Food ScienTech Journal Vol. 6 (1) 2024 ISSN : 2685-4279 DOI:10.33512/fsj.v6i1.23866

Determination of The Mineral Composition of Foam-Mat Dried *Ngu* Powder Using Response Surface Methodology

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Submitted: 07.01.2024; Revised: 04.05.2024; Accepted: 26.06.2024

ABSTRACT

Foam-mat drying of Ngu using egg white as a foaming agent was investigated. Three concentrations of Ngu sample- 60, 80, and 100% were used for the study. The Ngu samples were enriched with egg white at 20, 25, and 30% concentration respectively at room temperature. The mixture was beaten for 5, 9, and 12 mins. A central composite response surface design was employed to investigate the impact of whipping duration, egg white, and Ngu concentration on the mineral composition of dried Ngu powder. Regression models showed that the experimental variables had significant ($p<0.05$) effects on the dry Ngu powder's iron, zinc, calcium, sodium, phosphorus, potassium, and magnesium contents. The optimal values for all responses were achieved using a combination of 10 mins of whipping time, 20.8% egg white, and 100% Ngu concentration. The optimal values for the mineral content of Ngu powder were determined to be 17.46 mg/g for iron, 1.03mg/g for zinc, 0.58 mg/g for calcium, 12.72 mg/g for sodium, 2.26 mg/g for phosphorus, 1.36 mg/g for potassium and 0.26 mg/g for magnesium.

Keywords: Emulsion, Foam-mat drying, Food waste, Ngu, Response surface methodology

INTRODUCTION

Food waste is one of the most challenging issues humankind is currently facing worldwide (Garcia-Garcia *et al.*, 2017). Currently, food systems are extremely inefficient: it is estimated that between one-third and one-half of the food produced is lost before reaching a human mouth (Griffin *et al.*, 2009). Nevertheless, reduction of the current levels of food waste must be accompanied by better management of the waste: inevitably there will always be some food waste. Food waste management, recovery, and utilization involve activities where discarded food materials are collected, sorted, processed, and converted into edible or non-edible new products (Thyberg and Tonjes, 2015). Agricultural waste materials such as palm bunch waste, cocoa pod, plantain peels, banana peels, maize cob, sugar beet waste, etc. contain a good percentage of potash (Hung Mo *et al.*, 2014). When these materials are burnt, the resulting ashes contain oxides of potassium and sodium which when dissolved in water yield alkalis - the corresponding hydroxides, a basis for the production of various emulsions (Onyekwere, 1996). The filtrate obtained from the filtration of the mixture of this ash and water normally has a brown color and can emulsify oil, thus producing an emulsion with it.

One of the largest agricultural waste is the palm inflorescence (Uzodinma *et al*., 2014). In the Eastern part of Nigeria, some communities use the filtrate to produce an edible emulsion base (a mild soap) called "*Ncha*" or "*Ngu*". *Ngu* is an African salad dressing (water-in-oil emulsion) commonly used in the preparation of African salad (*Abacha*, *Ighu*), bitter yam (*Dioscorea dumetorums*), and processed oil bean seed (*Ugba*). Emulsions are inherently thermodynamically unstable systems as when mixed, the oil and the aqueous phases continually strive to minimize contact (Rousseau, 2000). Drying the "*Ngu"* emulsion and rendering it into powder is therefore very important to create a convenient form of this popular traditional emulsion salad dressing and preserve the integrity of the emulsion.

The foam-mat drying technique is a process in which liquid or semi-solid food products like fruit juices, vegetable puree, or pastes from cereals are converted into stable foams by whipping air or inert gas in the presence of a food-grade foaming agent and/or stabilizer, with subsequent drying to reduce product moisture to 2-2.5% (Hardy and Jideani, 2017). Foam-mat drying can process hard-to-dry materials to produce products of the desired and required properties thereby retaining volatiles that otherwise would be lost during drying of non-foamed materials (Wilson *et al*., 2012). The process produces an end product with favorable rehydration/controlled density and retains volatiles that would be lost when using other forms of drying (Kudra and Ratti, 2006). Foam-mat dried products contain improved reconstitution characteristics due to their open structure. More interest has developed in foam-mat drying because of the simplicity, cost-effectiveness, high-speed drying, and improved product quality it provides (Kandasamy *et al*., 2012).

Response surface methodology (RSM) is a collection of mathematical and statistical techniques that are useful for designing experiments and analysis of problems in which the response of interest is influenced by several variables and objectives (Iwe, 2000; Kalil *et al*., 2000). The designs capable of generating a response surface include central composite and Box-Behnken designs (Lucas, 1994). The response surface methodology is being increasingly used in the industry, with even more recent emphasis and application in chemical and processing fields on finding regions where there is improvement in response rather than finding the optimum response (Myers *et al*., 1989). The multivariate approach in RSM reduces the number of experiments, improves statistical interpretation possibilities, and indicates interaction among different parameters. Combinatorial interactions of drying parameters with the quality of dehydrated products and the optimum processes may be developed using an effective experimental design procedure. This study investigated the impact of specific experimental factors, utilizing the response surface methodology, on the mineral content of foam-mat dried *Ngu* powder.

MATERIALS AND METHODS

Materials

Prepared *Ngu* (produced from 5litres of distilled water, 500g of *Ncha*, 800g of melted red palm oil, and 100g of *Ogiri*) was purchased from a professional *Ngu* maker at Amuda Isuochi, Umunneochi Local Government Area, Abia State, Nigeria. Fresh eggs were purchased from a local market in Umuahia, Abia State, Nigeria.

Dilution of *Ngu*

100% *Ngu* was diluted with 20% moisture to get 80% *Ngu*; and 40% moisture to get 60% *Ngu*. Three concentrations of *Ngu*

were used for the study: 100%, 80%, and 60% respectively.

Foaming agent preparation

The foaming agent used was egg white/albumin. Egg white was obtained from fresh whole eggs and prepared for use as a foaming agent according to the method described by Lomakina and Mikova (2005). Fresh whole eggs (24 in number) were washed with distilled water and allowed to dry. Then, the egg shell was cracked with a stainless fork to make a small opening for the egg white to flow out into a clean bowl. The egg white was then whipped for 1-2 mins and kept (1-3 mins) at room temperature until ready for use. The egg white was used at different concentrations of 20, 25 and 30% (w/w).

***Ngu* foam preparation and foam-mat drying**

The method for the production of foam-mat dried fruit and vegetable powder described by Balasubramanian *et al.* (2012) was modified and adopted for the production of foam-mat dried *Ngu* powder. One hundred milliliters (100 ml) of *Ngu* was mixed separately with the foaming agent (egg white) at different concentrations of 20, 25, and 30% EW (weight-to-weight basis). The different mixtures were blended using a high-speed mixer (Kenwood, 900 w) at speed of 6 for 5, 9, and 12 mins respectively (according to the different whipping times in the experimental design) at room temperature. Thereafter, the foamed *Ngu* emulsion was spread on trays (wrapped with foil), placed in the hot air oven (UNISCOPE SM9023 Surgifield Medicals, England), and dried at 70^{o}C for about 6-9 h. The dried *Ngu* was scraped off from the trays, pulverized, and packaged in a transparent bowl plate.

Experimental design

A central composite rotatable response surface design (CCD) for K = 3 described by Cornell (1990) was used (Equation 1)

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$$Y = \beta_0 + \sum \beta_i X_i + \sum \beta_{ii} X_i^2 + \sum\sum \beta_{ij} X_i X_j + \varepsilon \quad (1)$$

Where Y = dependent variable

X_i and X_j = independent variables

K = number of independent variables

β_0 = intercept (constant and regression coefficient of the model)

ε = random error terms

Twenty-five (25) experimental runs generated based on CCD (K = 3) were used to study the linear, interactive, and quadratic effects of the independent experimental variables. The runs include five (5) experiments at the start, center, and corner points respectively. The center point (0, 0, 0) was replicated six times. The corner and start points were not replicated (Iwe *et al.,* 1998).

Determination of mineral composition of dried *Ngu* powder

The dry ash acid extraction method (James, 1995) was used for mineral extraction. The weighed sample was burnt to ash in a muffle furnace. The resulting ash was dissolved in 10 ml of 2M HCl solution and diluted to 100 ml in a volumetric flask. It was filtered and the filtrate was then used for the determination of the different mineral elements.

Determination of Calcium and Magnesium

These minerals were determined by complexiometric titrimetry in which the versanate EDTA titrimetric method was employed. Twenty ml of the extract was dispersed into a conical flask and treated with pinches of the masking agents (sodium, potassium ferro cyanide). The flask was shaken to dissolve the mixture and 20 ml of ammonia buffer was added to raise the pH to

10.00 (a point at which both calcium and magnesium form complexes with EDTA). The mixture was titrated against 0.02N EDTA solution using Erichrome Black T as an indicator. A reagent blank was also titrated in each case, it turned from deep red to a permanent blue endpoint. The titration value represents both Ca^{2+} and Mg^{2+} alone in the test samples.

Titration of calcium alone was done in similarity with the above titration however, 10% NaOH was used in place of ammonia buffer and solochrome dark blue indicator in place of Erichrome Black T.

The Ca^{2+} and Mg^{2+} content from the titer values obtained was calculated as shown in Equation 2 below:

$$\text{Ca or Mg (mg/g)} = \frac{100}{W} \times T - B\ (N \times Ca \text{ or } Mg) \times \frac{V_t}{V_a}$$

Where:

W = Weight of sample
T = Titer value of sample
B = Titer value of blank
Ca = Calcium equivalent
Mg = Magnesium Equivalent
N = Normality of titrant (0.02N EDTA)
V_t = Total volume of extract
V_a = Volume of extract titrated

Determination of Phosphorus

The phosphorus content in the samples was determined by the Molydbo vandate colorimetric method (James, 1995). A measured volume of the dry ash (2mg) digest of the sample was dispersed into a 50-volume flask. The same volume of distilled water and standard phosphorus solution were measured into different flasks, at the same time, to serve as a reagent blank and standard, respectively. Two milliliters (2ml) of the phosphorus color reagent (Molybdo vandate solution) was added to each of the flasks and the mixture was allowed to stand at room temperature for 15 mins. The content of each flask was diluted to a 50ml mark with distilled water and its absorbance was measured using a spectrophotometer at a wavelength of 540nm with the reagent blank at zero.

The phosphorus content was calculated using Equation 3 below;

$$P\ (mg/g) = \frac{100 \times Au \times C \times V_t}{W \times A_s \times Va} \quad (3)$$

Where:

A_s = Absorbance of standard phosphorus solution
C = Concentration of standard phosphorus solution
V_t = Total extract volume
V_a = Volume of extract analyzed
W = Weight of sample
Au = absorbance of sample

Determination of Sodium and Potassium

These were determined using the flame photometer (AOAC, 1990). The instrument digital flame photometer was set up according to the manufacturer's instructions. It was switched on and allowed to stand for about 15 mins to equilibrate. On the other hand, standard sodium and potassium solutions were prepared separately and serially diluted to contain 10, 8, 6, 4, and 2pp of Sodium (Na) and Potassium (K) respectively.

Furthermore, 1 ml of each standard was aspirated into the instrument after calibration and sprayed over the non-luminous flame. The optical density of the resulting emission from each standard solution was recorded. The appropriate element filter (Na or K) was put in place with the standards measured before flaming while the test sample extract was measured in time and plotted into a standard curve which was used to extrapolate the content of each test element and calculated as shown below;

$$\text{Na or K (mg/g)} = \frac{X \times V_t \times D \times 100}{V_a \times W} \quad (4)$$

Where:

X = Concentration of the test element from the curve
V_t = Total extracted volume
V_a = Volume of extract analyzed
D = Dilution factor
W = Weight of sample

Determination of Iron

Iron was determined using the phenylthroline method as described by (James, 1995). The sample (5ml) with 3ml concentrated HCL and 1ml hydroxylamine solution were mixed in a test tube. A few glass beads were added and the mixture was heated till it started boiling. It was then cooled to room temperature and transferred to a 50ml volumetric flask. Ten milliliters of ammonium acetate buffer solution and 2ml phenylthroline solution were added and distilled water to the mark. It was thoroughly mixed and allowed to stand for about 10-15 mins for maximum development. The absorbance was read at 510nm. A standard curve using 2.0, 4.0, 6.0, 8.0, and 10.0 ml/std iron solution was prepared and put into a 100-volumetric flask from the stock solution.

Determination of Zinc

Zinc was determined using an atomic absorption spectrophotometer as described by James (1995). The standard series and suitable diluted sample and blank digests were aspirated into an atomic absorption spectrophotometer calibrated for zinc measurement at a wavelength of 213.9nm. A calibrated curve of the absorbance readings of the standard solution against the concentrations was plotted and used to determine the concentration of the unknown. The concentration of the Zinc in the dried sample was calculated as follows:

$$\text{Zn (mg/g)} = \frac{(a-b)\times v \times f \times 1000}{w} \quad (5)$$

Where:
a =concentration of Zn in the solution
b = concentration of Zn in the mean values of blanks
v = final volume of the digestion process
w = weight of the sample taken
f = the dilution factor

Optimization

The desirability method of optimization described by Nazni and Gracia (2014) was adopted in the optimization of these multi-responses simultaneously, formulation composition and setting the optimization goals. The application of the desirability function combines all the responses in one measurement and offers the possibility to predict optimum levels for the independent variables.

Experimental analysis, literature information, research objectives, and panelists' preferences were considered in maximizing/minimizing the independent variables and the responses. Sodium is the only response that was minimized. Low sodium is necessary for the system due to its support for cell functionality without promoting heartbeats or high blood pressure (Agu *et al.* 2023).

The general approach was to first convert each response (y_i) into an individual desirability function (d_i) that varies for the range $0 \leq d_i \leq 1$, whereas if the y_i is at its goal or target then, $d_i = 1$, and if the response is outside acceptable region $d_i = 0$. Then the design variables are chosen to maximize the overall desirability,

$$D = (d_1 \text{ x } d_2 \text{ x } \ldots\ldots\ldots d_n)^{1/n} \quad (6)$$

Where n = number of responses

Statistical analysis

The Statistical Package for Social Sciences (SPSS, version 20, IBM SPSS Statistics 20, IBM Corporation, Armonk, NY) was used to obtain the mean, standard deviation, and analysis of variance (ANOVA) was used to judge for significance ($p \leq 0.05$). Means were

separated using Duncan's Multiple Range Test.

RESULTS AND DISCUSSION

Mineral composition of dried Ngu powder

Results of the mineral composition and pH values of dried *Ngu* powder are shown in Table 1 below.

Iron (Fe)

Results in Table 1 show that there was a significant difference in the Fe content of the dried *Ngu* samples which varied from 17.00 to 17.71mg/g. Uzodinma *et al*. (2014) reported the Fe content of palm filtrate from palm bunch waste products to be 0.72 mg/g. Differences in the raw materials utilized, as well as environmental and experimental conditions, can explain the variation in Fe content. Dry *Ngu* powder produced from the formulation having 60% *Ngu* concentration, 30% egg white and whipped for 12 mins had the highest Fe content (17.71mg/g), while dry *Ngu* powder produced from the formulation having 60% *Ngu* concentration, 25% egg white and whipped for 9 mins and dry *Ngu* produced from the formulation having 80% *Ngu* concentration, 25% egg white and whipped for 5mins had the lowest Fe content (17.00mg/g). This variation in Fe content could be a result of the concentration of the egg white, as the Fe content was observed to vary directly with the quantity of egg white used. The same observation was made by Jyothsna *et al*. (2023) who reported that albumin has a statistically significant positive correlation with serum iron. On the other hand, Werner *et al*. (2022) noted that providing eggs daily for 6 months did not affect iron status or anemia prevalence among young Malawian children.

Response surface analysis showed (Table 2) that the iron content of the dried *Ngu* powder was significantly ($p \leq 0.05$) influenced by the quadratic effect of the egg white concentration. The non-significant effect of whipping time was not surprising as the whipping time is not expected to destroy or enhance the Fe content of the food. The model coefficients are presented in Table 2. An acceptable regression coefficient (R^2) value of 70.2% shows that 70% variability in the data is explained by the deduced model. Although the model was not significant, the non-significant ($p>0.05$) lack of fit in addition to the acceptable R^2 value ≥70%, shows the predictability of the response (iron) by the model (Gbenyi *et al.*, 2015).

Concerning optimization, the optimum possible Fe value is 17.46mg/g. To obtain this, a whipping time of 10 mins, egg white concentration of 20.8%, and *Ngu* concentration of 100% should be used.

The final model equation is:

$$Fe = 17.20 + 0.21X_2^2 - 0.025X_2X_3 \quad (7)$$

Where, X_2 = Egg white concentration and X_3 = *Ngu* concentration

Magnesium (Mg)

There was a significant ($p<0.05$) difference in the Mg content of the dry *Ngu* powder, which varied from 0.180 to 0.535mg/g as shown in Table 1. It was observed that the Mg content increased with a decrease in the *Ngu* concentration. This is evident in the negative coefficient of estimate (-0.050) shown by the regression analysis. The magnesium (Mg) content of palm filtrate has been reported in various studies. Vijayakumari *et al.* (2017) found that the pulp of the palmyra palm, a type of palm, contains 10.2 mg/100g of magnesium. Similarly, Santana *et al.* (2020) noted a magnesium content of 0.70-1.78% in the forage palm, another type of palm. Furthermore, Uzodinma *et al*. (2014), reported the Mg content of palm filtrate from palm bunch waste products to be 0.028mg/g. The concentration of magnesium (Mg) in palm filtrate is influenced by various factors. Szydłowska-Czerniak *et al.* (2013) found a significant positive correlation between Mg

and other metals in palm oils, suggesting that the presence of these metals may affect Mg concentration. Also, differences in the raw materials utilized may be another reason for the varied results.

Regression analysis showed (Table 3) that the linear effects of egg white concentration and *Ngu* concentration, interaction between whipping time and egg white concentration, and interaction between egg white and *Ngu* concentrations significantly ($p<0.05$) affected the magnesium content of dry *Ngu* powder. These variables accounted for a 74% variation in the Mg content of the product. The significant effect on the Mg content of the dried *Ngu* powder and the non-significant lack of fit of the model confers goodness of fit (Gbenyi *et al*., 2015). The optimum value of Mg is 0.26mg/g, obtainable by using 100% *Ngu* concentration, 20.8% egg white, and 10 mins whipping time.

The final model equation is:

$$Mg = 0.21 + 0.033X_2 – 0.050X_3 – 0.059X_1X_2 – 0.046X_2X_3 \quad (8)$$

Potassium (K)

The potassium content of *Ngu* powder as shown in Table 1 ranged from 0.86 to 1.56mg/g. Dry *Ngu* powder produced from 60% *Ngu* concentration, 20% egg white, whipped for 5 mins had the lowest K content (0.86mg/g) while dry *Ngu* powder produced from 100% *Ngu* concentration, 30% egg white, whipped for 5 mins and 80% *Ngu* concentration, 30% egg white, whipped for 9mins had the highest K content (1.56mg/g). It was observed that the K content of the product increased with the concentrations of *Ngu* and egg white. This could be attributed to the high K content of egg white which is 169mg/100g (USDA, 2015).

Regression results (Table 4) showed that the model was significant ($p<0.05$). The linear effect of whipping time, egg white, and *Ngu* concentrations significantly ($p<0.05$) affected the K content of dry *Ngu* powder. The quadratic term of the whipping time and interactions between whipping time and egg white concentration; egg white and *Ngu* concentrations were also significant ($p<0.05$). These accounted for 88% variation in the K content of the dry *Ngu* powder. The non-significant ($p>0.05$) lack of fit with the acceptable R^2 value of 88% shows the predictability of the response (K) by the model. Results further showed that all independent variables were significant ($p<0.05$). From optimization, the optimum K value is 1.36mg/g, obtainable from using 100% *Ngu* concentration, 20.8% egg white, and 10 mins whipping time.

The final model equation:

$$K = 1.43 + 0.054X_1 + 0.11X_2 + 0.13X_3 – 0.12X_1^2 – 0.070X_1X_2 \quad (9)$$

Phosphorus (P)

The phosphorus content of the dry *Ngu* powder ranged from 1.34mg/g to 2.51mg/g as shown in Table 1. There was a significant ($p<0.05$) difference in the phosphorus content of the dry *Ngu* product but no particular trend was observed. Uzodinma *et al*. (2014) reported no trace of P in the filtrate from palm bunch waste. The concentration of phosphorus in palm filtrate is influenced by a variety of factors. Saleh (2012) found that phosphorus levels significantly affected the chemical composition of date palm fruit, suggesting a potential impact on palm filtrate. Oviasogie and Uzoekwe (2011) demonstrated that the use of palm oil mill effluent can increase the concentration of available phosphorus in soil, which may subsequently affect the phosphorus content of palm filtrate. Finally, Maranguit *et al.* (2017) discussed the impact of land-use change on phosphorus availability in tropical soils, indicating that changes in land use, such as the conversion of forests to palm

plantations, could also affect the phosphorus concentration in palm filtrate.

Regression analysis showed (Table 5) that the linear effects of whipping time, egg white, and *Ngu* concentrations were significant ($p<0.05$) and they accounted for 94% of the total variation in the P content of the product. Results further showed that the quadratic effect of whipping time and interactions between whipping time and egg white; whipping time and *Ngu* concentration significantly ($p<0.05$) affected the P content of the product. The insignificant ($p>0.05$) lack of fit and the R^2 value of 94% show the predictability of the response (P) by the model. From optimization, the optimum P content in dry *Ngu* powder is 2.26mg/g and is obtainable from 100% *Ngu* concentration, 20.8% egg white, and 10 mins whipping time.

The final model equation is:

$$P = 1.94 + 0.29X_1 + 0.36X_2 + 0.60X_3 + 0.21X_1^2 - 0.15X_2X_3 - 0.22X_1^2X_2 - 0.057X_1^2X_3 - 0.36X_1X_2^2 \quad (10)$$

Zinc (Zn)

Results in Table 1 show that there was a significant ($p<0.05$) difference in the zinc content of dry *Ngu* powder which ranged from 1.025mg/g to 1.045mg/g The Zinc content of dry *Ngu* powder was lower than that of palm bunch waste (10.75mg/g) and higher than the filtrate from palm bunch waste product (0.72mg/g) as reported by Uzodinma *et al*. (2014). Differences in the raw materials utilized may be the reason for the varied results.

Regression analysis showed (Table 6) that the quadratic effect of *Ngu* concentration significantly ($p<0.05$) affected the Zn content of dry *Ngu* powder and they accounted for 71% of the total variation in the Zn content of the product. An acceptable regression coefficient (R^2) value of 0.7078 shows that 71% variability in the data is explained by the model. Optimization shows that optimum Zinc is 1.03%, obtainable from 100% *Ngu* concentration, 20.8% egg white, and 10 mins whipping time.

The final model equation is:

$$Zn = 1.03 + 2.714 - E\text{-}003X_3^2 \quad (11)$$

Calcium (Ca)

Dry *Ngu* powder produced from 80% *Ngu* concentration, 20% egg white, and whipped for 9 mins had the highest calcium content (0.805mg/g) while dry *Ngu* powder produced from 60% *Ngu* concentration, 30% egg white, 12 mins whipping time had the lowest calcium content (0.295%). There was a significant ($p<0.05$) difference in the calcium content of dry *Ngu* powder as shown in Table 1. However, no definite trend was observed. The calcium content of the product compared well with the calcium content of filtrate from palm bunch waste product which is 0.96mg/g (Uzodinma *et al.*, 2014). The interaction between calcium and fatty acids, such as palmitic acid, may affect the calcium concentration in the palm filtrate (Watras *et al*. 1984). Optimization shows the optimum calcium value is 0.58mg/g, obtainable from 100% *Ngu* concentration, 20.8% egg white, and 10 mins whipping time.

Regression analysis showed (Table 7) that the model was insignificant ($p>0.05$). The linear effect of whipping time significantly ($p<0.05$) affected the calcium content of the dry *Ngu* powder. The insignificant ($p>0.05$) model and significant lack of fit in addition to the low R^2 value of 42% shows the unpredictability of the response (Ca) by the model.

The final model equation is:

$$Ca = 0.05 - 0.080X_1 \quad (12)$$

Sodium (Na)

The sodium content of the dry *Ngu* powder varied from 9.33 to 15.06mg/g (Table 1). There was a significant ($p<0.05$) difference in the Na content of dry *Ngu* powder. It was

observed that the Na content increased with egg white concentration and decreased with an increase in *Ngu* concentration. This may be attributed to the high Na content of egg white (154mg/100g) reported by Roe *et al*. (2013). According to Uzodinma *et al*. (2014), the sodium content of oil palm biogenic waste ranged from 0.00mg/g (filtrate from palm bunch waste) to 0.013mg/g (palm bunch waste).

Regression analysis (Table 8) showed that the model was significant ($p<0.05$). The linear effect of egg white and *Ngu* concentrations significantly ($p<0.05$) affected the Na content of dry *Ngu* powder. The quadratic term of whipping time and egg concentration; interactions between whipping time and egg concentration and egg concentration and *Ngu* concentration significantly ($p<0.05$) affected the Na content of the product. These accounted for 81% of the total variation in the Na content of the product. There was a significant ($p<0.05$) lack of fit and a high coefficient of determination (R^2) value of 81% signifying the adequacy of the model. Regarding optimization, the optimum value of sodium content in the dry *Ngu* powder is 12.72mg/g, obtainable from 100% *Ngu* concentration, 20.8% egg white, and 10mins whipping time.

The final model equation is:

$$Na = 13.41 + 0.62X_2 - 1.43X_3 - 1.35X_1^2 + 1.16X_2^2 - 0.65X_1X_2 + 0.61X_2X_3 \quad (13)$$

Optimization Process Through Desirability Approach

The independent variables (factors and responses) were: whipping time (WT), *Ngu* concentration (NC), iron (Fe), magnesium (Mg), potassium (K), phosphorus (P), zinc (Zn), and calcium (Ca). These were based on the literature data, experimental analysis, and consumer preference (Pestoric *et al.*, 2011).

Applying the desirable function, the best optimum concentrations were attained for whipping time 10 mins, egg white concentration 20.80%, and *Ngu* concentration 100%. The calculated desirability for the formulation was 0.63. At these concentrations, the optimum values of the responses – Fe, 17.46mg/g, Mg, 0.26mg/g, K, 1.36mg/g, P, 2.26mg/g, Zn, 1.03mg/g, Ca, 0.58mg/g and Na, 12.72mg/g were desired.

CONCLUSION

Dry *Ngu* powder was produced by adopting selected whipping time, egg white, and *Ngu* concentration. There was a significant ($p<0.05$) difference in the mineral composition of dry *Ngu* powder. Iron content ranged from 17.01 to 17.05mg/g and regression analysis showed that the quadratic effect of egg white concentration had significant effects on the Fe content of the samples. The magnesium content of dry *Ngu* powder varied from 0.11 to 0.54mg/g. Linear effects of *Ngu* concentration, the interaction between whipping time and egg white, and the interaction between egg white and *Ngu* concentration had significant ($p<0.05$) effects on the magnesium content of dry *Ngu* powder. Potassium content varied from 0.86 to 1.56mg/g. Regression analysis showed that the linear effect of whipping time, egg white, and *Ngu* concentration had significant effects on the K content of the product. The quadratic term of whipping time and interaction between whipping time and egg white concentration were also significant ($p<0.05$). The phosphorus content varied from 1.34 to 2.51mg/g. Regression analysis showed that the linear effect of the independent variables had significant ($p<0.05$) effects on the phosphorus content of the dry *Ngu* powder. The quadratic effect of whipping time also significantly affected the dry *Ngu* powder. Zinc content varied from 1.025 to 1.045 mg/g. Calcium content ranged from 0.30 to 0.81 mg/g. Sodium content varied from 9.33 to 15.06 mg/g. Optimization showed the optimum value obtainable was

17.4mg/g of Fe, 0.26mg/g of magnesium, 1.36 mg/g of potassium, 2.26 mg/g of phosphorus, 1.03 mg/g of Zinc,. 12.72 mg/g of sodium, and the optimum value for calcium was 0.58 mg/g This research recommends that oil palm processing industries should incorporate into their processes the utilization of at least part of their palm lunch wastes for *Ngu* powder production as a way of recycling waste.

ACKNOWLEDGEMENTS

The authors are grateful to the Food Science and Technology Department of the Michael Okpara University of Agriculture, Umudike, Nigeria for providing laboratory assistance to carry out this research.

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Table 1. Mineral composition of dry *Ngu* powder

Runs	*Ngu*	Egg white	Whipping time (mins)	Fe (mg/g)	Mg (mg/g)	K (mg/g)	P (mg/g)	Zn (mg/g)	Ca (mg/g)	Na (mg/g)
1	60	20	5	17.60^{b} ±0.01	0.24^{d} ±0.01	0.86^{l} ±0.01	1.88^{l} ±0.01	1.033^{bc} ±0.00	0.70^{b} ±0.01	14.83^{e} ±0.01
2	60	30	5	17.39^{d} ±0.01	0.54^{a} ±0.01	1.12^{k} ±0.01	2.38^{c} ±0.01	1.040^{ab} ±0.00	0.59^{c} ±0.01	15.06^{a} ±0.01
3	60	20	12	17.34^{g} ±0.01	0.31^{bc} ±0.01	1.13^{j} ±0.01	1.69^{n} ±0.01	1.035^{ab} ±0.01	0.41^{e} ±0.01	14.30^{g} ±0.01
4	60	30	12	17.71^{a} ±0.01	0.31^{b} ±0.00	1.26^{h} ±0.01	2.36^{d} ±0.01	1.040^{ab} ±0.00	0.30^{f} ±0.01	15.03^{b} ±0.01
5	100	20	5	17.33^{e} ±0.01	0.19^{f} ±0.01	1.18^{i} ±0.01	2.16^{f} ±0.01	1.035^{abc} ±0.01	0.51^{d} ±0.01	9.33^{q} ±0.01
6	100	30	5	17.40^{d} ±0.01	0.24^{d} ±0.01	1.56^{a} ±0.01	2.29^{e} ±0.01	1.045^{a} ±0.01	0.61^{c} ±0.01	14.93^{c} ±0.01
7	100	20	12	17.11^{g} ±0.01	0.19^{f} ±0.01	1.31^{g} ±0.01	2.01^{i} ±0.01	1.045^{a} ±0.01	0.40^{e} ±0.01	11.43^{o} ±0.01
8	100	30	12	17.22^{f} ±0.02	0.30^{c} ±0.01	1.48^{c} ±0.01	2.11^{g} ±0.01	1.04^{ab} ±0.00	0.50^{d} ±0.01	11.63^{n} ±0.01
9	60	25	9	17.02^{h} ±0.01	0.24^{d} ±0.00	1.33^{f} ±0.01	1.34^{o} ±0.01	1.030^{bc} ±0.00	0.51^{d} ±0.01	14.91^{d} ±0.01
10	100	25	9	17.21^{f} ±0.01	0.24^{d} ±0.00	1.48^{c} ±0.01	2.51^{a} ±0.01	1.025^{c} ±0.01	0.61^{c} ±0.01	12.47^{m} ±0.01
11	80	25	5	17.01^{h} ±0.01	0.24^{d} ±0.00	1.26^{h} ±0.01	1.91^{k} ±0.01	1.030^{bc} ±0.00	0.70^{b} ±0.01	13.71^{h} ±0.01
12	80	25	12	17.31^{e} ±0.01	0.18^{f} ±0.00	1.32^{f} ±0.00	2.51^{a} ±0.01	1.030^{bc} ±0.00	0.70^{b} ±0.01	10.87^{p} ±0.01
13	80	20	9	17.51^{c} ±0.01	0.18^{f} ±0.00	1.13^{j} ±0.01	1.71^{m} ±0.01	1.035^{abc} ±0.01	0.81^{a} ±0.01	14.36^{f} ±0.01
14	80	30	9	17.21^{f} ±0.01	0.24^{d} ±0.01	1.56^{a} ±0.01	2.44^{b} ±0.01	1.025^{c} ±0.01	0.40^{e} ±0.01	15.06^{a} ±0.01
15	80	25	9	17.40^{d} ±0.01	0.19^{f} ±0.01	1.41^{e} ±0.01	1.91^{k} ±0.01	1.030^{bc} ±0.00	0.51^{d} ±0.01	13.25^{j} ±0.00
16	80	25	9	17.02^{h} ±0.02	0.31^{bc} ±0.01	1.43^{d} ±0.01	2.09^{h} ±0.01	1.030^{bc} ±0.00	0.50^{d} ±0.00	13.18^{k} ±0.01
17	80	25	9	17.21^{f} ±0.01	0.19^{f} ±0.01	1.53^{b} ±0.01	1.89^{l} ±0.01	1.025^{c} ±0.01	0.41^{e} ±0.01	13.37^{i} ±0.00
18	80	25	9	17.20^{f} ±0.00	0.21^{e} ±0.01	1.41^{e} ±0.01	2.01^{i} ±0.01	1.025^{c} ±0.01	0.41^{e} ±0.01	13.16^{l} ±0.01
19	80	25	9	17.50^{c} ±0.13	0.31^{bc} ±0.01	1.40^{e} ±0.00	1.91^{k} ±0.01	1.025^{c} ±0.01	0.51^{d} ±0.01	13.17^{kl} ±0.00
20	80	25	9	17.21^{f} ±0.01	0.30^{c} ±0.01	1.43^{d} ±0.01	1.96^{j} ±0.01	1.030^{bc} ±0.00	0.50^{d} ±0.00	13.17^{kl} ±0.01
21	80	25	9	17.00^{h} ±0.00	0.18^{f} ±0.00	1.53^{b} ±0.01	2.09^{h} ±0.01	1.030^{bc} ±0.00	0.41^{e} ±0.01	13.36^{i} ±0.01
22	80	25	9	17.20^{f} ±0.01	0.19^{f} ±0.00	1.53^{b} ±0.00	1.89^{l} ±0.01	1.025^{c} ±0.01	0.51^{d} ±0.01	13.26^{j} ±0.01
23	80	25	9	17.30^{e} ±0.01	0.19^{f} ±0.00	1.53^{b} ±0.01	1.88^{l} ±0.01	1.030^{bc} ±0.00	0.40^{e} ±0.00	13.18^{k} ±0.01

24	80	25	9	17.40^{d} ±0.00	0.18^{f} ±0.00	1.41^{e} ±0.01	2.09^{h} ±0.01	1.025^{c} ±0.01	0.41^{e} ±0.01	13.37^{i} ±0.01
25	80	25	9	17.41^{d} ±0.01	0.21^{e} ±0.01	1.43^{d} ±0.01	2.09^{h} ±0.01	1.030^{bc} ±0.00	0.40^{e} ±0.01	13.16^{kl} ±0.01

Means bearing different superscripts in the same column are significantly ($p<0.05$) different

Table 2. Regression coefficient of iron (Fe) of dried *Ngu* powder and analysis of variance of factor variables

Source	Coefficient Estimate	DF	Standard Error	p-value Prob>F	Sum of squares	Mean square	F value
Model(intercept)	17.20	1	0.044	0.1304	0.050	0.050	2.20
X_1	0.16	1	0.11	0.1660	0.055	0.055	2.42
X_2	-0.17	1	0.11	0.1484	0.022	0.022	0.98
X_3	0.11	1	0.11	0.3434			
X_1^2	-1.879E-003	1	0.092	0.9841			
X_2^2	0.21	1	0.091	0.0414			
X_3^2	-0.074	1	0.090	0.4269			
X_1X_2	0.100	1	0.053	0.0869			
X_1X_3	-0.025	1	0.053	0.06476			
X_2X_3	-0.025	1	0.053	0.0476			
$X_1^2X_2$	0.24	1	-0.024	0.0699			
$X_1^2X_3$	-0.21	1	-0.48	0.1157			
$X_1X_2^2$	-0.23	1	0.12	0.0738			
$X_1X_2X_3$	-0.100	1	0.053	0.0869			

X_1 whipping time; X_2 Egg white concentration; X_3 *Ngu* concentration

Table 3. Regression coefficient of magnesium (Mg) of dried *Ngu* powder and analysis of variance of factor variables

Source	Coefficient Estimate	DF	Standard Error	p-value prob>F	Sum of squares	Mean square	F value	Mean square
Model(intercept)	0.21	1	0.014	0.0034	2.890E-003	2.890E-003	1.13	2.890E-003
X_1	-0.017	1	0.016	0.3050	0.011	0.011	4.16	0.011
X_2	0.033	1	0.016	0.0593	0.025	0.025	9.70	0.025
X_3	-0.050	1	0.016	0.0071				
X_1^2	0.012	1	0.031	0.7116				
X_2^2	0.014	1	0.030	0.6534				
X_3^2	0.044	1	0.030	0.1676				
X_1X_2	-0.059	1	0.018	0.0051				
X_1X_3	0.030	1	0.018	0.1096				
X_2X_3	-0.046	1	0.018	0.0207				

X_1 Whipping time; X_2 Egg white concentration; X_3 *Ngu* concentration

Table 4. Regression coefficient of potassium (K) of dried *Ngu* powder and analysis of variance of factor variables

Factor	Coefficient Estimate	DF	Standard Error	p-value prob>F	Sum of square	Mean square	F-value
Modal(intercept)	1.43	1	0.021	<0.0001	0.029	0.029	5.37
X_1	0.054	1	0.023	0.0351	0.13	0.13	23.05
X_2	0.11	1	0.023	0.0002	0.18	0.18	32.70
X_3	0.13	1	0.023	<0.0001			
X_1^2	-0.12	1	0.045	0.0168			
X_2^2	-0.077	1	0.044	0.1027			
X_3^2	-0.070	1	0.044	0.7121			
X_1X_2	-0.070	1	0.026	0.0171			
X_1X_3	-0.048	1	0.026	0.0843			
X_2X_3	0.054	1	0.026	0.0570			

X_1 Whipping time; X_2 Egg white concentration; X_3 *Ngu* concentration

Table 5. Regression coefficient of phosphorus (P) of dried *Ngu* powder and Analysis of variance of factor variables

Source	Coefficient Estimate	DF	Standard Error	p-value prob>F	Sum of squares	Mean square	F-value
Model(intercept)	1.94	1	0.028	<0.0001	0.17	0.17	18.45
X_1	0.29	1	0.068	0.0013	0.25	0.25	26.75
X_2	0.36	1	0.070	0.0003	0.68	0.68	73.02
X_3	0.60	1	0.070	<0.0001			
X_1^2	0.21	1	0.059	0.0047			
X_2^2	0.080	1	0.058	0.1980			
X_3^2	-0.12	1	0.058	0.0601			
X_1X_2	0.050	1	0.034	0.1720			
X_1X_3	-0.15	1	0.034	0.6697			
X_2X_3	-0.15	1	0.034	0.0011			
$X_1^2X_2$	-0.22	1	0.078	0.0170			
$X_1^2X_3$	-0.57	1	0.078	<0.0001			
$X_1X_2^2$	-0.36	1	0.076	0.0006			
$X_1X_2X_3$	7.500E-003	1	0.034	0.8306			

X_1 Whipping time; X_2 Egg white concentration; X_3 *Ngu* concentration

Table 6. Regression coefficient of zinc (Zn) of dried *Ngu* powder and analysis of variance of factor variables

Source	Coefficient Estimate	DF	Standard Error	p-value prob>f	Sum of squares	Mean square	F- value
Model(intercept)	1.03	1	4.892E-004	0.0085	2.500E-006	2.500E-006	0.81
X_1	5.000E-004	1	5.548E-004	0.3817	8.357E-010	8.357E-010	2.715E-004
X_2	9.146E-006	1	5.551E-004	0.9871	4.421E-007	4.421E-007	0.14
X_3	-2.104E-004	1	5.551E-004	0.7100			
X_1^2	2.917E-004	1	1.073E-003	0.7895			
X_2^2	1.714E-003	1	1.048E-003	0.1228			
X_3^2	2.714E-003	1	1.048E-003	0.0205			
X_1X_2	-3.201E-004	1	6.190E-004	0.6126			
X_1X_3	3.628E-004	1	6.190E-004	0.5665			
X_2X_3	1.250E-004	1	6.203E-004	0.8430			

X_1 Whipping time; X_2 Egg white concentration; X_3 *Ngu* concentration

Table 7. Regression coefficient of calcium (Ca) of dried *Ngu* powder and Analysis of variance of factor variables

Source	Coefficient Estimate	DF	Standard Error	p-value prob>f	Sum of squares	Mean square	F-value
Model(intercept)	0.50	1	0.033	0.3698	0.064	0.064	4.45
X_1	-0.080	1	0.038	0.0522	0.016	0.016	1.10
X_2	-0.040	1	0.038	0.3106	7.280E-004	7.280E-004	0.051
X_3	8.537E-003	1	0.038	0.8251			
X_1^2	0.087	1	0.073	0.2518			
X_2^2	-2.857E-003	1	0.072	0.9687			
X_3^2	-0.053	1	0.072	0.4724			
X_1X_2	-5.691E-003	1	0.042	0.8948			
X_1X_3	0.051	1	0.042	0.2450			
X_2X_3	0.050	1	0.042	0.2569			

X_1 Whipping time; X_2 Egg white concentration; X_3 *Ngu* concentration

Table 8. Regression coefficient of sodium (Na) of dried *Ngu* powder and Analysis of variance of factor variables

Source	Coefficient Estimate	DF	Standard Error	p-value prob>f	Sum of squares	Mean square	F- value
Model(intercept)	13.41	1	0.22	0.0005	2.10	2.10	3.43
X_1	-0.46	1	0.25	0.0839	3.88	3.88	6.34
X_2	0.62	1	0.25	0.0236	20.51	20.51	33.52
X_3	-1.43	1	0.25	<0.0001			
X_1^2	-1.35	1	0.48	0.0131			
X_2^2	1.16	1	0.47	0.0253			
X_3^2	0.14	1	0.47	0.7662			
X_1X_2	-0.65	1	0.28	0.0337			
X_1X_3	-0.073	1	0.28	0.7943			
X_2X_3	0.61	1	0.28	0.0446			

X_1 Whipping time; X_2 Egg white concentration; X_3 *Ngu* concentration