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Research Article

# Impact of Ingredients Formulation and Processing Parameters on the Nutritional Quality of Foam-mat Dried Kunun-zaki Powder (A Nigerian fermented Cereal Beverage)

**Abbas Sadiq[1*], Bamidele Olaiya Atteh[1]**

[1]Department of Agricultural and Bioresources Engineering, Federal University of Technology Minna, Niger State, Nigeria

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Corresponding author:
Abbas Sadiq
Sadiqabbas032@gmail.com



**Abstract:** The study investigated the effects of different ingredient formulations and processing parameters on the proximate composition and sensory qualities of foam-mat dried kunun-zaki, a traditional Nigerian beverage. The research was conducted in two stages using a mixture-process design matrix. In the first stage, kunun-zaki was produced by steeping grains (millet, maize, and soybean) for varying durations, wet milling with other ingredients (ginger, sweet potatoes, pepper, and moringa seeds), and partial gelatinization of the slurry. The second stage involved foam-mat drying at different temperatures (40 and 70°C). The proximate composition evaluated included moisture content, ash content, crude protein, crude fiber, and fat, while sensory properties like color, flavor, taste, mouthfeel, and overall acceptability were also assessed. Numerical optimization through desirability technique was employed to determine the optimum formulation and process parameters for foam-mat dried kunun-zaki. The study found that the best quality product had 9.595% moisture content, 2.552% ash content, 28.195% crude protein, 54.443% carbohydrate, 11.949% fat, and 5.828% crude fiber. This quality was achieved using a drying temperature of 40.00°C and a steeping period of 12.0 hours, with 48.435% millet and 51.565% soya bean, and no maize in the formulation, resulting in a desirability index of 0.625.

**Keywords:** Optimization, processing, kunun-zaki, steeping, formulation

## 1. Introduction

Nigeria is currently going through a progressive stage in which there is a steadfast focus on local sourcing of raw materials, and the soft drink segment of the Nigerian beverage industry is incredibly dependent on imported raw material [1]. This knowledge has evolved into a widespread interest in commercially processing indigenous foods to support the limited foreign exchange by minimizing raw material imports. In Nigeria, cereals are the main native raw material used to make drinks such pito, burukutu, local gin, and kunun-zaki. Many Nigerians are switching from popular mineral-flavored effervescent drinks to regional, more natural options like kunun, zobo, ginger and others. Local beverages have quickly replaced carbonated soft drinks throughout most of Nigeria, particularly in the North [2]. These locally produced replacements are primarily made of ginger and cereals including millet, guinea corn, and maize [3]. Most of the Northern cities part of Nigeria have taken a liking to kunun-aya and kunun-zaki. However, kunun-zaki is increasingly becoming more popular in the Southern regions. It is therefore common to find kunun-zaki sellers and consumers in cities like Ibadan, Aba, Port Harcourt and Onitsha which [4]. Kunun-zaki is consumed by people of all social classes and economic levels as a food supplement, beverage, or even as a meal on its own. Low- and middle-class employees who cannot buy industrially produced beverages like Coca-Cola, Pepsi, etc. are increasingly consuming it. Its popularity can be attributed to its distinctive sweet-sour flavor, refreshing quality, creamy or milky look, nutritional quality and flowing consistency [5]. In contrast to other cereal-based non-alcoholic drinks, there is inadequate information on the manufacturing process, proximate composition and overall acceptability of kunun-zaki. The basic processes involved in the manufacture of this beverage are not systemized, the quantity of ingredients i.e. the spices and sweeteners are not specified. Another factor which affects the end product of kunun-zaki is the steeping or soaking period of the grains used which fluctuates from one processor to the other. Its conversion into powder form has not been yet much explored using a suitable drying method that results in better retention of its nutritional properties and reconstitution ability. The impact of these differences on the quality has not been investigated. Owing to the high demand for this product and the high consumption rate, it is thought that the present traditional production process is outdated, inefficient, time consuming and with product quality varying between batches. The indigenous beverages manufacturers face difficulties in optimizing both the mixture and process parameters and formulations to create this beverage that meet both sensory preferences and nutritional requirements. The absence of reliable empirical models hinders effective product development of this Nigerian beverage. Therefore, the aim of this research is to develop, characterize and optimize value-added foam-mat dried kunun zaki powder.

## 2. Materials and Method

### 2.1. Materials

The materials used were maize (Zea mays), millet (Pennisetum glaucum), soybeans, sweet potato (*Ipomoea batatas*), ginger (*Zingiber officinale*), red pepper (*Piper-annum*), moringa (*oleifera*) and granulated Sugar (Sucrose). The materials for this study were purchased from Kure market in Minna, Niger State. The preparation of kunun- zaki powder was carried out at the department of Agricultural and Bioresource Engineering laboratory while the analysis was done at the department of Food Science and Technology of Federal University of Technology Minna.

### 2.2. Experimental Design

Simplex lattice mixture design was used for the formulation of the experimental design. Millet ($x_1$), maize ($x_2$) and soybean ($x_3$) were mixed to formulate/produce kunun-zaki. The three grains comprised 82% of the total mixture with the remaining 18% reserved for other ingredients or additives which were kept constant throughout the experiment): Fresh ginger (1%), fresh sweet potatoes (5%), fresh pepper 1% fresh moringa seed flour (6%) and sugar (5%). The two process variables (drying temperature and steeping time) which were also studied were at two different variations (the low and high values) as shown in Table 1 using coded values, where -1 represents the lower temperature of 40°C and steeping time of 12hrs, in terms of actual value and +1 represents the higher temperature of 70° and steeping time of 36hrs. The process variables are also designated by $Z_1$ and $Z_{2,}$ where $Z_1$ and $Z_2$ represent the drying temperature and steeping time, respectively. By combining the simplex design and the factorial design together, twenty-eight run was established as shown in Table 1 The 29th run is the control which is the traditional method of kunun-zaki production.

**Table 1.** Experimental Design for the Formulation Experiment

| Run | $x_1$: Millet | $x_2$: Maize | $x_3$: Soya bean | $z_{1:}$Temp. | $z_2$: Time |
|---|---|---|---|---|---|
| 1 | 1 | 0 | 0 | -1 | -1 |
| 2 | 0.5 | 0.5 | 0 | -1 | -1 |
| 3 | 0.5 | 0 | 0.5 | -1 | -1 |
| 4 | 0 | 1 | 0 | -1 | -1 |
| 5 | 0 | 0.5 | 0.5 | -1 | -1 |
| 6 | 0 | 0 | 1 | -1 | -1 |
| 7 | 0.333 | 0.333 | 0.333 | -1 | -1 |
| 8 | 1 | 0 | 0 | 1 | -1 |
| 9 | 0.5 | 0.5 | 0 | 1 | -1 |
| 10 | 0.5 | 0 | 0.5 | 1 | -1 |
| 11 | 0 | 1 | 0 | 1 | -1 |
| 12 | 0 | 0.5 | 0.5 | 1 | -1 |
| 13 | 0 | 0 | 1 | 1 | -1 |
| 14 | 0.333 | 0.333 | 0.333 | 1 | -1 |
| 15 | 1 | 0 | 0 | -1 | 1 |
| 16 | 0.5 | 0.5 | 0 | -1 | 1 |
| 17 | 0.5 | 0 | 0.5 | -1 | 1 |
| 18 | 0 | 1 | 0 | -1 | 1 |
| 19 | 0 | 0.5 | 0.5 | -1 | 1 |
| 20 | 0 | 0 | 1 | -1 | 1 |
| 21 | 0.333 | 0.333 | 0.333 | -1 | 1 |
| 22 | 1 | 0 | 0 | 1 | 1 |
| 23 | 0.5 | 0.5 | 0 | 1 | 1 |
| 24 | 0.5 | 0 | 0.5 | 1 | 1 |
| 25 | 0 | 1 | 0 | 1 | 1 |
| 26 | 0 | 0.5 | 0.5 | 1 | 1 |

| Run | $x_1$: Millet | $x_2$: Maize | $x_3$: Soya bean | $z_1$:Temp. | $z_2$: Time |
|---|---|---|---|---|---|
| 27 | 0 | 0 | 1 | 1 | 1 |
| 28 | 0..333 | 0.333 | 0.333 | 1 | 1 |
| 29 | 1 | 0 | 0 | Room temp. | 24hrs |

### 2.3. Procedure for the Production of Foam-mat Dried Kunun-zaki

Kunun zaki was produced as described by Akoma *et al.* [6] using mixture of millet, maize and soybeans in accordance with the mixture-process variable design (i.e. Table 1). The process involved cleaning and steeping of the grains before addition of spices. 1g of fresh ginger, 5g fresh sweet potato chips, 1g fresh pepper, 6g of fresh moringa seed and 5g of sugar (as sweetener) were kept constant throughout the experiment. 82g of each of the ingredients was washed separately with tap water and soaked in 500ml of tap water using different steeping time of 12 and 36 hours respectively as indicated in Table 1. The water was then decanted off and the grains were washed before wet milling with the 18g of the spices. A total of twenty-eight samples were used for the experiment. The control experiment (i.e. sample 29) was treated at ambient conditions. Each of the paste after wet milling for each experiment was divided into two unequal portions. one of these was cooked and the other portion was set aside in a different container. The cooked portion was then mixed with the raw paste and the mixture was thoroughly stirred until it became uniform. The mixture was left to cool before filtration. After cooling for 2 hours, each of the mixture was then filtered using cheese cloth and allowed to ferment for 12 hours. After fermentation each of the slurry was subjected to oven drying using specified temperature ($40^0$C and $70^0$C) respectively. The dried samples were milled into fine particles using electric blender.

### 2.4. Proximate Composition of the Foam-mat Dried Kunun-zaki

The moisture content, crude protein, ash, crude fat content, and crude fibre were determined by the methods described by the AOAC [7]. The percentage carbohydrate content was determined by total difference.

### 2.5. Sensory Evaluation

A 20-member semi-trained panel of Federal University of Technology Minna students evaluated the foam-mat kunun-zaki powder samples for taste, colour, flavour, mouthfeel, and overall acceptability. According to Sengev et al. [7], a 9-point hedonic score system was employed with the following ratings: 9 = extremely like, 8 = very much like, 7 = moderately like, 4 = slightly like, 5 = neither like nor dislike, 4 = slightly dislike, 3 = moderately dislike, 2 = very much dislike, and 1 = extremely dislike.

### 2.6. Statistical Analysis

Analysis of Variance (ANOVA) and regression analysis were applied to the sensory evaluation and proximate composition data. The fitted equations were expressed as response surface plots, which were produced by the statistical package, Design expert® software (version 13.0.0), in order to visualize the relationship between the response and experimental levels of each factor and to determine the ideal conditions

## 3. Results and Discussion

### 3.1. Results

Table 2 shows the results of the proximate composition of foam-mat dried kunun-zaki. The moisture content ranged between 3.6 – 12.31%, with the least moisture content in sample 5 containing 100% maize and 0% millet and soybeans at $40^0$C drying temperature and 12hrs steeping duration. Similarly, the highest moisture was recorded in the controlled sample comprising 100% millet dried and steeped at $37^0$C and 24hrs respectively. The ash content varied significantly between 1.1 -3.87% with the highest amount recorded in a sample comprising 100% maize at $70^0$C drying temperature and 36 hours steeping period. On the other hand, kunun zaki of a mixture of 100% soybeans produced the lowest ash content at $70^0$C drying temperature and 12 hours steeping period. The crude protein content ranged from 9.87% to 42.67%. The sample with 100% soybeans and 50% maize and 50% millet had the highest and lowest crude protein content, respectively. The carbohydrate content ranged from 39.00% to 73.85%. The sample with 50% millet and 50% soybeans had the least carbohydrate content at a drying temperature of $40^0$C and steeping duration of 12 hours. Similarly, the sample having 50% millet and 50% soybeans at $40^0$C drying temperature and 36hours steeping time produced the highest amount.

**Table 2.** Mean Proximate Composition of the Foam-mat Dried Kunun-zaki Powder

| Run | $X_1$ | $X_2$ | $X_3$ | $Z_1$ | $Z_2$ | MC (%) | Ash content (%) | protein (%) | Crude fibre (%) | Fat (%) | CHO (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 0 | 0 | -1 | -1 | 5.403 | 2.96 | 17.64 | 1.18 | 4.65 | 68.166 |
| 2 | 1 | 0 | 0 | 1 | -1 | 9.47 | 2.37 | 28.076 | 1.29 | 6.44 | 52.353 |
| 3 | 1 | 0 | 0 | -1 | 1 | 4.417 | 2.49 | 29.05 | 2.57 | 4.78 | 56.693 |
| 4 | 1 | 0 | 0 | 1 | 1 | 10.33 | 2.11 | 28.48 | 1.33 | 6.43 | 51.32 |
| 5 | 0 | 1 | 0 | -1 | -1 | 3.6 | 2.6 | 11.2 | 3.34 | 6.88 | 72.38 |
| 6 | 0 | 1 | 0 | 1 | -1 | 5.6 | 2.333 | 12.42 | 1.36 | 5.03 | 73.263 |
| 7 | 0 | 1 | 0 | -1 | 1 | 11.103 | 2.873 | 25.32 | 2.08 | 5.78 | 52.843 |
| 8 | 0 | 1 | 0 | 1 | 1 | 4.903 | 3.87 | 11.15 | 2.36 | 4.67 | 73.046 |
| 9 | 0 | 0 | 1 | -1 | -1 | 4.207 | 2.43 | 15.08 | 2.43 | 2.14 | 73.716 |
| 10 | 0 | 0 | 1 | 1 | -1 | 10.787 | 1.1 | 25.01 | 2.05 | 6.44 | 54.623 |
| 11 | 0 | 0 | 1 | -1 | 1 | 4.487 | 1.6 | 42.66 | 1.41 | 5.25 | 44.593 |
| 12 | 0 | 0 | 1 | 1 | 1 | 9.46 | 2.5 | 14.9 | 2.36 | 2.52 | 68.26 |
| 13 | 0.5 | 0.5 | 0 | -1 | -1 | 10.48 | 1.98 | 9.87 | 3.2 | 3.99 | 70.48 |
| 14 | 0.5 | 0.5 | 0 | 1 | -1 | 5.7 | 3.2 | 17.93 | 1.16 | 5.58 | 66.433 |

| Run | $X_1$ | $X_2$ | $X_3$ | $Z_1$ | $Z_2$ | MC (%) | Ash content (%) | protein (%) | Crude fibre (%) | Fat (%) | CHO (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 15 | 0.5 | 0.5 | 0 | -1 | 1 | 5.56 | 2.6 | 40.25 | 1.07 | 5.59 | 44.93 |
| 16 | 0.5 | 0.5 | 0 | 1 | 1 | 9.71 | 2.5 | 28.9 | 2.56 | 4.1 | 52.23 |
| 17 | 0.5 | 0 | 0.5 | -1 | -1 | 11.633 | 2.54 | 42.12 | 1.42 | 6.29 | 39.00 |
| 18 | 0.5 | 0 | 0.5 | 1 | -1 | 8.647 | 2.52 | 28.16 | 2.51 | 5.34 | 52.813 |
| 19 | 0.5 | 0 | 0.5 | -1 | 1 | 6.45 | 1.34 | 11.45 | 3.23 | 3.68 | 73.85 |
| 20 | 0.5 | 0 | 0.5 | 1 | 1 | 3.407 | 1.56 | 28.88 | 2.45 | 3.43 | 60.273 |
| 21 | 0 | 0.5 | 0.5 | -1 | -1 | 8.147 | 3.49 | 17.55 | 1.12 | 3.21 | 66.493 |
| 22 | 0 | 0.5 | 0.5 | 1 | -1 | 5.78 | 1.55 | 27.99 | 2.12 | 7.56 | 55.00 |
| 23 | 0 | 0.5 | 0.5 | -1 | 1 | 4.877 | 2.36 | 14.29 | 2.39 | 3.24 | 72.843 |
| 24 | 0 | 0.5 | 0.5 | 1 | 1 | 3.517 | 2.32 | 28.53 | 1.34 | 5.44 | 48.853 |
| 25 | 0.333 | 0.333 | 0.333 | -1 | -1 | 3.6 | 2.6 | 11.2 | 3.34 | 6.88 | 72.38 |
| 26 | 0.333 | 0.333 | 0.333 | 1 | -1 | 4.6 | 3.22 | 19.1 | 1.6 | 4.90 | 66.58 |
| 27 | 0.333 | 0.333 | 0.333 | -1 | 1 | 10.483 | 1.67 | 25.63 | 1.37 | 6.56 | 54.29 |
| 28 | 0.333 | 0.333 | 0.333 | 1 | 1 | 4.363 | 1.06 | 31.67 | 2.1 | 5.50 | 55.306 |
| 29 | 1 | 0 | 0 | Room temp. | 24 | 12.306 | 2.8 | 18.04 | 2.4 | 1.82 | 57.63 |

**Table 3.** Mean of Sensory Score based on Hedonic Scale

| Run | Taste | Colour | Flavour | Mouth feel | Sweetness | Overall Acceptability |
|---|---|---|---|---|---|---|
| 1 | 7.67 | 8.00 | 7.67 | 9.00 | 8.33 | 8.67 |
| 2 | 7.00 | 7.67 | 7.00 | 9.00 | 8.00 | 8.50 |
| 3 | 6.33 | 7.00 | 6.33 | 8.33 | 8.00 | 8.17 |
| 4 | 6.67 | 5.67 | 6.33 | 8.67 | 7.67 | 8.17 |
| 5 | 6.67 | 6.33 | 5.67 | 9.00 | 7.67 | 8.33 |
| 6 | 6.67 | 7.33 | 6.67 | 8.67 | 7.67 | 8.17 |
| 7 | 6.67 | 7.33 | 8.00 | 9.00 | 7.67 | 8.33 |
| 8 | 7.67 | 8.00 | 7.67 | 9.00 | 7.67 | 8.33 |
| 9 | 6.67 | 7.67 | 7.00 | 9.00 | 7.67 | 8.33 |
| 10 | 6.33 | 7.67 | 6.33 | 7.33 | 7.33 | 7.33 |
| 11 | 7.67 | 7.00 | 7.33 | 9.00 | 7.33 | 8.17 |
| 12 | 7.00 | 7.33 | 7.33 | 6.33 | 7.33 | 6.83 |
| 13 | 7.00 | 6.67 | 6.67 | 5.67 | 7.33 | 6.50 |
| 14 | 5.67 | 6.67 | 5.67 | 9.00 | 7.00 | 8.00 |
| 15 | 8.00 | 8.00 | 8.33 | 9.00 | 7.00 | 8.00 |
| 16 | 7.67 | 8.33 | 7.67 | 8.33 | 7.00 | 7.67 |
| 17 | 7.33 | 7.33 | 7.33 | 8.67 | 7.00 | 7.83 |
| 18 | 7.67 | 7.67 | 7.33 | 7.33 | 7.00 | 7.17 |

| Run | Taste | Colour | Flavour | Mouth feel | Sweetness | Overall Acceptability |
|---|---|---|---|---|---|---|
| 19 | 7.00 | 7.33 | 8.50 | 9.00 | 7.00 | 8.00 |
| 20 | 7.33 | 7.67 | 7.67 | 7.33 | 7.00 | 7.17 |
| 21 | 7.00 | 7.33 | 6.67 | 8.33 | 6.67 | 7.50 |
| 22 | 8.00 | 8.00 | 8.00 | 7.33 | 6.67 | 7.00 |
| 23 | 7.33 | 7.67 | 7.67 | 8.67 | 6.67 | 7.67 |
| 24 | 7.33 | 7.00 | 7.33 | 8.33 | 6.67 | 7.50 |
| 25 | 7.00 | 8.00 | 7.67 | 6.33 | 6.67 | 6.50 |
| 26 | 6.33 | 7.33 | 6.67 | 8.67 | 6.33 | 7.50 |
| 27 | 7.00 | 7.67 | 7.33 | 10.00 | 6.33 | 8.17 |
| 28 | 7.67 | 6.67 | 7.00 | 8.33 | 6.33 | 7.33 |
| 29 | 8.33 | 8.33 | 8.00 | 9.00 | 5.67 | 7.33 |

Table 3 shows the mean scores for the sensory attributes of the kunun-zaki powder. The taste of the foam-mat dried kunun-zaki received generally positive ratings, with mean scores ranging from 5.67 to 8.33. This indicates that the taste was liked, though there was some variability in preferences among the panelists. The color of the product was well-received, with mean scores ranging from 5.67 to 8.33. The ratings suggest that the color was appealing to the panelist. The mean mouthfeel scores ranged from 5.67 to 10.00. Mouth feel refers to the tactile and textural sensations experienced while consuming the product. The sample with a score of 10.00 seems to have the most favorable mouth feel, but overall, the mouth feel of the product is generally well-liked. The flavor of the foam-mat dried kunun-zaki also received positive feedback, with mean scores ranging from 5.67 to 8.50. This indicates that the flavor was well-liked and generally satisfying. The mean sweetness scores range from 5.67 to 8.33. Sweetness is a critical taste attribute, especially in sweet products. The scores suggest that the level of sweetness is generally acceptable to the panelists. The overall acceptability of the product was quite favorable, with mean scores ranging from 6.50 to 8.67. This suggests that the panelists found the foam-mat dried kunun-zaki to be acceptable and enjoyable as a beverage.

**Table 4.** ANOVA Summary for the Proximate Composition of the Kunun-zaki Powder

| Nutrient | Sum of Square | Mean Square | F-Value | P-Value Prob>F | $R^2$ |
|---|---|---|---|---|---|
| Moisture Content | 202.920 | 101.460 | 23.648 | 0.0001 | 0.95 |
| Ash Content | 5.0195 | 1.673 | 5.283 | 0.0058 | 0.87 |
| Crude Protein | 2442.291 | 106.187 | 7608.902 | 0.0001 | 0.89 |
| Crude Fibre | 44.878 | 4.986 | 7.278 | 0.0001 | 0.76 |
| Carbohydrate | 2483.325 | 413.888 | 19.364 | 0.0001 | 0.93 |
| Fat | 247.74 | 123.87 | 43.68 | 0.0001 | 0.90 |

$$Moisture\ Content = +16.98717 - 0.17047\ z_1 - 0.0238892 z_2 \quad (1)$$

$$Carbohydrate = 65.54067x_1 + 72.49333x_2 + 44.95333x_3 + 11.79867x_1x_2 + 8.11867x_1x_3 - 12.88333x_2x_3 - 198.01800x_1x_2x_3 \quad (2)$$

$$Fat = +8.13x_1 + 5.85x_2 + 15.14x_3 + 5.243x_2x_3 + 0.83x_3x_4 + 1.26x_3x_4 + 41.26x_1x_2x_3 - 51.12x_1x_3x_4 + 27.76x_1x_2x_3x_4 \quad (3)$$

$$Ash = +7.64335x_1 + 7.06680x_2 + 6.65013x_3 - 4.15048x_1x_2 - 5.98381x_1x_3 + 0.012464x_1z_2 + 2.10742E^{-0.03}x_2z_2 + 9.05186E^{-0.03} + 0.10477x_1x_2z_2 + 0.14644x_1x_3z_2 \quad (4)$$

$$Crude\ Fibre = +0.079742x_1 + 0.059127x_2 + 0.070690x_3 + 4.95690E^{-0.04}x_1z_2 \quad (5)$$

$$Protein = +8.78x_1 + 8.17x_2 + 8.00x_3 - 0.78x_4 + 0.86x_5 - 2.51x_2x_3 + 1.11x_3z_1z_2 \quad (6)$$

**Table 5.** Optimization of the Foam-mat Dried Kunun-Zaki Powder

| No. | Millet | Maize | Soya bean | DT | SP | MC | AC | CP | CF | CHO | FC | DI |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1.000** | **48.435** | **0.000** | **51.565** | **40.000** | **12.000** | **9.595** | **2.552** | **28.195** | **5.828** | **54.443** | **11.949** | **0.625** |
| 2.000 | 45.004 | 0.000 | 54.996 | 40.000 | 13.300 | 9.595 | 2.522 | 28.480 | 5.875 | 53.657 | 12.182 | 0.621 |
| 3.000 | 0.000 | 34.171 | 65.829 | 40.000 | 12.000 | 9.595 | 2.154 | 29.583 | 4.681 | 52.882 | 11.775 | 0.609 |
| 4.000 | 0.000 | 31.774 | 68.226 | 43.910 | 12.000 | 8.929 | 2.152 | 30.157 | 4.740 | 52.213 | 12.052 | 0.608 |
| 5.000 | 0.000 | 35.249 | 64.751 | 45.970 | 12.000 | 8.578 | 2.154 | 30.213 | 4.656 | 53.183 | 11.928 | 0.607 |

*MC: moisture content, AC: ash content, CP: crude protein, CF: crude fibre, CHO: carbohydrate FC: fat content, DI: desirability index, SP: steeping period, DT: drying temperature*

Table 4 presents the result of an optimization study of the foam-mat dried kunun-zaki powder. The corresponding values for moisture content, ash content, crude protein, crude fibre, carbohydrate, fat content and desirability index are recorded for each optimized component experiment generated by the software. The goal of this optimization study is to find the best combination of ingredients and processing conditions to achieve a foam-mat dried Kunun-Zaki powder with desired nutritional properties. The desirability index help determine which combination yields the most desirable product. Figure 1 – 6 shows the response surface plot for the proximate composition of the kunun-zaki powder.

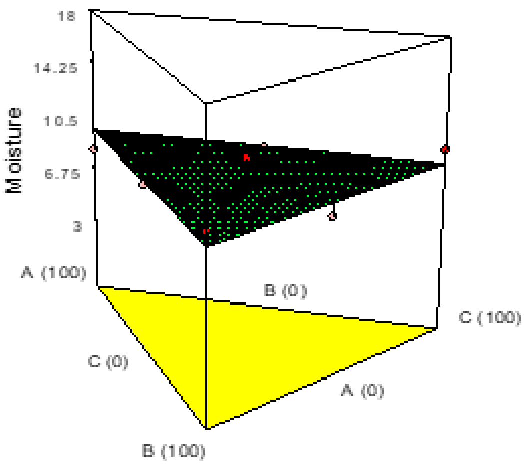


**Figure 1**. 3D Surface Plot for Moisture Content

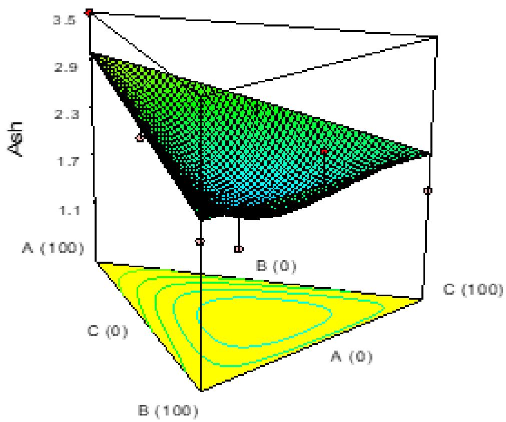


**Figure 2**. 3D Surface Plot for Ash Content

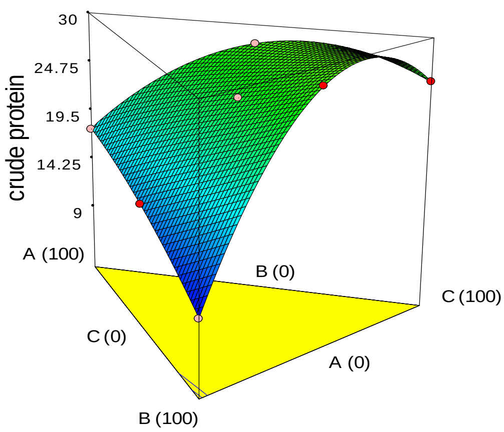


**Figure 3**. 3D Surface Plot for Crude Protein

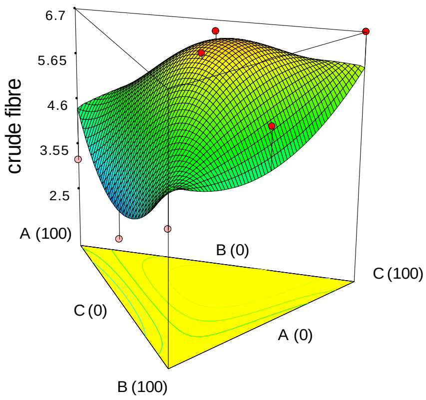


**Figure 4.** 3D Surface Plot for Crude Fibre

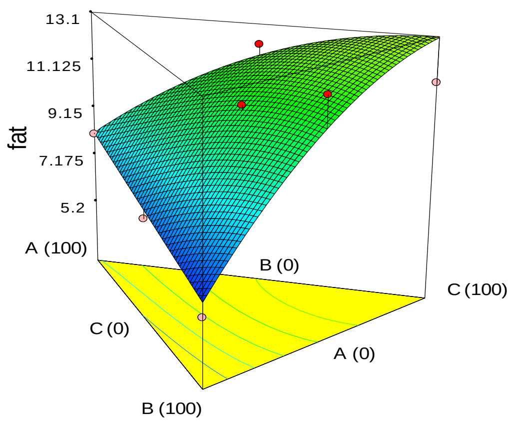


**Figure 5.** 3D Surface Plot for Fat

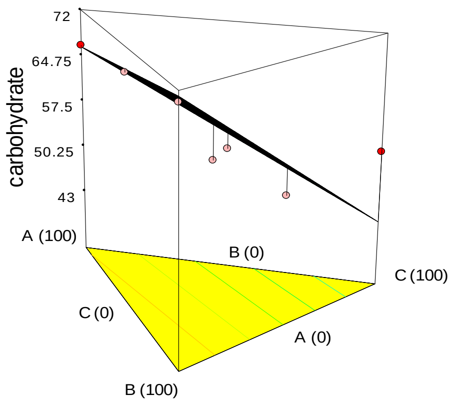


**Figure 6.** 3D Surface Plot for Carbohydrate

https://doi.org/10.58612/jafce351

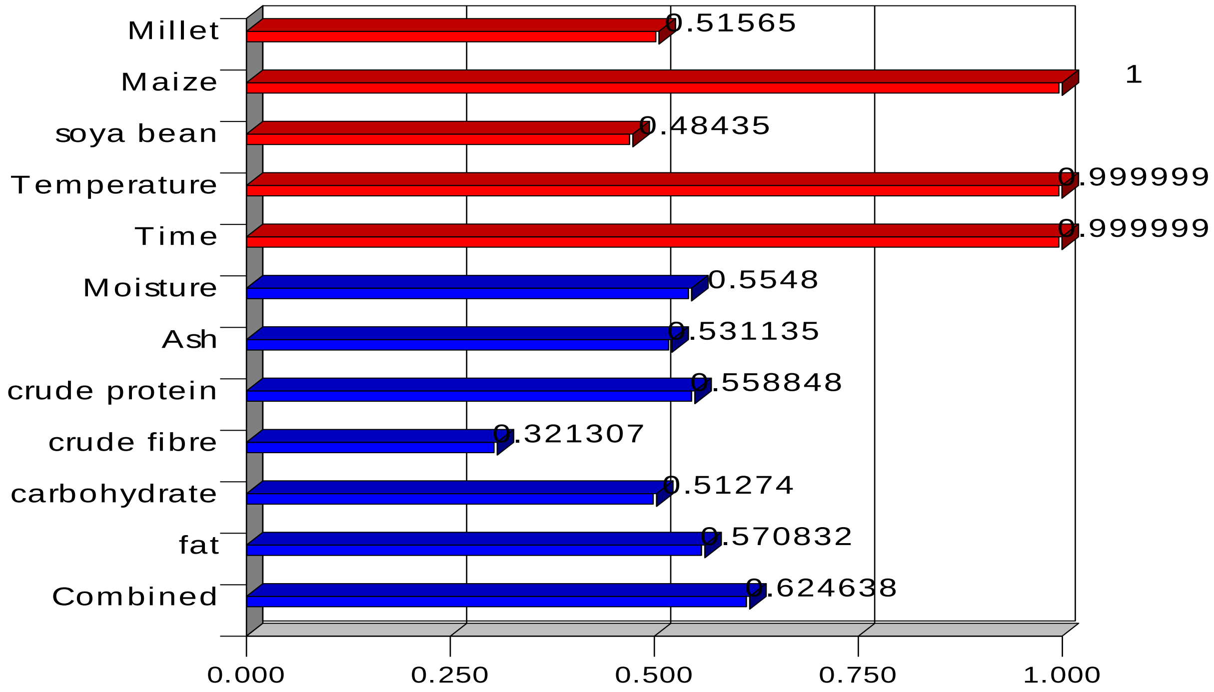


**Figure 7.** Desirability plot of foam-mat dried kunun-zaki powder

### 3.2. Discussion

Kunun-zaki is a non-alcoholic, lactic acid and bacterially fermented cereal beverage with a short shelf life. The product's high moisture content (88 to 92 percent) and the unsanitary production procedures are responsible for its short shelf life (24 to 48 hours), which has worried both its producers and customers [8]. Foam-mat drying significantly decreased the moisture contents of the kunun-zaki powders made in this study, as evidenced by the noticeably decreased weight. Similar result was observed by Ogunyemi et al. [8] for the freeze-dried kunun zaki. The ANOVA results in Table 4 indicate that the drying temperature ($Z_1$) and steeping period ($Z_2$) significantly affect the moisture content of the foam-mat dried Kunun-Zaki powder (p-value < 0.0001). Higher drying temperatures and longer steeping periods seemed to reduce the moisture content in the final product. The highest mean moisture content was 12.306% in sample 29, comprising 100% millet which was steeped at 36 hours and dried at room temperature ($Z_1$ = 24$^0$C). The variation in the moisture content of the kunun-zaki may also be attributed to the activities of the microorganisms. As shown in Table 4, the ANOVA indicates that all factors significantly influence the proximate composition of the kunun-zaki powder i.e p < 0.005. The highest mean crude protein content is 42.66% in sample 11 (Table 1), which had a mixture of 100% soybeans and was steeped and dried at 36 hours and 40$^0$C, respectively. The results obtained were higher to those of Oluwajoba *et al.* [9] that ranged between 13.97 and 18.54 % for kunun zaki made from germinated and un-germinated composite cereal grains. The results also contradicted the ones obtained by Eneke *et al.* [10] that ranged between 17.22 to

17.93%. This high protein value of the foam-mat dried kunun-zaki powder could be attributed to the high-quality nature of the soybean which formed 100% mixture of the samples exhibiting this high protein and the longer steeping period. The longer the soaking time, the higher the protein. The cause of this is because, during fermentation, protein enzymes are hydrolyzed, releasing free amino acids that resulted in new protein content. This may be because of the metabolic activities of microorganisms and because high temperatures denaturize fat [11]. The ash content varied significantly between 1.1 to 3.87%. The fat content varied between 1.82 – 6.88%, with the highest content found in a sample containing equal proportion of the ingredients, 33% millet, 33% maize and 33% soybean. This amount of the fat is higher to those observed by Akoma *et al*. [2006] This may be attributed to the composite nature of the kunun-zaki. This appreciable amount of fat/lipid in these samples is an indication of the capability of the food samples to supply sufficient energy in diets. The carbohydrate of the kunun-zaki powder also varied significantly between 39.00% to 73.85%. The sample (50% Millet and 50% Maize) soaked for 12 hours and dried at $70^0$C produced the highest carbohydrate. Other samples' low carbohydrate values could have resulted from microflora using a lot of energy during fermentation or from a significant rise in protein content [11]. This amount is almost similar to the one reported by Omowaye and Oluwamukomi [13]. According to Ihekoronye and Ngoddy's (1985) report on high carbohydrate foods, the beverage's high carbohydrate values implied that it contained high calories and promoted protein sparing. The crude fibre ranged between 1.07 to 2.87. The sample soaked for 12 hours and dried at $40^0$C produced the highest crude fibre. The average of triplicate responses obtained for each experimental combination was fitted in the general form of linear models as shown in Equation 1 to 6. Response fit analyses, regression coefficient estimations and model significance evaluations were conducted. The estimated regression coefficients of the fitted model equation as well as the correlation coefficients for each model are given in Table 3. The adequacy of the models was tested using p-values and coefficient of determination ($R^2$). The F-Value of 23.648 with a P-Value (Prob>F) of 0.0001 indicates that there is a significant difference among the proximate composition the foam-mat dried Kunun-Zaki samples. The $R^2$ value of 0.95 suggests that 95% of the variation in moisture content can be explained by the model. This indicates a strong relationship between the drying conditions and moisture content. Similarly, the fitted model equations for the other nutritional qualities as in equation 1 to 6 have been shown to be significantly adequate, based on their coefficient of determination and p-values. The developed models were validated using numerical optimization. The equation 1 which represents the empirical model equation for the moisture content showed that the moisture content of foam-mat dried kunun-zaki is influenced by two factors, drying temperature and steeping period. Both factors have negative coefficients, implying that as the values of $Z_1$ and $Z_2$ increase, the moisture content decreases. Equation 4.2 to 4.6 showed that the AC, CP, CHO, CF, FC were greatly affected by the proportion of the ingredient (maize, millet and soybeans). Thus, the interaction between these ingredients played a significant role in determining the predictability of their nutritional qualities. A numerical optimization method exploiting the desirability technique was utilized to generate a new formulation with the anticipated responses. The ideal formulation was chosen based on the criteria of achieving minimum moisture content, maximum protein, minimum carbohydrate, minimum steeping period, minimum temperature, maximum fat, maximum crude fibre, and maximum ash content. The goal of this optimization is to obtain an excellent series of conditions that will meet all the goals. Table 4 shows the optimization of the proximate composition of foam-mat dried kunun-zaki. It can be deduced from the optimization table, which is graphically represented in Figure 7, that kunun-zaki of desirability index of 0.625, with ingredient formulation of 48.435% millet, 0.0005 maize, 51.565% soybeans dried at $40^0$C drying temperature and steeping period of 12hours produced the desirable, optimized kunun-zaki powder. The DI was obtained from the optimal conditions selected based on the chosen criteria. Desirability is an objective function which varies between 0 and 1. The numerical optimization locates a point that maximizes the desirability.

## 4. Conclusion

Optimization analysis based on the response model revealed that kunun-zaki of 9.595 % moisture content 2.552% ash content, 28.195% crude protein, 54.443% carbohydrate, 11.949% fat and 5.828% crude fibre could be produced from 48.435 % of millet, 51.565% of soya bean and 0.000% of maize. This optimized ingredient formulation produced kunun-zaki of 0.625 desirability index. This model postulates a foundation for choosing process variables for optimal condition in the production of foam-mat dried kunun-zaki. Statistical analysis of variance of the result shows that both the interaction of the mixture components and the process parameters have significant effect on the proximate composition and sensory quality of foam-mat dried kunun-zaki with the level of probability ($p < 0.05$).

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