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Modelling and optimization of the quality indices for the production of ingredient-mix based dried chicken product (chicken *kilishi*)

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A b s t r a c t: This study was designed to investigate, model and optimise the influence of cooking treatments (untreated, boiling and steaming), ingredient-mix infusion temperature (30°C, 40°C and 50°C) and infusion duration (5, 10 and 15 min) on the quality indices of *ingredient-mix based dried chicken product (chicken kilishi)* produced from chicken breast. *The quality indices (proximate composition and mineral contents) of the produced* chicken kilishi *were determined and analysed statistically using a hybrid Taguchi-Response Surface Methodology design. The production of* chicken kilishi *from untreated chicken breasts favours an increase in ash content (9.04%), crude protein content (50.28%) and zinc content (16.34 ppm). However, the* chicken kilishi *produced from the steaming treatment gives the highest fat content (14.02%), carbohydrate content (28.97%) and phosphorus content (12.07 ppm), while the kilishi subjected to the boiling treatment have increased iron content (18.24 ppm) but decreased moisture content (5.32%). The developed polynomial regression models for the quality indices were significant with R^2 and R^2_{adj} that ranges from 0.88 to 1.00, respectively. The optimum process conditions were attained when the chicken breasts were not treated and* ingredient-mix *infusion was conducted for 6 min at 41°C.*

Keywords: *chicken breast; chicken kilishi; modelling; optimization; quality indices.*

Introduction

Ingredient-mix based dried meat is also known as *kilishi*. This is one of the most popular dried meat snacks produced in developing countries. It is a traditional sun-dried Nigerian and Sahara African meat product obtained from defatted lean beef meat in conjunction with spices of plant origin (*Abubakar et al.,* 2011). It constitutes one of the daily delicacies in the region and is equivalent to pemmican and charqui consumed in South and Western America. *Kilishi* contains about 46% meat and 54% non-meat ingredients (*Iheagwara and Okonkwo,* 2016).

Chicken and other poultry products are consumed for their nutritional qualities and characteristics flavour in all countries of the world (Latshaw and Musharaf, 2007). Chicken is the most common meat type in the poultry category. Nevertheless, turkey and duck also are important poultry meats (FAO, 2017). In most developed countries of the world, chicken meat is usually cut into different types and forms ranging from the complete and whole carcass, cut-up parts like breast, drumstick, wings, whole legs, thighs and other cuts or is further processed into chicken meat products.

Chicken meat provides a high amount of minerals; selenium, phosphorus, zinc, iron, potassium, magnesium and vitamins of B complex as well as A, C and K (Fernandes and Rodrigues, 2008). Meat produced in the northern part of Nigeria is processed into numerous products, including snack products such as kilishi, tsire, dambunnama and balangu, with differing physiochemical, sensory attributes and shelf life (Muhammad et al., 2011). Seini et al. (2018) produced kilishi from dried meat and evaluated its effect on the nutritional and microbiological characteristics of the product. Seydou et al. (2019), also compare the physicochemical properties of two types of beef manufactured kilishi and a sliced grilled meat. Iheagwara et al. (2021) evaluated the textural, rheological and sensory properties of ingredient-mix dried beef (kilishi). However, literature is sparse on the use of chicken breast to produce ingredient-mix dried chicken snacks, also known as chicken kilishi.

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Chicken is an excellent source of protein providing about 10% of total daily needs (*Soares et al.,* 2017). A need to improve the nutrition attributes of chicken meat calls for producing value-added products with improved nutrition composition compared to that of chicken alone that would meet consumer needs. Food additives and ingredients rich in nutrients such as ginger, clove and condiments can be added and processing techniques used which could improve the nutritional composition. The development of an ingredient-mix dried chicken snack (*kilishi)* with high nutritional value would greatly limit consumer dependence on beef. The in-depth understanding of the optimum processing technique for producing a chicken *kilishi* would aid in the development of a functional product with a high nutritional composition that can improve the health of the consumers.

Modelling is a technique that is used in food engineering to predict the future of food processes and products with good accuracy depending on the purpose of the model (*Trystram*, 2012). *Perrot et al*. (2011) reported that food process modelling is an important technique to understand, design and control food processes. The use of Taguchi and Response Surface Methodology has been widely reported as a statistical techniques meant for experimental designs, developing models, evaluating the effects of variables on response and searching for the optimum conditions (*Hussein et al.,* 2019; *Sanusi and Akinoso,* 2021). *Sanusi et al.* (2020) reported that one of the advantages of Taguchi is that it could be used to minimise the number of experimental runs while Response Surface Methodology could be used to establish the linear, quadratic and interaction effects of independent variables on responses or dependent variables (*Sanusi and Akinoso*, 2020). The modelling and optimisation of the cooking treatment, ingredient-mix infusion temperature and duration (hereafter called time) using a hybrid of Taguchi-Response Surface Methodology approach would guide producers on how to predict the quality indices of the chicken *kilishi* snack and also help in establishing its optimum condition. Thus, considerable savings can be achieved in processing time, cost and establishing a laboratory system for monitoring product quality. Therefore, the objective of this study was to investigate, model and optimise the influence of cooking treatment, infusion temperature and infusion time on the quality indices of chicken *kilishi* using a hybrid Taguchi-Response Surface methodology technique.

Materials and Methods

Ingredient-mix preparation

The recipe used for the ingredient-mix formulation is presented in Table 1. Red pepper, chilli pepper, sweet pepper, whole ginger, garlic and onion were first blended using a blender (Model: SFP 2203, Japan) to form a liquor. Thereafter, granulated black pepper, clove, seasoning, locust bean con-

Table 1. Recipe for ingredient-mix preparation

Ingredient/spice common name	Scientific name	Mass (kg)
Groundnut paste	*Arachis hypogea*	28.50
Black pepper	*Piper guineense*	3.40
Red pepper	*Capsicum frutescens*	2.30
Sweet pepper	*Capsicum annum*	1.90
Chilli pepper	*Afromomum meleginata*	2.10
Cloves	*Eugenice caryophylc*eta	2.60
Whole ginger	*Zingiber officin*ale	3.80
Garlic	Al*lium sativum*	0.10
Palm oil	*Elaeis guineensis*	5.00
Vegetable oil	*Arachis hypogaea*	5.00
Onion	Al*lium cepa*	8.40
Locust bean condiment (Iru)	*Parkia biglobosa*	0.40
Salt	*Sodium chloride*	0.70
Seasoning	*Monosodium glutamate*	5.80
Water		30.00

diment (*Iru*), salt, palm oil and vegetable oil were added and further blended. To form a suitable ingredient-mix texture, a controlled amount of groundnut paste and water was finally added and blended.

Chicken breast preparation

Fresh *ZARTECH* chicken breasts of 13.5 kg were purchased from Shoprite mall, Ilorin, Nigeria. The chicken breasts were carefully cut and trimmed into a thin, flat sheet of 2 mm thickness. The weight of each flat chicken sheet was recorded.

Experimental design

A hybrid of Taguchi experimental design and response surface methodology was used to study the influence of processing technique on the quality indices of chicken kilishi snack using Minitab version 16, U.K. Table 2 shows the experimental outline for the interactions of the cooking methods, ingredient-mix infusion temperature and infusion time on chicken kilishi using Taguchi design, while Response Surface Methodology (RSM) was used to evaluate the effect of the cooking method, infusion temperature and infusion time on the quality indices of chicken kilishi as shown in Table 2. The quality indices were related to the cooking method, infusion temperature and time by the second-order polynomial model of RSM that has linear, quadratic and interaction relationships as shown in Equation 1.

$$Y = C + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_1 x_1^2 + + \beta_2 x_2^2 + \beta_3 x_3^2 + \beta_{12} x_{12} + \beta_{13} x_{13} \quad (1)$$

where C is the coefficient of the model constant, β_1, β_2 and β_3 are the linear terms, $\beta_1 x_1$, $\beta_2 x_2$ and $\beta_3 x_3$ are the quadratic terms, $\beta_{12} x_{12}$, $\beta_{13} x_{13}$ are the interaction terms, Y is the response for each model (proximate composition, phosphorous, zinc and iron), and x_1, x_2 and x_3 are cooking method, infusion temperature and infusion time, respectively. Analysis of variance (ANOVA) was used to find the interactions between the processing conditions and responses (proximate composition and phosphorous, zinc and iron content), and the p-values at 95% confidence level and Fischer-values (F-value) were determined. The fitness of the models for the responses was determined by the coefficient of determination, R^2 and R^2_{adj}.

Production of chicken kilishi from chicken breast

The flow chart for the production of chicken *kilishi* is presented in Figure 1. The thin, flat 2 mm thick chicken breasts were weighed into 500 g amounts in three separate lots. The first lot was spread on red trays without cooking treatment. The second lot was boiled for 5 min in a 100°C water bath (Model 10–101, Dae Han Co, Korea), while the third lot was steamed for 10 min in a preheated convective oven at 120°C. The three lots (untreated, boiled and steamed chicken breast meat) were dried in a cabinet oven (Model AMP-9P, China) at 60ºC for 10 h. The drying was accomplished by regular turning over of the chicken breast sheet every 1 h to support even drying. The chicken breast sheets were removed from the oven and weighed. The dried pieces of chicken meat were then steeped in the prepared ingredient-mix for 5 min, 10 min and 15 min at an ingredient-mix temperature of 30ºC, 40ºC and 50ºC using the design in Table 1. The steeped chicken breasts were further dried in the cabinet oven (Model AMP-9P, China) for 5 h to heat-seal the ingredients on the products (*Kilishi*). The chicken kilishi samples were allowed to cool naturally on the

Table 2. Experimental design using Taguchi design

Cooking treatment	Infusion time (min)	Infusion temperature (°C)
Untreated	5	30
Untreated	10	40
Untreated	15	50
Boiling	5	40
Boiling	10	50
Boiling	15	30
Steaming	5	50
Steaming	10	30
Steaming	15	40

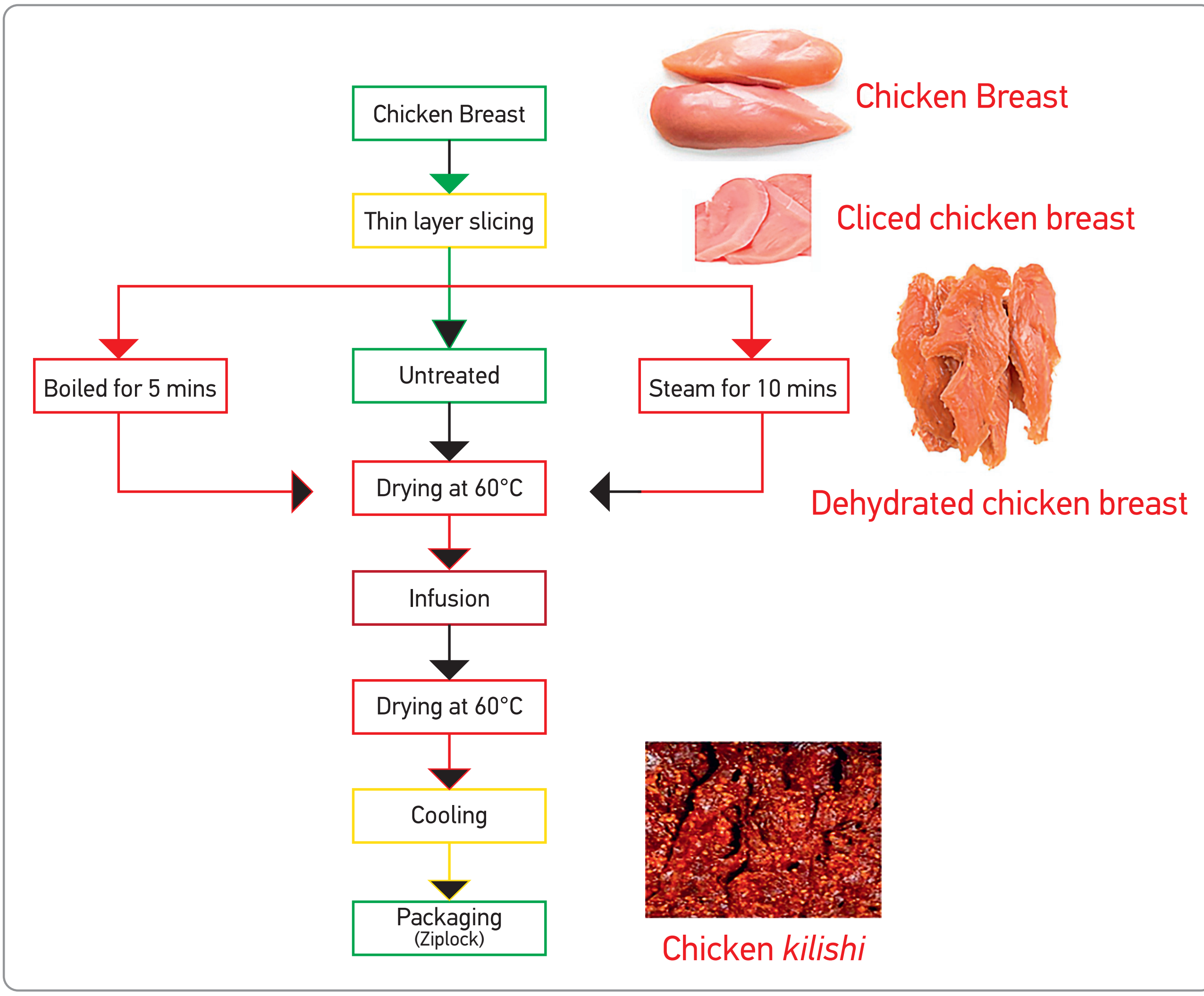

Figure 1. Flow chart for chicken *kilishi* production

trays, then were packed in Ziploc storage bags and stored until they were needed for analysis and sensory evaluation.

Quality indices

The proximate composition of the chicken *kilishi* samples was analysed using the *AOAC*, (2000) methods. For moisture content, method 925.09 was used, crude fat (Method 969.24), protein (Method 950.48, Nx6.25), and ash content (Method 923.03). The crude fibre was estimated according to *ISO* 5498:1981. The chicken *kilishi* was crumbled, mixed uniformly and a portion of the mixed material was taken to represent the whole *kilishi*. The analysis was carried out in triplicate. Phosphorous (P), zinc (Zn) and iron (Fe) contents in the samples were determined by Flame Atomic Absorption Spectrophotometer (VARIAN model AA240FS, United States) (*AOAC,* 2010).

Optimisation of the processing conditions

The second-order polynomial regression model was used to develop predictive model equations for the proximate composition and mineral content of the chicken *kilishi*. The cooking method, infusion temperature and infusion time were optimised using the desirability approach to maximise the crude protein content and minimise the moisture content. The Derringer and Suich methodology was used for the optimisation of the protein content and moisture content and was transformed into a desirability function. For perfect optimisation, the desirability values of the moisture content and crude protein content must be close to one (1). The second-order predictive models for moisture content and protein content were obtained, and the desirability function was calculated based upon the characteristics of using the following Equations 2 and 3 (*Sanusi and Akinoso,* 2020). Equation 2 and 3 were used for maximising the protein content and for minimising the moisture content, respectively.

$$d(y_i) = \begin{pmatrix} 0 & if\ y_i \le A_i \\ \left(\frac{y_i - A_i}{C_i - A_I}\right)^s & if\ A_i \le y_i\ \le C_i \\ 1 & if\ y_i \ge C_1 \end{pmatrix} \quad (2)$$

$$d(y_i) = \begin{pmatrix} 0 & if\ y_i \le A_i \\ \left(\frac{y_i - A_i}{C_i - A_I}\right)^t & if\ A_i \le y_i\ \le C_i \\ 1 & if\ y_i \ge C_1 \end{pmatrix} \quad (3)$$

The lowest acceptable and highest permissible values were represented by A_i, and C_i for moisture and crude protein content, respectively. The weights assigned to the moisture content and protein content was represented by s and t and was chosen to equal one. The individual desirability of moisture and protein content optimisation is d, while the targeted moisture and protein content is y_i. The composite desirability (Z) was used to jointly optimise the discrete desirability of moisture and protein content by finding the geometric mean using Equation 4 as described by *Sanusi and Akinoso* (2020).

$$Z = (d_1^{u_1} \times d_2^{u_2} \times d_3^{u_3} \times d_4^{u_4} \times d_5^{u_5} \times \ldots\ldots d_1^{u_1})^{\frac{1}{\Sigma u_i}} \quad (4)$$

where u_1 is the factor for moisture and crude protein content. Minitab 16 Statistical Software was used to compute the optimal solution that can guarantee desirable crude protein content and minimum moisture content.

Validation of the Optimum Processing Conditions

To validate the optimum processing conditions obtained from the response optimiser, the conditions were experimented with within the laboratory to determine their effects on crude protein content and moisture content of chicken *kilishi*. The experimental values from the laboratory and predicted values from the response optimiser were compared. The percentage errors were then determined by the validity of the optimisation as shown in Equation 5 as described by *Sanusi and Akinoso* (2021).

$$Percentage\ Deviation = \\ = \frac{(Experimental\ value - Predicted\ value)}{Predicted\ value} \times 100 \quad (5)$$

Sensory evaluation

Sensory evaluation of the chicken *kilishi* was carried out by 15 semi-trained panellists from the Department of Food Engineering, University of Ilorin, Nigeria. A nine-point hedonic scale was used with 9 representing 'extremely like' and 1 'extremely dislike'. The panellists were presented with the coded samples and were asked to judge the samples based on appearance, taste, flavour, spiciness, texture and overall acceptability.

Statistical analysis

Data were analysed using analysis of variance (SPSS-20). Means were separated using Duncan multiple tests. Significance was accepted at $p \le 0.05$. Replicated measurements were taken and values were recorded as means ± standard deviation (SD).

Results and Discussion

Effect of cooking treatment, infusion temperature and infusion time on proximate composition of chicken kilishi – moisture content

The effect of cooking treatment, infusion temperature and infusion time on the proximate composition of chicken *kilishi* is shown in Table 3. The moisture content ranged from 5.32 to 11.75%. The least moisture content was observed in sample D (5.32%), wherein the sliced chicken breasts were treated by boiling before drying and infused in ingredient-mix for 5 min at 40°C, while sample G with the highest moisture content was obtained when the sliced chicken breasts were treated with steaming before drying, then infused in ingredient-mix for 5 min at 50°C. Figure 2 shows the contour plot for the effect of cooking treatment, infusion temperature and time on the moisture content of chicken *kilishi.* The highest moisture content, observed in sample G, could be attributed to the high infusion temperature (50°C) and the steaming treatment. The infusion of food material at a high temperature usually increases the rate of moisture absorption. The high amount of moisture content in the steaming treatment could be attributed to the formation of coating at the surface of the sliced chicken breasts which then prevents water loss during the steaming processing.

This result corroborates the findings of *Choi et al.* (2016), wherein the moisture content of marinated chicken steak that was treated with superheated steaming was higher than that treated by boiling. In the current study, for the sliced chicken breasts that were not treated before drying, it was observed that greater infusion time and temperature produced chicken *kilishi* with higher moisture content, while among the chicken *kilishi* that were produced from sliced chicken breasts that were treated by boiling before drying, greater infusion time resulted in high-

Table 3. Effect of cooking treatment, infusion temperature and infusion time on proximate composition of chicken *kilishi*

Sample	Cooking treatment	Infusion time (min)	Infusion tempera-ture (°C)	Moisture content (%)	Ash content (%)	Crude fat (%)	Crude protein (%)	Crude fibre (%)	Carbohy-drate (%)
A	Untreated	5	30	7.13±0.03[f]	8.40±0.08[b]	10.36±0.02[h]	48.25±0.01[c]	2.05±0.01[bc]	23.81±0.05[d]
B	Untreated	10	40	9.00±0.06[d]	9.04±0.01[a]	12.46±0.01[b]	50.28±0.01[a]	1.46±0.02[e]	17.76±0.05[g]
C	Untreated	15	50	10.74±0.01[c]	8.35±0.02[b]	12.35±0.01[c]	50.08±0.05[b]	1.63±0.00[de]	16.86±0.06[h]
D	Boiling	5	40	5.32±0.03[i]	7.35±0.02[d]	11.64±0.02[f]	46.71±0.01[e]	2.80±0.00[a]	26.19±0.06[c]
E	Boiling	10	50	6.11±0.02[h]	8.16±0.04[c]	10.57±0.02[g]	46.21±0.00[g]	2.31±0.01[b]	26.64±0.03[b]
F	Boiling	15	30	8.31±0.01[e]	6.41±0.00[g]	12.03±0.01[e]	47.05±0.02[d]	2.36±0.44[b]	23.86±0.47[d]
G	Steaming	5	50	11.76±0.08[a]	6.31±0.02[h]	12.31±0.01[c]	46.24±0.00[g]	1.54±0.01[e]	21.84±0.09[e]
H	Steaming	10	30	10.97±0.02[b]	7.08±0.05[f]	14.02±0.01[a]	46.49±0.01[f]	2.13±0.01[bc]	19.30± 0.04[f]
I	Steaming	15	40	6.45±0.03[g]	7.226±0.01[e]	12.19±0.04[d]	43.23±0.01[h]	1.94±0.09[cd]	28.97±0.14[a]

Legend: *Values with the same subscript letters in the same column have no significant difference (p≥0.05)

er moisture content of the final product. However, chicken *kilishi* produced from the sliced chicken breasts that were treated with steaming before drying had the highest moisture content, which was observed at a high infusion temperature (50°C) but at low infusion time. Hence, the variation in the infusion temperature, infusion time and cooking treatment accounted for the significant differences in the moisture content of the products. Low moisture content in food products would aid proper food preservation. The moisture contents observed in the chicken *kilishi* were either lower or within the range of 10.00 to 12.02% that was reported by *Ogunsola and Omojola* (2008) and *Iheagwara and Okonkwo* (2016) for beef *kilishi*. Therefore, sample D with the least moisture content is expected to have a longer shelf life and be less prone to microbial spoilage than sample G.

The second-order polynomial regression equation for the effect of cooking treatment, infusion temperature and infusion time on the moisture content of chicken *kilishi* is presented in Equation 7. The predictive model equation for the moisture content showed that cooking treatment (X_1), infusion temperature (X_2), double effect of infusion time and interaction of cooking treatment and infusion time signifies that decrease of these parameters will increase the moisture content of chicken *kilishi*.

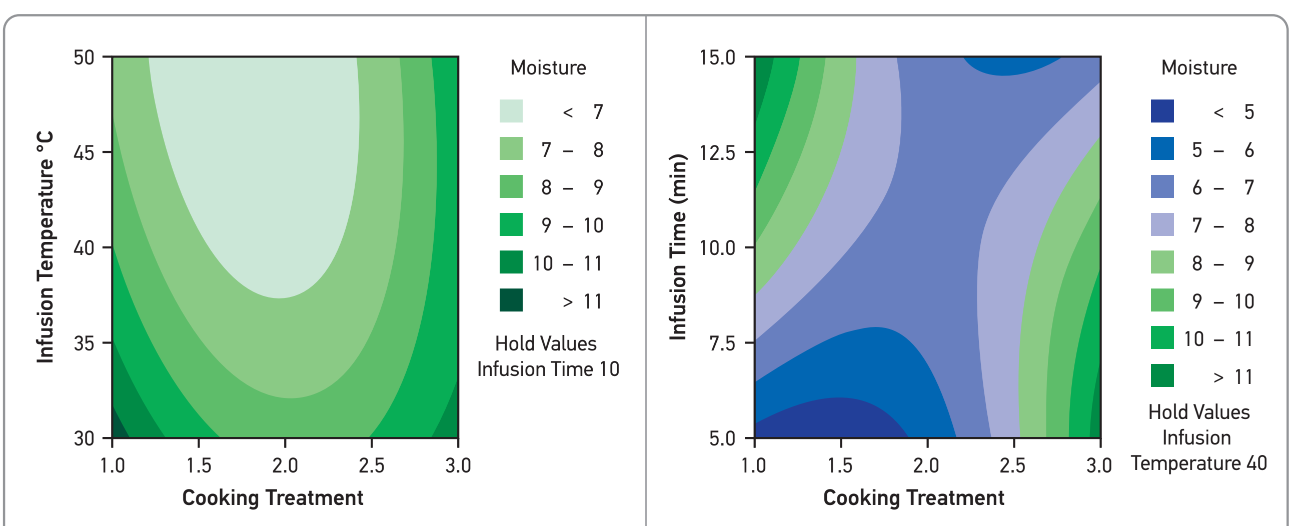

Figure 2. Effect of cooking treatment, infusion temperature and time on the moisture content of chicken *kilishi*

Moreover, increase in infusion time (X_3), the double interaction effect of cooking treatment, double interaction effect of infusion temperature and the interaction of cooking treatment and infusion temperature would increase the moisture content of the product. The R^2 and $R^2_{(adj)}$ obtained from the polynomial regression model in Equation 7 were 0.99 and 0.99 while the p-value and F-value were 0.000 and 7121.25, respectively. This shows that the polynomial regression equation is capable of predicting the effect of cooking treatment, infusion temperature and infusion time on the moisture content of chicken *kilishi*.

$$Moisture\ content = 21.439 - 7.138X_1 - 0.801X_2 + 1.960X_3 + 2.764X_1^2 + 0.007X_2^2 - 0.030X_3^2 + 0.068X_1X_2 - 0.625X_1X_3 \quad (6)$$

Effect of cooking treatment, infusion temperature and infusion time on proximate composition of chicken kilishi – ash content

From Table 3, the ash content ranged from 6.31 to 9.04%. Sample B had the highest ash content (9.04±0.01%), wherein the sliced chicken breasts were untreated before drying, infused in ingredient-mix for 10 min at 40°C infusion temperature. The ash contents of samples A and C were not significantly different at $p \geq 0.05$, and with high ash contents, they ranked next to sample B. Therefore, the untreated *kilishi* had higher ash contents than the *kilishi* that were boiled or steamed. Figure 3 shows the effect of cooking treatment, infusion temperature and infusion time on the ash content of chicken *kilishi.* The ash contents that were obtained for the chicken *kilishi* samples in our current study were higher than the ash content of raw chicken breast (<2%) that was reported by *Chen et al.* (2016). This implies that cooking treatment and infusion with the ingredient-mix at different temperatures and for different times could improve the ash content of raw chicken breast. The ash content of the seasoned dried chicken snack samples obtained in this study was higher than 3.93 to 4.48%, which was reported for beef *kilishi* by *Inusa and Said* (2017) and 7.40 to 7.60% that was reported by *Daminabo et al.* (2013). The higher ash content could be attributed to the use of non-meat ingredients and the processing technique.

$$Ash\ content = 5.922 - 2.575X_1 + 0.183X_2 + 0.161X_3 + 0.429X_1^2 - 0.001X_2^2 - 0.023X_3^2 + 0.3388X_1X_2 + 0.135X_1X_3 \quad (7)$$

Equation 8 shows that a decrease (from steaming to not cooked) in cooking treatment severity increased the ash content. This could account for the chicken *kilishi* produced from untreated sliced chicken breasts having higher ash content than the steamed and boiled *kilishi*. Also, a decrease in the double interaction of infusion temperature and time increased the ash content. The increase in infusion temperature, infusion time, double interaction of cooking treatment, the interaction of cooking treatment and infusion temperature and interaction of cooking treatment and infusion time increased the ash content. The R^2 and $R^2_{(adj)}$ for the ash content of the polynomial regression model were 0.99 and 0.99 while the p-value and F-value were 0.000 and 1343.23, respectively. This shows that the polynomial regression model is capable of predicting the effect of cooking treatment, infusion temperature and infusion time on the ash content of chicken *kilishi*.

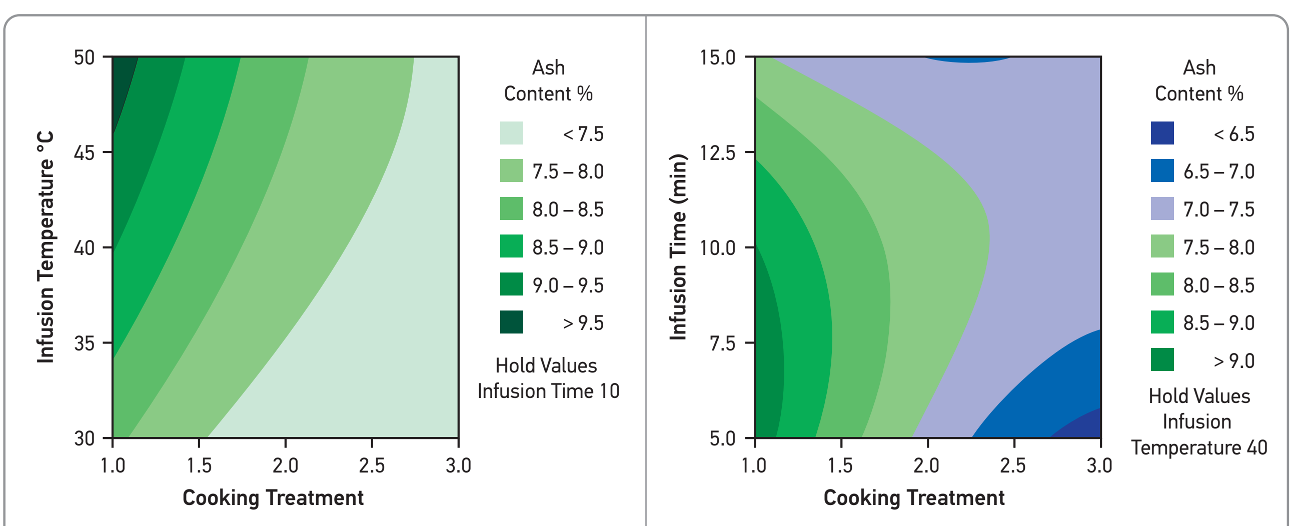

Figure 3. Effect of cooking treatment, infusion temperature and time on the ash content of chicken *kilishi*

Effect of cooking treatment, infusion temperature and infusion time on proximate composition of chicken kilishi – crude fat content

The crude fat content (Table 3) of the chicken *kilishi* ranged from 10.36 to 14.02%. Sample H had the highest fat content (14.02%), and was produced by steaming the sliced chicken breasts before drying, ingredient-mix infusion at 30°C and 10 min infusion time. Figure 4 shows the effect of cooking treatment, infusion temperature and infusion time on the crude fat content of chicken *kilishi.* The crude fat content obtained in this study was higher than the 2.12 to 2.14% that was reported for chicken steaks under different cooking methods by *Choi et al.* (2016) and 1.12 to 2.03% that was reported for raw chicken breast by *Chen et al.* (2016). The higher crude fat content in sample H could be due to the low infusion temperature of the *Kilishi* at 30°C and infusion time of 10 min. This is in agreement with *Asmaa et al.* (2015), who reported an increase in fat content at a low cooking temperature and time. The application of high temperature makes the fat globules break up, form bonds with available radicals, and thereby, results in lower fat content. Sample A with the least crude fat content could be attributed to the fat solidification of the ingredient-mix at the very low infusion temperature and time. Therefore, the infusion temperature and infusion time needed for the fat in the ingredient-mix to be dissolved and absorbed by the sample was likely not reached. Thus, the fat absorption rate was probably slower than in the other samples. The crude fat content obtained in this study was higher than 8 to 10% reported by *Inusa and Said* (2017), but lower than 17.34 to 19.20% that was reported *Mgbemere et al.* (2011) for beef *kilishi*.

The polynomial regression model in Equation 9 shows that an increase in cooking treatment, infusion temperature, infusion time, double interaction of cooking treatment and interaction of infusion time and cooking treatment produced an increase in the crude fat content. This corroborates the findings of *Zzaman et al.* (2015), that fat is release as temperature and holding time increase. In the current study, however, decrease in the double interaction of infusion temperature and infusion time, and the interaction of cooking treatment and infusion temperature increased the crude fat content. The R^2 and $R^2_{(adj)}$ for the crude fat content of the polynomial regression model were 0.99 and 0.99 while the p-value and F-value were 0.000 and 7692.83, respectively. This shows that the polynomial regression model is capable of predicting the effect of cooking treatment, infusion temperature and infusion time on the crude fat content of chicken *kilishi* snacks.

$$Crude\ fat\ content = 4.399 + 1.1432X_1 + +0.612X_2 + 0.796X_3 + 0.870X_1^2 - 0.008X_2^2 - - 0.014X_3^2 - 0.040X_1X_2 + 0.245X_1X_3 \quad (8)$$

Effect of cooking treatment, infusion temperature and infusion time on proximate composition of chicken kilishi – crude protein

The crude protein levels obtained in the chicken *kilishi* ranged from 43.23 to 50.28% as shown in Table 3. The highest protein contents were found in samples A, B and C, which were not heat-treated by boiling or steaming. Figure 5 shows the effect

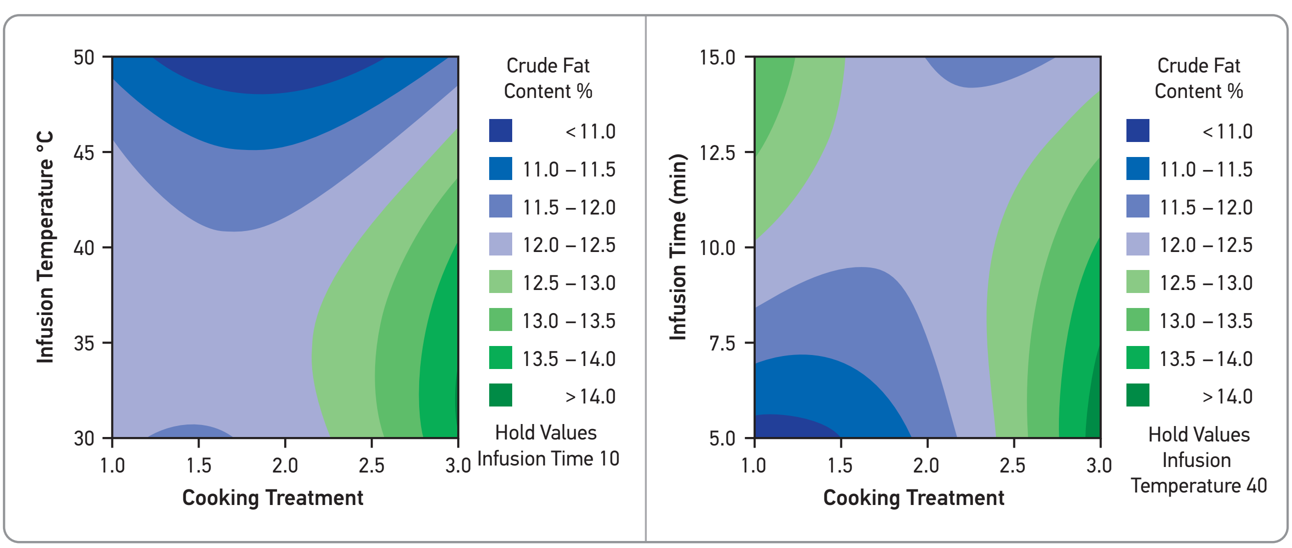

Figure 4. Effect of cooking treatment, infusion temperature and time on the crude fat content of chicken *kilishi*

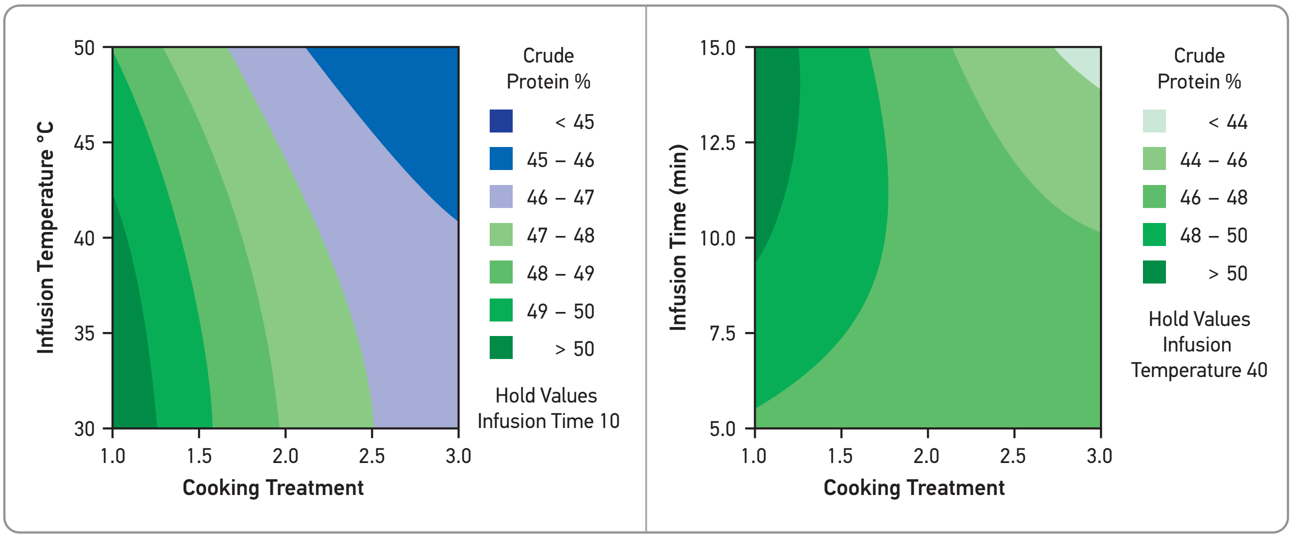

Figure 5. Effect of cooking treatment, infusion temperature and time on the crude protein content of chicken *kilishi*

of cooking treatment, infusion temperature and infusion time on the crude protein content of chicken *kilishi.* There was a clear significant difference in the protein content of the samples at $p<0.05$. The highest protein content was observed in sample B, wherein the sliced chicken breasts were not treated before preparation and had a 10 min infusion time at 40°C, while the least protein was measured in sample I, wherein the chicken breasts were treated by steaming for 15 min infusion time and at 40°C. This result agrees with *Seo et al.* (2016), who stated that superheated steam treatment contributes to the decrease in protein content of meat products. Also, *Choi et al.* (2016) reported that the protein content of chicken steak that was treated with boiling was higher in protein content than steamed treatment.

Bogosavljevic-Boskovic et al. (2010) and *Chen et al.* (2016) reported an average of 23% protein in raw chicken, which is much lower than the least level of protein that we measured in sample I (43.23%) of this study. The high protein content in the *kilishi* could be traced to the non-meat ingredients used in the ingredient-mix formulation. This is because the non-meat ingredients contain some ingredients that are naturally high in protein. *Ogunsola and Omojola* (2008), *Emmanuel et al.* (2020) and *Inusa and Said* (2017) reported 59–60%, 64% and 58.33–64.10%, respectively, for protein content in beef *kilishi*. These values were higher than the protein contents obtained in our current study. According to *Ogunsola and Omojola* (2008), raw beef contains 45% of protein while *Bogosavljevic-Boskovic et al.* (2010) reported an average of 23% of protein for raw chicken. Therefore, the initial protein content of beef meat might be responsible for the higher protein content obtained in beef *kilishi* than in the chicken *kilishi.*

The polynomial regression model in Equation 10 shows that an increase in infusion temperature, infusion time, double interaction of cooking treatment and interaction of infusion temperature and cooking treatment increased the crude protein content, while a decrease to less severe cooking treatment, the double interaction effect of infusion temperature and time, and interaction of cooking treatment and infusion time increased the crude protein content. The R^2 and $R^2_{(adj)}$ for the crude protein content of the polynomial regression model were 1.00 and 0.99 while the p-value and F-value were 0.000 and 24130.98, respectively. This shows that the polynomial regression model is adequate to effectively predict the effect of cooking treatment, infusion temperature and infusion time on the crude protein content of seasoned chicken dried meat.

$$Crude\ protein = 42.789 - 1.666X_1 + 0.162X_2 + \\ + 1.319X_3 + 0.773X_1^2 - 0.003X_2^2 - 0.031X_3^2 + \\ + 0.012X_1X_2 - 0.392X_1X_3 \quad (9)$$

Effect of cooking treatment, infusion temperature and infusion time on proximate composition of chicken kilishi – crude fibre

The effect of cooking treatment, infusion temperature and infusion time on the crude fibre of chicken *kilishi* is presented in Table 3. Sample D had the highest (2.80%) and Sample B the lowest (1.46%) amount of crude fibre. Figure 6 shows the

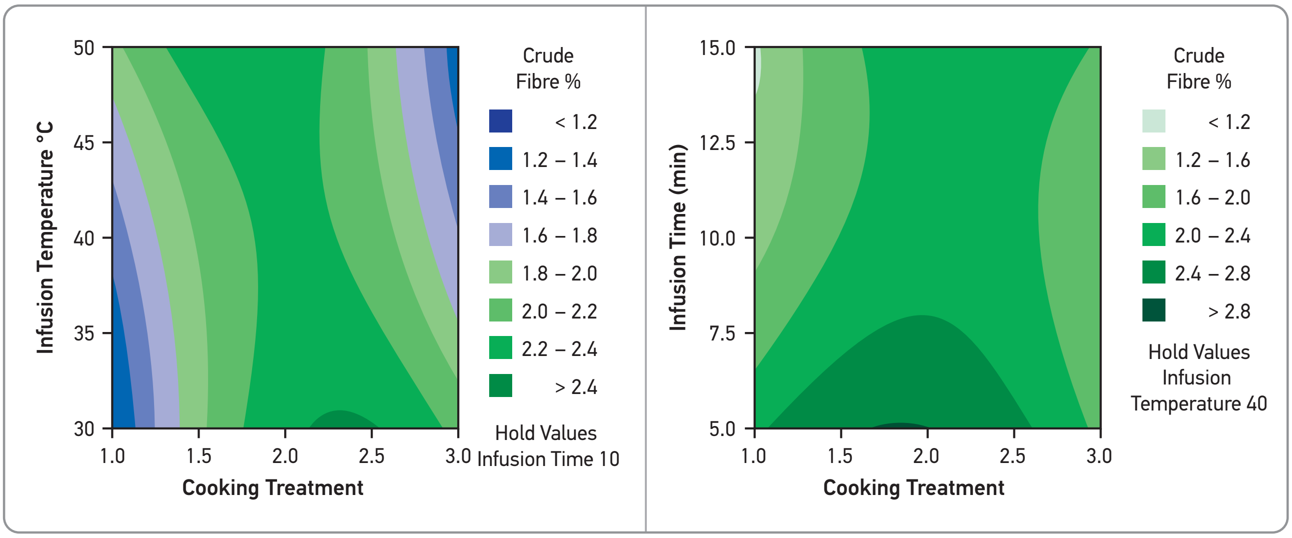

Figure 6. Effect of cooking treatment, infusion temperature and time on the crude fibre content of chicken *kilishi*

effect of cooking treatment, infusion temperature and time on the fibre content of chicken *kilishi.* The results obtained were higher than those obtained by *Soriano-Santos* (2010) and *Ogunmola et al.* (2013). The high content of crude fibre in the chicken *kilishi* could result from some of the ingredients used for the ingredient-mix preparation. *Ipinjolu et al.* (2004) reported ginger to have 24.5% of crude fibre, 5% in groundnut cake and traces of fibre content in pepper, clove and onion. The polynomial regression model in Equation 11 shows that the double interaction effect of infusion temperature, the interaction of infusion temperature and cooking treatment and interaction of infusion time and cooking treatment could lead to an increase in the crude fibre content, while a decrease in the cooking treatment, infusion time, double interaction effect of cooking treatment and double interaction effect of infusion time increased the crude fibre content. The R^2 and $R^2_{(adj)}$ for the crude fibre content of the polynomial regression model were 0.94 and 0.88 while the p-value and F-value were 0.000 and 16.79, respectively. This shows that the polynomial regression model is adequate to predict the effect of cooking treatment, infusion temperature and infusion time on the crude fibre content of chicken *Kilishi*. According to *Sanusi and Akinoso* (2021), R^2 that is greater than 0.8 shows a good fit to predict experimental results.

$$Crude\ fibre\ content = 0.578 - 3.852X_1 - \\ -0.408X_3 - 0.700X_1^2 + 0.001X_2^2 - 0.011X_3^2 + \\ + 0.04X_1X_2 + 0.062X_1X_3 \quad (10)$$

Effect of cooking treatment, infusion temperature and infusion time on proximate composition of chicken kilishi – carbohydrate content

From Table 3, the carbohydrate content of the chicken *kilishi* ranged from 16.86 to 28.97%. Sample I, with the highest carbohydrate content (28.97%), was treated with steam and infused at 40°C for 15 min. Figure 7 shows the effect of cooking treatment, infusion temperature and time on the carbohydrate content of chicken *kilishi.* There were significant differences ($p \leq 0.05$) in the carbohydrate contents of the *kilishi*, which is a result of differences in the infusion temperature and time and the cooking treatment used. *Soriano-Santos* (2010) and *Emmanuel et al.* (2020) reported carbohydrate content of 2.1% and 2.3%, respectively, for chicken meat. However, the values obtained for this study were higher than those reported by *Soriano-Santos* (2010) and *Emmanuel et al.* (2020), and this could be attributed to the infusion of the chicken breast in the ingredient-mix for specific temperatures and times. The ingredients in the ingredient-mix formulation might be responsible for the high carbohydrate content.

The polynomial regression model in Equation 12 shows that an increase in cooking treatment, double interaction of infusion temperature and time, the interaction of infusion temperature and cooking treatment and interaction of infusion time and cooking treatment could lead to an increase in the carbohydrate content, while a decrease in the infusion temperature and time and double interaction effect of cooking treatment increases the carbohydrate content of chicken *kilishi*. The R^2 and $R^2_{(adj)}$ for

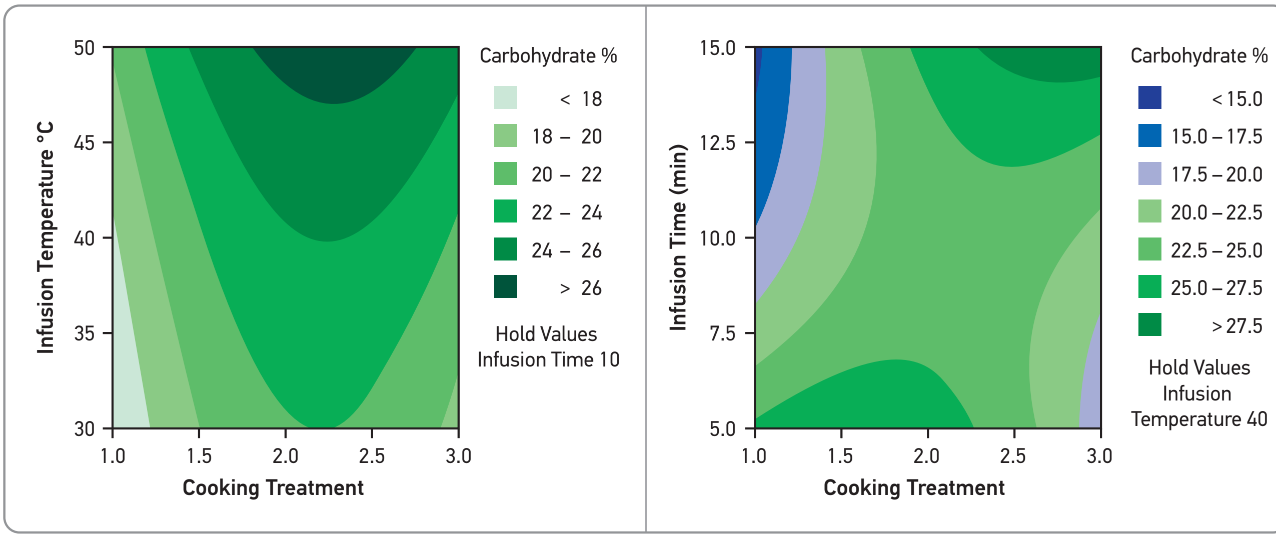

Figure 7. Effect of cooking treatment, infusion temperature and time on the carbohydrate content of chicken *kilishi*

the carbohydrate content of the polynomial regression model were 0.99 and 0.99 while the p-value and F-value were 0.000 and 1200.83, respectively. This shows that the polynomial regression model is adequate to predict the effect of cooking treatment, infusion temperature and infusion time on the carbohydrate content of chicken *kilishi*.

$$Carbohydrate\ content = 33.629 + 6.39X_1 - 0.161X_2 - 3.9X_3 - 4.140X_1^2 + 0.004X_2^2 + 0.087X_3^2 + 0.037X_1X_2 + 1.065X_1X_3 \quad (11)$$

Effect of cooking treatment, infusion temperature and infusion time on proximate composition of chicken kilishi –phosphorous content

The effect of cooking treatment, infusion temperature and infusion time on the phosphorous content of chicken *kilishi* is as shown in Figure 8. The phosphorous content of chicken *kilishi* samples ranged from 7.29 ppm to 12.07 ppm. Figure 9 shows the effect of cooking treatment, infusion temperature and time on the phosphorus content of chicken *kilishi*. Sample H had the highest phosphorous

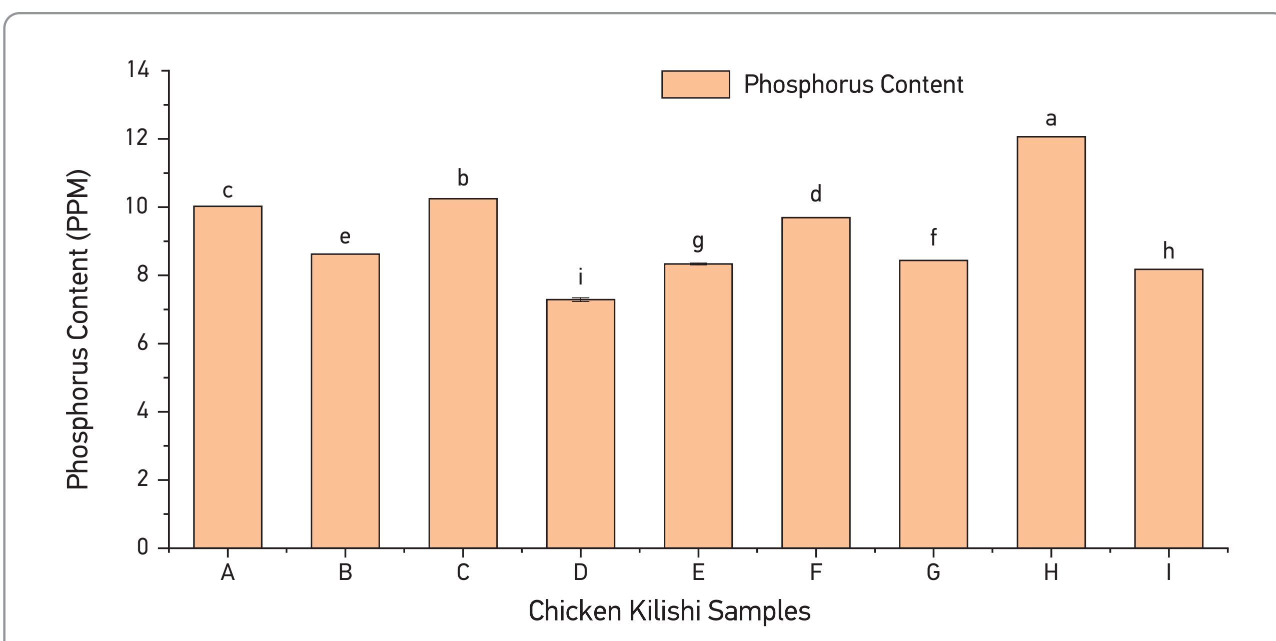

Figure 8. Effect of cooking treatment, infusion temperature and infusion time on the phosphorous content of chicken *kilishi*

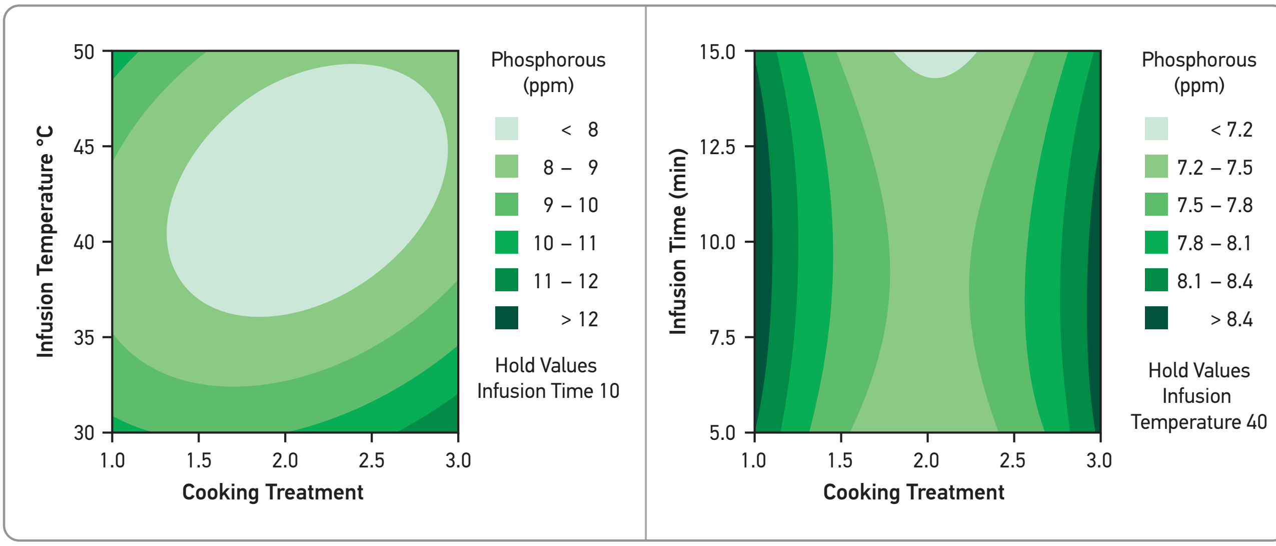

Figure 9. Effect of cooking treatment, infusion temperature and time on the phosphorus content of chicken *kilishi*

content (12.07 ppm), wherein the chicken breasts were steamed before drying and were infused at 30°C for 10 min, while the lowest phosphorous content (7.29 ppm) was observed in sample D, wherein the chicken breasts were steamed before drying and were infused at 40°C for 5 min. There was a significant difference at p<0.05 in the phosphorus content of the *kilishi*.

$$Phosporus\ content = 34.562 - 0.714X_1 - 1.28X_2 + 1.192X_3 + 1.158X_1^2 + 1.017X_2^2 - 0.009X_3^2 - 0.095X_1X_2 - 0.015X_1X_3 \quad (12)$$

The polynomial regression model in Equation 13 shows that an increase in infusion time, double interaction of cooking treatment, double interaction of infusion temperature, interaction of infusion time and cooking treatment could increase the phosphorous content, while decrease in the cooking treatment, infusion temperature and double interaction effect of infusion time and interaction of cooking treatment and infusion temperature increased the phosphorus content of chicken *kilishi*. *Livana et al.* (2018) reported that 69% of phosphorous could be leached into water within one minute, which is similar to our models that predict that phosphorus content should be higher in

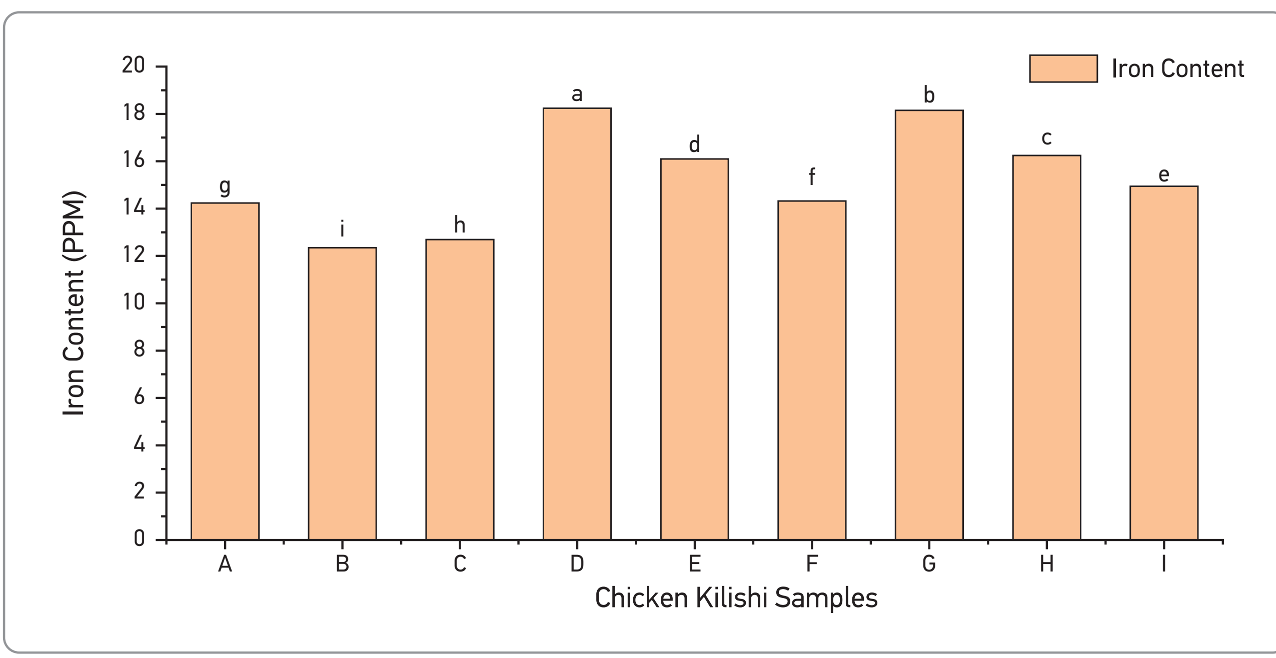

Figure 10. Effect of cooking treatment, infusion temperature and infusion time on the iron content of chicken *kilishi*

untreated *kilishi* than in the boiled and steamed *kilishi*. Moreover, the phosphorus content also decreased as infusion temperature increased because phosphorous solubility increases with temperature. The R^2 and $R^2_{(adj)}$ for the phosphorus content of the polynomial regression model were 0.99 and 0.99, while the p-value and F-value were 0.000 and 12065.73, respectively. This shows that the polynomial regression model is adequate to predict the effect of cooking treatment, infusion temperature and infusion time on the phosphorus content of chicken *kilishi*.

Effect of cooking treatment, infusion temperature and infusion time on proximate composition of chicken kilishi – iron content

Figure 10 shows the effect of cooking treatment, infusion temperature and infusion time on the iron content of chicken *kilishi.* The iron content of chicken *kilishi* ranged from 12.35 ppm to 18.24 ppm. Sample D had the highest iron content (18.24 ppm), wherein the chicken breast was treated with boiling before drying and was infused at 40°C for 5 min, while the least iron content (12.35 ppm) was observed in sample B, wherein the chicken breasts were not treated before drying and were infused at 40°C for 10 min (Figure 11). There was a significant difference at $p \leq 0.05$ in the iron content of the *kilishi*. The iron content differed greatly across all *kilishi* due to different processing conditions and, most especially, the cooking treatment. According to *Inusa and Said* (2017), the iron content of different beef *kilishi* from a different location in Kano state, Nigeria had iron content ranging from 15.25 to 17.25 ppm, levels which were lower than the iron contents obtained in the *kilishi* snacks produced in our current study.

$$Iron\ content = 9.337 + 10.330X_1 + 0.049X_2 - 1.174X_3 - 1.45X_1^2 + 0.02X_2^2 + 0.037X_3^2 - 0.079X_1X_2 + 0.131X_1X_3 \quad (13)$$

The polynomial regression model in Equation 14 shows that an increase in cooking treatment, infusion temperature, the double interaction of infusion temperature and time and interaction of infusion time and cooking treatment increases the iron content, while a decrease in infusion time, the double interaction effect of cooking treatment and interaction of infusion temperature and cooking treatment increases the iron content of *kilishi*. The R^2 and $R^2_{(adj)}$ for the iron content of the polynomial regression model were 1.00 and 1.00, while the p-value and F-value were 0.000 and 1520171.18, respectively. This shows that the polynomial regression model can adequately predict the effect of cooking treatment, infusion temperature and infusion time on the iron content of chicken *kilishi*.

Effect of cooking treatment, infusion temperature and infusion time on proximate composition of chicken kilishi – zinc content

Figure 12 shows the effect of cooking treatment, infusion temperature and infusion time on the zinc content of chicken *kilishi.* The zinc contents of chicken *kilishi* ranged from 9.08 to 16.34 ppm. Sample C had the highest zinc content (12.07 ppm), wherein the chicken breast was untreated before drying and the ingredient-mix was infused at

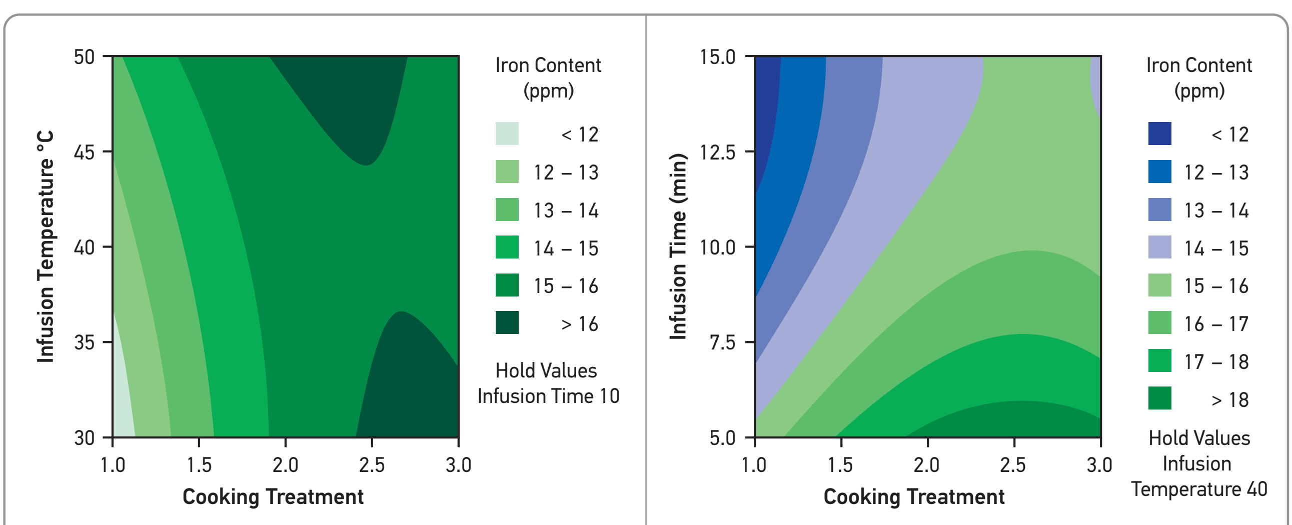

Figure 11. Effect of cooking treatment, infusion temperature and time on the iron content of chicken kilishi

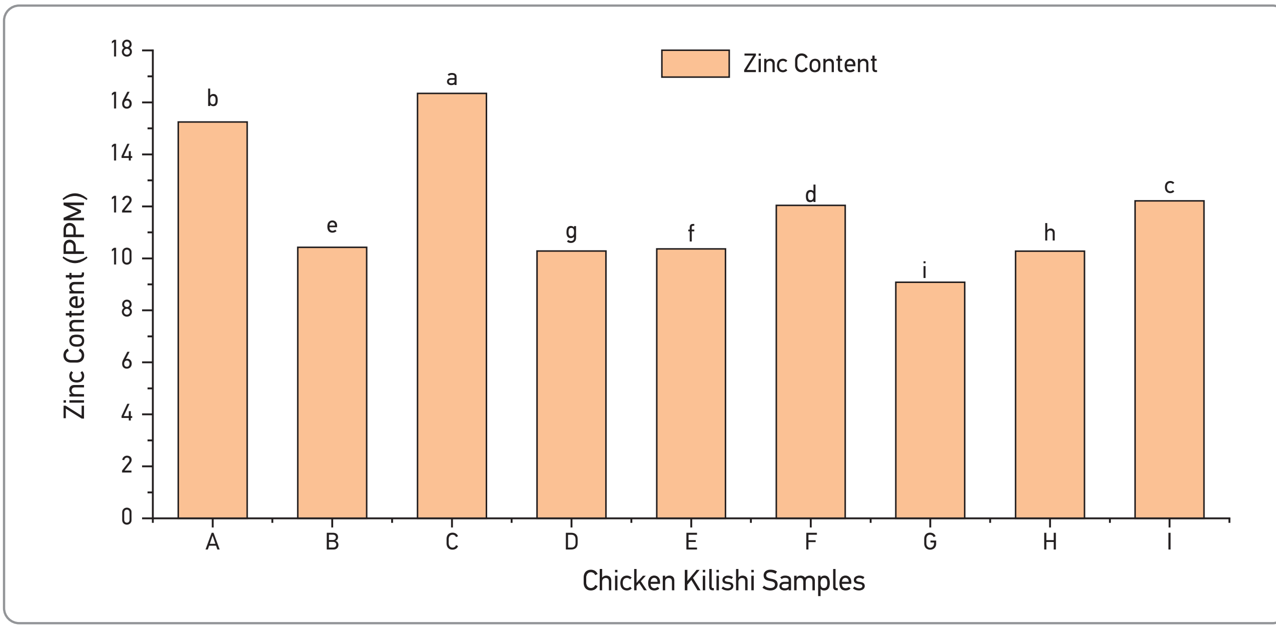

Figure 12. Effect of cooking treatment, infusion temperature and infusion time on the zinc content of chicken *kilishi*

50°C for 15 min, while the least zinc content (9.08 ppm) was observed in sample G wherein the chicken breast was steamed prior drying and the ingredient-mix was infused at 50°C for 5 min (Figure 13). There was a significant difference at $p<0.05$ in the zinc content of the *kilishi*. The differences in zinc content could be traced to the ingredient-mix infusion time. It was observed that zinc content increases as infusion time increases when the sliced chicken breast is steamed before drying. Therefore, the *kilishi* infused for 15 min had the highest zinc content. The zinc obtained in this study was higher than the 3.31 to 5 ppm reported by *Inusa and Said* (2017) for beef *kilishi*.

$$Zinc\ content = 56.718 - 4.259X_1 - 1.405X_2 - 3.273X_3 + 1.370X_1^2 + 0.023X_2^2 + 0.123X_3^2 - 0.1795X_1X_2 + 0.415X_1X_3 \quad (14)$$

The polynomial regression model in Equation 14 shows that an increase in the double interaction of cooking treatment, double interaction of infusion temperature and time and interaction of infusion time and cooking treatment increases the zinc content, while increase in the cooking treatment, infusion temperature and time and interaction of infusion temperature and cooking treatment decreases the zinc content of chicken *kilishi*. The zinc con-

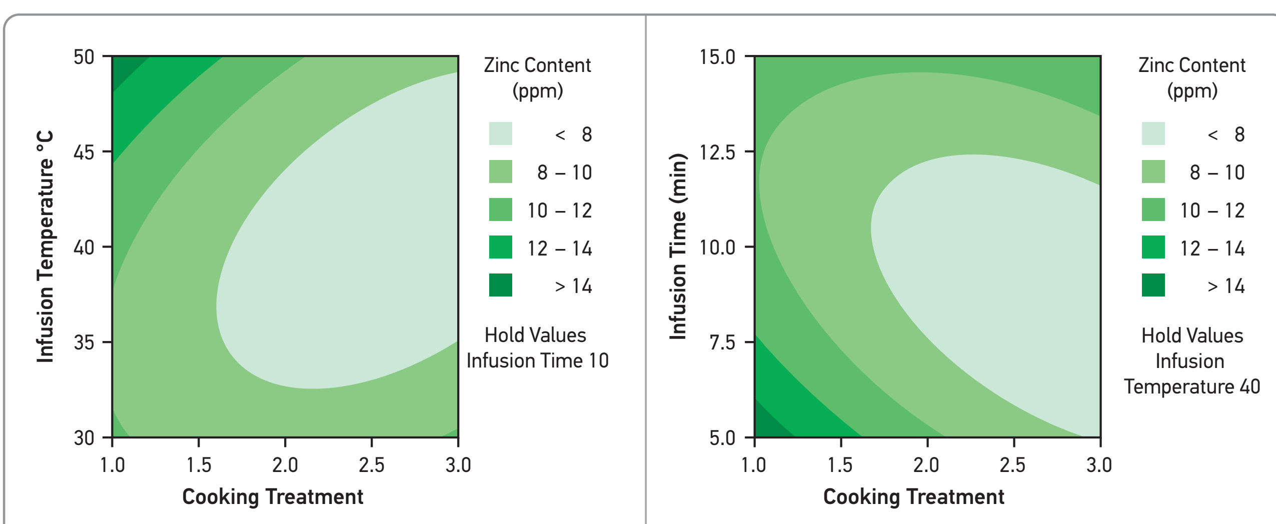

Figure 13. Effect of cooking treatment, infusion temperature and time on the zinc content of chicken *kilishi*

tent should decrease as cooking treatment increases, as reported by *Joyce et al.* (2018), due to leaching of the mineral into the cooking liquid. The R^2 and $R^2_{(adj)}$ for the zinc content of the polynomial regression model were 1.00 and 1.00, while the p-value and F-value were 0.000 and 1673234.40, respectively. This shows that the polynomial regression model can adequately predict the effect of cooking treatment, infusion temperature and infusion time on the zinc content of chicken *kilishi*.

Sensory attributes of chicken kilishi

Figure 14 shows the effect of cooking treatment, infusion temperature and infusion time on the sensory attributes of chicken *kilishi*. The panellists' scores for the appearance of the samples were within the range of 6.33 to 7.93. Sample C was rated as having the best appearance, while the appearance of sample E was rated the least liked. The preference for sample C could be because it did not undergo any cooking treatment. The panellists' scores for the taste of the samples were within the range of 6.33 to 7.67. Sample A was rated as giving the best taste, while the taste of sample E was rated as the least liked. The preference for samples A, B and C could be attributed to the lack of any cooking treatment applied to the chicken breast prior to drying. The panellists' scores for the flavour of the *kilishi* were within the range of 6.47 to 7.53. Sample A was rated as having the best flavour, while sample E was rated as having the least liked flavour. The panellists' scores for the spiciness of the *kilishi* were within the range of 6.40 to 6.93. Sample G gave the best spiciness, while sample B was rated as having the least liked spiciness. The panellists' scores for the texture of the *kilishi* were within the range of 5.27 to 7.20. Sample C gave the best texture, while sample E had the least liked texture. The overall acceptability of the chicken *Kilishi* samples produced was within the range of 6.07 to 7.73. Sample A had the highest overall acceptability score, while sample E was the least preferred. Therefore, Sample C was rated as having the best appearance and texture. Sample A was rated as having the best taste, flavour and overall acceptability, while sample G was rated as having the best spiciness. Therefore, it can be deduced that those chicken *kilishi* produced without any cooking treatment prior to drying were the most acceptable in terms of sensory attributes.

Optimisation of moisture content and protein of chicken kilishi

Figure 15 shows an optimisation plot for moisture content and protein content. The optimum process conditions were attained when the chicken breasts were not heat-treated and ingredient-mix infusion was conducted at approximately 41°C and for 6 min infusion time. The desirability values obtained for the moisture content and protein content were 1.00 and 0.69, respectively. The optimum protein content and moisture content was 48.12% and 5.34%, respectively. The composite desirability for achieving minimum moisture content and protein content was 0.84.

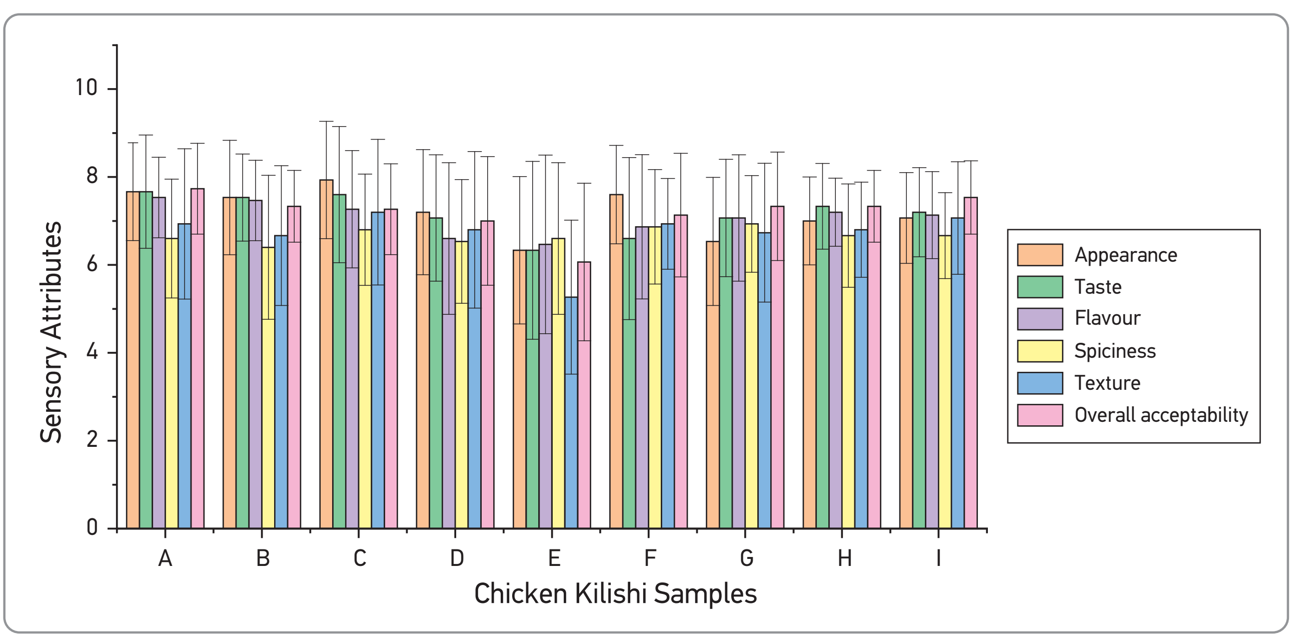

Figure 14. Effect of cooking treatment, infusion temperature and infusion time on the sensory attributes of chicken *kilishi*

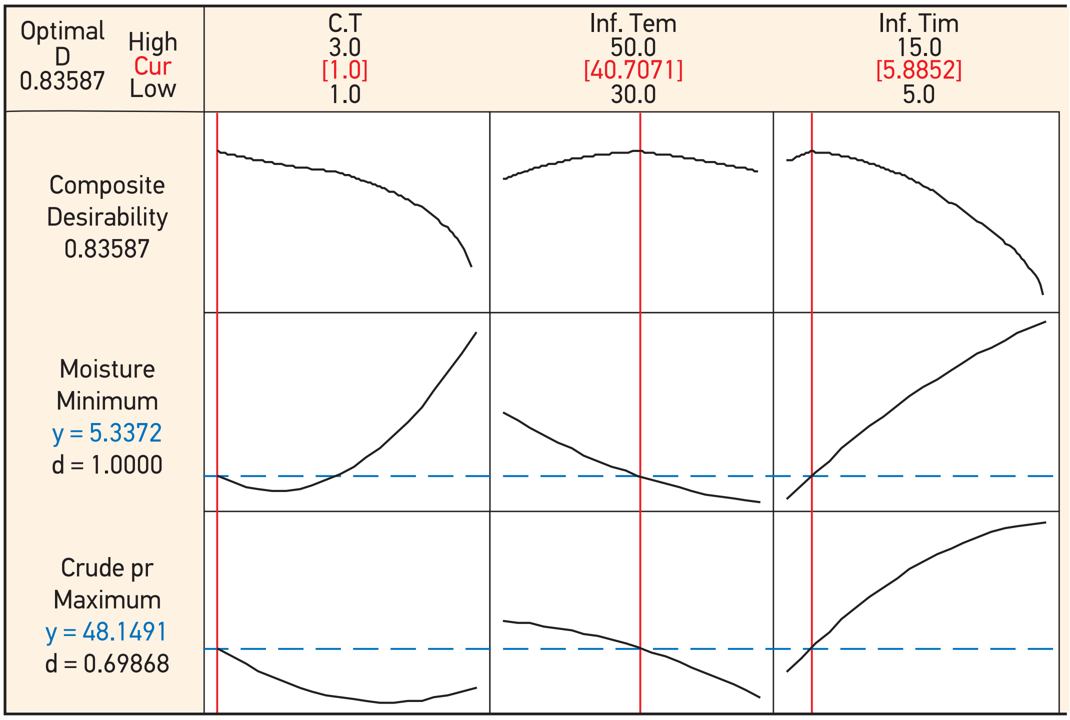

Figure 15. The optimum condition for the production of chicken *kilishi* with desirable moisture content and protein content. C.T is the cooking treatment, Inf. Temp. is the infusion temperature and Inf. Time is the infusion time.

Table 4. Validation of the optimum condition

Goal	Minimum values	Maximum values	Predicted optimum values	Desirability values	Experimental values	Error deviation (%)
Minimum moisture content (%)	5.34	11.81	5.34	1.00	5.55	3.93
Maximum protein content (%)	43.22	50.27	48.15	0.70	49.00	1.77

Sanusi and Akinoso (2021) reported that the closer the composite desirability to unity, the more reliable the proposed optimum condition. Therefore, according to Table 4, it can be adduced that there is a good agreement between the optimum predicted values and experimental values with minimum error deviation of 3.93 and 1.77% for minimum moisture content and maximum protein content, respectively. In addition, the crude fat, crude fibre, ash content, carbohydrate content, phosphorus content, zinc content and iron content obtained at optimum condition were 10.36%, 2.05%, 8.40%, 23.81%, 10.02 ppm, 15.24 ppm and 14.24 ppm, respectively. This validates the reliability of the proposed optimum condition for chicken *kilishi* with minimum moisture content and protein content.

Conclusion

Chicken *kilishi* was successfully produced under the influence of different cooking treatments, infusion temperatures and infusion times. The cooking treatment, ingredient-mix infusion temperature and infusion time significantly influence the proximate composition, phosphorus, iron and zinc content. The polynomial regression models were significant at $p<0.05$ and are capable of predicting the proximate and mineral composition of the ingredient-mix based dried chicken *kilishi* with R^2 and R^2_{adj} that range from 0.88 to 1.00. Chicken *kilishi* produced from untreated chicken breast produces *kilishi* with the most acceptable sensory attributes.

Modeliranje i optimizacija indikatora kvaliteta u proizvodnji sušenog pilećeg proizvoda na bazi mešavine sastojaka (pileći *kiliši*)

Mayowa S. Sanusi, Musliu O. Sunmonu, Ahmed O. Abdulkareem Abdulquadri Alaka

A p s t r a k t: Cilj ovog ispitivanja je bio da se istraži, modelira i optimizuje uticaj tretmana kuvanja (netretirano, kuvanje i tretman na pari), temperature infuzije mešavine sastojaka (30°C, 40°C i 50°C) i trajanja infuzije (5, 10 i 15 min) na indikatore kvaliteta sušenog pilećeg proizvoda (pileći kiliši) na bazi mešavine sastojaka od pilećih prsa. Indikatori kvaliteta (približan sastav i mineralni sadržaj) proizvedenog pilećeg kilišija su određeni i statistički analizirani korišćenjem hibridnog dizajna metodologije Taguchi-Response Surface. Proizvodnja pilećih kilišija od netretiranih pilećih prsa utiče na povećanje sadržaja pepela (9,04%), sadržaja sirovih proteina (50,28%) i sadržaja cinka (16,34 ppm). Međutim, pileći kiliši proizveden tretmanom na pari daje najveći sadržaj masti (14,02%), sadržaj ugljenih hidrata (28,97%) i sadržaj fosfora (12,07 ppm), dok kiliši podvrgnuti kuvanju imaju povećan sadržaj gvožđa (18,24 ppm), ali smanjen sadržaj vlage (5,32%). Razvijeni modeli polinomske regresije za indikatore kvaliteta bili su značajni sa R2 i R2adj koji se kreće od 0,88 do 1,00, respektivno. Optimalni uslovi procesa su postignuti kada pileća prsa nisu tretirana i infuzija mešavine sastojaka je sprovedena u trajanju od 6 minuta na 41°C.

Ključne reči: *pileća prsa; pileći kiliši; modeliranje; optimizacija; indikatori kvaliteta*

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