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PROCESS OPTIMIZATION OF SAUSAGE PRODUCED FROM RABBIT MEAT USING RESPONSE SURFACE METHODOLOGY

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Abstract: *This study investigated the process optimization of sausage produced from rabbits. Response surface methodology was used to investigate the effect of cooking time (45-60 minutes), frying temperature (170-190 °C) and frying time (45-60 minutes) resulting into seventeen experimental runs. The rabbit meat was pre-cooked and frying was carried out using an electric deep fryer with a temperature control of ±10 °C. Proximate composition (moisture content, total ash, crude fat, crude fibre, crude protein and total carbohydrate content) colour (lightness, redness and yellowness) and textural properties (hardness, springiness, adhesiveness, cohesiveness and chewiness) was carried out on the sausage from rabbit meat using standard laboratory procedures. The moisture content, total ash, crude fat, crude fibre, crude protein and total carbohydrate content ranged from 56.98-59.64%, 0.93-5.92%, 13.41-17.18%, 0.32-2.41%, 12.53-15.60% and 5.37-9.41%. Also, the range of values for lightness, redness and yellowness were: 31.08-45.33, 2.58-6.83 and 10.31-20.32 respectively. However, cooking time, frying temperature and frying time had no significant (p>0.05) effect on hardness, springiness, adhesiveness, cohesiveness and chewiness respectively. The study shows that proximate composition and colour properties of sausage produced from rabbit meat were significantly affected by the independent variables (cooking time, frying temperature and frying time). However, the optimum condition of leading to desirable proximate composition, colour and textural properties is 45minutes of cooking time, 180 °C of frying temperature and 9minutes of frying time.*

Keywords: *Sausage, Rabbit meat, Optimization*

1. Introduction

Rabbits, which belong to the family *Laporidae* in the order *Lagomorpha*, are compact mammals that can be found in various regions across the globe. They are commonly bred in both small-scale and large-scale (commercial) farming setups. Rabbits are distributed across multiple geographic locations worldwide. The family comprises eight distinct genera, with the domestic rabbit (*Oryctolaguscuniculus*) being one of them. [1]. Rabbit meat is highly valued for its exceptional nutritional properties [2, 3], boasting a protein content as high as 22.4% in the loin. Among the different cuts of rabbit carcass, the loin stands out as the leanest, containing a regular lipid content of 1.8 g/100 g of meat. Conversely, the foreleg is the fattiest cut, with a regular lipid content of 8.8 g/100 g of meat. The vitamin content in rabbit meats exhibits more significant variations compared to other nutrients, primarily influenced by the composition of the diet and the level of vitamin supplementation. Traditional consumers appreciate rabbit meat for its positive sensory characteristics, as it is tender, lean, and possesses a delicate flavor [2]. To enhance commercial acceptance, fresh rabbit meat should be made available in convenient retail packs that are ready to

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cook and serve, and competitive packaging systems should be employed.

Deep-fat frying involves cooking food by completely submerging it in edible oils and fats at high temperatures, resulting in rapid dehydration [1]. This cooking method combines heat and mass transfer, as moisture evaporates from the food material as vapor bubbles at the same time as absorbing oil [4]. The oil temperature typically ranges from 130 to 200 °C, with a general range of 170 to 190 °C [5]. One crucial aspect of deep frying is the amount of oil that remains in the fried product, which is incompatible with current health trends. In diets where fried foods are prominent, excessive fat consumption can contribute to various health issues, including obesity, coronary heart disease, and potentially certain types of cancer [6, 7]. These health risks, coupled with consumer preferences for lower-fat products, have created pressure on food processors to modify their processing conditions and reduce the amount of oil absorbed or entrained in their products [8].

Meat, in spite of the fact that being a part in a large portion of our food varieties as a significant wellspring of proteins, fundamental amino corrosive, B-complex nutrients, minerals and other bioactive mixtures are likewise connected with negative parts. These incorporate fats with elevated degrees of soaked unsaturated fats, cholesterol and caloric items which are normal in hamburgers and pork and are connected to weight, hypertension and a few cardiovascular illnesses [7]. In response to consumer expectations, the food processing industry is striving to introduce healthier products. This has led to the exploration of underutilized sources of protein/meat, which offer improved health benefits compared to conventional options. Rabbit meat is one such protein source with minimal fat content, and it is consumed worldwide. However, despite the potential of rabbit meat for industrial use, only a few meat processors have focused on developing processed rabbit meat products for consumers [9]. Currently available processed rabbit meat products, such as meat patties and sausages, are typically made from coarsely ground meat [10].

The market has not shown much interest in traditional coarse-ground sausages made from rabbit meat [10]. Consequently, the demand for rabbit meat remains low [2]. The establishment and accomplishment of innovative rabbit meat products present new challenges for meat processors, with new challenges due to the increasingly dynamic, complex, and differentiated needs of recent consumers and the importance of high-quality, convenient foods that are also well-off in sensory and organoleptic properties [11, 12].

Utilizing optimization methods can be highly valuable in identifying the optimal production conditions for sausages made from rabbit meat, with the objective of minimizing the amount of oil retained in the final product. Process parameter optimization can be achieved through various techniques, and one commonly employed and effective approach is Response Surface Methodology (RSM). RSM is a set of statistical and mathematical techniques that proves beneficial in the development, enhancement, and optimization of processes [13].

However, there has been very limited information on the use of response surface methodology to optimize deep fat frying conditions (cooking time, frying temperature and frying time) of sausage made from rabbit meat. Hence, the objective of this study is to utilize response surface methodology to optimize and examine the deep fat frying conditions and quality characteristics of sausages made from rabbit meat.

2. Materials and Methods

Materials

Mature rabbits were sourced from local farmers at Osiele, Abeokuta while seasoning (nutmeg, white pepper, powder garlic) vegetable oil and packaging materials used for the production of the sausage, were purchased from Kuto Open market in Abeokuta, Ogun State, Nigeria.

Sample preparation

The Cavani and Petracci, [14] method with minor modification was used. The matured rabbits were slaughtered and bleeded; it was then eviscerated to remove the offals. The rabbit meat obtained was washed with fresh water and precooked as described by Asmaa [15]. The filleted rabbit meat was manually ground using a mincer, and the raw materials were combined based on their leanness and fat content, along with the appropriate amount of salt. A small amount of water (10%) was added, and the mixture was manually mixed for approximately 3-7 minutes to allow the salt to dissolve and ensure proper homogenization of the other ingredients through continuous mixing.

Pre-cooking operation

The pre-cooking method was adapted from the procedure detailed by Asmaa [15]. The meat sample was cleaned and divided into three portions, and each portion was seasoned with the same percentage of seasoning. While the seasoned water was brought to a boil, each portion of meat was cooked for a different duration: 45 minutes, 52.5 minutes, and 60 minutes, respectively. After cooking, the meat portions were stuffed into bowls that were labeled with distinct names. Subsequently, the samples were allowed to cool before being ground using a meat grinder, following the previously described method, to produce the sausages.

Frying operation

Sobowale [16] method was used for the deep fat frying process. In accordance with the experimental runs listed in Table 1, the pre-cooked sausage samples were fried. Searing was finished utilizing an electric profound fryer with a temperature control of ±10 ºC. The hotdog tests were broiled at various temperatures at their relating time. Before analysis, the sausage samples were drained and allowed to cool after each frying.

Experimental design and process optimization

Response Surface Methodology (RSM) utilizing a Box-Behnken design was employed for the experimental design. The design included three independent variables, one of which was the cooking time (X_1), frying temperature (X_2) and frying time (X_3) as indicated in Table 1. The levels for each variable were determined through a series of preliminary experiments. These levels were then used to create a total of seventeen experimental runs, as shown in Table 2, using Design-Expert Version 6.0.8 (Stat-Ease Inc., Minneapolis, MN. USA)

Table 1

Independent Variables for the Experimental Design

		Range and Level		
Variables	Code	-1	0	+1
Cooking time (mins.)	X_1	45.0	52.5	60.0
Frying temperature (ºC)	X_2	170	180	190
Frying time (mins.)	X_3	6.0	7.5	9.0

X_1 = Cooking time (mins.); X_2 = Frying temperature (ºC); X_3 = Frying time (mins.).

Table 2
Experimental Design Showing Independent Variables using Response Surface Methodology

Cooking Time (Mins)	Frying Temperature (° C)	Frying Time (Mins)
45.00	180.0	6.00
45.00	170.0	7.50
60.00	170.0	7.50
52.50	180.0	7.50
45.00	190.0	7.50
60.00	180.0	6.00
60.00	190.0	7.50
52.50	180.0	7.50
52.50	190.0	9.00
52.50	180.0	7.50
52.50	170.0	6.00
52.50	180.0	7.50
52.50	190.0	6.00
52.50	170.0	9.00
52.50	180.0	7.50
45.00	180.0	9.00
60.00	180.0	9.00

Proximate composition
Moisture content, total ash, crude protein, crude fat, crude fibre was carried out using the procedure of AOAC, [17] while carbohydrate was calculated by difference method

Colour properties of sausage from rabbit meat
The method described by Feili [18] and Oke [4] was used. To measure the colour of sausage from rabbit meat, the Minolta chroma meter (CR-410, Japan) was utilized. The colour measurements were conducted based on the (CIE) L* a* b* scale. To calibrate the instrument, a zero calibration mask was placed over it, followed by using a white calibration plate. The sausages were then placed on a petri dish, and images of the samples were captured using the instrument. The color attributes, including lightness (L*), redness (a*), and yellowness (b*), were recorded from the captured images.

Textural properties of sausage from rabbit meat
The method described by Abdelghafor [19] was used. Textural properties of sausage from rabbit meat (hardness, springiness, adhesiveness, cohesiveness and chewiness) were determined using Texture Profiles Analysis (TPA). A Testometric Universal Testing Machine (M500-25KN, UK) was used for the TPA. The personal computer (PC) was set for Test works programming and a fitting test was chosen for the TPA investigation. Samples were place in between the two cell plates of the machine, and the load cell was gradually brought to a lower level, so it contacted the samples. Before the sample was compressed, parameters like height, diameter, speed, the percentage of compression, and the number of cycles (two) were entered. Then, the heap cell began gradually moving downwards, compacting the example with 5sec and stand by among first and second pressure cycles.

Statistical analysis
Data obtained were subjected to statistical analysis. Means, analysis of variance were determined using SPSS version 21.0 and the difference between the mean values were evaluated at $p<0.05$ using Duncan multiple range test. The optimization procedure was investigated using Design expert version (6.0.8) software which was used to predict the effects of the variation on sausage produced from rabbit meat. The statistical parameters, including the adjusted coefficients of determination (adjusted R^2), coefficient of determination (R^2) and regression (F value) were used to evaluate and select the best-fitting mathematical method [20]. The design was expressed by the polynomial regression equation to generate the model as shown as follows:

$Y_i = \beta_o + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 - \beta_{11}X_1^2 + \beta_{22}X_2 + \beta_{33}X_3^2 + \beta_{44}X_4^2 + \beta_{12}X_1X_2 + \beta_{13}X_1X_3 + \beta_{14}X_1X_4 + \beta_{23}X_2X_3 + \beta_{24}X_2X_4 + \beta_{34}X_3X_4$

Where Yi is the anticipated response and the linear, quadratic, and interaction coefficients respectively were β_o, β_i, and β_{ii}. The fittest model was used to select the appropriate polynomial equations for the design, such as linear, quadratic, or special cubic models.

3. Results and Discussion

Proximate composition of sausage produced from rabbit meat

Significant ($p<0.05$) variations were observed in the proximate composition of sausage from rabbit meat as shown in Table 3. The moisture content of fried foods is a critical parameter that not only affects their textural properties but also plays a significant role in determining their microbial stability [21, 22]. The moisture content of sausage produced from rabbit meat ranged from 56.98 to 59.64%. The regression table (4) indicated the model originated for moisture content had a coefficient of performance of 0.4918. The regression coefficient showed that the main effects, quadratic effects and the interaction effects of the cooking time, frying temperature and frying time were not significantly ($p>0.05$) influenced by the moisture content of the sausage produced from rabbit meat. However, the interaction effect of cooking time and frying temperature were affected negatively when frying time was held constant. This may be caused by varying moisture losses from the meat products [5]. Since low moisture would result in hardness of the sausage samples, which may affect its acceptance by customers, a drop in the moisture level of the sausage samples with an increase in frying temperature is desirable [23]. However, this confirms the report of Wambui [24].

The amount of total ash in a meal provides a general indicator of its estimated mineral content [25]. The total ash of sausage produced from rabbit meat ranged from 0.93 to 5.92%. According to Table 4's regression coefficient, the model created for total ash had a coefficient of 0.4532. From Table 4 the total ash content of the sausage from rabbit meat had no significant ($p>0.05$) effect on the main, quadratic or interaction effect of the independent variable. However, an increase in cooking time and frying temperature when frying time was held constant caused an increase in the total ash content, this might be due to the addition of some ingredients such as salt and spices which, throughout processing, contain varying concentrations of minerals like sodium and iron [26]. This indicates that rabbit sausage meat will likely be a good source of mineral elements. The total ash content obtained in this study were within the percentage obtained by Wambu [24] on rabbit sausages while the values are higher than those obtained for camel, beef and goat sausages by Alamin, [27].

According to several studies, eating too much fat is a major dietary factor in coronary heart disease and other linked disorders [7]. The crude fat content of sausage produced from rabbit meat ranged from 13.41 to 17.18%. The regression table indicated that the quadratic effect of frying temperature significantly ($p<0.05$) affects the crude fat content of the sausage from rabbit meat. When frying temperature was maintained constant, it was found that increasing frying temperature and frying duration resulted in an increase in the crude fat content. The rise in crude fat content may have been caused by the product's surface and pore size being changed by oil absorption during frying. However, Sobukola [28] reported that the length of time, temperature, and thickness of the food being fried are some of the elements that have the most effects on how much oil is absorbed. This observation was in agreement with the report of Adesala [29] and Sobukola [28].

Table 3

Proximate Composition of Sausage Produced from Rabbit Meat

Cooking Time (Mins)	Frying Temperature (°C)	Frying Time (Mins)	Moisture Content (%)	Total Ash (%)	Crude Fat (%)	Crude Fibre (%)	Crude Protein (%)	Carbohydrate Content (%)
45.00	180.0	6.00	58.63^{fg}	3.16^{d}	15.75^{b}	1.13^{e}	13.93^{e}	7.41^{gh}
45.00	170.0	7.50	57.94^{cd}	4.35^{fg}	16.19^{bcde}	1.65^{h}	14.19^{f}	5.70^{abcd}
60.00	170.0	7.50	58.19^{de}	3.48^{e}	16.41^{bcdefg}	1.22^{f}	15.04^{hi}	5.67^{abcd}
52.50	180.0	7.50	57.14^{a}	5.19^{h}	13.87^{a}	2.28^{m}	14.97^{hi}	6.56^{def}
45.00	190.0	7.50	58.92^{gh}	3.06^{d}	16.81^{cdefg}	1.02^{c}	12.90^{d}	7.30^{efg}
60.00	180.0	6.00	57.88^{cd}	4.44^{g}	16.02^{bc}	1.76^{i}	14.54^{g}	5.37^{ab}
60.00	190.0	7.50	58.84^{gh}	3.02^{d}	16.87^{defg}	1.07^{d}	12.86^{cd}	7.35^{gh}
52.50	180.0	7.50	57.56^{bc}	4.43^{g}	16.09^{bcd}	1.82^{j}	14.65^{g}	5.47^{abc}
52.50	190.0	9.00	59.64^{j}	0.93^{a}	17.18^{g}	0.32^{a}	12.53^{a}	9.41^{i}
52.50	180.0	7.50	59.32^{ij}	1.82^{b}	17.03^{fg}	0.71^{b}	12.68^{ab}	8.42^{h}
52.50	170.0	6.00	58.59^{fg}	4.11^{f}	16.29^{bcdef}	2.06^{l}	14.07^{ef}	4.89^{a}
52.50	180.0	7.50	57.06^{a}	5.54^{i}	13.62^{a}	2.39^{o}	15.29^{j}	6.12^{bcd}
52.50	190.0	6.00	58.34^{ef}	3.21^{de}	16.45^{bcdefg}	1.09^{de}	12.96^{d}	7.97^{gh}
52.50	170.0	9.00	59.03^{hi}	2.38^{c}	16.95^{efg}	1.28^{g}	12.74^{bc}	7.28^{efg}
52.50	180.0	7.50	57.29^{ab}	4.64^{g}	13.96^{a}	1.92^{k}	14.89^{h}	7.31^{efg}
45.00	180.0	9.00	56.98^{a}	5.92^{j}	13.41^{a}	2.41^{o}	15.60^{k}	5.70^{abcd}
60.00	180.0	9.00	57.11^{a}	5.38^{hi}	13.71^{a}	2.33^{n}	15.10^{i}	6.39^{cde}

Mean values with different superscripts within the same column are significantly different ($p<0.05$)

Fibre is useful for delivering roughage, which speeds up the digestive process [30, 31]. The coefficient of determination for the quadratic model created for the crude fiber content was 0.4544. This might be due to the fact that sausage is low fibre foods; hence such nutrient is not expected in higher amount in the product. This corroborates with the report of Naveen [32] for duck meat sausages. However, the amount of crude fibre in rabbit meat sausage obtained in this study could assist during the digestion process. Additionally, the FAO/WHO recommends that dietary products ingested have a maximum fiber level of 5%. The study's results on fibre content show that it is safe to consume.

Protein content is indicative of nutritional quality of the product [32]. The calculated regression coefficient revealed that the crude protein quadratic model has an R^2 of 0.614 for its coefficient of determination. The regression table demonstrates that the sausage made from rabbit meat's crude protein content was significantly affected ($p <0.05$) by the quadratic influence of frying temperature. It was shown that when frying time was maintained constant, increases in cooking time and frying temperature resulted in a drop in the protein content, but increases in cooking time and frying temperature resulted in a decrease in the protein value when frying temperature was held constant. This may have been caused by the product receiving an excessive amount of heat treatment during frying, which might have reduced the quantity of protein and destroyed certain amino acids [4]. According to the results of this investigation, the crude protein concentration decreased as frying temperature and duration increased [33].

The samples' carbohydrate content is not very high. The quadratic model created for the carbohydrate has an R^2 coefficient of 0.6486, according to the regression coefficient shown in Table 4. The main effect of frying temperature was significantly ($p<0.05$) affected as shown in Table 4. An increase in cooking time and frying temperature led to an increase in the carbohydrate when frying time was held constant while the increase in cooking time and frying time lead to an increase in carbohydrate when frying temperature was held constant. The dehydration that happens during the frying process, which results in moisture loss, may be the cause of the rise in carbohydrate content [34].

Table 4

Regression Coefficient of Proximate Composition of Sausage Produced from Rabbit Meat

Parameters	Moisture Content	Total Ash	Crude Fat	Crude Fibre	Crude Protein	Carbohydrate
β_o	57.67	4.32	14.91	1.82	14.50	6.78
A	-0.056	-0.021	0.11	0.021	0.12	-0.17
B	0.25	-0.51	0.18	-0.34	-0.60	1.06*
C	-0.085	-0.039	-0.41	0.038	0.059	0.39
A^2	-0.23	0.61	-0.17	0.068	0.48	-0.72
B^2	1.02	-1.46	1.83*	-0.65	-1.23*	0.45
C^2	0.20	0.21	-0.022	0.016	-0.19	0.16
AB	-0.082	0.21	-0.040	0.12	-0.22	0.020
AC	0.220	-0.46	7.500E-003	-0.18	-0.28	0.68
BC	0.220	-0.14	0.018	2.500E-003	0.22	-0.24
R^2	0.4918	0.4532	0.5268	0.4544	0.6141	0.6486
Adj–R Squared	-0.1616	-0.2499	-0.0815	-0.2471	0.1180	0.1967
F-value	0.75	0.64	0.87	0.65	1.24	1.44

**Significant at ($p<0.05$); β_0- Intercept, A- Main effect of cooking time, B- Main effect of frying temperature, C- Main effect of frying time, A^2-Quadratic effect of cooking time, B^2-Quadratic effect of frying temperature, C^2-Quadratic effect of frying time, AB- Interaction effect of cooking time and frying temperature, AC- Interaction effect of cooking time and frying time, BC- Interaction effect of frying temperature and frying time,, R^2- Coefficient of determination*

Colour properties of sausage produced from rabbit meat

One of the most crucial fried food quality criteria is colour, which also significantly affects customer acceptance of meat products at the moment of purchase [35]. Table 5 shows the colour properties of sausage made from rabbit meat. The lightness, redness, and yellowness of sausage made from rabbit meat differ significantly ($p<0.05$). The scale of lightness, redness, and yellowness values were 31.08 to 45.33, 2.58 to 6.83 and 10.31 to 20.32 respectively.

The degree of lightness plays a vital role in the frying sector as it is typically the primary factor assessed by consumers when gauging their acceptance of a product [36].

It was observed that at a constant frying temperature, while the cooking time and frying time increases, the lightness decreases. This implies that extra moisture is evaporated from rabbit meat sausage and this is an indication that the product resulted into a darker colour during processing and this could be attributed to Maillard browning reaction [22, 37]. The response surface plots for lightness on sausage from rabbit meat are shown in Figure 1. The redness and yellowness ranged from 2.58 to 6.83 and 10.31 to 20.32 respectively. The main, quadratic and interaction effect of cooking time, frying temperature and frying time had no significant (p>0.05) effect on the redness and yellowness of sausage produced from rabbit meat as shown in Table 6.

It was observed that at a constant frying temperature, while cooking time and frying time increases, the redness and yellowness increases and this shows a lower acceptability of sausage produced from rabbit meat and increase in browning of the products [34]. The graphical representations of the response surfaces for redness and yellowness on sausage from rabbit meat are shown in Figure 2 and 3

Table 5

Colour properties of sausage produced from rabbit meat

Cooking Time (Mins)	Frying Temperature (°C)	Frying Time (Mins)	Lightness (L*)	Redness (a*)	Yellowness (b*)
45.00	180.0	6.00	31.08^{a}	3.31^{c}	10.31^{b}
45.00	170.0	7.50	39.75^{de}	4.82^{gh}	13.90^{e}
60.00	170.0	7.50	40.40^{e}	6.73^{m}	19.40^{k}
52.50	180.0	7.50	38.40^{c}	6.72^{l}	13.07^{d}
45.00	190.0	7.50	35.80^{b}	4.75^{g}	10.27^{b}
60.00	180.0	6.00	39.38^{cde}	3.75^{e}	10.87^{c}
60.00	190.0	7.50	38.34^{c}	3.57^{d}	15.42^{g}
52.50	180.0	7.50	45.20^{h}	2.92^{b}	10.33^{b}
52.50	190.0	9.00	44.98^{h}	2.58^{a}	9.06^{a}
52.50	180.0	7.50	42.99^{fg}	5.61^{j}	18.12^{i}
52.50	170.0	6.00	44.87^{h}	5.94^{k}	20.32^{l}
52.50	180.0	7.50	44.13^{gh}	4.87^{gh}	17.13^{h}
52.50	190.0	6.00	42.30^{f}	4.86^{gh}	14.52^{f}
52.50	170.0	9.00	45.33^{h}	4.20^{f}	16.71^{h}
52.50	180.0	7.50	36.68^{cd}	4.92^{h}	15.68^{g}
45.00	180.0	9.00	39.29^{cde}	5.34^{i}	12.81^{d}
60.00	180.0	9.00	39.61^{cde}	18.73^{j}	18.73^{j}

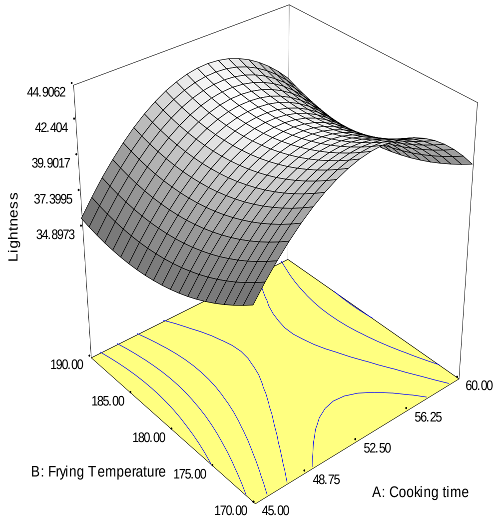
Mean values with different superscripts within the same column are significantly different (p<0.05)

Table 6

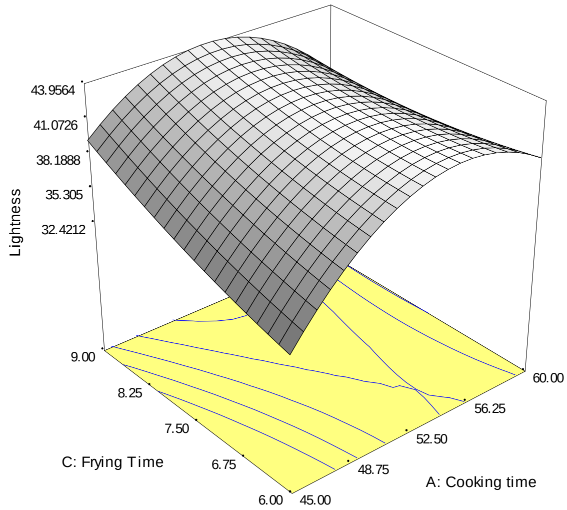
Regression coefficient of colour properties of sausage produced from rabbit meat

Parameters	Lightness	Redness	Yellowness
β_o	41.88	4.93	14.86
A	1.48	0.33	2.14
B	-1.12	-0.74	-2.63
C	1.45	0.14	0.16
A^2	-5.17*	0.23	-1.04
B^2	1.86	-0.19	0.93
C^2	0.63	-0.35	-0.64
AB	0.47	-0.77	-0.088
AC	-2.00	0.26	1.34
BC	0.55	-0.13	-0.46
R^2	0.7949	0.3454	0.5398
Adj–R Squared	0.5311	-0.4961	-0.0520
F-value	3.01	0.41	0.91

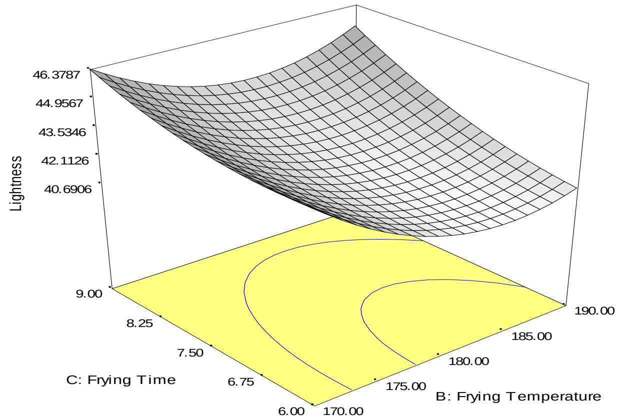
**Significant at (p<0.05); β_0- Intercept, A- Main effect of cooking time, B- Main effect of frying temperature, C- Main effect of frying time, A^2-Quadratic effect of cooking time, B^2-Quadratic effect of frying temperature, C^2-Quadratic effect of frying time, AB- Interaction effect of cooking time and frying temperature, AC- Interaction effect of cooking time and frying time, BC- Interaction effect of frying temperature and frying time,, R^2- Coefficient of determination*



(AB)



(AC)

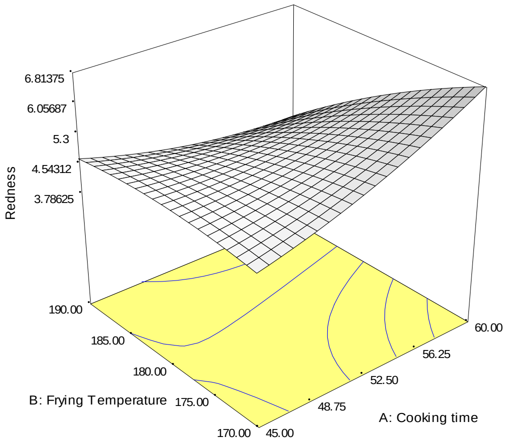


(BC)

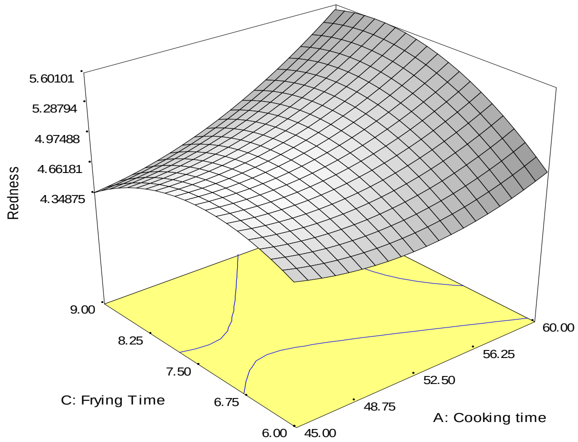
Fig.1: Response surface plots of lightness on the sausage produced from rabbit meat
AB- Interaction effect of cooking time and frying temperature, AC- Interaction effect of cooking time and frying time, BC- Interaction effect of frying temperature and frying time

Textural properties of sausage produced from rabbit meat

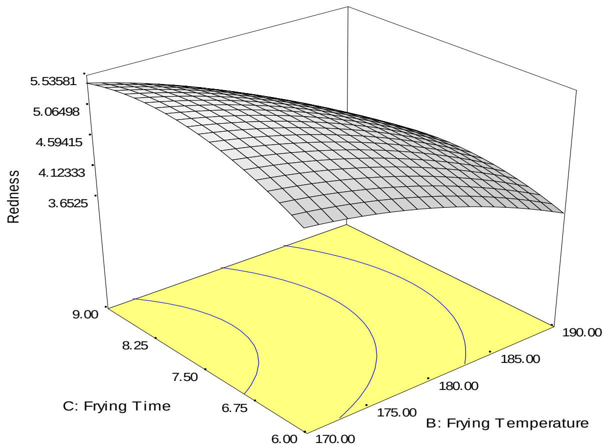
Any processed food product's perception and acceptance are greatly influenced by its textural attributes. The textural behavior of food items is directly influenced by processing conditions and constituent compositions [35, 36]. Significant ($p<0.05$) variations in the textural characteristics of sausage made from rabbit meat were noted. The hardness of sausage from rabbit meat ranged from 19.73 to 83.54N as shown in Table 7. It was noticed that raising the frying temperature and prolonging the frying time led to an elevation in hardness, which ultimately resulted in a harder texture. This phenomenon can be attributed to the significant loss of moisture during the frying process [36, 37]. However, according to Lin [38], a higher temperature was found to produce a fried product with a harder consistency.



(AB)



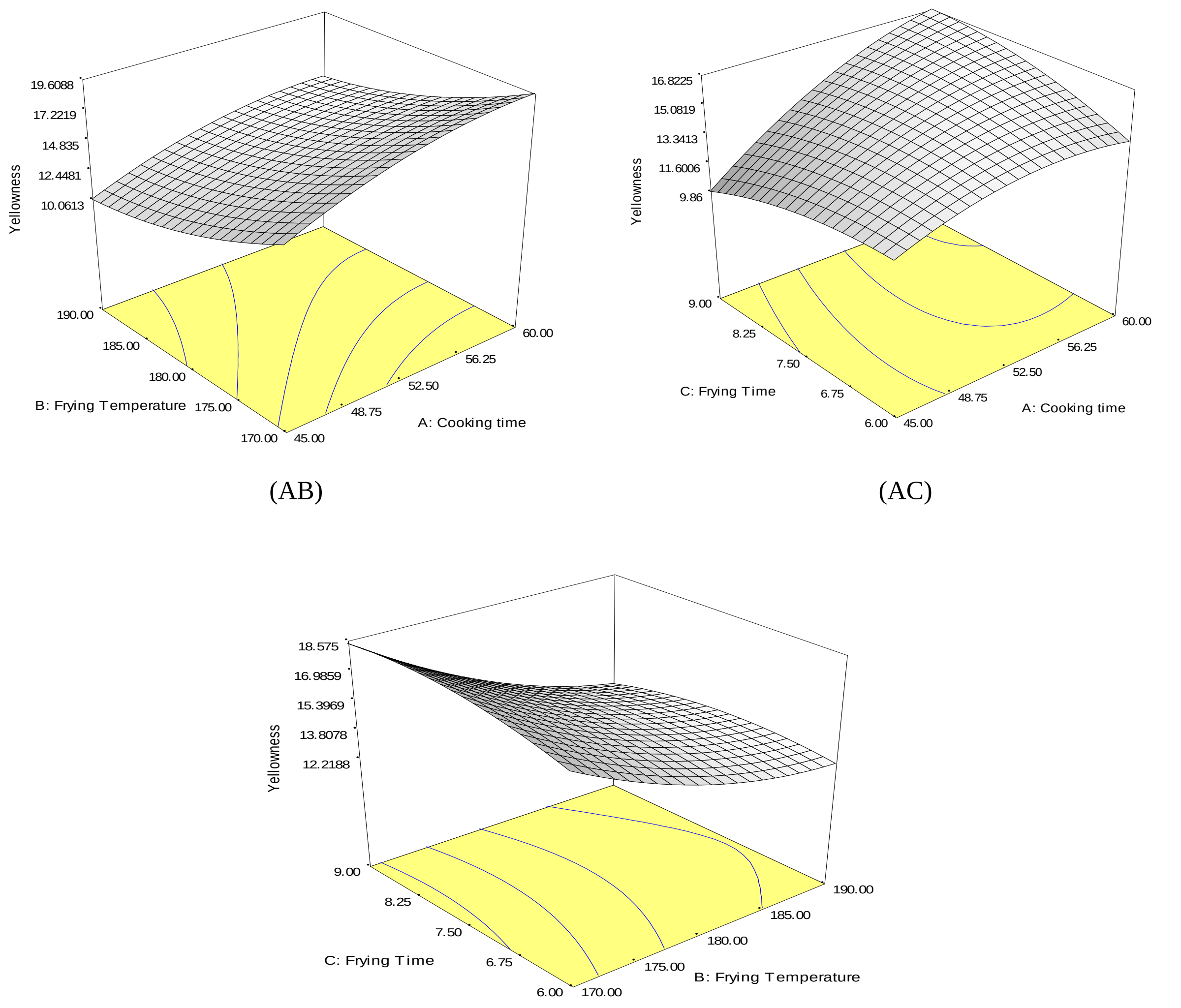
(AC)



(BC)

Fig.2: Response surface plots of redness on the sausage produced from rabbit meat
AB- Interaction effect of cooking time and frying temperature, AC- Interaction effect of cooking time and frying time, BC- Interaction effect of frying temperature and frying time

The springiness and cohesiveness of the sausage ranged from 0.44 to 0.93 and 0.328 to 0.548 respectively as shown in Table 7. From the regression table, it was observed that main, quadratic and the interaction effect of cooking time, frying temperature and frying time had no significant ($p>0.05$) effect on the springiness and cohesiveness of the sausage. The viscoelastic features of fried food products may be seen in their cohesion and springiness. The resistance to a matrix's internal structure being broken down is precisely measured by cohesiveness [39]. Increases in cooking time and frying temperature led to increased cohesiveness when the frying duration remained constant. This is explained by the greater moisture content seen in this specific investigation. However, Hsu and Yu [40] reported that increased cohesiveness and springiness may be connected to the effect of product moisture.



(AB) (AC)

(BC)

Fig.3: Response surface plots of yellowness on the sausage produced from rabbit meat
AB- Interaction effect of cooking time and frying temperature, AC- Interaction effect of cooking time and frying time, BC- Interaction effect of frying temperature and frying time

The effort necessary to resist the attraction forces between the surface of the food product and the surface of the object it comes into touch with can be used to define adhesiveness [41]. More surface features, according to Adhikari [42], are influenced by the interaction of adhesive and cohesive forces. The adhesiveness of the sausage ranged from -0.001 to 0.572 as shown in Table 7. From the regression table, increase in cooking time and frying temperature at a constant frying time, caused an increase in the adhesiveness of sausage produced from rabbit meat could be due to high moisture content observed in this study. The primary factor contributing to adhesiveness in low moisture foods is the interaction of water with solids [42].

Hardness, cohesiveness, and springiness are mathematically combined to form the attribute of chewiness, which refers to how long it takes to consistently chew a food sample to break it down into a consistency that can be ingested [35]. The chewiness ranged from 3.78 to 31.74N. The regression table showed that increasing cooking and frying temperatures while maintaining the same frying time resulted in a decrease in chewiness, and conversely, increasing cooking and frying temperatures while maintaining the same frying temperature resulted in a decrease in chewiness. This could be attributed to the amount of moisture lost during the frying process [43]

Table 7

Textural properties of sausage produced from rabbit meat

Cooking Time (Mins)	Frying Temperature (°C)	Frying Time (Mins)	Hardness (N)	Springiness	Adhesiveness	Cohesiveness	Chewiness (N)
45.00	180.0	6.00	26.24^{ab}	0.46^{ab}	-0.023^{b}	0.328^{a}	4.001^{a}
45.00	170.0	7.50	56.57^{bcde}	0.45^{ab}	0.000^{ab}	0.405^{bc}	10.79^{abc}
60.00	170.0	7.50	62.36^{cde}	0.59^{de}	-0.001^{ab}	0.340^{a}	12.37^{abc}
52.50	180.0	7.50	28.88^{ab}	0.55^{bcd}	-0.075^{ab}	0.427^{bcd}	6.85^{ab}
45.00	190.0	7.50	75.75^{de}	0.67^{ef}	0.000^{ab}	0.442^{bcde}	22.58^{d}
60.00	180.0	6.00	20.21^{a}	0.53^{abcd}	0.020^{ab}	0.398^{bc}	4.25^{a}
60.00	190.0	7.50	39.22^{abc}	0.44^{a}	0.015^{ab}	0.432^{bcde}	7.388^{ab}
52.50	180.0	7.50	83.54^{e}	0.70^{f}	0.062^{ab}	0.544^{gh}	31.74^{e}
52.50	190.0	9.00	49.83^{abcd}	0.57^{cd}	0.572^{b}	0.548^{gh}	15.82^{bcd}
52.50	180.0	7.50	44.35^{abcd}	0.73^{f}	-0.003^{ab}	0.577^{h}	18.60^{cd}
52.50	170.0	6.00	49.59^{abcd}	0.51^{abcd}	-0.008^{ab}	0.473^{def}	12.11^{abc}
52.50	180.0	7.50	38.16^{abc}	0.49^{abc}	-0.204^{a}	0.427^{bcd}	7.89^{ab}
52.50	190.0	6.00	75.95^{de}	0.69^{f}	0.000^{ab}	0.460^{cdef}	21.20^{d}
52.50	170.0	9.00	38.32^{abc}	0.50^{abcd}	-0.053^{ab}	0.492^{efg}	9.33^{ab}
52.50	180.0	7.50	19.73^{a}	0.49^{abc}	0.553^{b}	0.400^{b}	3.78^{a}
45.00	180.0	9.00	76.46^{de}	0.71^{f}	0.004^{ab}	0.460^{bcde}	24.69^{de}
60.00	180.0	9.00	63.52^{cde}	0.74^{fi}	-0.008^{ab}	0.520^{fgh}	24.54^{de}

Mean values with different superscripts within the same column are significantly different (p<0.05)

Table 8

Regression coefficient of textural properties of sausage produced from rabbit meat

Parameters	Hardness	Springiness	Adhesiveness	Cohesiveness	Chewiness
β_o	42.93	0.63	0.667	0.48	13.77
A	-6.21	1.250E-003	5.625E-003	6.875E-003	-1.69
B	4.24	0.040	0.081	0.022	2.80
C	7.02	0.041	0.066	0.045	4.10
A^2	4.36	-0.026	-0.096	-0.068	-0.37
B^2	11.18	-0.069	0.033	-1.750E-003	-0.12
C^2	-0.69	4.000E-003	0.028	0.020	0.97
AB	-10.58	0.093	4.000E-003	0.014	-4.19
AC	-1.73	-1.000E-002	-0.014	-2.500E-003	-0.10
BC	3.71	-0.028	0.15	0.017	-0.65
R^2	0.2937	0.3125	0.3538	0.5582	0.2556
Adj–R Squared	-0.6143	-0.5713	-0.4771	-0.0098	-0.7014
F-value	0.32	0.35	0.43	0.98	0.27

**Significant at (p<0.05); β_0- Intercept, A- Main effect of cooking time, B- Main effect of frying temperature, C- Main effect of frying time, A^2-Quadratic effect of cooking time, B^2-Quadratic effect of frying temperature, C^2-Quadratic effect of frying time, AB- Interaction effect of cooking time and frying temperature, AC- Interaction effect of cooking time and frying time, BC- Interaction effect of frying temperature and frying time,, R^2- Coefficient of determination*

4. Conclusion

The study shows that proximate, colour and textural properties of sausage produced from rabbit meat were significantly affected by the cooking time, frying temperature and frying time. However, the optimum condition leading to desirable proximate, colour and textural properties is 45 mins of cooking time, 180 °C of frying temperature and 9 mins of frying time. Further studies should be carried out on the sensory and microbial qualities of sausage produced from rabbit meat.

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6. Declaration of interest

No disagreement of interest was reported by the authors concerning this work.

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