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Quality attributes of chicken nuggets extended with different legume flours

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Abstract

Chicken nugget is a comminuted meat product commonly prepared from spiced chicken meat and other ingredients. The tenderness of chicken meat lowers its firmness and mouth feel which may reduce acceptability of chicken nugget made from it. Thus, acceptability of chicken nugget could be harnessed when legume flour extenders are used along. Therefore, acceptability as well as quality of chicken nugget from different legume flours were evaluated. Soyabean, groundnut and cowpea flours were used as meat extenders for development of raw chicken nuggets and thereafter cooked for consumption. The quality of both raw and cooked legume flour extended chicken nuggets were assessed based on functional properties, sensory properties, proximate composition, amino acid content and shelf stability in terms of lipid peroxidation and microbial load. In their raw state, the legume flour extenders competed favourably with each other. Among all, soyabean flour extender maintained remarkable functional properties that transcend into significant ($P < 0.05$) yield of 86.93% of chicken nugget in comparison to the control (86.37%), groundnut (84.95%) and cowpea (84.50%). Upon cooking, all the legume flour extended chicken nuggets varied in their quality attributes. Apart from the high level of flavour and low microbial load, cowpea extended chicken nugget was of low quality based on the parameters evaluated in comparison with other legume flour extended chicken nuggets. Of interest, soyabean extended chicken nugget followed by groundnut extended chicken nugget were of good quality based on sensory properties, high crude protein and amino acid levels, low cholesterol content and lipid peroxidation value as well as low microbial load.

Keywords: Chicken nuggets, Legume flour, Proximate compositions, Amino acids, Soyabean, Cowpea, Groundnut

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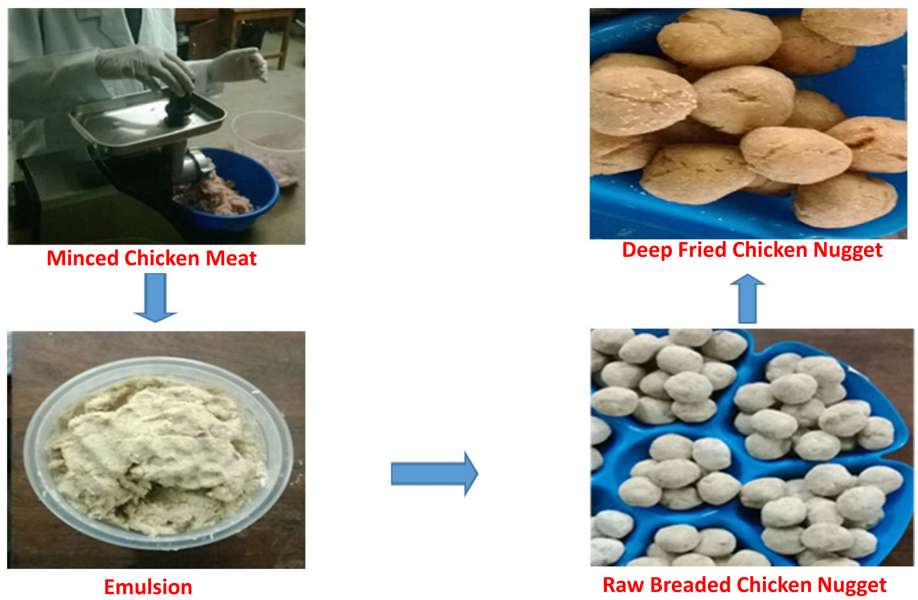
Graphical abstract



Major Steps in Chicken Nugget Preparation

Introduction

Poultry meat consumption is increasing with growing population especially in developing countries (FAO 2020; Latino et al. 2020). Among the poultry meats, chicken meat is mostly consumed (Cricelli et al. 2015; Pakseresht et al. 2022) and has been developed into different forms for consumption which include chicken nuggets (El-Sohaimy et al. 2022). Chicken nuggets has gained popularity due to its variety of benefits such as reduced preparation time, low cost, and long shelf life under frozen storage (Abd-El-Aziz et al. 2021). Also, it has become an important ready for sale food served at almost all fast food restaurant chains (Abd-El-Aziz et al. 2021; Pakseresht et al. 2022). This has led to an increasing demand for chicken nuggets with respect to preference for quality, taste and health value (Pakseresht et al. 2022). Thus, in order to diversify the quality, taste and health value, the use of legume flour extenders was embraced in this study specifically to meet up with consumers demand (Yeater et al. 2017).

Extenders are protein additives usually from plant origin used to enhance the water binding and textural properties of meat (Kyriakopoulou et al. 2021). Higher water binding ability bulk up the meat product which result in more improved yield (Okuskhanova et al. 2017). So, inclusion of legume flour extenders in meat formulations will not only enhance the nutritional value but also provides a vehicle to promote the use of legume flours to maintain target protein intake (Baugreet et al. 2016). Among other flours, protein from legume flours cannot be under estimated because of their high protein content (Kyriakopoulou et al. 2021). Legume flours also have potentials to improve product quality by helping to retain moisture during cooking, freezing, thawing and reheating (Kyriakopoulou et al. 2021; Riaz 2005).

So far, soyabean, is the most widely used legume flour extender (Kurek et al. 2022; Ma et al. 2022), nevertheless, as a result of increased functionality, other legume based flour (Shoaib et al. 2018) are becoming increasingly famous as they all have promising nutritional and sensory properties of food products. Thus, along with soyabean, it is important to screen other legume based flour as extenders to chicken nuggets. This study therefore hypothesized that apart from soyabean, other legume based flour extenders will enhance quality of chicken nuggets. In order to ascertain our hypothesis, we have used different legume flour which are soyabean, groundnut and cowpea flours as extenders in the development of high quality chicken nuggets.

Materials and methods

Sample collection and preparation of legume flours

Clean seeds of soyabean, cowpea and groundnut were obtained accordingly and each of the legume flour seeds was processed into flour following the method of Omojola et al. (Omojola et al. 2013). Briefly, cowpea seeds (*Vigna* *unguiculata*) were soaked in hot water (54 °C) for a period of ten minutes while soyabean (*Glycine max*) seeds were soaked in hot water (85 °C) for about an hour. The soaked bean seeds were rubbed between palms to remove the testa. Thereafter, the seeds of the beans were soaked in hot water (80 °C) for one hour to remove the beany flavour and sun dried for 48 hours at an ambient temperature of 28 °C and then ground into flour using a conventional grinder. Groundnut (*Arachis hypogea*) seeds were soaked in hot water (80 °C), this was left over night in order to enable easy removal of the testa and dried in an oven (Wagtech oven, model GP/20SE300HYD) for 48 hours at 60 °C. After wards the naked seeds were ground into powdery form. The three legume flours were separately packaged inside clean and well labeled polyethylene bags for further use. Experimental treatment: T1 - chicken meat without extender (control); T2 - chicken meat + soyabean flour; T3 - chicken meat + groundnut flour; T4 - chicken meat + cowpea flour. The extenders were used at 10% inclusion level (Table S1). The experiment was a complete randomized design. Each legume flour represent a treatment, making a total of four treatments with the control. Each treatment was replicated six times.

Functional properties of legume flour flours

The functional properties of the legume flour extenders which include bulk density, foaming capacity, foaming stability, water absorption capacity (WAC), emulsion capacity, emulsion stability and oil absorption capacity (OAC) were determined as described by Akpossan et al. (Akpossan et al. 2015).

Products properties

Colour properties

Colour measurement was carried out using a Hunter Colorimeter model 45/0-L mini scan XE PLUS (Hunter Associates Labs, Reston, VA, USA) on the basis of three variables, namely, L, a, and b (American Meat Science Association-AMSA 1991). The instrument was calibrated against a standard black as well as white reference tiles. The samples were placed in a transparent Petri dish and positioned directly on the light path to measure the colour parameter values of L, a and b. Four colour readings were taken from each chicken nugget sample and the average was used for analysis.

Yield and pH

Product yield was determined by measuring the difference in the sample weight before and after cooking. Product yield (%) = [Weight of cooked nugget / Weight of uncooked nugget] X 100. pH was carried out using 1 g of chicken nugget samples which was homogenized in 9 mL distilled water for a period of 5 minutes. A pH meter (Model H18424 Micro-Computer, Havana Instruments, Romania) was inserted into each of the homogenate and pH for each sample was measured thrice and average value recorded (Marchion and de Felico 2005).

Sensory evaluation of prepared chicken nuggets

This was conducted using a 20 member semi-trained taste panels at each stage according to the method described by AMSA (1995). The taste panelists were made up of male and female students and workers in the Department of Animal Science, University of Ibadan in the age range of 25–45 years. Unsalted cracker biscuit and water were provided for mouth cleansing in between treatments. The room was well ventilated and devoid of all forms of distractions that could affect panelist. Chicken nuggets were blind coded and the orders of serving were randomized. Chicken nuggets were assessed using a 9-point hedonic scale for colour, juiciness, flavour, aroma, hotness, tenderness and overall acceptability.

Proximate composition of raw and cooked chicken nuggets

Proximate analysis of all samples were determined according to AOAC (2000). Moisture, crude protein, ether extract, and ash content of cooked nuggets were determined. Moisture was determined using hot air oven. Crude protein was analyzed by kjeldhal's apparatus. Fat and ash contents were determined by using Soxhlet apparatus and muffle furnace, respectively. In addition, the groundnut flour was defatted using solvent extraction method as described by AOAC (2000).

Amino acid of raw and cooked chicken nuggets

Essential amino acids were determined by the spectrophotometric method using ninhydrin chemical reaction according to Moore and Stein (Moore & Stein 1954). Percentage amino acid (%) was calculated as; Amino acid (%) = Absorbance of sample x Gradient factor x Dilution factor/10,000.

Thiobubaturic acid reactive substances (TBARS) content in chicken nuggets

The degree of lipid oxidation was determined for each meat and meat product sample at days 0, 5, 10 and 15. TBARS assay was done using the method of Zeb and Ullah (Zeb & Ullah 2016). Exactly 5 g of each sample was weighed into the conical flask, 10 mL of distilled water was added and homogenized for 2 minutes. Thereafter, 2 mL of 10% trichloroacetic acid (TCA) was added and each was filtered through Whatman No 1 filter paper. Freshly prepared thiobubatunic acid (TBA) was added to each sample filtrate on ratio 1:1. To a blank of 10 mL distilled water, 2 mL of 10% TCA and freshly prepared TBA were prepared in another conical flask. The solutions of each sample and the blank were stirred for 4–5 seconds and stored in the dark for 1 hour to develop the colour (slightly reddish). Absorbance wavelength was measured using an (UV-Vis spectrophotometric CE1020 model, cecic-UK) at 530 nm. The results were expressed as mg malonaldehyde (MDA) per kg products using the formulae: TBA = K + OD5 nm, where K = 9.242.

Microbial load of cooked chicken nuggets prepared from different legume flour extenders

Three different culture media (nutrient agar, MacConkey agar and potato dextrose agar) were used to carry out the microbial analysis of chicken nugget samples using pour plating method. The plates were incubated at 35-37 °C for 48 hours. Coliforms, bacterial and mould loads were determined from plates bearing the colonies. All analysis were carried out as described by Reynolds (Reynolds 2005). All analysis were carried out in triplicates for days 0, 5, 10 and 15.

Cholesterol content of chicken nuggets prepared from different legume flour extenders

Cholesterol of the chicken nugget was carried out by adding 5 mL of chloroform into a conical flask containing 5 g of the sample and then ground. Additional 5 mL of chloroform and 10 mL of distilled water were added and mixed thoroughly. The mixture was poured into a separating flask and the lower layer was released into a test tube. Thereafter, 1 mL of acetic anhydride and 1 ml of concentrated sulphuric acid (H_2SO_4) were poured into the separated solution. Green colour was observed at the interface. Absorbance wavelength of the solution was measured in spectrophotometer at 640 nm (Nawar et al. 1991).

Statistical analyses

Experimental treatments were compared using SAS software, version 9.1 (SAS Institute, Cary, NC, USA). For each of the experiment, replicated data sets were subjected to the analysis of variance (ANOVA) technique according to the experimental design to find out the significance of the treatments. ANOVA was also used to determine the effect of treatments and error associated with each experiment. Mean comparison of traits was used and carried out by protected LSD ($p = 0.05$; Students-Newman-Keuls Test) where the error mean square served as the standard error of differences between mean.

Results and discussion

Functional properties of different legume flours

Soyabean flour had higher swelling capacity, foaming capacity, foaming stability, water absorption capacity and pH than cowpea and groundnut flours. However, groundnut flour was remarkable for oil absorption and emulsion capacity while cowpea flour maintained good bulk density in comparison to other legume flour extenders (Table 1). The groundnut flour had the lowest bulk density value of 0.59 g/cm^3 which is however lower than 1.35 g/cm^3 reported by Odedeji and Oyeleke (Oyedeji & Oyeleke 2011). Functional properties such as swelling capacity, foaming capacity and emulsifying capacity/ stability (Oyedeji & Oyeleke 2011).are pH dependent. As alkaline pH are known to improve these properties more than acidic pH (Ocheme et al. 2012). Soyabean flour had a higher pH of 6.61 which could have resulted to a positive influence on its swelling capacity, foaming capacity stability and emulsion stability as it rated highest among other legume flours used for chicken nugget preparation. Furthermore, WAC and OAC were reported to be higher for soyabean flour with values 3.45 and 2.32 respectively. The OAC is of great importance as it improves the mouthfeel and helps retain flavour. The ability of proteins to bind with oil makes it useful in food system where optimum oil absorption is needed (Chandra & Samsher 2013). The high emulsifying capacity of groundnut and cowpea flour compared to soyabean flour could be attributed to the fact that they contain proteins that have lower molecular weights and better interfacial properties at the oil water interface (Singh 2001).

Legume flour extenders influenced the colour, yield and pH of chicken nuggets

The lightness coefficient (L), a* and b* values for raw chicken nuggets without extenders (control) was higher than that with soyabean, groundnut and cowpea extenders. Among the legume flour extenders, groundnut exhibited a more significant ($P < 0.05$) L value, while cowpea revealed higher a* and b*. This however reveals that the presence of these extenders in the meat systems had a strong influence on the colour differences recorded

Table 1 Functional properties of legume flours used for chicken nugget preparation

Parameters	Soya bean	Cowpea	Groundnut
BD (g/cm^3)	0.65 ± 0.07^b	0.69 ± 0.04^a	0.59 ± 0.05^c
SC (%)	54.32 ± 15.05^a	25.53 ± 13.74^c	37.95 ± 1.32^b
FC (%)	47.53 ± 9.20^a	45.43 ± 7.10^b	22.03 ± 16.30^c
FS (%)	22.02 ± 0.79^a	20.43 ± 0.80^b	0.00 ± 0.00^c
WAC (%)	3.45 ± 0.91^a	1.87 ± 0.67^c	2.31 ± 0.23^b
OAC (%)	2.32 ± 0.00^b	1.75 ± 0.57^c	2.89 ± 0.57^a
EC (%)	39.83 ± 3.98^c	45.50 ± 1.69^b	46.12 ± 2.31^a
ES (%)	1.15 ± 0.08^b	1.87 ± 0.64^a	0.66 ± 0.57^c
pH	6.61 ± 0.06^b	6.53 ± 0.02^a	6.51 ± 0.04^c

WAC Water Absorption Capacity, *BD* Bulk Density, *SC* Swelling Capacity, *FC* Foaming Capacity, *ES* Emulsion Stability, *EC* Emulsion Capacity, *FS* Foaming Stability

[abc] Means in the same row with varying superscripts are significantly different ($P < 0.05$).

for the extended raw chicken nugget samples. Also, raw samples extended with soyabean flour had the lowest L* value, this agreed with the findings of Gnanasambandam and Zayas (1992) where Frankfurters containing soy protein had the lowest L* value among other treatments. Similar results was also recorded for chicken nuggets containing soyabean flour where lowest L* values were obtained. This could be as a result of higher protein content of soyabean flour compared to other flours (Dogan et al. 2005). Upon cooking, it was observed that groundnut extended chicken nugget had higher L value than other legume flour extenders including the control. On the other hand, soyabean extended chicken nugget had high a* and b* value of cooked chicken nugget. The control had significantly ($P < 0.05$) lower a* and b* values than those recorded for soyabean, groundnut and cowpea extended chicken nuggets (Table 2). This implies that there was a drastic drop in the L* values in all the chicken nugget samples with a slight increase in the a* and b* values of chicken nuggets extended with legume flours. These results however showed the influence of cooking on colour of meat and meat products as end of cooking is usually marked by colour change and flavour development. Lowest L* value (45.18) and highest a* value (2.88) of cooked chicken nuggets extended with soyabean flour in this study corresponds to the findings of Dogan et al. (Dogan et al. 2005) where nuggets containing soyabean flour had the lowest L* values but highest a* values.

Table 2 Colour differences of raw and cooked broiler chicken nugget extended with legume flours

Parameters	Control	Soyabean	Groundnut	Cowpea
Raw CN				
L	70.81 ± 5.92^a	57.52 ± 7.37^d	69.38 ± 4.49^b	61.84 ± 3.05^c
a*	2.27 ± 0.41^a	1.82 ± 0.04^c	1.25 ± 0.61^d	2.11 ± 0.25^b
b*	19.39 ± 3.86^a	12.34 ± 3.19^d	12.98 ± 2.55^c	17.39 ± 1.86^b
Cooked CN				
L	52.85 ± 0.57^c	45.18 ± 7.10^d	55.82 ± 3.54^a	55.25 ± 2.97^b
a*	1.57 ± 0.63^d	2.88 ± 0.68^a	1.97 ± 0.23^c	2.36 ± 0.16^b
b*	11.42 ± 1.18^d	12.89 ± 0.29^c	12.97 ± 0.37^b	13.11 ± 0.51^a

[abcd] Means in the same row with varying superscripts are ($P < 0.05$), *CN* Chicken Nuggets

Yield of chicken nuggets were enhanced by legume flour extenders

Based on the yield, soyabean significantly ($P < 0.05$) enhanced the yield of chicken nugget than other legume flour extenders (Table 3). The product yield of chicken nuggets with or without extenders in this study falls within the values of 81.98 to 83.77% and 85.2 to 93.2% that was also obtained by Serdaroglu et al. (Serdaroglu & Yildiz 2005). In addition, the remarkable product yield of chicken nugget extended with soyabean flour could be attributed to the ability of soyabean flour to hold water tenaciously (Riaz 2005), which probably had a positive influence on the water retention capacity of the chicken nuggets by helping to minimize the level of shrinkage and also improving yield percentage.

pH and volume of the adsorbed oil varied across the legume flour extended chicken nuggets

The pH of the emulsion and cooked chicken nuggets were relatively higher in soyabean and cowpea extended chicken nuggets in comparison to the control and groundnut extended chicken nuggets (Table 3). It is expected that the pH of any product is of significant to the product. Ideal meat pH for making sausages or emulsified product ranges from 5.8 to 6.3. From the results obtained in this study, soyabean extended chicken nuggets had higher pH values for both emulsion and cooked product compared to other extenders. This however implies that soyabean extended chicken nugget is of better quality in terms of water retention capacity and texture because meat with higher pH has better water retention capacity thereby improving product quality while meat with lower pH value reduces water retention/binding capacity in meat systems (Mir et al. 2017). The volume of the adsorbed oil was higher in control, followed by groundnut extended chicken nugget while the least was recorded for soyabean extended chicken nugget (Table 3). This could be attributed to their high oil adsorption capacity as this therefore reveals the ability of these flours to reduce amount of oil uptake during the

Table 3 Yield, pH and oil adsorption of chicken nugget extended with legume flours

Parameters	Control	Soyabean	Groundnut	Cowpea
Yield (%)	86.37 ± 0.68^a	86.93 ± 1.24^a	84.95 ± 0.74^b	84.50 ± 1.19^b
pH (emulsion)	5.88 ± 0.05^b	5.97 ± 0.04^a	5.90 ± 0.03^b	5.96 ± 0.03^a
pH (cooked nugget)	5.97 ± 0.15^d	6.32 ± 0.20^a	6.06 ± 0.06^c	6.11 ± 0.01^b
Volume of oil adsorbed (mL)	17.50 ± 7.56^a	3.00 ± 6.94^b	13.75 ± 3.81^a	5.50 ± 4.44^b

[abcd] Means in the same row with varying superscripts are significantly different ($P < 0.05$)

process of deep fat frying if incorporated in meat/food formulation systems.

Legume flour extenders enhanced sensory properties of cooked chicken nuggets

Freshly cooked chicken nuggets were assessed based on sensory properties (Table 4). Apart from tenderness that was low for soyabean extended chicken nugget, others such as colour, aroma, flavour, juiciness, hotness and overall acceptability had similar values across the legume flour extenders. Interestingly, soyabean and cowpea extended chicken nuggets had good flavour. Palatability of meat products depends greatly on aroma, flavour, colour, appearance, tenderness and juiciness. However, consumer studies have proven that flavour and texture are more important among the meat quality attributes (Biswas et al. 2011). From the nine point hedonic scale used for sensory evaluation in this study, five (5) represent intermediate while seven (7) represent very tender. This however implies that the desired amount of chewiness required by consumers was recorded in chicken nuggets extended with soyabean flour as the product was not too tough neither was it too tender.

Table 4 Sensory evaluation of broiler chicken nugget extended with different legume flours

Parameters	Control	Soyabean	Groundnut	Cowpea
Colour	5.30 ± 0.05^{b}	5.30 ± 0.05^{b}	6.20 ± 0.85^{a}	4.60 ± 0.75^{c}
Aroma	5.20 ± 0.15^{a}	5.20 ± 0.15^{a}	4.90 ± 0.15^{b}	4.90 ± 0.15^{b}
Flavour	4.70 ± 0.33^{c}	5.20 ± 0.17^{a}	5.00 ± 0.03^{b}	5.20 ± 0.17^{a}
Tenderness	6.10 ± 0.00^{b}	5.40 ± 0.70^{d}	7.10 ± 1.00^{a}	5.80 ± 0.30^{c}
Juiciness	5.70 ± 0.47^{a}	4.50 ± 0.73^{c}	5.70 ± 0.47^{a}	5.00 ± 0.23^{b}
Ropiness	6.10 ± 0.40^{a}	5.80 ± 0.10^{ab}	5.90 ± 0.20^{ab}	5.00 ± 0.70^{b}
OA	7.30 ± 0.42^{a}	6.70 ± 0.18^{c}	7.00 ± 0.12^{b}	6.50 ± 0.38^{d}

OA Overall Acceptability

[abcd] Means in the same row with varying superscripts are significantly different ($P < 0.05$)

Legume flour extenders improved proximate composition of chicken nuggets

The proximate composition of raw and cooked chicken nugget extended with different legume flours were presented in Table 5. In the raw form, chicken nuggets without extender had higher moisture content compared to nuggets with legume flour extenders. Lower moisture content of chicken nuggets containing legume flour extenders could be attributed to the ability of these protein flours to absorb moisture in any meat system. The crude protein of raw chicken nuggets without extender was significantly ($P < 0.05$) higher in comparison to chicken nuggets with extenders. However, raw chicken nuggets containing soyabean flour had the highest crude protein compared to nuggets containing groundnut and cowpea extenders. Increase in protein content when soyabean protein was used in formulating patties as reported by Angor and Al-Abdullah (Angor & Al-Abdullah 2010) also agreed with our study. The fat content of raw chicken nuggets without extender rated lowest compared to raw chicken nuggets containing legume flour extenders. This suggest the ability of these legume extenders to adequately absorb oil when present in any meat formulations or food system. We observed increased ash contents in raw chicken nuggets extended with legume flours. Thus, the increased ash content could be attributed to presence of other non-meat ingredients such as legume flours, corn flour, salt and spices used in the chicken nugget preparation

Table 5 Proximate composition of raw and cooked broiler chicken nugget extended with legume flours

Parameters (%) Raw	Control	Soyabean	Groundnut	Cowpea
Moisture	60.18 ± 6.41^{a}	51.18 ± 2.59^{c}	51.04 ± 2.73^{c}	52.67 ± 1.10^{b}
Crude protein	25.17 ± 0.52^{a}	24.94 ± 0.29^{b}	24.78 ± 0.13^{bc}	23.71 ± 0.94^{c}
Ether extract	6.18 ± 0.38^{c}	6.52 ± 0.04^{b}	6.78 ± 0.22^{a}	6.74 ± 0.18^{a}
Ash	2.04 ± 0.28^{b}	2.38 ± 0.06^{a}	2.44 ± 0.12^{a}	2.40 ± 0.08^{a}
Crude fibre	0.80 ± 0.03^{b}	0.90 ± 0.07^{a}	0.82 ± 0.01^{b}	0.80 ± 0.03^{b}
Nitrogen Free Extract	5.63 ± 6.27^{c}	14.10 ± 2.20^{a}	14.16 ± 2.26^{a}	13.68 ± 1.78^{b}
Cooked				
Moisture	43.10 ± 0.35^{b}	43.38 ± 0.63^{a}	42.80 ± 0.05^{c}	41.70 ± 1.05^{d}
Crude protein	32.91 ± 0.61^{a}	32.90 ± 0.60^{a}	32.40 ± 0.10^{b}	31.00 ± 1.30^{c}
Ether extract	9.80 ± 0.29^{a}	9.12 ± 0.39^{d}	9.44 ± 0.07^{c}	9.66 ± 0.15^{b}
Ash	3.88 ± 0.03^{ab}	3.94 ± 0.03^{ab}	4.00 ± 0.09^{a}	3.80 ± 0.11^{b}
Crude fibre	0.90 ± 0.03^{a}	0.90 ± 0.03^{a}	0.86 ± 0.01^{c}	0.80 ± 0.07^{d}
Nitrogen Free Extract	9.41 ± 1.27^{d}	9.76 ± 0.92^{c}	10.50 ± 0.18^{b}	13.04 ± 2.36^{a}

[abcd] Means in the same row with varying superscripts are significantly different ($P < 0.05$)

(Fernadez-lopez et al. 2006). Higher crude fibre content observed in raw soyabean extended chicken nuggets could also be as a result of high fibre content of soyabean as it has been reported that soyabean contain about 50% dietary fibre most especially flour made from soyabean hull (Batajoo & Shaver 1998). The nitrogen free extracts of raw chicken nuggets extended with legume flours were higher than that of control samples in this study. This could be due to the presence of legume flours alongside meat fillers which were present in the raw extended chicken nuggets (Joly & Anderstein 2009). In comparison, the value obtained for proximate composition of raw samples with or without extender in this study were slightly different from 60.8–61.6%, 17.3–17.6%, 15.4–15.5%, 1.7–2.6% and 3.5–4.7% reported for moisture, protein, fat, ash and NFE by Pakseresht et al. (Pakseresht et al. 2022) for raw chicken nuggets containing added fat and variable salt contents. Upon cooking, chicken nuggets extended with soyabean flour had higher moisture, crude protein, ash and crude fibre values which were similar to values obtained in the control (without legume flour). This however reveals the high functionality and nutritional value of soyabean, which further improves the overall quality of meat and meat products. The proximate composition of cooked sample with or without extenders in this study were higher than 40.83–54.42%, 12.52–16.62%, 18.64–25.00%, 1.35–1.58% and 2.49–7.52% reported for moisture, protein, fat, ash and nitrogen free extract by Ismed et al. (Ismed et al. 2009) for commercial chicken nuggets.

Amino acid contents in legume flour extended chicken nuggets

After the proximate composition, due to high crude protein in soyabean, we followed up and determined the essential amino acids of raw and cooked chicken nuggets with or without legume flour extenders (Table 6). Raw soyabean extended chicken nuggets rated highest in their amino acid scores most especially for isoleucine, leucine, lysine and valine among other legume flour extenders. Thus, the mentioned essential amino acids are high in soyabean flour. This therefore implies that soyabean flour if incorporated in any food/meat system could result in products that can be good alternatives to animal products such as meat, eggs, casein which are required for tissue growth and development (Mahfuz et al. 2020). For cooked chicken nugget, the control had the highest for histidine, leucine, lysine, phenylalanine, tryptophan, valine and methionine/cysteine, this was followed by soyabean and then groundnut while the least was recorded for cowpea extended chicken nugget. Surprisingly, there was a drop in the values of all essential amino acid assayed for in all the extended chicken nugget samples which was not observed in the control samples (chicken nugget without extender). It was also observed that the control samples rated highest in their methionine/cysteine percentages, this however is as a result of meat

Table 6 Essential amino acid profile of raw and cooked broiler chicken nugget extended with legume flours.

Raw				
Amino acid	**Control**	**Soyabean**	**Groundnut**	**Cowpea**
Histidine	4.65 ± 0.00^a	4.65 ± 0.00^a	4.65 ± 0.00^a	4.65 ± 0.00^a
Isoleucine	18.60 ± 1.94^c	24.81 ± 4.27^a	20.16 ± 0.38^b	18.60 ± 1.94^c
Leucine	17.05 ± 1.17^b	21.71 ± 3.49^a	17.05 ± 1.17^b	17.05 ± 1.17^b
Lysine	9.30 ± 0.78^b	12.40 ± 2.32^a	9.30 ± 0.78^b	9.30 ± 0.78^b
Phenylalanine	9.30 ± 0.39^b	12.40 ± 2.71^a	9.30 ± 0.39^b	7.75 ± 1.94^c
Tryptophan	6.20 ± 1.36^c	10.85 ± 3.33^a	7.75 ± 0.19^b	5.43 ± 2.13^d
Valine	6.20 ± 2.33^d	10.85 ± 2.32^a	7.75 ± 0.78^c	9.30 ± 0.71^b
Methionine/Cysteine	22.95 ± 5.33^a	18.29 ± 0.67^b	15.35 ± 2.27^c	13.88 ± 3.74^d
Cooked				
Histidine	8.13 ± 3.55^a	4.07 ± 0.51^b	4.07 ± 0.51^b	2.03 ± 2.55^c
Isoleucine	28.46 ± 2.03^a	28.46 ± 2.03^a	26.42 ± 0.01^b	22.36 ± 4.07^c
Leucine	18.29 ± 2.54^a	14.23 ± 1.52^c	16.26 ± 0.51^b	14.23 ± 1.52^c
Lysine	16.26 ± 6.10^a	10.16 ± 0.00^b	8.13 ± 2.03^c	6.10 ± 4.06^d
Phenylalanine	14.23 ± 4.07^a	10.16 ± 0.00^b	8.13 ± 2.03^c	8.13 ± 2.03^c
Tryptophan	12.20 ± 5.59^a	6.10 ± 0.51^b	4.07 ± 2.54^c	4.07 ± 2.54^c
Valine	12.20 ± 3.56^a	10.16 ± 1.52^b	6.10 ± 2.54^c	6.10 ± 2.54^c
Methionine/Cysteine	30.18 ± 12.55^a	15.45 ± 2.18^b	13.72 ± 3.91^c	11.18 ± 5.83^d

[abcd] Means in the same row with varying superscripts are significantly different ($P < 0.05$)

being considered as a complete protein that contains all essential amino acids in amounts sufficient for live sustainability while lower methionine/cysteine percentages observed in the extended chicken nuggets samples could be attributed to the fact that the legume flour processed into flours for production of these nuggets are incomplete in their amino acid balances as they are known to be deficient in sulphur containing amino acids methionine and cysteine (Kannan et al. 2001).

Shelf stability of chicken nuggets as influenced by different legume flour extenders

The shelf stability of meat product is an important attribute that must be considered by the producers as well as consumers. In this study, the shelf stability was attributed to lipid peroxidation and microbial load. Lipid oxidation is of economic importance in the meat industry because it leads to the development of rancidity and chemical spoilage in food (Yang et al. 2001). The lipid oxidation for raw and cooked chicken nuggets were estimated in terms of TBARS (Table 7). Lipid peroxidation in terms of TBARS values of both raw and cooked extended and non-extended chicken nuggets samples increased steadily throughout the 15 days of storage. For raw, the TBARS in the chicken nuggets increases as the days of storage increases irrespective of the control and the legume flour extenders. The legume flour chicken nuggets depreciated more with high TBARS contents in comparison to the control with low TBARS. Based on interaction between the increase in days of storage and extenders, soyabean extended chicken nuggets had lower values compared to groundnut and cowpea extended chicken nuggets. Similar trend was also observed in the cooked samples as soyabean extended nuggets also had lower TBARS values among the extenders. Though lecithin was not used in this study, however, this could as well be as a result of lecithin a common food additive which is a lipid extracted from soyabeans. This lecithin when present in foods such as cake mixes, beverages, whipped hoppings, salad dressings and others stabilizes them and extends their shelf life. (List 2015). In addition to TBARS content in legume flour extended chicken nuggets, it was observed that the TBARS levels reduced in comparison to raw samples. This could be attributed to effect of the soya oil that was used in deep frying these chicken nuggets. The oil is known to be rich in vitamin E which has an antioxidant property that may have helped suppressed the level of lipid oxidation (Tinello et al. 2020) in all the chicken nuggets samples over the period of storage. Next, in addition to the lipid oxidation, we investigated the total coliforms, bacterial and mould loads in cooked chicken nugget extended with different legume flours so as to ascertain the shelf stability of the cooked chicken nugget extended with different legume flours for at least 15 days (Table 8). The control had higher coliforms especially from day 10 to 15 while lower coliforms were obtained from soyabean and groundnut extended chicken nuggets on similar days. However, no coliforms was recorded for cowpea extended chicken nugget from day 0 to 15. Soyabean extended chicken nugget, followed by cowpea were not really affected by bacteria in comparison to control and groundnut with high level of bacterial load especially on day 10 and 15. Thus, this could be attributed to the antimicrobial properties of soyabean and cowpea legume flour flours (Laodheerasiri & Horana Pathirage 2017) which could have suppressed the level of microbial multiplication in the chicken nugget samples. Interestingly, apart from the control with high mould load, all the legume flour

Table 7 Lipid oxidation of raw and cooked broiler chicken nugget extended with legume flours.

Treatment	TBARS (mgMA/1000 g) Raw	TBARS (mgMA/1000 g) Cooked
Control	0.044 ± 0.009[d]	0.040 ± 0.014 [c]
Soyabean	0.080 ± 0.012[c]	0.040 ± 0.012 [c]
Groundnut	0.088 ± 0.011[b]	0.044 ± 0.012 [b]
Cowpea	0.098 ± 0.009[a]	0.048 ± 0.010 [a]
Time (Days)		
0	0.064 ± 0.020 [d]	0.029 ± 0.005 [d]
5	0.073 ± 0.021[c]	0.036 ± 0.028 [c]
10	0.082 ± 0.020[b]	0.048 ± 0.003 [b]
15	0.091 ± 0.022 [a]	0.059 ± 0.002 [a]
Interaction between Extenders and Storage Days		
Control 0	0.033 ± 0.001[k]	0.023 ± 0.001[i]
5	0.041 ± 0.001[j]	0.033 ± 0.001[g]
10	0.049 ± 0.001[i]	0.048 ± 0.001[d]
15	0.055 ± 0.001[h]	0.058 ± 0.001[ab]
Soyabean 0	0.064 ± 0.002[g]	0.028 ± 0.001[h]
5	0.074 ± 0.002[f]	0.032 ± 0.002[g]
10	0.085 ± 0.002[e]	0.044 ± 0.002[e]
15	0.096 ± 0.002[c]	0.056 ± 0.002[b]
Groundnut 0	0.072 ± 0.002[f]	0.031 ± 0.001[gh]
5	0.085 ± 0.002[e]	0.036 ± 0.002[f]
10	0.092 ± 0.001[d]	0.048 ± 0.002[cd]
15	0.102 ± 0.001[b]	0.060 ± 0.001[a]
Cowpea 0	0.087 ± 0.002 [e]	0.037 ± 0.001 [f]
5	0.092 ± 0.002 [d]	0.042 ± 0.001 [e]
10	0.101 ± 0.001 [b]	0.051 ± 0.002 [c]
15	0.110 ± 0.001 [a]	0.061 ± 0.002 [a]

MA Malonialdehyde

[abcdefghijk] Means in the same row with varying superscripts are significantly different ($P < 0.05$)

Table 8 Microbial loads (cfu/g × 10^3) of chicken nuggets as affected by legume flours and storage days

Treatment	Coliforms	Bacterial load	Mould load
Control	2.563 ± 0.370^a	3.250 ± 4.370^b	1.250 ± 2.430^a
Soyabean	0.250 ± 0.710^c	0.375 ± 0.520^c	0.125 ± 0.380^b
Groundnut	1.125 ± 0. 200^b	6.250 ± 5.610^a	0.125 ± 0.350^b
Cowpea	0.000^c	0.875 ± 1.130^c	0.373 ± 0.740^b
Time (Days)			
0	ND	ND	ND
5	0.125 ± 0.350^a	0.000^b	0.000^b
10	1.125 ± 2.470^b	1.175 ± 1.390^b	0.125 ± 0.350^b
15	3.000 ± 3.420^a	9.000 ± 9.640^a	1.750 ± 2.250^a
Interaction between Plant Protein Extenders and Time (Days)			
Control 0	0.000^b	0.000^c	0.000^b
5	0.500 ± 0.580^b	0.000^c	0.000^b
10	4.500 ± 2.890^a	3.500 ± 0.580^b	0.500 ± 0.580^b
15	5.250 ± 1.710^a	9.500 ± 2.890^a	4.500 ± 2.890^a
Soyabean 0	0.000^b	0.000^b	0.000^b
5	0.000^b	0.000^b	0.000^b
10	0.000^b	0.500 ± 0.580^a	0.000^b
15	1.000 ± 1.150^a	1.000 ± 0.000^a	0.500 ± 0.580^a
Groundnut 0	0.000^b	0.000^c	0.000^b
5	0.000^b	0.000^c	0.000^b
10	0.000^b	2.000 ± 1.150^b	0.000^b
15	4.500 ± 0.580^a	20.00 ± 5.030^a	0.500 ± 0.580^a
Cowpea 0	ND	0.000^c	0.000^b
5	ND	0.000^c	0.000^b
10	ND	1.000 ± 0.000^b	0.000^b
15	ND	2.500 ± 0.580^a	1.500 ± 0.580^a

ND Not Determined

[abc] Means in the same row with varying superscripts are significantly different ($P < 0.05$)

Table 9 Total cholesterol (mg/100 g) of raw and cooked broiler chicken nugget as influenced by legume flours

Treatment	Cholesterol (mg/100 g) Raw	Cholesterol (mg/100 g) Cooked
Control	1.456 ± 0.167^d	1.813 ± 0.141^c
Soyabean	2.344 ± 0.179^c	1.656 ± 0.146^d
Groundnut	2.700 ± 0.175^b	1.975 ± 0.181^b
Cowpea	3.150 ± 0.121^a	2.288 ± 0.150^a
Time (Days)		
0	2.438 ± 0.707^a	1.850 ± 0.261^b
5	2.450 ± 0.645^a	1.956 ± 0.285^a
10	2.381 ± 0.693^a	1.956 ± 0.318^a
15	2.381 ± 0.595^a	1.956 ± 0.263^a
Interaction between Extenders and Storage Days		
Control 0	1.300 ± 0.081^h	1.850 ± 0.261^{de}
5	1.375 ± 0.096^h	1.875 ± 0.096^{de}
10	1.475 ± 0.095^{gh}	1.900 ± 0.141^{cde}
15	1.675 ± 0.096^g	1.625 ± 0.500^{ef}
Soyabean 0	2.550 ± 0.058^d	1.550 ± 0.058^f
5	2.450 ± 0.058^{de}	1.625 ± 0.150^{ef}
10	2.250 ± 0.058^{ef}	1.625 ± 0.150^{ef}
15	2.125 ± 0.050^f	1.825 ± 0.050^{def}
Groundnut 0	2.825 ± 0.050^c	1.775 ± 0.096^{def}
5	2.850 ± 0.058^{bc}	1.950 ± 0.058^{bcd}
10	2.625 ± 0.150^{cd}	1.975 ± 0.096^{bcd}
15	2.500 ± 0.115^d	2.200 ± 0.141^{ab}
Cowpea 0	3.075 ± 0.050^{ab}	2.225 ± 0.096^{ab}
5	3.125 ± 0.150^a	2.425 ± 0.150^a
10	3.175 ± 0.096^a	2.325 ± 0.150^a
15	3.225 ± 0.150^a	2.175 ± 0.150^{abc}

[abcdefgh] Means in the same row with varying superscripts are significantly different ($P < 0.05$)

extended chicken nuggets had low mould load. Also, important to note that the microbial loads (coliforms, bacteria and mould) were more significant ($P < 0.05$) on day 10 and 15 irrespective of the control and the legume flour extenders. In all, the microbial loads obtained across the treatments (with or without extenders) were within the acceptable limits (6.0 $\log_{10}$ cfu/g) as reported by Shapton and Shapton (Shapton & Shapton 1991) which makes these products fit for consumption until the 15th day.

Legume flour extenders reduced total cholesterol content of extended chicken nuggets

The raw and cooked chicken nugget extended with different legume flours were further evaluated for total cholesterol (Table 9). It was observed that for raw chicken nuggets, days of storage did not have significant ($P < 0.05$) effect on the total cholesterol content of the extended legume flours and control. However, there were significant ($P < 0.05$) differences across the legume flour extenders with the lowest cholesterol content recorded for soyabean, followed by groundnut while cowpea extended chicken nugget was the least. Upon cooking and subject to the days of storage, the control (without extenders), followed by soyabean extended chicken nuggets had the lowest total cholesterol contents. On a more similar note, low cholesterol content was also recorded for groundnut extended chicken nugget while that of cowpea extended chicken nugget was on the high side.

Conclusion

Quality raw chicken nugget was developed from soyabean flour used as extender in comparison to that of groundnut and cowpea flours. The soyabean flour did not only enhance product texture, binding ability and firmness of the raw chicken nugget but also increased the yield. Upon cooking, the soyabean and groundnut extended chicken nuggets were outstanding as both improved not only the protein quality, amino acid profile but also reduced cholesterol content, lipid peroxidation and microbial load and this eventually reflected in their quality and consumer acceptability.

Supplementary Information

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Additional file 1.

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Authors' contributions
Opeyemi Adepeju Abiala – conceptualization, acquisition, methodology, interpretation of data, writing, review and editing the original draft; Moses Akindele Abiala – analysis, interpretation of data, review and editing the original draft; Andrew Babatunde Omojola - conceptualization, methodology, interpretation of data, review and editing the original draft. The authors read and approved the final manuscript.

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Approval for ethics was not needed for the present research.

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