruded product supplemented with defatted soy meal flour, as earlier reported by Tadesse *et al.* (2019), but lower than 7.22 to 8.44 earlier recorded for pulse-based snacks (Alemayehu *et al.*, 2019). The highest score for texture (6.02) was recorded for the snacks produced at 110 °C barrel temperature, 130 rpm screw speed and 37% feed moisture, while the lowest score of 4.38 was recorded for the snacks produced at 110 °C barrel temperature, 100 rpm screw speed and 33% feed moisture. The high range of values of recorded scores for texture shows that the snacks produced from aerial yam-soybean flour blends were moderately liked by the panelists.

Taste

For taste, the recorded scores ranged from 4.68 to 6.78 (Table 3.1.), which is relatively comparable to 5.3 to 7.6 for root and tuber composite flour noodles (Akonor *et al.*, 2017); and 5.44 to 6.58 for selected Aerial yam cultivar and African Breadfruit extruded snacks (Olatoye and Arueya, 2021). The highest score of 6.78 was obtained from snacks produced at 105 °C barrel temperature, 115 rpm screw speed and 35% feed moisture, while the lowest

score of 4.68 was obtained from snacks produced at 105 °C barrel temperature, 145 rpm screw speed and 35% feed moisture.

Colour

The recorded scores for colour of the snacks ranged from 4.58 to 6.97 (Table 3.1). This recorded range of values falls within the range of 2.96 to 6.68 for sorghum-based extruded product supplemented with defatted soy meal flour earlier reported by Tadesse *et al.* (2019), but lower than 6.89 to 8.22 for pulse-based snacks (Alemayehu *et al.*, 2019). The highest score of 6.97 for colour was obtained from the snacks produced at 100 °C barrel temperature, 130 rpm screw speed and 33% feed moisture, while the lowest score of 4.58 was recorded for snacks produced at 95 °C barrel temperature, 115 rpm screw speed and 35% feed moisture. The relative higher score at high barrel temperature and lower feed moisture is however attributed to non-enzymic browning as a result of Maillard and caramelization reactions, high expansion of extrudate and starch dextrinization (Tadesse *et al.*, 2019).

Aroma

The recorded scores for aroma are shown in Table 3.1. Results showed that the values ranged from 4.45 to 7.00. This range of values is higher than 4.88 and 6.80 for sorghum-based extruded product supplemented with defatted soy meal flour earlier reported by Tadesse *et al.* (2019). However, it is comparable to 5.3 and 7.4 for root and tuber composite flour noodles, earlier reported by Akonor *et al.* (2017). Snacks produced at 110 °C barrel temperature, 100 rpm screw speed and 37% feed moisture had the highest score of 7.00, while snacks produced at 95 °C barrel temperature, 115 rpm screw speed and 35% feed moisture had the least score of 4.45 for aroma.

Effect of Extrusion Process Parameters on Organoleptic Properties

Effects on Texture

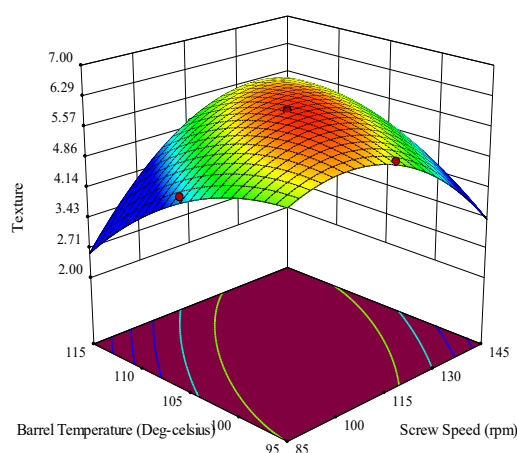


Figure 1: Response surface plot showing the effect of Barrel temperature and Screw Speed on Texture

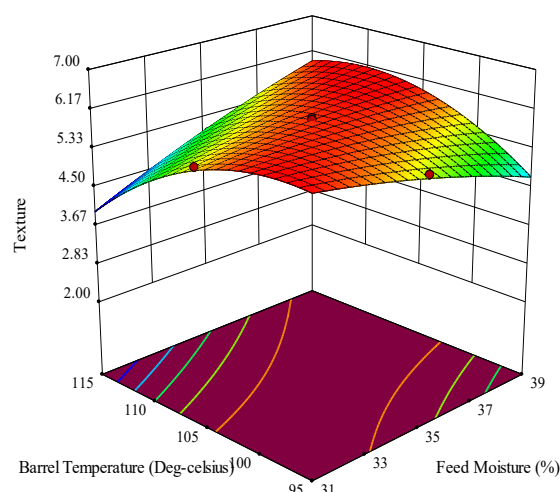


Figure 2: Response surface plot showing the effect of Barrel temperature and Feed moisture on Texture

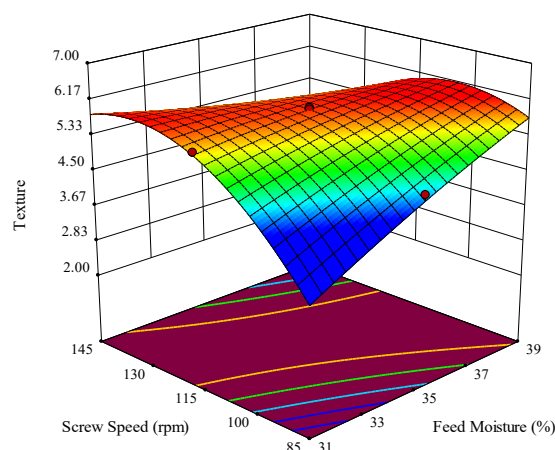


Figure 3: Response surface plot showing the effect of Screw speed and Feed moisture on Texture

Increase in barrel temperature and screw speed of the extruder resulted in an initial increase in texture, while further increase in the barrel temperature and screw speed resulted in a slight decrease in the texture of the snacks (Figure 1).

Increase in barrel temperature led to an initial increase in texture. Increasing further the barrel temperature decreased the texture score of the snacks, while increase in feed moisture resulted in a corresponding increase in the texture score of the snacks (Figure 2). This is in agreement with the earlier findings of Peluola-Adeyemi and Idowu (2014); Olusegun *et al.* (2016); Tadesse *et al.* (2019); Nkubana *et al.* (2020).

In Figure 3, the response surface plot showing the effect of screw speed and feed moisture on the texture of the snacks, indicated that increase in screw speed of the extruder resulted in an initial increase in texture score. Further increase in screw speed beyond 115 rpm led to a gradual decrease in texture, whereas increase in feed moisture resulted in a corresponding increase in the texture score of the snacks.

Increase in texture of the snacks with increase in feed moisture may be attributed to decreased expansion which resulted in increased moisture content. Increase in temperature causes decrease in texture which could be due to the reduction in melting viscosity, favouring bubble growth, increasing expansion and lowering the density, resulting in a softer extrudates (Peluola-Adeyemi and Idowu, 2014). Increasing the screw speed could have lowered the melting viscosity of the mix resulting in a less dense and softer extrudates. Analysis of variance indicates that only feed moisture showed non-significant ($p > 0.05$) effect on the texture, while barrel temperature and screw speed significantly ($p < 0.05$) affected the texture of the snacks.

Effect of Extrusion Process Parameters on Taste

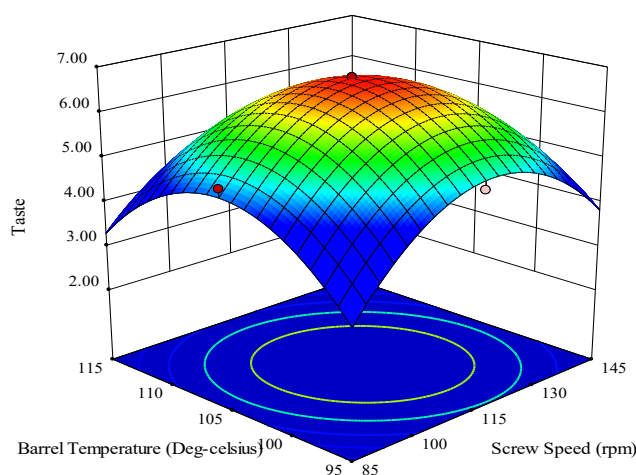


Figure 4: Response surface plot showing the effect of Barrel temperature and Screw speed on Taste

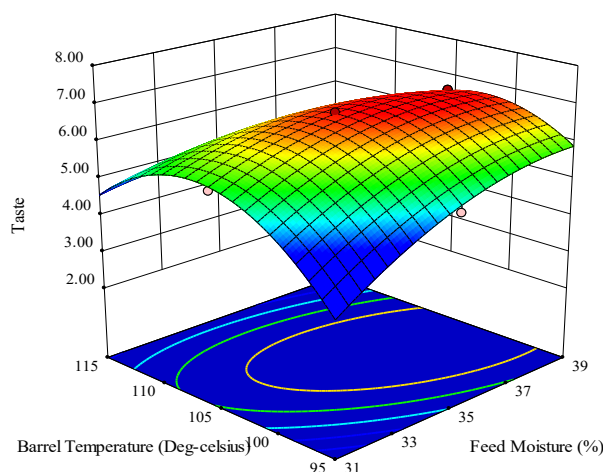


Figure 5: Response surface plot showing the effect of Barrel temperature and Feed moisture on Taste

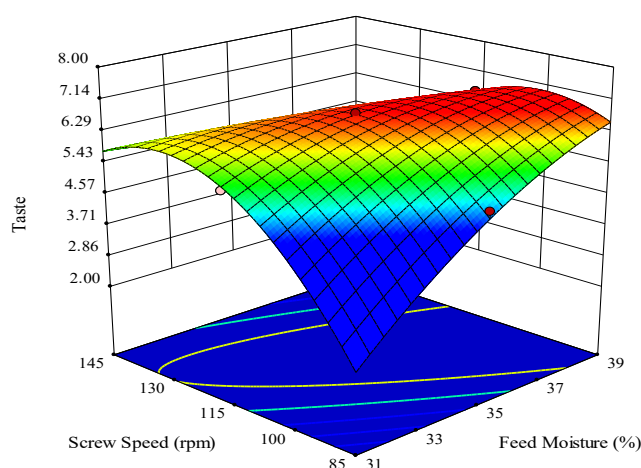


Figure 6: Response surface plot showing the effect of Screw speed and Feed moisture on Taste

Response surface plot showing the effect of barrel temperature and screw speed on the taste of the snacks indicated that increase in both the barrel temperature and screw speed of the extruder resulted in an initial increase in taste. Further increase in the barrel temperature and screw speed beyond 105 °C and 115 rpm respectively, resulted in a decrease in taste of the snacks (Figure 4).

Increase in barrel temperature resulted in an initial increase in taste, but further increase in barrel temperature above 105 °C resulted in decrease in the taste of the snacks. Increase in feed moisture led to a corresponding increase in the taste of the snacks (Figure 5).

Response surface plot for the effect of screw speed and feed moisture showed that increase in screw speed up to 115 rpm led to an initial increase in taste. Further increase in screw speed resulted in a slight decrease in the taste of the snacks. The taste was also observed to increase steadily with increase in feed moisture (Figure 6). Increase in taste as a result of increase in barrel temperature and screw speed may be attributed to the effect of Maillard reactions, caramelization of sugar, gelatinization of starch and dextrinization.

Analysis of variance showed that all the three extrusion process parameters; barrel temperature, screw speed and feed moisture had significant effect ($p < 0.05$) on the taste of the snacks.

Effect of Extrusion Process Parameters on Colour

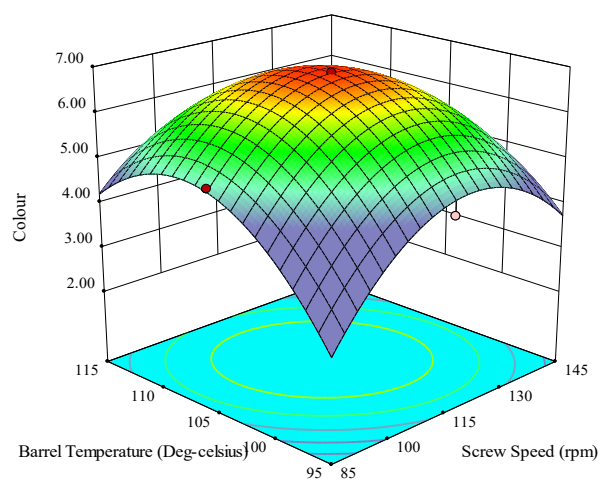


Figure 7: Response surface plot showing the effect of Barrel temperature and Screw speed on colour

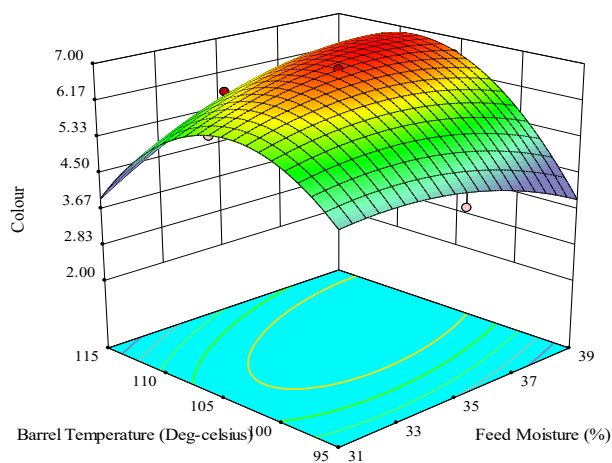


Figure 8: Response surface plot showing the effect of Barrel temperature and Feed Moisture on colour

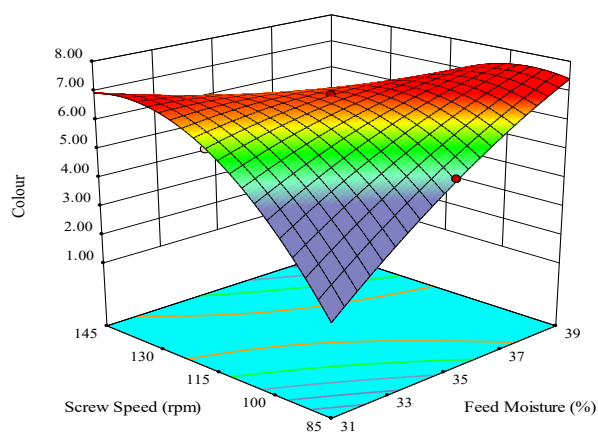


Figure 9: Response surface plot showing the effect of Screw speed and Feed moisture on Colour

The effects of extrusion process parameters; barrel temperature, screw speed and feed moisture on the colour of the extruded aerial yam-soybean flour blends are shown by the Response surface plots, as presented in Fig 4.84 to 4.86.

Response surface plot showing the effect of barrel temperature and screw speed on colour indicates that increase in both the barrel temperature and screw speed of the extruder resulted in an initial increase in colour score for the snacks (Figure 7). This observation agrees with the earlier report of Tadesse *et al.* (2019). Further increase in barrel temperature and screw speed of the extruder beyond 105 °C and 115 rpm, respectively, resulted in a decrease in the colour score of the extrudates.

Increasing the barrel temperature of the extruder initially increased the colour score of the extrudates. Increasing further, the barrel temperature beyond 105 °C resulted in a decline in the colour score of the extrudates. More so, increasing the feed moisture led to an increase in the colour score of the snacks (Figure 8).

In Figure 9, it was observed that increase in barrel temperature of the extruder resulted in an initial increase in colour. Further increase resulted in a slight decrease in colour score of the extrudates. Increase in feed moisture led to a corresponding increase in the colour of the snacks (Figure 9). Increase in colour, as a result of increase in temperature may be attributed to Maillard and caramelization reactions, high expansion of extrudates and starch dextrinization (Tadesse *et al.*, 2019).

Analysis of variance indicates that barrel temperature and feed moisture had significant ($p < 0.05$) effect on colour, while screw speed showed non-significant ($p > 0.05$) effect on the colour of the snacks.

Effect of Extrusion Process Parameters on Aroma

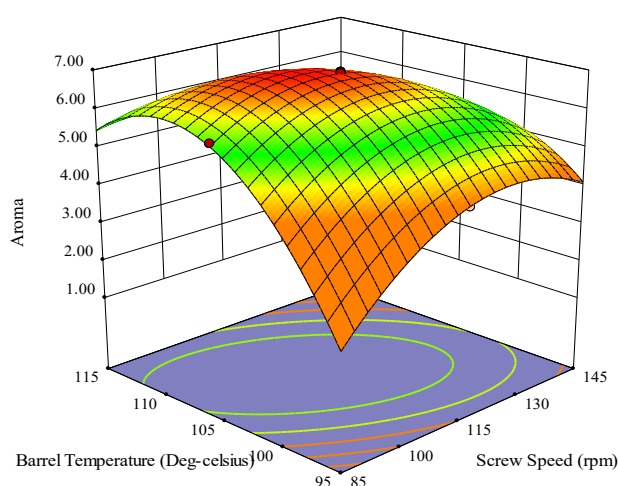


Figure 10: Response surface plot showing the effect of Barrel temperature and Screw speed on Aroma

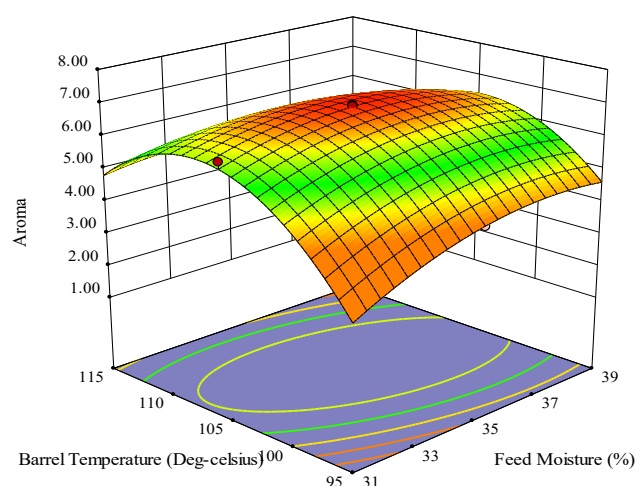


Figure 11: Response surface plot showing the effect of Barrel temperature and Feed moisture on Aroma

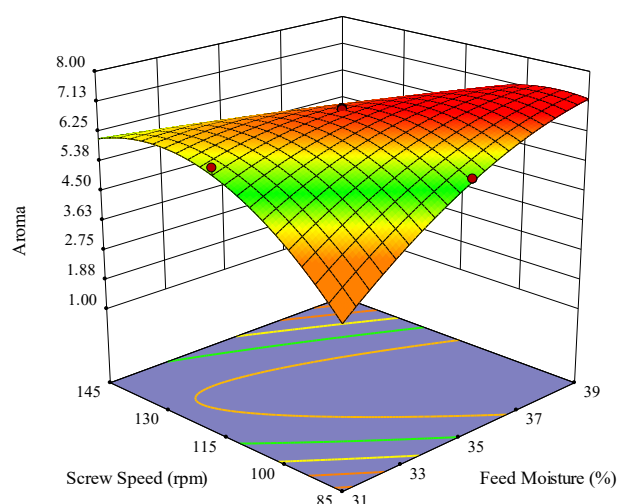


Figure 12: Response surface plot showing the effect of Screw speed and Feed moisture on Aroma

In Figure 10, the Response surface plot for the effect of barrel temperature and screw speed on aroma shows that increase in barrel temperature and screw speed resulted in an initial increase in aroma. Further increase in barrel temperature and screw speed beyond 105 °C and 115 rpm respectively, led to slight decrease in the aroma of the snacks. Similar observation had been reported by Tadesse *et al.* (2019). Maillard reactions occur during extrusion, particularly, at high barrel temperature, low moisture and high shear (Ajita and Jha, 2017). Increase in aroma as a result of increase in barrel temperature may be due to the increased volatile compounds and flavour intensity as a result of high degree of Maillard and caramelization reactions (Tadesse *et al.*, 2019).

Increase in barrel temperature of the extruder resulted in initial increase in aroma. Increasing the barrel temperature further led to a reduction in the aroma of the extrudates.

Increasing the feed moisture brought about a corresponding increase in the aroma of the extrudates (Figure 11).

In Figure 12, increasing the screw speed up to 115 rpm resulted in increase in the aroma. Increasing the screw speed further, beyond 115 rpm brought about decrease in aroma. It was also observed that increase in feed moisture resulted in a corresponding increase in the aroma of the snacks (Figure 12).

Analysis of variance showed that only barrel temperature significantly ($p < 0.05$) affected the aroma, while screw speed and feed moisture had no significant ($p > 0.05$) effect on the aroma of the snacks.

Conclusion

This study has shown that barrel temperature, screw speed, and feed moisture, as extrusion process parameters, have both positive and negative effects on the organoleptic properties (texture, taste, colour and aroma) of aerial yam-soybean flour blend extruded snacks. The organoleptic properties of the snacks were dependent on the extrusion process parameters (barrel temperature, screw speed and feed moisture content).

Barrel temperature and screw speed had significant effect on texture, while feed moisture had no significant effect on the texture of the snacks. All the extrusion parameters had significant effect on the taste of the snacks. Barrel temperature and feed moisture had significant effect on the colour, while screw speed showed non-significant effect on the colour. Barrel temperature had significant effect on the aroma, while screw speed and feed moisture had no significant effect on the aroma of the snacks. The results obtained for the organoleptic properties of the snacks can attest to the fact that it is possible to obtain expanded or ready-to-eat (RTE) products from aerial yam-soybean flour blends by extrusion processing technology, that possess desirable organoleptic properties.

Recommendations

- Extrusion study should be carried out, using a twin-screw extruder, for the feed material to undergo more shear, and produce products that might have different quality attributes.
- It is also recommended that other necessary food ingredients/spices be incorporated into the feed to further boost or improve the organoleptic properties of the aerial yam and soybean flour extruded snacks.
- Other physical, chemical and organoleptic properties apart from those examined in this particular study, 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 extrusion technology.

Conflicts of Interest

The Authors hereby declare that no conflicts of interest exist.

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