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PROXIMATE COMPOSITION, SENSORY CHARACTERISTICS AND ECONOMIC ANALYSES OF THREE FORMS OF SOY/MORINGA BEEF MEATBALLS

S. E. Evivie[1,2]*, P. A. Ebabhamiegbebho[1], Q. A. Udefiagbon[1], E. S. Abel[1] and J. O. Igene[1]

[1]Food Science & Human Nutrition Unit, Department of Animal Science, University of Benin, Benin City 300001, Nigeria

[2]Key Laboratory of Dairy Science, Ministry of Education, College of Food Sciences, Northeast Agricultural University, Harbin 150030, China

*Correspondence author: smith.evivie@uniben.edu

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Abstract: Recent evidence suggest that aside producing enough food to meet the worlds soaring population, nutritious diets are also an important means of lowering incidences of malnutrition. This study aimed to show the effects of three processing methods on the proximate composition, sensory characteristics and production cost of three types of beef balls using Nigeria as a case study. The soy moringa beef meatballs were formulated to contain 0/0, 10/0.5, 15/1.0 and 20/1.5% soy and moringa, respectively with 80% beef and other condiments making up 20%. A 5-point hedonic scale was used to assess the organoleptic (sensory) characteristics of the products using a semi-trained taste panel. Proximate composition, varied methods of processing and production cost were also determined. Treatments were analyzed in triplicates in a Randomized Complete Block Design (RCBD); among the soy moringa inclusion, fried beef balls of 10/0.5 and 15/1.0% inclusions were high in protein content and most accepted at score rating of 3.82 and 3.78 respectively. Soy moringa inclusion reduced production cost in beef balls by ₦67.07, ₦64.75 and ₦62.43 of 10/0.5, 15/1.0, and 20/1.5%, respectively of soy moringa inclusion. The produced meatballs were rich in protein; steamed pork balls of 0/0% had the highest protein content (43.63%), fried beef balls of 15/1.0% soy moringa inclusion level with the second-highest protein content (42.75%). It is recommended that further studies of soy moringa incorporation in other meat products be carried out to ensure the availability of cheaper, nutritious and acceptable convenience food to the teeming sub Saharan population.

Keywords: Convenience food malnutrition, meatballs, policy, product development, sub-Saharan Africa

Introduction

In spite of the agricultural bounty and apparent food security in many parts of the world today, malnutrition and its attendant manifestations remain a growing concern which has not received the needed priority (Wallace, 2019; Webb *et al.*, 2018). This is especially challenging in low and middle-income countries (Hume-Nixon and Kuper, 2018; Polack *et al.*, 2018; Turner *et al.*, 2018). In evaluating the food security status of many countries in sub-Saharan Africa for example, the four main indices – accessibility, availability, acceptability and affordability – are still largely unaddressed by various regional and national governments (You *et al.*, 2018; Xie *et al.*, 2018; Olawuyi, 2018). These have been so for a number of reasons ranging from natural disasters, absence of foreign investors, stagnant indigenous technology mechanisms and widespread corruption in several government agencies (Park, 2019; Coulibaly, 2019). Nevertheless, a number of coordinated research works have been ongoing to address the malnutrition dilemma (Willis and Hamon, 2019; Smith, 2018; Clark and Hobbs, 2018; Igene *et al.*, 2016; Udefiagbon *et al.*, 2016; Evivie *et al.*, 2015).

It has been recently argued by the World Committee on Food Security that malnutrition and all its forms, is a critical challenge for both developing and developed countries. Therefore, lowering its incidences in the 21st century and beyond requires a better understanding of the determinants and processes that influence diets (WCFSR, 2017). Fortified convenience food products can be a viable alternative in the fight against malnutrition in developing parts of the world (UNICEF, 2018). They are a rich source of protein and other important nutrients needed for proper body functioning. In addition, they are relatively cheap compared to many imported snack products and can be a major source of employment and income for indigenes. However, owing to some of the above-mentioned challenges, the indigenous technology needed to drive this potential industry is still at its infancy stage and thus remains largely untapped. In Nigeria for example, private sector investment in this industry can have significantly positive effects but this is yet to be seen due to a number of limiting factors. In the past, it has been shown that meatball development is not only nutritious but could be cost-effective (Igene *et al.*, 2016; Udefiagbon *et al.*, 2016; Evivie *et al.*, 2015; Odiase *et al.*, 2013; Igene *et al.*, 2012).

Moringa is capable of preserving food quality and reducing bacterial contamination due to mixed antioxidant, antibacterial and protease inhibiting properties (Bijina *et al.*, 2011; Hazra *et al.*, 2012). Moringa has been successfully used in food processing such as beef burger patties to a level of 12% (Sharaf *et al.*, 2009). Its use in meat processing can also be justified by the significant effect of its leaf extract in inhibiting cholesterol micelle formation (40% inhibition at 10 mg/ml) as shown in a previous study (Adisakwattana and Chanathong, 2011). In another study, *Moringa* leaf aqueous extract therapy was administered to hyperglycemic rats and the results showed that 200 mg/kg dose decreased blood glucose level of normal animal by 26.7 and 29.9% during fasting blood glucose level and oral glucose tolerance test. In case of severely diabetic rats, fasting blood glucose and post prandial glucose levels were reduced by 69.2 and 51.2%, respectively, where as total protein body weight and haemoglobin were increased by 11.3, 10.5 and 10.9%, respectively after 21-day treatments (Jaiswal *et al.*, 2009). This study validates scientifically the widely claim of *Moringa oleifera* leaf being capable of treating diabetes mellitus. Many justifiable researches have also shown that *Moringa oleifera* numerous medicinal claims are true (Sharma and Paliwal, 2013). Studies have also justified the safety of moringa leaves extract in that it has a wide safety margin when administered with caution over a long period of time (Kwaghe and Ambali, 2011; Ojo *et al.*, 2013). The use of soy flour has been earlier incorporated into the formulation of meatballs and evaluated in terms of proximate composition, sensory characteristics and cost production cost (Odiase *et al.*, 2013). Similarly, *Moringa* meatballs have been evaluated recently (Evivie *et al.*, 2015), but no literature exists on the formulation of a soy/moringa beef meatball pilot product in view of combating malnutrition in sub-Saharan Africa.

Given the above knowledge gap, the current study assessed the effects of processing methods, proximate properties, sensory characteristics and production cost of three types of soy/moringa meatballs produced from beef (steamed, baked and fried). It is anticipated that these findings will culminate in feasibility studies that will detail their production and accessibility by average-income earning consumers and replace the currently more expensive meat/fish products.

Materials and Methods

Source of raw materials

Beef (20 kg) was purchased at New Benin Market in Benin City, Nigeria. The connective tissues were trimmed off, followed by washing and subsequently minced using a Monlinex meat mincer, model (Hv6) and were stored in a deep freezer prior to use. Grains of soybean (9 kg) were purchased from New Benin market, and processed into flour as earlier described (Odiase *et al*., 2013). *Moringa oleifera* leaf powder was purchased from an accredited processor.

Experimental treatments and design

A total of four combinations of soy flour were investigated for all the meat types each in three replications. The combinations were; (i) 0/100% soy flour/meat control (ii) 10/90% soy flour/meat (iii) 15/85% soy flour/meat (iv) 20/80% soy flour/meat respectively. Four different combinations of moringa leaf powder were also investigated for all the meat types and catfish each in three replications. The combinations were as follows (i) 0/100% moringa leaf powder/meat (ii) 0.5/99.5% moringa leaf powder/meat (iii) 1/99% moringa leaf powder/meat (iv) 1.5/98.5% moringa leaf powder/meat. A 4x4x3 factorial design was used to accommodate all the experimental treatments in this study; 4 levels of soy flour (0, 10, 15 and 20%), 4 levels of Moringa leaf powder (0, 0.5, 1 and 1.5%) and 3 processing methods (steaming, frying and baking). Mix formulation and processing of soy/moringa beef meatballs were prepared as previously outlined (Igene *et al*., 2016; Evivie *et al*., 2015; Odiase *et al*., 2013).

Weight loss and yield determination

The weights of produced beef meatballs before and after processing (frying, steaming and baking) were taken and then, the following parameters were estimated as follows

Weight loss (g) = meat mix - processed meatballs

$$\text{Weight loss (\%)} = \frac{weight\ loss}{meat\ mix}\ x\,100$$

$$\text{Yield (\%)} = \frac{weight\ of\ \ procesed\ meatball}{weight\ of\ \ meat\ mix}\ x\,100$$

Proximate analysis

The processed samples were analyzed for moisture, ash, ether extract, protein and carbohydrate (NFE) as described by AOAC (2000). These experiments were carried out in two replications.

Sensory evaluation

This was carried out as earlier described (Igene *et al*., 2016). Briefly, panelists were served the coded samples in a testing room far away from the sample cooking and preparation area. A 5-point hedonic scale having 5: like very much as the highest score and 1: dislike very much as the lowest score was used (British Nutrition Foundation, 2004).

Economic evaluation (or cost analysis)

The cost analysis of produced meatballs was determined at various levels of inclusion. The cost of meat and each ingredient constituent were added up.

Statistical analysis

Data obtained were subjected to analysis of variance (ANOVA) using Genstat statistical package (2005). Significant means were separated using Duncan Multiple Range Test at 5% level of significance.

Results and Discussion

Total ball, weight loss and yield of meatball

The result of the effect of different processing methods on weight loss and yield of meatballs at varying levels of soy/moringa inclusion is shown in Tables 1. Formulated baked, steamed and fried beef meatballs are also shown in Fig. 1. The result showed that as the level of soy/moringa increases in all three meatball types there was a corresponding increase in the number of balls rolled out and total ball of the meatball mixtures. Ball rolled out from the machine and the total ball at the control treatment (166 and 224, respectively) were not significantly different (P>0.05) from 10/0.5 (206 and 274, respectively) and 15/0.5% (213 and 278, respectively) treatments but were significantly different (P<0.05) from the highest level of soy/moringa inclusion (258 and 333, respectively). There were no significant differences (P>0.05) between all baked, steamed and fried beef ball samples before and after weighing. Soy/moringa inclusion reduced weight loss from 56.90 to 19.9% due to baking and 20.20 to 11.10% due to frying. There was no significant difference (P>0.05) in reduction in weight loss due to steaming. In baked beef balls, weight loss (%) was significantly different the 10/0.5 (51.20%) and the 15.0/1.5 (27.30%) treatments. For steamed beef balls, there was no significant difference (P>0.05) between the control (0.09) and the highest soy/moringa inclusion level (0.12). The frying process showed significant difference (P>0.05) between the control (20.20 g) and the 10/0.5 treatment (11.50 g). The cooking yields of beef balls were increased by 61.18% in baked balls, 97.43% in steamed balls and 86.08% in fried balls.

The result of proximate composition of beef ball showed that fried balls of 15/1.0% soy moringa inclusion level had the highest protein (42.75%). This result is in concordance with Bognar, (1998) who investigated the effects of certain cooking methods on the protein content of selected foods and showed that retention of protein in the investigated cooked food varied from 90% in boiled meat and 96 to 100% in deep fried potatoes, meat and fish. The findings of Bognar (1998) findings also confirmed earlier results (Gall *et al*., 1983; Varela *et al*., 1988) that frying did not change the digestibility of protein. In addition, Unal *et al*. (2018) reported that barbecuing process can improve the protein content of *sucuk* (Turkish meat product) and inclusion of spices could confer antioxidant effects. Although the latter was beyond the scope of this research, future studies on the antioxidant effects of these types of beef meatballs would significantly enhance their health benefits and consequently their consumption. This study also showed that the steaming process retained more nutrients and this may explain the high protein content observed after processing. The effects of processing methods on the microbial quality of soy/moringa beef meatballs also requires further research as frying has been shown recently to lower microbial load and increase the nutritive composition of mealworms in Europe (Megido *et al*., 2018).

B1 **B2** **B3** **B4**

B_1 = 0/0 % Soy moringa inclusion level of Beef Ball; B_2 = 10/0.5 % Soy moringa inclusion level of Beef Ball; B_3 = 15/1.0 % Soy moringa inclusion level of Beef Ball; B_4 = 20/1.5 % Soy moringa inclusion level of Beef Ball

Fig. 1: Processed beef meatballs produced and evaluated in this study

Table 1: Effect of processing method on each concentration level in weight loss and cooking yield of beef ball

Parameters	Soy/moringa inclusion level (%)	Baked	Steamed	Fried	Overall SEM ±
Machine ball roll out	0/0	166^{b}	166^{b}	166^{b}	6.24
	10/0.5	206^{ab}	206^{ab}	206^{ab}	37
	15/1.0	213^{ab}	213^{ab}	213^{ab}	11.86
	20/1.5	258^{a}	258^{a}	258^{a}	27.3
	Overall SEM ±	24	24	24	
Total ball produced (n)	0/0	224.3^{b}	224.3^{b}	224.3^{b}	4.91
	10/0.5	274.0^{ab}	274.0^{ab}	274.0^{ab}	31.1
	15/1.0	278.0^{ab}	278.0^{ab}	278.0^{ab}	7.51
	20/1.5	333.0^{a}	333.0^{a}	333.0^{a}	14.74
	Overall SEM ±	17.78	17.78	17.78	
Weight before (g)	0/0	6.95^{a}	5.98^{a}	6.25^{a}	0.71
	10/0.5	6.98^{a}	5.87^{a}	6.79^{a}	0.99
	15/1.0	5.76^{a}	6.30^{a}	6.94^{a}	1.08
	20/1.5	6.23^{a}	4.58^{a}	6.57^{a}	1.21
	Overall SEM ±	1.11	0.97	0.95	
Weight after (g)	0/0	3.06^{a}	5.89^{a}	4.99^{a}	0.57
	10/0.5	3.41^{a}	5.67^{a}	6.03^{a}	0.81
	15/1.0	4.18^{a}	6.10^{a}	6.01^{a}	0.97
	20/1.5	5.05^{a}	4.45^{a}	5.89^{a}	1.11
	Overall SEM ±	0.88	0.92	0.86	
Weight loss (g)	0/0	3.89^{a}	0.09^{a}	1.26^{a}	0.18
	10/0.5	3.58^{a}	0.20^{a}	0.76^{a}	0.31
	15/1.0	1.58^{b}	0.20^{a}	0.93^{a}	0.23
	20/1.5	1.18^{b}	0.12^{a}	0.69^{a}	0.13
	Overall SEM ±	0.34	0.058	0.17	
Weight loss %	0/0	56.90^{a}	1.50^{a}	20.20^{a}	2.24
	10/0.5	51.20^{a}	3.30^{a}	11.50^{b}	1.06
	15/1.0	27.30^{b}	2.83^{a}	12.87^{b}	2.75
	20/1.5	19.90^{b}	2.57^{a}	11.10^{b}	1.58
	Overall SEM ±	2.85	0.60	1.91	
Yield %	0/0	43.10^{b}	98.50^{a}	79.80^{a}	2.24
	10/0.5	48.80^{b}	96.70^{a}	88.50^{b}	1.06
	15/1.0	72.70^{a}	97.10^{a}	87.13^{b}	2.75
	20/1.5	80.10^{a}	97.43^{a}	88.90^{b}	1.58
	Overall SEM ±	2.85	0.60	1.91	

Mean superscripted by the same alphabet within rows and columns are not significantly different (P>0.05). Each parameter is expressed as mean ± SEM (Standard Errors of Means).

Sensory evaluation results

In beef ball, there was no significant difference (P>0.05) in colour due to frying as soy flour/moringa inclusion increases (Table 2). As soy/moringa increases, there were significant differences (P<0.05) in colour due to baking and steaming. The highest colour score rating was observed in control balls of baked and fried beef ball (4.17) and 4.10), respectively; while the least was in 20/1.5% (2.75) treatment of baked beef ball. In baked beef balls the score rating foraroma reduced significantly from control balls (4.22) to 20/1.5% treatment (3.22). In steamed beef ball, in respect to aroma, 20/1.5 treatment differed significantly (P<0.05) from the other levels of inclusion, among which there were no significant difference (P>0.05). Meanwhile, there were no changes in aroma as soy/moringa inclusion increases in fried beef ball. There was slight significant difference (P<0.05) in taste down the soy flour/moringa inclusion levels in all processing methods. In regard to texture, there was no significant difference in steamed and baked balls down the inclusion levels while slight change was observed in baked balls. As soy/moringa inclusion increased the overall acceptability of baked and steamed beef balls reduced while level of inclusion had no effect on consumers' preference in fried balls. Mean organoleptic scores show that fried and steamed beef meatballs were the most and least accepted by sensory panelists, respectively (Fig. 2).

Table 2: Table of sensory evaluation of beef ball

Parameters	Soy/moringa inclusion level (%)	Baked	Steamed	Fried	Overall SEM ±
Colour	0/0	4.17^{a}	3.60^{a}	4.10^{a}	0.17
	10/0.5	3.65^{a}	3.80^{a}	3.97^{a}	0.20
	15/1.0	3.65^{a}	3.50^{a}	3.83^{a}	0.15
	20/1.5	2.75^{b}	2.88^{b}	3.53^{a}	0.23
	Overall SEM ±	0.21	0.16	0.20	
Aroma	0/0	4.22^{a}	3.75^{a}	4.23^{a}	0.20
	10/0.5	3.63^{ab}	3.93^{a}	4.08^{a}	0.21
	15/1.0	3.80^{ab}	3.75^{a}	3.93^{a}	0.14
	20/1.5	3.22^{a}	3.12^{b}	3.70^{a}	0.26
	Overall SEM ±	0.18	0.19	0.23	
Taste	0/0	3.90^{a}	3.55^{a}	4.13^{a}	0.20
	10/0.5	3.32^{ab}	3.40^{ab}	3.98^{ab}	0.25
	15/1.0	3.42^{ab}	3.48^{ab}	3.93^{ab}	0.16
	20/1.5	2.73^{b}	2.83^{b}	3.42^{a}	0.21
	Overall SEM ±	0.24	0.20	0.17	
Texture	0/0	3.83^{a}	3.32^{a}	3.78^{a}	0.17
	10/0.5	3.37^{bc}	3.38^{a}	3.80^{a}	0.19
	15/1.0	3.53^{ab}	3.18^{a}	3.72^{a}	0.13
	20/1.5	3.02^{c}	2.83^{a}	3.60^{a}	0.11
	Overall SEM ±	0.13	0.18	0.15	
Overall Acceptability	0/0	3.77^{a}	3.42^{a}	3.87^{a}	0.10
	10/0.5	3.28^{ab}	3.37^{a}	3.82^{a}	0.17
	15/1.0	3.17^{b}	3.30^{a}	3.78^{a}	0.13
	20/1.5	2.77^{b}	2.57^{b}	3.38^{a}	0.14
	Overall SEM ±	0.17	0.098	0.14	

Mean superscripted by the same alphabet within rows and columns are not significantly different (P>0.05). Each parameter is expressed as mean ± SEM (Standard Errors of Means).

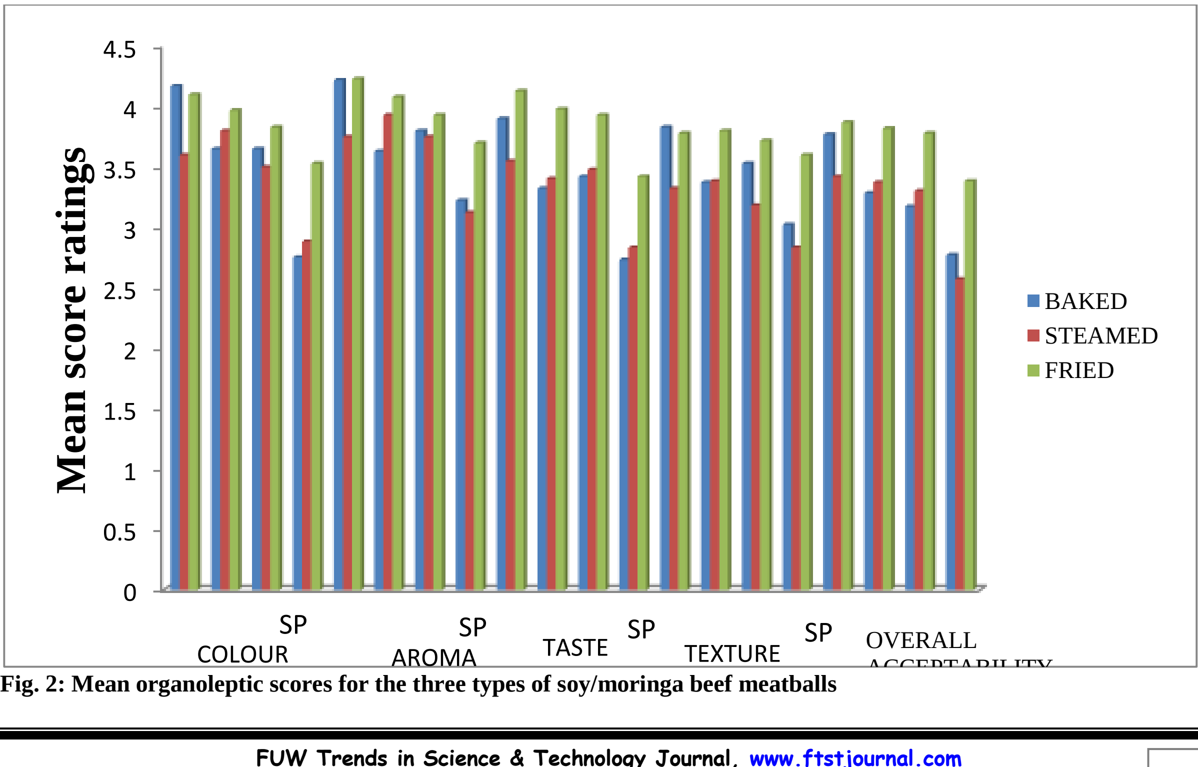

Fig. 2: Mean organoleptic scores for the three types of soy/moringa beef meatballs

The mean score value from sensory assessment showed that the mean of 20/1.5% inclusion level was lowest compared to the other levels in all beef meatballs (Table 2, Fig. 2). This was as a result of higher percent level of moringa which added characteristic colouration to products introduced and thus making it unappealing to potential consumers. This observation was in consonance with a recent study on improving beef meatballs with rice bran as a natural antioxidant (Kartikawati and Purnomo, 2019). Colour measurement is an important parameter in meat products because consumers associate this product with a bright and characteristics pink colour (Bognar, 1998; Boles and Peg, 2005). In beef meatballs, baking and steaming had no effect on the varied soy moringa inclusion levels except in 20/1.5% level of inclusion which was significantly different ($P<0.05$) from the others. This could be as a result of high moringa level in this products and the characteristic colour retained by ground beef in the course of processing. Colour is the main factor affecting meat product acceptability at the time of consumer purchase (Faustman and Cassens, 1989). The colour of cooked meat products arise mainly from pigmentation of the meat from which they are made and the ingredients used in the processing (Serdaroglu, 2006). Aroma of all fried beef meatballs showed no significant difference (P>0.05) irrespective of soy/moringa inclusion. Frying improves the sensory quality of food by formation of aroma compounds, attractive colour, crust and texture. This is in consonance with results of sensory analysis carried out by Bognar (1998) that good to very good sensory quality can be achieved when breaded meat poultry and fish are deep fried. There were significant differences (P<0.05) in all meatball types due to baking and steaming except in catfish where there was no significant difference (P>0.05) among levels of soy/moringa inclusion due to steaming. In beef balls, although there were no significant differences in taste in relation to processing level the mean scores showed that fried balls had a higher score compared to baking and frying at each inclusion levels. Frying improves crust. It was also observed that 20/1.5% levels were least accepted mostly due to hardness of the meatball from soy/moringa inclusion level. In relation to texture, frying had little or no effect on texture. This must be as a result of frying sensory qualities on food. In all beef meatball types, there were significant differences (P<0.05) in texture due to baking. This finding agreed with Otunola *et al*. (2013), where the cookies without moringa leave waste were superior. Based on the organoleptic study of meatball types produced it was recommended that soy/moringa beef ball should be processed fried at 10/0.5 and 15/1.0% inclusions

Cost analysis

The results of cost evaluation of soy/moringa beef ball is shown in Table 3. In beef balls soy/moringa inclusion reduced cost of 10/0.5, 15/1.0, and 20/1.5% level of inclusion by ₦67.07, ₦64.75 and ₦2.43, respectively. The reduction in cost of meatballs produced from combination of soy flour and *Moringa oleifera* leaf powder as observed in this study, shows that the use of functional food materials such as soybean and moringa which are relatively cheap can lead to economic production of these nutritious products. These findings are further confirmed by three earlier studies carried out on physical, chemical and economic properties of meatballs as a weapon to curb the alarming protein malnutrition rates in sub-Saharan Africa (Evivie *et al*., 2015, Igene *et al.*, 2012; Odiase *et al.*, 2013). These soy moringa meatballs can therefore be recommended for inclusion into the diets of different categories of individuals based on health needs. They can also serve as fast foods/snacks for the Nigerian consumers who have been earlier projected to buy more of pastries and other convenience foods to complement their busy lifestyles (DFM, 2007). Soy/moringa inclusion reduced production cost in beef balls of 10/0.5% by ₦67.07. Therefore, in beef meatballs the most expensive ball produced were 20/1.5% treatment level and the least expensive was 10/0.5. Bearing in mind that it is possible to have nutritious, cost-effective but less appealing beef meatballs, the present study went further to assess the sensory characteristics of the formulated products.

Table 3: Cost analysis of beef ball production at varying levels of soy/moringa inclusion

Ingredient	Control (0/0%)	10/0.5%	15/1.0%	20/1.5%
Beef	1658.89	1484.70	1393.47	1302.23
Soy flour	-	27.12	40.67	54.23
Moringa oleifera leaf powder	-	80	160	240
Corn Starch	19.69	19.69	19.69	19.69
Wheat flour	14.63	14.63	14.63	14.63
Sugar	2.25	2.25	2.25	2.25
MSG	4.50	4.50	4.50	4.50
Seasonal	10.05	10.05	10.05	10.05
Paprika	11.93	11.93	11.93	11.93
Pepper	9.38	9.38	9.38	9.38
Curry	9.90	9.90	9.90	9.90
Thyme	3.00	3.00	3.00	3.00
Ginger	18.00	18.00	18.00	18.00
Ice water	0.14	0.14	0.14	0.14
Shalliot	3.00	3.00	3.00	3.00
Onion	14.85	14.85	14.85	14.85
Garlic	6.35	6.35	6.35	6.35
Total Cost	**₦1786.56**	**₦1719.49**	**₦1721.81**	**₦1724.13**

Proximate analysis

The proximate analysis of beef all is shown in Table 4. Significant differences were observed in the moisture and dry matter percentage within soy flour/moringa level of inclusion and across the processing method. The highest value for ash were observed in 20/1.5% level of inclusion in baked (1.93%), steamed (1.85%) and fried (1.70%) beef balls. Although there were significant differences in crude fat in all processed balls, frying created a distinct difference observed at each level of soy/moringa incorporation. Fried beef balls had the highest value of crude fat (29.65%) at 20/1.5% level of inclusion while the least (18.0%) was from baked balls of 15/1.0 % treatment. Treatments with the highest level of soy flour and moringa leaf powder inclusion had the highest level of crude fibre. In respect to the crude protein (CP) value of beef balls, baking reduced the %CP by an average of 36.80% while steaming by an average of 35.37% and frying increased it by an average of 36.03%. The result of proximate composition of beef ball showed that fried balls of 15/1.0% soy/moringa inclusion level had the highest protein (42.75%) with fried 0/0% inclusion level having the lowest (28.03%) It was observed that the treatment with higher value of CP was followed by a smaller value of Nitrogen Free Extract.

Table 4 Proximate composition of beef balls

Beef Ball	Soy/moringa inclusion level (%)	Baked	Steamed	Fried	Overall SEM ±
Moisture Content (%)	0/0	12.40^{a}	10.75^{a}	7.75^{b}	0.21
	10/0.5	9.25^{b}	11.35^{a}	7.90^{b}	0.18
	15/1.0	7.25^{c}	9.50^{b}	7.90^{b}	0.16
	20/1.5	7.35^{c}	10.80^{a}	9.00^{a}	0.14
	Overall SEM ±	0.20	0.18	0.14	
Dry Matter (%)	0/0	87.60^{c}	89.25^{b}	92.25^{a}	0.21
	10/0.5	90.75^{b}	88.65^{b}	92.10^{a}	0.18
	15/1.0	92.75^{a}	90.50^{a}	92.10^{a}	0.16
	20/1.5	92.35^{a}	89.20^{b}	91.00^{b}	0.14
	Overall SEM ±	0.20	0.18	0.14	
Ash (%)	0/0	0.75^{c}	1.08^{b}	0.80^{b}	0.16
	10/0.5	1.10^{bc}	1.20^{b}	1.10^{b}	0.10
	15/1.0	1.53^{ab}	1.45^{b}	1.50^{a}	0.05
	20/1.5	1.93^{a}	1.85^{a}	1.70^{a}	0.15
	Overall SEM ±	0.23	0.10	0.09	
Crude fat (%)	0/0	23.50^{b}	24.50^{a}	26.50^{c}	0.50
	10/0.5	25.50^{a}	19.50^{c}	28.00^{b}	0.41
	15/1.0	18.00^{c}	24.50^{a}	25.25^{d}	0.32
	20/1.5	23.50^{b}	22.00^{b}	29.65^{a}	0.30
	Overall SEM ±	0.43	0.43	0.29	
Crude fibre (%)	0/0	0.88^{c}	1.00^{d}	1.00^{d}	0.072
	10/0.5	1.25^{bc}	1.20^{c}	1.25^{c}	0.041
	15/1.0	1.50^{ab}	1.55^{b}	1.50^{b}	0.029
	20/1.5	1.84^{a}	2.00^{a}	2.00^{a}	0.09
	Overall SEM ±	0.10	0.025	0.025	
Crude protein (%)	0/0	40.25^{a}	36.58^{b}	28.03^{d}	0.05
	10/0.5	34.75^{c}	38.63^{a}	36.75^{b}	0.16
	15/1.0	36.18^{b}	29.53^{c}	42.75^{a}	0.10
	20/1.5	36.03^{b}	36.75^{b}	36.58^{c}	0.05
	Overall SEM ±	0.15	0.074	0.04	
Nitrogen free Extract (%)	0/0	22.23^{c}	26.10^{b}	35.93^{a}	0.57
	10/0.5	28.15^{b}	28.12^{b}	25.00^{b}	0.37
	15/1.0	35.55^{a}	33.25^{a}	21.10^{c}	0.26
	20/1.5	29.36^{b}	26.60^{b}	21.08^{c}	0.20
	Overall SEM ±	0.35	0.51	0.19	

Mean superscripted by the same alphabet within rows and columns are not significantly different (P>0.05). Each parameter is expressed as mean ± SEM (Standard Errors of Means)

The result of the proximate composition showed that baking, steaming and frying of beef meatballs reduced fat content by an average of 22.63, 22.75 and 27.50, respectively. Baking reduced fat content significantly while steaming did so slightly. The fat content of all classes of beef meatballs ranged from 18.00 to 29.65%. Specifically, fat levels of fried beef meatballs were 25.25 to 29.65%. This observation was higher than that recently reported by Lu *et al*. (2018) who formulated spiced, deep-fried beef meatballs. While it may not be clear why there were discrepancies, it does suggest that the fat content may not be suitable for certain groups of consumers. Techniques on lowering this are thus warranted. Also, the protein content of fried beef meatballs was 28.03 to 42.75% which was higher than those previously reported (Lu *et al*, 2018; Ulu, 2004) and indicates that fried soy/moringa beef meatballs can be an important source of protein to combat malnutrition in sub Saharan Africa.. Preliminary studies on the production of soy/moringa beef balls have been carried out previously (Evivie *et al*., 2015; Odiase *et al*., 2013), but the effects of processing methods on the overall quality of these products were not within the scope of the study. Although all processing methods were significantly proved the nutritional characteristics of the three types of beef meatballs in the present study, frying was the most effective method.

Conclusion

Malnutrition in sub Saharan Africa is a stubborn problem that needs to be tackled both aggressively and proactively. This study assessed the processing methods, proximate composition, sensory characteristics and production cost of three types of three beef meatballs with varying levels of soy flour and *Moringa oleifera* powder. Fried beef meatballs were the most acceptable and soy/moringa inclusion level of 20/1.5% was adjudged the best and generally most nutrient-dense via proximate analysis. However, this inclusion level was more expensive to produce compared to the 10/1.0%. Studies on the microbial safety, antioxidant properties and other health benefits of these formulated products are thus recommended. Government and private involvement in the pilot plant production of nutritious beef meatballs is also strongly encouraged.

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Conflict of Interest

The authors declare no conflicts of interest in this study.

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