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Effects of Cowpea, Yeast and Trisodium Hydrogen Dicarbonate Dehydrate [$Na_3CO_3.HCO_3.2H_2O$] Levels on Proximate and Mineral Composition of *Yar'tsala*, a Traditional Rice-based Snack of Northern Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. Authors FAM and ND designed the study, performed the statistical analysis. Authors IN, FAM and IAG wrote the protocol and wrote the first draft of the manuscript. Authors ND and FAM managed the analyses of the study. Author YMA managed the literature searches. All authors read and approved the final manuscript.

Article Information

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ABSTRACT

Aims: This study aims to evaluate the effects of cowpea, yeast and trisodium hydrogen dicarbonate dehydrate (trona) on quality of *yartsala*, a traditional rice-based snack of northern Nigeria and to optimize process conditions for optimum product quality and acceptability.
Study Design: Response surface methodology (RSM) in a five-level three-factor central composite rotatable design (CCRD) was used to access the linear, square and combined effects of cowpea (25-45 g/100 g), yeast (1-3 g/100 g) and trona (1-3 g/100 g) on proximate and mineral composition of the snack.
Place and Duration of Study: Department of Food Science and Technology, University of

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Maiduguri, Nigeria and Central Laboratory of the National Agency for Food and Drug Administration (NAFDAC), Nigeria, between January 2016 and February, 2017.
Methodology: Seventeen (17) formulation based on CCRD was prepared and Low moisture deep fried snack balls were produced before proximate and mineral compositions were evaluated using standard methods. Data were subjected to regression analysis and coefficients fitted to a second-order polynomial. Fitted models were validated using ANOVA, R^2 and lack-of-fit test. Product moisture, protein, fat, ash, carbohydrate, zinc, potassium, phosphorus, sodium, calcium, iron and copper were evaluated.
Results: Addition of cowpea and resulted in significant increase in protein while addition of trona increase essential minerals. The regression models for response data were significant ($p<0.05$) with satisfactory R^2 and adjusted R^2 of 61.3, 97.7, 91.8, 83.6, 98.2 % and 52.8, 97.1, 90.0, 80.0, 97.7% respectively for moisture, protein, fat, ash and carbohydrate indicating a good fit. Fe had 85.2 and 82.0% values of R^2 and $R^2_{adj,}$ but Calcium had 99.2 and 98.9% R^2 and R^2_{adj} respectively, suggesting good fitted models. Optimization procedure indicated optimum process conditions of 35% cowpea, 2% yeast and 2% trona, with optimum protein of (12.0%), fat (26.0%), ash (2.0%), with Fe optimum value of (1.0 mg/100 g), Ca (42.0 mg/100 g).
Conclusion: RSM and CCRD could be used to produce and optimize conditions for the preparation of *yartsala* that are of good nutritional profile that could meet the growing consumer needs for nutritious fast foods across Africa.

Keywords: Rice; cowpea; trona; snack; response surface methodology; optimization.

1. INTRODUCTION

Cereals based foods are important sources of energy, protein, B-vitamins and minerals for significant number of world population. Generally, cereals are cheap to produce, are easily stored and transported, and do not deteriorate readily if stored at the appropriate moisture level. Cereals are consumed in a variety of forms like pastes, noodles, cakes, bread, drinks, depending on the ethnic or religion affiliations [1]. Some of the food product produced from cereal grains in northern Nigeria include; *burabusko, tuwo, ndaleyi, ogi, masa*, and many more [2]. Cereals are grown for their highly nutritious edible seeds and have been staple both directly for human consumption and indirectly via livestock feed since the beginning of civilization [3].

Yar'tsala is a traditional cereal-based food mostly consumed in Northern part of Nigeria. It is a fermented puff made from cereal flour batter which is deep fat fried. *Yar'tsala* production is similar to that of *masa* except that it is deep fat fried instead toasting in a greased pan with cup like depressions. The snack preparation and marketing is a good source of income for women and normally served as breakfast cereal when served with spices or '*yajinkuli-kuli'* (mixture of pepper and groundnut cake). Traditionally, Yar'tsala is prepared from single cereal-based and therefore it is inadequate in protein. Several studies have shown that, when cereal based foods are supplemented with grain legumes, the overall protein quality of the food in the mixed diet is enhanced and hence become good diet for mitigating protein energy malnutrition [4,5]. Protein energy malnutrition (PEM) has been identified as one of the most important health challenges in developing countries. Attempts have been made to devise strategies for combating these nutritional problems. Nutritious foods of high protein and energy value such as those based on cereal-legume combination have been suggested. Grain legumes and oil seeds contain protein with higher lysine level, and a combination of cereals and grain legumes in traditionally prepared foods will improve their protein quality [4].

Legumes are sources of low-cost dietary vegetable proteins and minerals when compared with animal products such as meat, fish and egg [6]. Indigenous legumes therefore are important source of affordable alternative protein to resource poor people in many tropical countries [7] especially in Africa and Asia where they are predominantly consumed. Cowpea is a popular leguminous crop in Africa which is known as 'beans' in Nigeria and 'niebe' in the Francophone countries. Cowpea plays a critical role in the lives of millions of people in Africa and other parts of the developing world, where it is a major source of dietary protein that nutritionally complements staple low-protein cereal and tuber crops, and is a valuable and dependable commodity that provide income for farmers and other actors in the cowpea value-chain [8,9]. The appropriate combination of cereals and legumes in the production of high protein, energy dense and consumer acceptable foods that are traditionally known to the people using processing technologies that minimize nutrient loss and improve the overall quality of the final product has been proposed by many workers as the safest pathway for the mitigation of PEM in developing countries [10,11,12,13].

The objectives of the current study was to (1) develop an improved production process of *yar'tsala* by blending rice and cowpea, (2) evaluate the nutritional composition and consumer acceptability of the product and (3) use designed experiment to optimize the production process parameters for optimum product quality.

2. MATERIALS AND METHODS

2.1 Sourcing of Plant Materials and Preliminary Handling

Milled raw rice, cowpea, vegetable oil, yeast, trona (*kanwa*), salt, used for this study were purchased from Maiduguri Monday Market, Borno state. They were cleaned manually and kept at room temperature (36±2°C). Sample production was carried out at the Food Processing Laboratory, Department of Food Science and Technology, University of Maiduguri, while chemical analyses were carried out at National Agency for Food and Drug Administration and Control (NAFDAC) area laboratory, Maiduguri, Nigeria.

2.2 Production of Rice and Cowpea Flours

Rice and cowpea flours were produced as described in Fig. 1. Essentially, milled raw rice (Dikol) was cleaned, washed, sun dried and then soaked, wet milled, strained, dried and pulverized into flour using attrition mill, then sieved to obtain fine flour. The cowpeas (Bornoji) were cleaned, steeped for 5-10 minutes, dehulled using pestle and mortar, washed then sun dried before milling using attrition mill and sieved to obtain a fine flour. All flours were stored at room temperature in a plastic buckets tiredly covered and placed in cardboard.

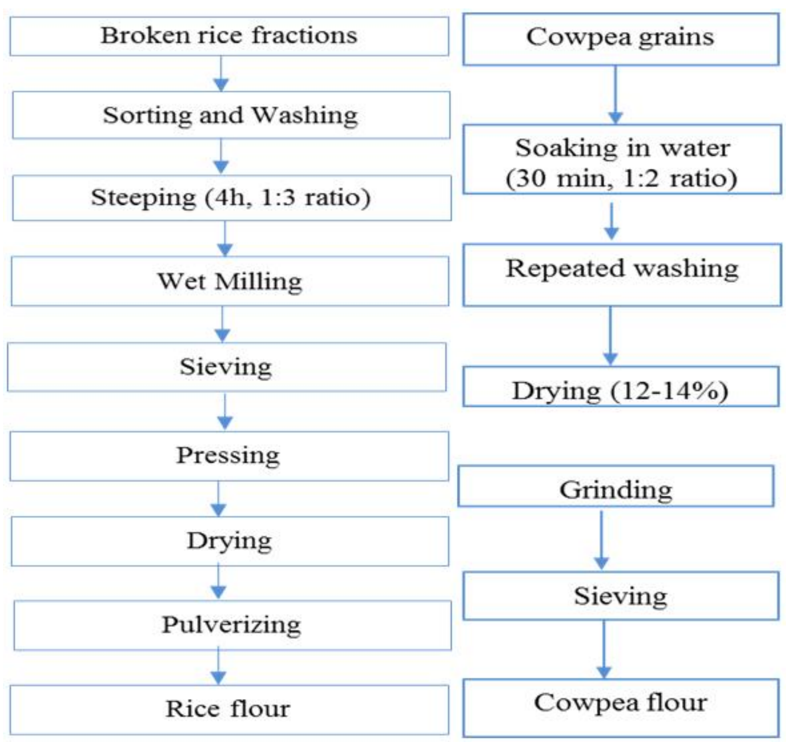

Fig. 1. Flow charts for production of rice and cowpea flours
Sources: [13,14]

2.3 Production of *Yar'tsala*

Yar'tsala was produced as described by Nkama, [14] for masa production as shown in Fig. 2. Rice grits (1 part) was first cooked to doneness and cooled. This was added to the rice flour (2 parts), yeast and the water. The matrix was mixed thoroughly to form a batter which was allowed to ferment for 10 – 12 hours. After fermentation, trona (kanwa) was added to neutralize the batter; salt was added before frying in deep hot oil for 3 – 4 minutes to obtain a golden brown coloured product.

2.4 Experimental Design

Response surface methodology (RSM) in a 3-factors 5-levels central composite rotatable design (CCRD) was used to formulate the products and optimize production process parameters and to evaluate the effects of the independent variables on the responses. A second order polynomial equation was modelled (Eq. 1, 2) to evaluate the relationship between the process variables and response variable [11].

$$\dot{y} = \beta_o + \sum_{i=1}^{k} \beta_i X_i + \sum_{i=1}^{k-1} \sum_{j=i+1}^{k} \beta_{ij} X_i X_j + \sum_{i=1}^{k} \beta_{ii} X_i^2 + \varepsilon \quad (1)$$

$$y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_{11} X_1^2 + \beta_{22} X_2^2 + \beta_{33} X_3^2 + \beta_{12} X_1 X_2 + \beta_{13} X_1 X_3 + \beta_{23} X_2 X_3 \quad (2)$$

Where: y = response, X_1 = level of cowpea, X_2 = yeast level, X_3 = trona level and ε = error term. The independent variables and the levels used for central composite rotatable design are shown in Table 1.

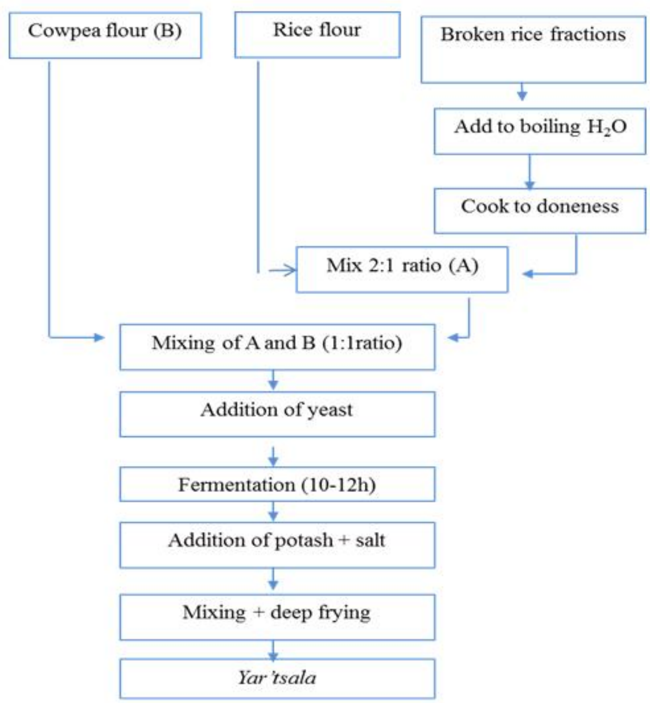

Fig. 2. Flow chart for the production of *Yar'tsala* from rice–cowpea flour blend
Sources: Nkama, [14]

Table 1. Independent variables and their levels used in the CCRD

No	Independent variable	Symbols	Levels				
			-1.682	-1	0	+1	+1.682
1	Cowpea (g/100 g)	X_1	18.18	25	35	45	51.8
2	Yeast (g/100 g)	X_2	0.32	1	2	3	3.7
3	Potash (g/100 g)	X_3	0.32	1	2	3	3.7

Transformation of coded variables (X1) levels to un-coded variables (X1) levels could be obtained from X1 = 25X1 + 35; X2 =5X2 +2; X3 = 5X3 + 2. (X_1) = Level of cowpea (X_2) = Yeast level (X_3) = Trona level

The experimental layout indicating different levels of the independent variables and the coded value for the 17 experimental runs carried out after the preliminary study is shown in Table 2.

2.5 Chemical Analysis

2.5.1 Proximate composition analysis

The proximate analysis of the finished product was determined using the established procedures of the American Association of Cereal Chemist [15]. Moisture was estimated by weighing 5g of each sample and dried in hot air at 130oC in pre-heated dishes until constant weight. The moisture content in percent was then calculated as weight loss. Crude protein was estimated by Kjeldahl method by digesting 1.0g of sample with 20 ml concentrated H_2SO_4 and cold content volume made to 250 mL. 5 ml of mixed aliquot is and 40% NaOH and ammonium borate was distillated and collected through a condenser. The distillate was titrated with 0.1 N H_2SO_4. A blank sample was also titrated and protein content calculated using the factor 6.25 for converting N content into crude protein. Fat content was determined by ether extraction using Soxhlet extraction apparatus for 6 hr. The extract was completely dried and increase in beaker weight is recorded as percent crude fat. Ash was measured by weighing 20 g of snack sample in a pre-weight silica crucible and burned at 550oC for 3 hr. The difference between the weight of empty dish and dish with sample amount to total ash multiplies by 100. Total carbohydrate were calculated by difference (CHO = 100 – protein – fat – ash – moisture).

2.5.2 Mineral analysis

Mineral content of *yar'tsala* was determined following the procedures described in a manual for Smart Spectrophotometer Versions 1.0, (La Motte Co., CHESTERTOWN, MD, 2000). The following minerals were examined; Zinc, Potassium, Iron, Sodium, Calcium, Phosphorus and copper. The snack samples were first digested in a mixture of HNO_3 and $HClO_4$ (2:1 v/v). After complete digestion, the amount of iron, copper, calcium, phosphorus and zinc were determined using atomic absorption spectrophotometer (AAS), while sodium potassium was determined by flame photometer (Jenway, U.K).

2.6 Sensory Evaluation

Samples prepared from the table of experimental design as shown in Table 2 (CCRD) were examined by the panellist to test the possible attributes perceived and other comments on

Table 2. Experimental layout showing the independent variables in their coded and un-coded forms

Runs	Coded independent variables			Natural independent variables (%)		
	X_1	X_2	X_3	X_1	X_2	X_3
1	-1	-1	-1	25	1	1
2	+1	-1	-1	45	1	1
3	-1	+1	-1	25	3	1
4	+1	+1	-1	45	3	1
5	-1	-1	+1	25	1	3
6	+1	-1	+1	45	1	3
7	-1	+1	+1	25	3	3
8	+1	+1	+1	45	3	3
9	-1.682	0	0	18.2	2	2
10	+1.682	0	0	51.8	2	2
11	0	-1.682	0	35	-0.32	2
12	0	+1.682	0	35	+3.7	2
13	0	0	-1.682	35	2	-0.32
14	0	0	+1.682	35	2	+3.7
15	0	0	0	35	2	2
16	0	0	0	35	2	2
17	0	0	0	35	2	2

(X_1) = Level of cowpea (X_2) = Yeast level (X_3) = Trona level

quality aspects. Qualitative Descriptive Analysis (QDA) scale given by Nkama, [14] and Stone et al. [16] was used to rate intensity of the different attributes. The scale is a 15 cm long horizontal lines anchored at 1.5 cm from either ends by suitable descriptors such as low and high. Overall quality was rated on the same scale with additional anchoring at the centre also. The attributes included in the score card for sensory analysis belongs to different categories. Those perceived visually, such as colour and spongy appearance, those perceived by finger feel, like firmness and sponginess, those perceived by eating such as grittiness, flavour attributes and finally overall quality. The 17 experimental runs were executed in (3) three sessions. The judges evaluated the products by placing a mark between the two ends which represents the most desirable and undesirable attributes. The results were obtained by measuring the distance from the left (most undesirable) side of the scale to the right (most desirable) rating in cm.

2.7 Statistical Analysis

Experiment values were subjected to regression analysis using MINITAB 4.13 (Minitab, USA). The coefficients were fitted to the second-order polynomial equation (Eq. 2). The fitted models were validated by considering the ANOVA p-value at 5%, coefficient of determination R^2 and R^2_{adj}, lack-of-fit test [12]. All the significant model coefficients were then used to optimize the process variables using 3D surface plots and contour plots.

3. RESULTS AND DISCUSSION

3.1 Effect of Process Variables on Proximate Composition of *Yar'tsala* Using RSM

The proximate composition of *yar' tsala* as affected by cowpea composition, yeast and trona levels are presented in Table 3 and the 3D surface plots for the relationship between the process variables and moisture, protein, fat, ash and carbohydrates are presented in Figs. 3 to 7 respectively. Moisture content of food product has been established as one of the principal determinants of shelf life stability. The moisture content of *yartsala* varied narrowly between 5.01 and 5.37 g/100 g (Table 3). These results revealed that moisture content increases with increasing feed cowpea and yeast contents. As the cowpea content increases from 35 to 45 g/100 g, and yeast from 2 to 3 g/100 g, the product moisture content increased significantly. In a food system, moisture content between 6 and 10% has been established to prolong shelf life beyond which the storageability of the system could be impeded by chemical and microbiological agents [17]. The moisture level of less than 6% reported in this study therefore is

Table 3. Effect of process variable on the proximate composition of rice-based *yar'tsala*

Run	Actual units			Proximate composition (%)				
	X_1	X_2	X_3	MC	PROT	Fat	Ash	CHO
1	25	1	1	5.11^{b}	10.55^{de}	25.39^{b}	2.08^{ab}	56.87^{b}
2	45	1	1	5.15^{abc}	11.96^{c}	25.00^{bcd}	2.18^{a}	55.71^{f}
3	25	3	1	5.07^{bc}	12.31^{bcde}	25.06^{bc}	1.54^{cd}	56.03^{e}
4	45	3	1	5.23^{abc}	12.22^{bcde}	25.00^{bcd}	1.43^{cde}	56.13^{de}
5	25	1	3	5.15^{abc}	12.67^{b}	24.10^{cdef}	1.66^{bcd}	56.42^{bcd}
6	45	1	3	5.16^{abc}	12.55^{bc}	24.46^{cd}	1.67^{bcd}	56.16^{de}
7	25	3	3	5.08^{b}	12.22^{bcde}	24.62^{c}	1.84^{bc}	56.23^{d}
8	45	3	3	5.37^{a}	10.61^{d}	25.11^{bc}	1.64^{bcde}	57.27^{abc}
9	18.18	2	2	5.06^{bc}	11.30^{cd}	24.61^{c}	1.67^{bcd}	57.96^{a}
10	51.82	2	2	5.10^{b}	11.13^{cde}	24.27^{cde}	1.59^{c}	57.92^{a}
11	35	0.32	2	5.02^{d}	11.34^{cd}	25.00^{bcd}	1.89^{bc}	56.75^{bc}
12	35	3.68	2	5.33^{ab}	11.19^{cde}	24.46^{cd}	1.40^{cde}	57.62^{ab}
13	35	2	0.32	5.10^{b}	13.07^{ab}	25.95^{a}	2.15^{a}	53.74^{h}
14	35	2	3.68	5.01^{d}	13.50^{a}	25.00^{bcd}	1.97^{b}	54.52^{g}
15	35	2	2	5.21^{abc}	12.47^{bcd}	25.98^{a}	2.15^{a}	54.18^{gh}
Mean	NA	NA	NA	5.143	11.939	24.934	1.791	56.234

X_1 = Cowpea level, X_2 = Yeast level, X_3 = Trona level, MC = Moisture content, PROT = Protein, CHO = Carbohydrate. Means of the same column with different superscript differs significantly ($p<0.05$)

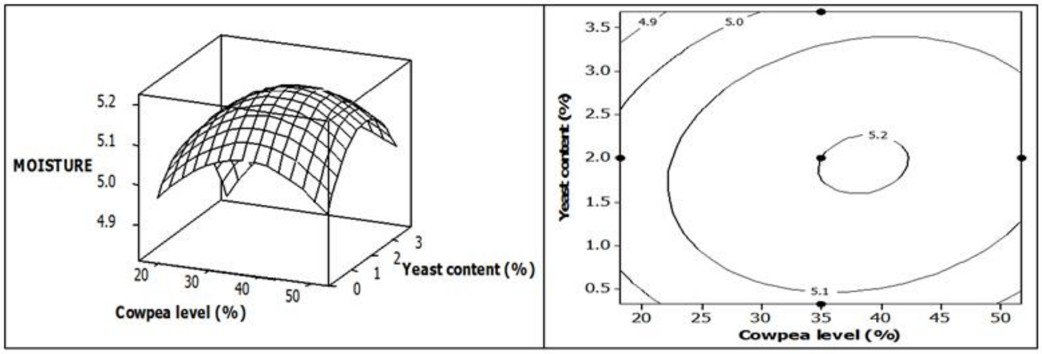

Fig. 3. 3D surface plot (left) and countour (right) plots of moisture versus cowpea composition and yeast holding trona constant at 2%

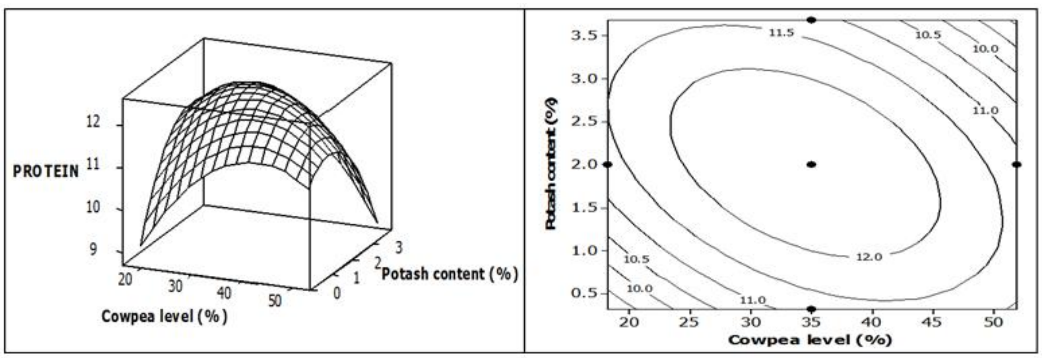

Fig. 4. 3D surface (left) and contour (right) plots of protein content of yartsala versus cowpea level and trona level holding yeast constant at 2%

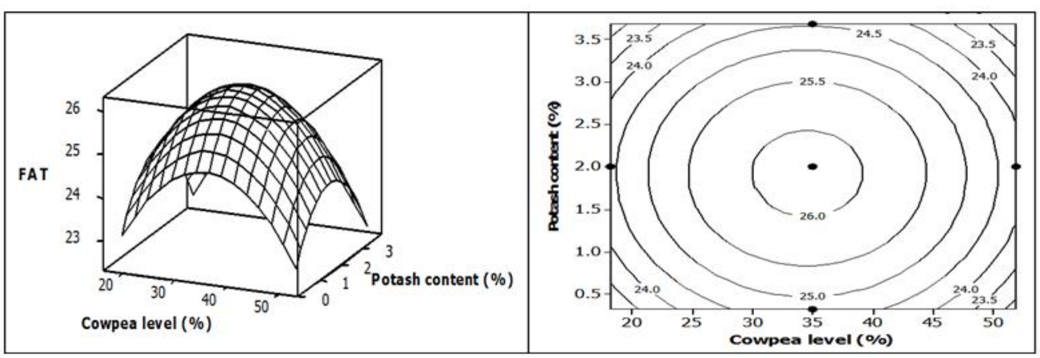

Fig. 5. 3D surface (left) and contour (right) plots of fat content of yartsala versus cowpea level and trona level holding yeast constant at 2%

advantageous in terms of shelf life of the product. The increase in moisture level as the cowpea level increased suggest that incorporation of cowpea flour might have resulted in the absorption of more water molecules by protein and other components of the flour. Sefa-Dedeh and Saalia [18] and Asare et al. [17] reported similar findings in cereal-legume composite flour products and noted that cowpea proteins are known to have good water binding effects, hence its observed impact on the moisture level of the snack. Though the snack seems to have low moisture content, proper handling need to be taken if extended shelf life is intended.

The 3D response surface plot and contour (Fig. 3) indicating the effects of cowpea and yeast on the moisture content holding the trona constant indicated that the moisture content of the snack increased with increasing level of cowpea and yeast, but reaches optimum before decreasing when the level of trona is held constant which confirms earlier reports that cowpea protein have high water binding capacity [17,18]. The circular contour plot (Fig. 3) signify that the interaction effects between the test variables are not significant and optimum value of the response variable can easily be located.

The regression equation fitted to predict product moisture content and the process variables in terms of coded variables is presented in Eq. 3.

Moisture content (%) = 5.03577 + 0.01906X_1 - 0.30010X_2 + 0.05763X_3 – 0.00040 X_1^2 + 0.02271 X_2^2 -0.05001 X_3^2 + 0.00466 X_1X_2 + 0.00145 X_1X_3 + 0.03979 X_2X_3 (R^2=61.3, R^2_{adj}. 52.3) (3)

Eq. (3) could explain 61.3% of the variation observed in the moisture content. Danbaba et al. [13] reported that in a high temperature processed food products, regression model, R^2 greater than 60% is acceptable, but Zaibunnisa et al. [19] suggested that R^2 value should be at least 80% to have good fit of a regression model, suggesting appropriateness of the model to represent the variables in their natural state. Analysis of variance (ANOVA) test for the model parameters indicated significant ($p \leq 0.05$) effect of cowpea and yeast on the moisture level at a constant trona level.

The protein content varied between 10.55% in samples produced from formulation made of 25% cowpea, 1% trona and 1% yeast and 13.50% when the level of cowpea, yeast and trona in the formulation increased to 35%, 2% and 3.68% respectively (Table 3). These results indicate positive contribution of cowpea when combined with rice for the production of *yar' tsala*. In an earlier study, Nkama and Malleshi, [4] found similar response when cowpea and groundnut were added to rice and millet in the production of *masa*. Rice like most cereal grains are known to be low in protein both qualitatively and quantitatively and therefore require complementation with legumes to provide basic nutritional requirement for normal growth and development. The combination rice with cowpea in the production of *yartsala* has increased the average protein content of rice (7.0%) with about 51.85 to 66.35% when cowpea incorporated between 25 and 35 g/100 g (Table 3). This indicated therefore that the product would help the protein system to be complete as cowpea will contribute lysine and other limiting amino acids in rice. Following the consumption of this snack, essential nutrient could be provided for normal growth and development especially in developing countries where rice consumption is fast increasing.

Response surface and contour plots representing the effects of cowpea and trona when holding yeast at 2% show that protein content increase as the feed cowpea level increased (Fig. 4). The response surface plot revealed that increasing both cowpea and trona levels caused drastic and consistent increase in the protein content until at about 35g/100g cowpea and 2.0g/100 trona it start to decline (Fig. 4). The circular contour graph Karupaiya et al. [20] and Danbaba et al. [21] reported that circular in RSM is an indication interaction effects between the independent variables were not significant and optimum point for the response variable could easily be obtain.

Protein content (%) = -1.04573 + 0.44640X_1 + 4.08139X_2 + 1.50150X_3 -0.00427X_1^2 -0.44130X_2^2 + 0.28272X_3^2 – 0.03568X_1X_2 - 0.04010X_1X_3 - 0.53529X_2X_3 (R^2=97.7, R^2_{adj}. 97.1) (4)

On the basis of the coded form of independent variable, it may be stated that the relationship between them and the response could be represented by equation for the response variable protein which takes the form in Eq. 4. It is clear that at the linear level, the variable had positive effect on the protein content and only cowpea had negative impact on protein at quadratic level, but all the variables had non-significant negative impact on protein at interactive level. The model could explain 97.7% of the variation in protein (Table 3) and the non-significant p-value of lack-of-fit (2.56) indicate acceptability of the model to fit the relationship in their natural state.

For the effect of the process variable on the fat composition of *yar'tsala*, the results indicated varying fat content ranging from 24.10 to 25.98%, with the highest value recorded in sample produced in formulation made by combining rice with 35% cowpea, 2% trona with 2% yeast, while the least value was observed in formulation made with 25% cowpea, 1% yeast and 3% trona (Table 3). There was a significant increase in fat content as the level of cowpea increased from 25 to 35% (Table 3). The increase in fat may be attributed to oil absorption by other components of food during frying. The presence of protein and carbohydrate in fed materials during food processing creates conducive conditions for the formation of lipid-starch and lipid-protein complexes [22,23]. Sobota et al. [24] reported that the degree of lipid complexion with other component of food materials is dependent on the level of high temperature treatment. This phenomenon was seen in this study as the product was fried, the heat treatment might have favoured the binding of lipid to other components of the food material, thereby increasing the fat content.

Ash and carbohydrate contents ranged from 1.40 to 2.18 g/100 g and 53.74 to 57.96 g/100 g with an average value of 1.79 and 56.23 g/100 g respectively. The highest ash value was at process conditions of 45, 1, and 1 while the lowest was at 35, 3.68 and 2. This result indicated that increasing cowpea content favour ash content but reverse is the case for yeast and trona (Table 3). The carbohydrate content increases with increasing cowpea and trona contents. This may be as a result of low carbohydrate and high protein contents of cowpea.

Fat content (%) = 17.8250 + 0.4125 X_1 +1.7433 X_2 -0.1859 X_3 – 0.0065 X_1^2 -0.5382 X_2^2 - 0.2562 X_3^2 + 0.0002 X_1X_2 + 0.0176 X_1X_3 + 0.1575 X_2X_3 (R^2=91.8, $R^2_{adj.}$ = 90.0) (5)

Ash content (%) = -0.733618 + 0.162261 X_1 + 0.480469 X_2 -0.238270 X_3 – 0.002041 X_1^2 - 0.206551 X_2^2 – 0.023410 X_3^2 – 0.006412 X_1X_2 - 0.005004 X_1X_2 + 0.219542 X_2X_3 (R^2=83.6, $R^2_{adj.}$ = 80.0) (6)

Carbohydrate (%) = 81.8196-1.0619 X_1 - 7.8484 X_2 -2.7133 X_3 + 0.0131 X_1^2 + 1.5337 X_2^2 + 0.3397 X_3^2 + 0.0450 X_1X_2 + 0.0340 X_1X_3 + 0.1843 X_2X_3 (R^2=98.2, $R^2_{adj.}$ = 97.7) (7)

Equations 5, 6 and 7 are the response models fitted to represent the variation of fat, ash and carbohydrates contents of *yartsala* respectively. Following observations can be made from

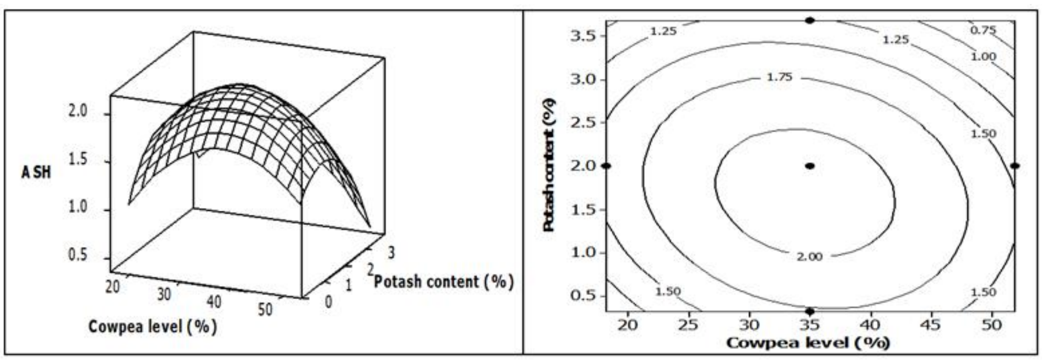

Fig. 6. 3D surface (left) and contour (right) plots of ash content of yartsala versus cowpea level and trona level holding yeast constant at 2%

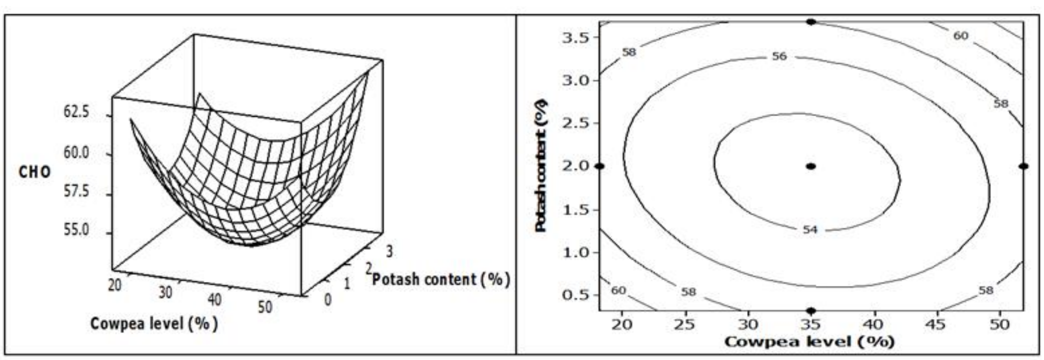

Fig. 7. 3D surface (left) and contour (right) plots of CHO content of yartsala versus cowpea level and trona level holding yeast constant at 2%

Equation 6. At linear level, the coefficients X_1, X_2 are negative, while at square levels, all the coefficients are negative, but at interaction levels, only X_2X_3 is positive. Therefore, increasing X3 (trona) at linear level, all the variables at square level and interaction between X_1X_2, X_1X_3 will reduce ash content. Since all this parameters coefficients are negative, maximum ash content will occur in the range for the variables selected for the study while positive coefficients indicated that a minimum ash value will be in the variables considered for the study. Similar observations were reported by Kumar et al. [25]. The coefficients of determination for the models 6 and 7 are R^2=83.6, R^2_{adj}. = 80.0 and R^2=98.2, R^2_{adj}. = 97.7 respectively. R^2 is the ratio of the explained variation to the total variation and measures the degree of fitness of a regression model [11,26]; it therefore defines the proportion of the variability in the observed response variables which is accounted for by regression analysis [11,21,27]. From our results, the significantly high values for these parameters indicates that the models can be used to navigate the design space as it is greater than 80%.

3.2 Effect of Process Variables on Mineral Composition of *Yar'tsala* Using RSM

Variation of responses (zinc, potassium, phosphorus, sodium, calcium, iron and copper) of *yartsala* with independent variables (cowpea, yeast and trona) are shown in Table 4. A complete second-order polynomial model equations (Eq. 8-14) were fitted and tested for their adequacy to decide the variability of responses with independent variables. The mineral contents analyzed indicated that Zn varied between 0.09 (35, 0.3, 2) and 0.25 (35, 2, 3.68) with an average of 0.17mg/100g, potassium from 2.70 (35, 0.3, 2) - 5.46 (35, 2, 3.68) with a mean value of 3.86 mg/100 g (Table 4). Results for P, Na, Ca, Fe and Cu indicated variations of 0.79-1.47, 195.0 – 255.09, 39.0 – 49.0, 0.49 – 1.21 and 0.22 – 1.00mg/100g respectively. It is clear from these results that all the variables show profound impact on the level of mineral. Naturally, it has been reported in literatures, that essential minerals such as calcium, iron and phosphorus are lower in cereals but recognized among the main minerals found in legumes. The increase in essential minerals therefore was expected as cowpea contains relatively higher levels than rice.

Zinc= $0.066464 + 0.003375X_1 + 0.105123X_2 - 0.115555X_3 - 0.000038X^2{}_1 - 0.014393X^2{}_2 + 0.027680X^2{}_3 - 0.000608X_1X_2 + 0.000558X_1X_3 - 0.000333X_2X_3$ (R^2=52.0, R^2_{adj}. = 41.4) (8)

Potassium= $-2.17367 + 0.23663X_1 + 3.31000X_2 - 0.34782X_3 - 0.00418X^2{}_1 - 0.83696X^2{}_2 - 0.11123X^2{}_3 - 0.00109X_1X_2 + 0.02476\,X_1X_3 + 0.09233X_2X_3$ (R^2 = 96.2, R^2_{adj}. = 95.3) (9)

Table 4. Effects of process variable on the mineral composition of rice-based *yar'tsala*

Runs	Variables			Mineral composition (mg/100 g)						
	X1	X2	X3	Zn	K	P	Na	Ca	Fe	Cu
1	25	1	1	0.11^{c}	3.09^{e}	1.33^{b}	230.77^{cd}	44.32^{cd}	0.86^{cd}	0.45^{de}
2	45	1	1	0.12^{c}	3.00^{ef}	1.12^{c}	255.09^{a}	43.27^{d}	0.84^{cd}	0.39^{e}
3	25	3	1	0.16^{bcd}	3.87^{de}	0.91^{de}	223.00^{de}	43.28^{d}	0.72^{de}	0.23^{fg}
4	45	3	1	0.16^{bcd}	3.12^{e}	1.15^{bcd}	241.92^{b}	41.73^{f}	0.49^{e}	0.22^{fg}
5	25	1	3	0.15^{bcd}	3.55^{def}	0.90^{de}	251.01^{ab}	40.15^{g}	0.79^{d}	0.40^{e}
6	45	1	3	0.19^{bc}	3.97^{d}	0.79^{e}	217.10^{def}	44.27^{cd}	1.04^{b}	0.49^{d}
7	25	3	3	0.22^{b}	4.16^{cd}	1.00^{d}	205.11^{e}	45.28^{bc}	1.15^{ab}	1.00^{a}
8	45	3	3	0.24^{b}	4.49^{c}	1.47^{a}	195.00^{f}	49.00^{a}	1.18^{ab}	0.81^{b}
9	18.2	2	2	0.15^{bcd}	4.00^{cde}	0.89^{de}	226.10^{d}	47.04^{b}	1.19^{a}	0.23^{fg}
10	51.8	2	2	0.18^{bc}	3.87^{de}	1.16^{bcd}	213.23^{def}	49.21^{a}	1.21^{a}	0.41^{e}
11	35	0.3	2	0.09^{c}	2.70^{f}	1.08^{cd}	240.27^{bcd}	39.00^{gh}	0.71^{de}	0.29^{f}
12	35	3.7	2	0.18^{bc}	2.90^{efg}	1.17^{bcd}	214.69^{def}	42.12^{e}	0.87^{cd}	1.00^{a}
13	35	2	0.3	0.15^{bcd}	4.47^{c}	1.24^{bc}	236.23^{c}	42.03^{ef}	0.45^{e}	0.51^{d}
14	35	2	3.7	0.25^{a}	5.46^{a}	1.07^{cd}	215.39^{def}	44.55^{c}	0.90^{c}	1.00^{a}
15	35	2	2	0.17^{bc}	5.26^{b}	1.12^{c}	240.61^{bc}	43.22^{d}	1.06^{b}	0.70^{c}
Mean	NA	NA	NA	0.17	3.86	1.09	227.03	43.90	0.88	0.54

X_1 = Cowpea level, X_2 = Yeast level, X_3 = Trona level. Means of the same column with different superscript differs significantly (p<0.05)

Phosphorus= $2.16980 + 0.00344X_1 -0.68818X_2 -0.44069X_3 -0.00048X^2_1 -0.01824X^2_2 -0.01824X^2_3 + 0.01353X_1X_2 + 0.00413X_1X_3 + 0.15992X_2X_3$ ($R^2 = 92.6$, $R^2_{adj.} = 91.0$) (10)

Sodium= $106.693 + 4.940X_1 + 9.464X_2 + 58.741X_3 -0.073X^2_1 -4.636X^2_2 -5.177X^2_3 + 0.611 X_1X_2 -0.712 X_1X_3 -9.880 X_2X_3$($R^2 = 99.9$, $R^2_{adj.} = 99.7$) (11)

Calcium= $65.9450 – 1.2427X_1 + 2.9308X_2 - 6.1458X_3 + 0.0152X^2_1 -1.1906X^2_2 -0.1699X^2_3 - 0.0084 X_1X_2 + 0.1295 X_1X_3 + 1.5145 X_2X_3$ ($R^2 = 99.2$, $R^2_{adj.} = 98.9$) (12)

Iron= $1.18743 -0.04756X_1 + 0.47499X_2 + 0.09404X_3 + 0.00053X^2_1 -0.13985X^2_2 -0.12188X^2_3 -0.00465 X_1X_2 + 0.00925 X_1X_3 + 0.11596 X_2X_3$ ($R^2 = 85.2$, $R^2_{adj.} = 82.5$) (13)

Copper= $-0.870100 + 0.075805X_1 + 0.244467X_2 -0.199988X_3 -0.001117X^2_1 -0.088038X^2_2 - 0.005778X^2_3 -0.001779 X_1X_2 + 0.002821X_1X_3 + 0.133208 X_2X_3$ ($R^2 = 84.5$, $R^2_{adj.} = 81.1$) (14)

The goodness of the models can be checked by the determination coefficient R^2 and adjusted R^2 (multiple correlation coefficients R). Adjusted R^2 values for zinc (41.4%), potassium (95.3%), phosphorus (91.0%), sodium (97.7%), calcium (98.9%), iron (82.5%) and copper (81.1%) for Eq. 8-14 suggest that the total variation of 41.4%, 95.3%, 91.0%, 97.7%, 98.9%, 82.5% and 81.1% for zinc, potassium, phosphorus, sodium, calcium, iron, and copper respectively is attributed to the independent variables and only about 58.6%, 4.7%, 9.0%, 2.3%, 10.1%, 17.5% and 19.9% of the total variations in Zn, K, P, Na, Ca, Fe and Cu respectively cannot be explained by the models. The closer the adjusted R^2 values to unity, the better the correlation between the observed and predicted values [5,21,28]. These models therefore could be used to navigate the design space.

The fitted response plots (3D surface and 2D contour plots) was generated by significant models above by MINITAB 16.0 to understand the interaction of the independent variables as it affect mineral composition and is presented in Figs. 8 to 12 for Zn, K, P, Na, Ca, Fe and Cu respectively. These plots were developed by plotting two parameters at a time on the X and Y axes and response in Z axis. The remaining third parameter was set at its centre point value automatically by the software to make each plot. The shape of the contour plots either circular or elliptical is an indication of whether the mutual interactions between variables are significant or not. The circular plots observed in Zn, K, Na and Cu are indication that the interaction between cowpea, yeast and trona levels are negligible. An elliptical contour plots in P, Ca and Fe are indication that the interaction between the variables are significant. Mannan et al. [28] and Muralidhar et al. [29] reported similar observations.

By analysing the plots (Figs. 6, 7, 8, 9, 10, 11, and 12), the predicted mineral composition as affected by the independent variables are 0.175 mg/100 g at process conditions of 30-45 g/100 g cowpea, 2.5-.9 g/100 g trona and 2.0 g/100 g yeast (Fig. 6), while potassium was 5.0mg/100g at 30-40 g/100 g cowpea, 1.7-2.4 g/100 g trona and 2.0 g/100 g yeast (Fig. 7). Analysis of Fig. 8 indicated that 1.2 mg/100 g phosphorus was maximized at process cowpea level of 35-40 g/100 g sample, 2.0-3.5 g/100 g trona and 2.0 g/100 g held constant. For sodium, 240 mg/100 g optimum predicted value was observed when 20-35 g/100 g cowpea was used

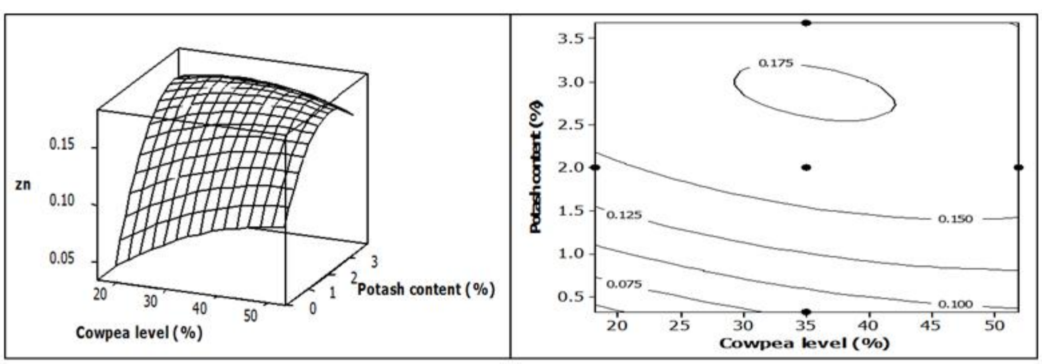

Fig. 8. 3D surface (left) and contour (right) plots of Zn content of yartsala versus cowpea level and trona level holding yeast constant at 2%

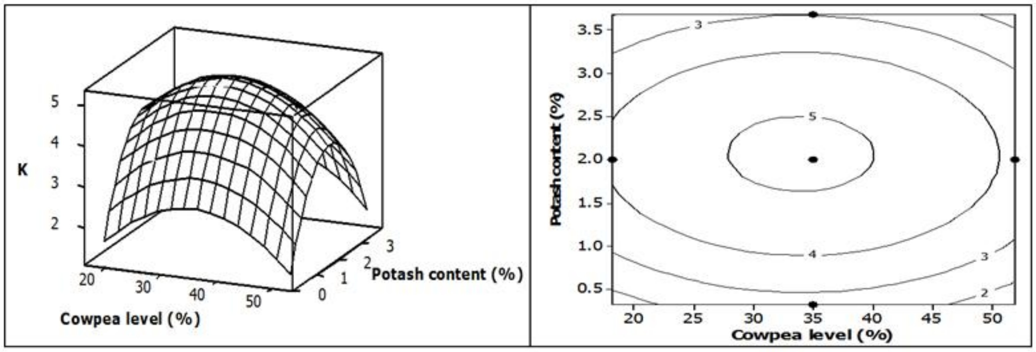

Fig. 9. 3D surface (left) and contour (right) plots of potasium content of yartsala versus cowpea level and trona level holding yeast constant at 2%

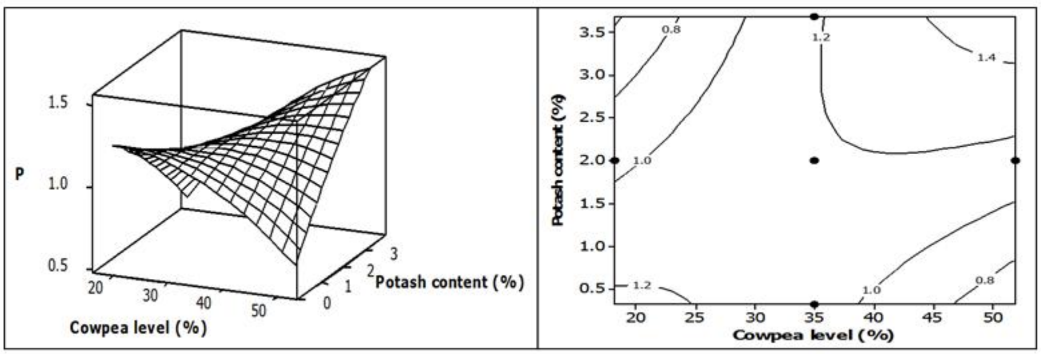

Fig. 10. 3D surface (left) and contour (right) plots of phosphorus content of yartsala versus cowpea level and trona level holding yeast constant at 2%

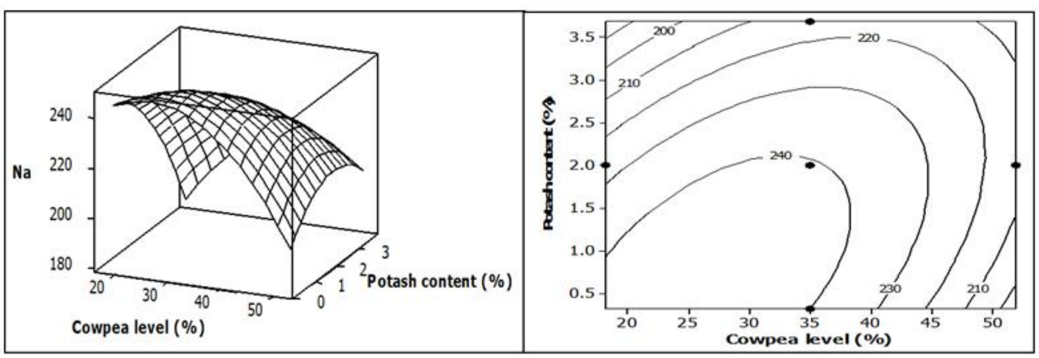

Fig. 11. 3D surface (left) and contour (right) plots of sodium content of yartsala versus cowpea level and trona level holding yeast constant at 2%

and 0.5-1.0 g/100 g trona, holding yeast at 2.0 g/100 g sample (Fig. 9). Similar observations were seen in calcium where predicted optimum was 44 mg/100 g at 35-40 g/100 g cowpea, 0.5-2.0 g/100 g trona and 2.0 g/100 g yeast (Fig. 10). Optimum predicted values of 1.0 mg/100 g and 0.75 mg/100 g was obtained for iron and copper respectively, at process conditions of 35-40 g/100 g cowpea, 2.0-2.5 g/100 g trona and 2.0 g/100 g yeast for iron, 30-35 g/100 g cowpea, 2.2-2.9 g/100 g trona and 2.0 g/100 g yeast for copper respectively.

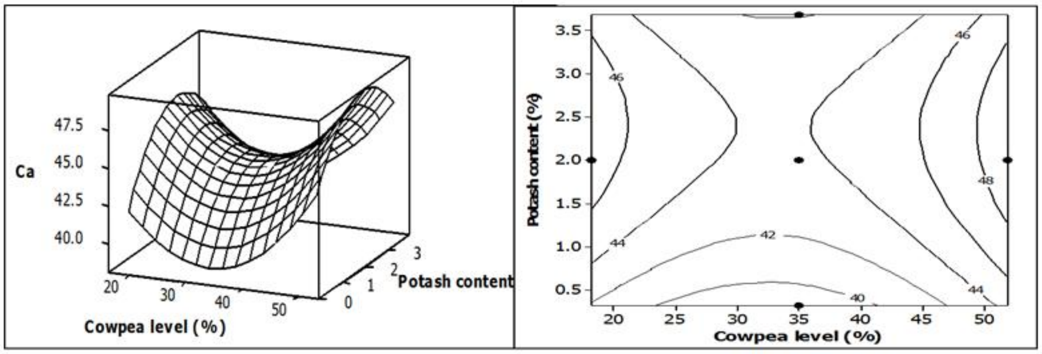

Fig. 12. 3D surface (left) and contour (right) plots of protein content of yartsala versus cowpea level and trona level holding yeast constant at 2%

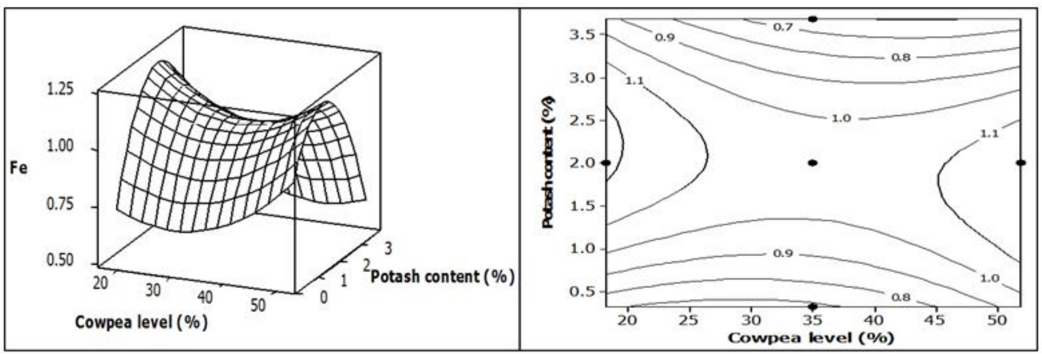

Fig. 13. 3D surface (left) and contour (right) plots of Zn content of yartsala versus cowpea level and trona level holding yeast constant at 2%

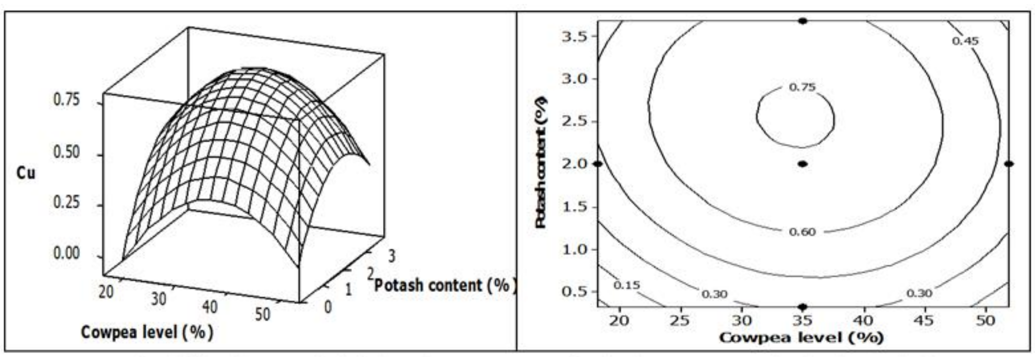

Fig. 14. 3D surface (left) and contour (right) plots of calcium content of yartsala versus cowpea level and trona level holding yeast constant at 2%

4. CONCLUSIONS

Using single variable at a time approach for the studying effect of multiple variables on a food process operations are time consuming and non cost effective. It is monotonous, cannot explain actual interaction between the parameters and can lead to misinterpretation of research results that are needed to select the precise factor that influence the process and responses observed. The adoption multi-parameter optimization approach using RSM and CCD yielded more accurate results from which one could choose that values of the variables that indicate clear optimum and interactive effects. It is clear from the results that irrespective of the process conditions, frying of *yartsala* could reduce the moisture to a low level that enhance storageability. The incorporation of legume and trona resulted in significant increase in protein and essential minerals respectively. The models fitted showed that addition of cowpea, yeast and trona could be optimized to enable production of product with optimum nutritional values at low moisture level. Combining response surface methodology and designed experiment such as central composite design, have simplified the experimental process for the enhancement of nutritional quality of rice-based *yartsala* and this will provide a scientific theoretical basis for the industrial development of the product and improve the utilization of low grade rice fraction and cowpea at community levels to increase access to nutritious food for sustainable food and nutrition security.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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