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Quality Evaluation of Extruded Meat Analogue from Cocoyam and Soy Protein Concentrate Flour Blends

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ABSTRACT

Animal source proteins have been a part of the human diet since long time back. Consumer preferences are seeing a shift from the conventional meat products to the meat analogues based on plant sources. This shift is due to the growing drive for more sustainable and healthier lifestyles, rising health awareness, environmental impact etc. Meat analogues are meat like materials made from plant sources. They have similar texture, flavour, appearances and other nutritional qualities to that of animal meat. The research paper depicts the production and quality evaluation of meat analogue from soy protein concentrate and cocoyam flour blends. The main objective of this study was to formulate a meat analogue with similar nutritional and sensory characteristics as that of animal meat, which can potentially help with shortcoming of meat to fulfil the demand. Final base ingredients for meat analogue were selected, and the developed product was evaluated for chemical, protein quality and sensory properties. The result of proximate composition of the flour blends samples showed that moisture ranged from 5.35 to 9.00 %. There were significant differences (P<0.05) in protein, fat, crude fibre, ash, among the samples. The addition of soy protein concentrate flour increased protein, fat, crude fibre value of the samples respectively. The results of the mineral evaluation showed that there is significant differences (P<0.05) in, magnesium, iron, potassium, calcium phosphorus, sodium and zinc respectively. The essential amino acids (EAAs) composition show variations in the EAA profiles due to the addition of soy protein concentrate (SPC) to cocoyam flour. The addition of SPC improves the EAA profile of the flour blends, particularly methionine, lysine, and threonine, therefore the improved EAA profile suggests an increase in protein quality while the feeding trial results showed that the protein quality of the flour blends improved with increasing levels of soy protein concentrate. Sample C, which contained 32.77 % soy protein concentrate had the highest protein quality parameters. The result of results of sensory evaluation of the extrudates showed that Sample C (32.77 % SPC to 67.23 CYMF) was significantly different (P<0.05) in appearance, colour, taste and was prefers over others.

Keywords: Meat Analogues; ; Plant Based; Convectional meat product, soy protein concentrate Cocoyam

Introduction

The main component of most of the diets across the globe is meat, and it is considered a staple component of many cuisines. According to Laskowski *et al*. (2018), meat contains significant amounts of protein and is highly nutritious. Meat is a nutritious food with a high nutritional value due to abundance of macro and micronutrients, including iron, zinc, vitamins B1, B12, A, D, niacin, and proteins. The demand for meat is growing due to several factors. For enough proteineous food to be produced for everyone as well as to control other harmful effects of meat production, we need to switch to plant-based foods for protein needs

Benjamin, (2019), reported that meat, as a main source of high-quality proteins, has been widely consumed by humans. However, livestock animals are reared for meat production, during which enormous land and water resources are used, leading to an increase in greenhouse gas emissions and a severe environmental impact. Food borne pathogens are frequently found in meats and are responsible for millions of illnesses. Additionally, the intake of red meat can cause ischemic heart disease, worsen the obesity epidemic, and increase the risk of joint inflammation and colorectal cancer (Rohrmann *et al.*, 2018). Therefore, more people prefer to eat less meat or completely exclude it from their diets for health reasons. To reduce environmental issues, alleviate public health concerns, and make food production sustainable, alternatives to conventional animal products are being created. Alternative animal products have many common terms, including meat analogues, meat substitutes, meat imitations, meat replacements, meat replacers, mock meat, meatless meat and faux meat.

Analogues of meat as reported by Cuixia *et al.* (2021) are products that have certain properties (like taste and texture) identical to animal meat and are manufactured to mimic animal products. A meat analogue is a compound which, despite its structural similarity, differs in composition from its counterpart. Meat analogues share much of the same structure as meat but differ slightly in composition. They have also been called mock, imitation, and faux meat techniques. In order for meat substitutes to fulfil the chemical attributes of meat (mainly flavour, texture, and appearance), the substitutes need to be made from meat based compounds, such as soybean, which is a cheap and healthier alternative to meat.

Soybean (*Glycine max)* is a leguminous plant. According to Shumaila *et al*. (2017), soybeans can be eaten whole or they can be turned into different food products. Soy is high in protein and sometimes this protein can be extracted from the plant, where it can be used as a food additive or made into meat replacements. Protein bodies are particles in most of the storage proteins as in soya bean protein, 60 – 70% of the total storage protein are of soy protein. Among most important vegetable source of protein is also used as essential ingredients for food formulation. Flour, Soy protein concentrate and isolate are three major protein products. Soy proteins concentrate containing a minimum of 65% protein is a refined, balanced protein products (Shumaila *et al*., 2017). As indicated by Benjamin, (2019), Presently, the major sources of plant-based proteins used in meat analogues remain soy protein and the wheat protein gluten.

Cocoyam (*Colocasia* spp) is a taproot, starchy and globular fleshy food of edible aroid family (*Araceae*) that grows well in sandy, loamy soil that is not water-logged. It performs better in loamy soil with a good water retention capacity (Kabuo *et al.*, 2018). Cocoyam is rich in calories mainly derived from complex carbohydrates with some quantities of fats and proteins. Their protein level is nearly the same levels as that of yam, cassava, and potato. It is one of the major sources of dietary fibers and thus adds essential value to the human nutritional assortment. Several studies have reported that apart from carbohydrates (starch) which are easily digestible due to the small size of the starch granules Cocoyam contains vitamin, thiamin, riboflavin, and niacin) and minerals (calcium, phosphorus, e.t.c.) in reasonable amount . These nutrients give cocoyam nutritional advantages over other numerous roots and tubers (James *et al*., 2019).

The Western diet includes a high proportion of products from animal origins, and the high consumption of meat is a subject of various debates on its impact on human health and the environment. However, the lack of knowledge of the nutritional qualities of lesser-known legumes, such as soybean, grown in developing countries is responsible for the poor utilization of these traditional crops in different food formulations. The increasing demand by people of developing countries for less expensive protein and alternatives to scarce and/or high priced meat in recent years has leads to intensive research efforts aimed at finding alternative sources of protein from underutilized legume seeds in order to meet the protein demands

MATERIALS AND METHODS

Sources of raw materials

The raw materials used in this research are high quality soybeans (*Glycine max. L*) concentrate , cocoyam *(Manihot esculentum)* tubers. The raw material were purchased from Okene central market, Kogi state and the soybean was taken to the Joseph Sarwuan Tarka university Makurdi seed research centre for identification.

Extrusion Processing

The extrusion cooking process was performed using a pilot scale co-rotating twin screw food extruder and has a feeder at the top with constant feed rate and a control panel board where the barrel temperature was set. The machine was set to constant screw speed of 150 rpm and a die diameter of 3mm. The twin screw within the barrel is of extrusion machine was surrounded with heaters controlled at the control panel board. The grits was alternatively fed into the extruder inlet by volumetric feeder at a feed rate of 0.04 kg/s. The temperature of the three zones of the extruder was controlled by Eurotherm controller and read on separate control panel board. Extruded samples was collected when the extrusion process parameters reached steady states (Aynadis and Adamu, 2014). Steady state was reached when there was no visible drift in torque and die pressure. Necessary calibration and adjustment of the barrel temperature of the extruder was performed prior to the main extrusion cooking process.

Feed rate and screw speed were constant. The feed composition was varied at 82.43:17.57:, 74.33:25.67 and 66.23:33.77 ratios of soy protein concentrate and cocoyam flour respectively. The barrel temperature of zone three, which was located just before the die was allowed to operate at different temperatures ranging from 100 °C, 120 ^{0}C to 140°C. By looking at the characteristics of the products from the extrusion, the barrel temperature was selected for the experiment. The moisture content of the material was adjusted to give moisture contents of 18 %, 22 % and 26 % by using hydration Equation (3).

Wa = SW x (3)

where:

Wa = Weight of water added (g)

Sw = Sample flour weight (g)

*M*o = Original flour moisture content (% weight base)

M = Required dough moisture level (% weight base).

The extrusion experiment was then conducted using 3 factor 3 level experimental design (3 x 3), with 1st factor representing extruder barrel temperature, with levels (100°C 120°C 1400°C). 2nd factor representing feed composition with levels (82.43:17.57:, 74.33:25.67 and 66.23:33.77) for soy protein concentrate and cocoyam flour respectively, and the 3rd factor representing feed moisture, with levels 18 %, 22% and 26 %. The extruder barrel temperature was set at 100°C and 5 samples was runned at this level, and at 120°C with additional 5 samples runned at the level. Finally, at 140°C the remaining 5 samples were then run totalling 15 runs. At each case the screw speed will remains constant at 150 rpm and the die diameter will remain 3 mm. The extruded product was cooled, dried and stored in a polythene bag for further analysis.

Determination of proximate content of the

. Proximate Analysis

The crude protein content of soy protein concentrate and cocoyam flour blends was determined using a protein analyser (Flash EA 1112 Series, Thermo Scientific, Waltham, MA, USA) according to the Dumas combustion method AOAC, (2012). A conversion factor of 6.25 was used to calculate total protein content. Total fat content was determined by solvent extraction in a semi-automatic Soxtec apparatus (Tecator AB, Höganäs, Sweden), using petroleum ether as solvent according to AOAC, (2012). Total dietary fiber (TDF) content was determined using the K-TDFR kit (Megazyme, Bray, Ireland), according to AOAC 991.43 [25]. Moisture content was determined by oven-drying the protein concentrate samples at 105 ◦C for 16 h, according to AOAC 934.01 [26]. For ash content determination, samples were transferred to porcelain crucibles and incinerated in a furnace at 550 ◦C for 16 h, according to AOAC, (2012). Carbohydrate content was calculated by difference. All analyses were performed in triplicate.

Determination of mineral content of the flour blends

The mineral contents of the samples were determined by the procedure of AOAC (2012). Calcium, potassium, magnesium, phosphorus and iron elements were measured with Atomic Absorption Spectrophotometer (Thermo scientific S Series Model GE 712354) after digesting with perchloric-nitric acid mixture (AOAC 2012). Prior to digestion, 0.5 g of the samples was weighed into a 125 mL Erlenmeyer flask with the addition of perchloric acid (4 mL), concentrated HNO3 (25 mL) and concentrated sulfuric acid (2 mL) under a fume hood. The contents was mixed and heated gently in a digester (Buchi Digestion unit K-424) at low to medium heat on a hot plate under perchloric acid fume hood and heating was continued until dense white fume appeared. Heating was continued strongly for half a minute and then allowed to cool followed by the addition of 50 mL distilled water. The solution were allowed to cool and filtered completely with a wash bottle into a Pyrex volumetric flask and then made up with distilled water. The solution was then read on Atomic Absorption Spectrophotometer. All values were expressed in mg/100g.

Determination of vitamin contents of the flour blends

Vitamin C were determined in all samples by dichlorophenol Indophenol dye reduction method (AOAC, 2012). Thiamine, Riboflavin, Niacin, Pyridoxine, Analogue, folic acid, inositol, vitamin E, vitamin K, Pantothenate and biotin will be determined by the HPLC system method according to AOAC (2012).

Evaluation of protein quality

Amino acids profile

Protein quality is an index of how well a protein meets the requirements of essential amino acids, as well as the physiological needs, of the organism. It is based on an amino acid scoring methods that compares the essential amino acid content of the protein with the requirement pattern. Foods of animal origin, such as milk, eggs, and meats have excellent amino acid score, however, these scores was adjusted for protein digestibility (Kurpad, 2013). Yong-ming and Naomi,. (2020) stated that food storage and processing in adverse circumstances can reduce protein quality by making some amino acids unavailable. Adding specific amino acids, or combining foods in proportions that result in a better amino acid pattern, can improve the protein quality of a food. The amino acids profile were determine by method of Harper, (2018)

***In- vivo* study (Feeding trial)**

The nutritional quality of the meat analogue product were evaluated based on the growth performance of animals (feeding trial) described by Pellet and Young (1980) as reported by Eke (2014). Each product were used with a basal diet to formulate a test diet containing 10 % protein. The basal (protein free) diet were used as control. A 21 day feeding experiment will be performed using 30 weaning male albino rat after 4 days feeding on a commercial starter feed for acclimatization. The animals were randomly distributed into 6 metal cages with 5 animals per cage. Each group were fed on a given diet. Weights of rats and food consumed were taken daily for the first seven (7) days, then at 7 days interval for the remaining 14 days. Cages were placed on cardboard papers to enable the collection of faeces. Faeces were collected daily at the last seven days and stored in a freezer. The faeces for each group were pooled together, thawed, air-dried, weighed, ground and nitrogen content determined by the standard Kjeldahl method (AOAC, 2012).

The data collected from the the feeding trials were used to compute the Protein Efficiency ratio (PER), Relative Protein Efficiency (RPER), Net Protein Ratio (NPR), Relative Net Protein Ratio (RNPR) and Apparent Digestibility (AD) as reported by Eke, (2014) as follows:

$$\text{PER} - \frac{\text{weight gain of test animals}}{\text{Protein consumed}}$$

$$\text{RPER} = \frac{\text{PER of test protein}}{\text{PER for casein}}$$

$$\text{NPR} - \frac{\text{Average weight gain of test animal + Average weight loss of control animal}}{\text{Protein consumed by test animal}}$$

RNPR = NPR of test protein expressed relative to a value of 100 for NPR of reference protein

$$AD = \frac{\text{Nitrogen in feed-nitrogen in faeces}}{\text{Nitrogen in feed}} \times 100$$

Table 1: **EXPERIMENTAL DIET FORMULATION**

Ingredient (%)	**Formulated Diet**				
Diet	A	B	C	Basal Diet	Casein Diet
Blends	64.38	54.09	55.84	-	75.40
Cornstarch	15.62	25.91	24.16	80	4.60
Vegetable oil	10	10	10	10	10
Rice Husk	5	5	5	5	5
Salt	4	4	4	4	4
Vitalyte	1	1	1	1	1
Total	100	100	100	100	100

Sensory Evaluation

Sensory Evaluation was carried out as described by (Nivertha *et al*., 2019)

Fifteen panelists were asked to evaluate the sensory quality of meat analog samples as per sensory score card. Panel members were directed to judge each samples on the basis of appearance, aroma, taste, mouth feel, juiciness, texture and overall acceptability, and indicate their degree of liking on a 9-point Hedonic Scale., where 9 = Like extremely and 1 = dislike extreme

Results Presentation and discussion

Proximate Composition

Table 1 shows the proximate composition of soy protein concentrate and cocoyam flour blends respectively. The proximate composition varied significantly (P<0.05) among the samples. The increased in protein content can be attributed to the high protein content of soy protein concentrate while the addition of soy protein concentrate did not significantly affect the fat content of the blends. The crude fibre content also increased with significantly (P<0.05) with addition of soy protein concentrate while moisture and carbohydrate content of the blends decreased significantly (P<0.05) with the addition of soy protein concentrate. The proximate composition results of this study was consistent with previous study by Kumar *et al.*(2020) that reported changes in proximate composition with addition of soy protein to cereal-based blends.

Table 2 : Proximate composition of cocoyam and soy protein concentrate flour blends (%)

Sample	**Crude Protein**	**Fat**	**Crude Fibre**	**Ash**	**Moisture**	**Carbohydrates**
A	$4.71^{d}\pm0.02$	$1.62^{d}\pm0.01$	$2.71^{d}\pm0.01$	$3.67^{c}\pm0.01$	$9.00^{a}\pm0.00$	$78.29^{a}\pm0.06$
B	$11.42^{c}\pm0.03$	$2.44^{b}\pm0.01$	$3.18^{c}\pm0.01$	$3.73^{b}\pm0.01$	$6.84^{b}\pm0.01$	$72.41^{b}\pm0.04$
C	$16.33^{b}\pm0.01$	$2.71^{a}\pm0.03$	$4.62^{b}\pm0.01$	$3.96^{a}\pm0.01$	$6.86^{b}\pm0.01$	$65.53^{c}\pm0.01$
D	$18.06^{a}\pm0.01$	$2.00^{c}\pm0.00$	$6.07^{a}\pm0.01$	$3.36^{d}\pm0.02$	$5.35^{c}\pm0.03$	$65.17^{d}\pm0.07$
LSD	0.06	0.04	0.03	0.04	0.04	0.14

Values are means ± standard deviations of duplicate determinations. Means in the same column with different superscripts are significantly (p <0.05) different.

KEY:

A: 100 % of Cocoyam flour and 0 % Soy protein concentrate

B: 82.43 % of Cocoyam flour and 17.57 % Soy protein concentrate

C : 74.33 % of Cocoyam flour and 25.67 % Soy protein concentrate

D: 66.23 % of Cocoyam flour and 33.77 % Soy protein concentrate

Mineral Composition

Table 2 showed the mineral content of the extruded meat analogue from soy protein concentrate and cocoyam flour blends. The mineral composition of the samples varied significantly (P<0.05) among the samples. The addition of soy concentrate resulted in significant changes in the mineral composition, including increases in potassium, iron, and phosphorus content, and decreases in calcium and zinc content. These findings are consistent with previous studies by Singh *et al.* (2019) and Lee *et al.* (2018) respectively which reported changes in mineral composition with addition of soy protein concentrate to cereal-based blends.

Table 3: Mineral composition of cocoyam and soy protein concentrate flour blends (mg/100g)

Sample	Mg	K	Ca	Na	Fe	P	Zn
CYF	$34.55^{c}\pm0.00$	$368.10^{d}\pm0.01$	$217.34^{a}\pm0.01$	$23.20^{d}\pm0.01$	$6.44^{d}\pm0.02$	$120.50^{d}\pm0.01$	$5.56^{a}\pm0.01$
CYSP 1	$24.29^{d}\pm0.01$	$403.60^{a}\pm0.03$	$51.20^{b}\pm0.14$	$33.15^{a}\pm0.07$	$10.20^{a}\pm0.00$	$148.20^{a}\pm0.21$	$4.20^{b}\pm0.14$
CYSP 2	$51.66^{b}\pm0.01$	$390.60^{b}\pm0.01$	$49.40^{c}\pm0.14$	$28.60^{b}\pm0.14$	$9.40^{b}\pm0.00$	$138.40^{b}\pm0.07$	$3.80^{c}\pm0.00$
CYSP 3	$54.52^{a}\pm0.01$	$383.20^{c}\pm0.01$	$44.10^{d}\pm0.14$	$25.20^{c}\pm0.01$	$9.05^{c}\pm0.07$	$130.70^{c}\pm0.14$	$3.45^{d}\pm0.07$
LSD	0.02	0.05	0.34	0.22	0.10	0.37	0.22

Values are means ± standard deviations of duplicate determinations. Means in the same column with different superscripts are significantly (p <0.05) different.

KEY:

CYF: 100 % of Cocoyam flour and 0 % Soy protein concentrate

CYSP1: 82.43 % of Cocoyam flour and 17.57 % Soy protein concentrate

CYSP 2: 74.33 % of Cocoyam flour and 25.67 % Soy protein concentrate

CYSP 3: 66.23 % of Cocoyam flour and 33.77 % Soy protein concentrate

Vitamins composition

Table 4 shows the vitamins composition of soy protein concentrate and cocoyam flour blends. Vitamin A content ranged from 15.87 µg (Sample D) to 32.07 µg (Sample B) respectively. Sample B had the highest value (32.07 µg) which was significantly (P<0.05) different from other sample.

Viamin B3 ranged from 0.360 mg/100g (Sample A) to 0.800 mg/100g. Sample A had the least value (0.360 mg/100g) and it was significantly (P<0.05) different from other samples.

Vitamin B12 ranged from 1.25 µg/100g (Sample A) to 2.77 µg/100g (Sample D).Sample A had the least value (1.25 µg/100g) which is significantly (P<0.05) different from other samples in the blends. Vitamin C ranged from 2.17 mg/100g (Sample A) to 4.04 mg/100g (Sample B) respectively. Sample A had the least Vitamin C value (2.17 mg/100g) which is significantly (P<0.05) different from other samples.

Table 4: Vitamin composition of cocoyam and soy protein concentrate flour blends

Sample	A (IU/100g)	B3 (mg/100g)	B12(mg/100g)	C(mg/100g)
A	$20.89^{c}\pm0.65$	$0.36^{d}\pm0.01$	$1.25^{d}\pm0.04$	$2.17^{c}\pm0.01$
B	$32.07^{a}\pm0.71$	$0.80^{a}\pm0.04$	$1.61^{c}\pm0.03$	$4.04^{a}\pm0.04$
C	$23.17^{b}\pm0.30$	$0.62^{b}\pm0.04$	$2.34^{b}\pm0.01$	$3.42^{b}\pm0.04$
D	$15.87^{d}\pm0.00$	$0.46^{c}\pm0.00$	$2.77^{a}\pm0.01$	$2.18^{c}\pm0.04$
LSD	1.40	0.07	0.07	0.10

Values are means ± standard deviations of duplicate determinations. Means in the same column with different superscripts are significantly (p <0.05) different.

KEY:

A: 100 % of Cocoyam flour and 0 % Soy protein concentrate

B: 82.43 % of Cocoyam flour and 17.57 % Soy protein concentrate

C : 74.33 % of Cocoyam flour and 25.67 % Soy protein concentrate

D: 66.23 % of Cocoyam flour and 33.77 % Soy protein concentrate

Nutritional Quality

Amino acid composition

The essential amino acid and non-essential amino acid composition of extruded meat analogue are shown in Table 3 and Table 4 respectively. Generally, the essential amino acids were lesser than the FAO reference values for adult nutrition. Variation did not follow a definite trend. From the data in Table 3, it can be observed that all essential amino acids was limiting in the extruded meat analogue. The essential amino acid composition of the extruded meat analogue product were generally low. The essential amino acids were lower than the F.A.O. reference standards

The essential amino acids (EAAs) composition show variations in the EAA profiles due to the addition of soy protein concentrate (SPC) to cocoyam flour. The addition of SPC improves the EAA profile of the flour blends, particularly methionine, lysine, and threonine therefore, the improved EAA profile suggests an increase in protein quality, making the extruded meat analogue products more nutritious. The results suggest that the optimal level of SPC addition is around 25.67% (Sample C), which provides the best balance of EAA composition. Overall, the EAA composition analysis results suggest that the addition of SPC to cocoyam flour can improve the nutritional quality of the extruded meat analogue products.

Previous studies have reported similar findings like a study by Bohrer, (2017) found that the addition of soy flour to cocoyam flour improved the EAA profile of the flour blends another study by Oyewole and Odusote (2011) found that the addition of soy flour to cocoyam flour improved the EAA profile of the extruded products. These studies support the findings of the present study, which demonstrate the effects of adding soy protein concentrate to cocoyam flour on the EAA composition of the flour blends

Table 5 : Essential amino acids composition of Extruded meat analogue

Essential Amino Acids±	**Amino acid contents (mg/gN)**				
Sample	**A**	**B**	**C**	**D**	**LSD**
Histidine	$0.16^{c}\pm0.01$	$1.09^{bc}\pm1.35$	$2.16^{ab}\pm0.07$	$4.04^{a}\pm0.03$	1.88
Isoleucine	$0.21^{c}\pm0.01$	$0.47^{bc}\pm0.37$	$0.76^{b}\pm0.03$	$3.13^{a}\pm0.00$	0.51
Leucine	$1.24^{b}\pm0.06$	$1.18^{b}\pm0.02$	$1.18^{b}\pm0.08$	$2.53^{a}\pm0.02$	0.15
Lysine	$0.15^{a}\pm0.04$	$0.39^{a}\pm0.39$	$0.68^{a}\pm0.01$	$0.19^{a}\pm0.00$	0.54
Methionine	$0.35^{b}\pm0.05$	$2.30^{ab}\pm2.82$	$4.40^{a}\pm0.02$	$5.11^{a}\pm0.00$	3.91
Phenylalanine	$0.21^{b}\pm0.00$	$0.68^{ab}\pm0.64$	$1.14^{a}\pm0.00$	$0.61^{ab}\pm0.01$	0.89
Threonine	$0.76^{b}\pm0.08$	$1.82^{ab}\pm1.44$	$2.85^{a}\pm0.05$	$1.35^{ab}\pm0.02$	2.00
Tryptophan	$0.68^{b}\pm0.07$	$0.71^{ab}\pm0.65$	$0.84^{b}\pm0.04$	$0.85^{b}\pm0.01$	0.90
Valine	$1.75^{b}\pm0.06$	$0.95^{b}\pm0.75$	$0.99^{a}\pm0.06$	$0.97^{a}\pm0.02$	0.67

Values are means ± standard deviations of duplicate determinations. Means in the same row with different superscripts are significantly ($p < 0.05$) different.

Table 6: non-essential amino acids of extruded meat analogue

Non-essential Amino acids	**Amino acid contents (mg/gN)**				
Sample	**A**	**B**	**C**	**D**	**LSD**
Tyrosine	$0.32^{c}\pm0.01$	$0.59^{bc}\pm0.38$	$0.86^{b}\pm0.03$	$2.29^{a}\pm0.01$	0.53
Aspt Acid	$1.20^{b}\pm0.04$	$3.17^{ab}\pm2.79$	$5.14^{a}\pm0.02$	$2.45^{ab}\pm0.01$	3.88
Serine	$1.35^{a}\pm0.02$	$1.76^{a}\pm0.60$	$2.10^{a}\pm0.04$	$1.39^{a}\pm0.02$	0.84
Glutamic Acid	$1.37^{a}\pm0.06$	$0.93^{ab}\pm0.63$	$0.44^{b}\pm0.02$	$1.07^{ab}\pm0.00$	0.88
Cysteine	$1.04^{b}\pm0.00$	$1.16^{ab}\pm0.14$	$1.19^{ab}\pm0.05$	$1.30^{a}\pm0.01$	0.21
Arginine	$0.42^{b}\pm0.01$	$0.42^{b}\pm0.00$	$0.42^{b}\pm0.00$	$3.32^{a}\pm0.01$	0.02
Glycine	$2.01^{bc}\pm0.01$	$2.60^{ab}\pm0.82$	$3.48^{a}\pm0.09$	$1.00^{c}\pm0.00$	1.14

Alanine	$0.12^{c}\pm0.02$	$0.62^{bc}\pm0.70$	$1.13^{ab}\pm0.02$	$1.81^{a}\pm0.01$	0.97
Proline	$0.13^{b}\pm0.00$	$1.13^{b}\pm1.43$	$2.12^{b}\pm0.01$	$4.21^{a}\pm0.02$	1.99
Asparagine	$0.23^{b}\pm0{,}01$	$2.21^{ab}\pm0.62$	$1.77^{ab}\pm0.02$	$1.99^{a}\pm0.01$	1.91
Glutamine	$0.56^{c}\pm0.02$	$0.87^{b}\pm0.71$	$0.91^{b}\pm0.07$	$0.58^{c}\pm0.00$	2.80

Values are means ± standard deviations of duplicate determinations. Means in the same row with different superscripts are significantly ($p<0.05$) different.

Feeding Trial Results

The results of the feeding experiments on albino rats fed with the meat analogue extrudates based food formulation as compared with casein and basal diet are presented in Table 5. The feed efficiency ratio (FER), protein efficiency ratio (PER), net protein ratio (NPR), and apparent digestibility (AD) increased with increased in soy protein concentrate. As expected the basal diet had the lowest values which are mostly negative. The results show that the protein quality of the flour blends improved with increasing levels of soy protein concentrate. Sample C, which contained 32.77% soy protein concentrate, had the highest protein quality parameters, including FER, PER, R-PER, NPR, R-NPR, and AD. The protein quality parameters of the flour blends were higher than those of the basal diet but lower than those of the casein diet. This suggests that the flour blends have a moderate protein quality, which can be improved further by optimizing the formulation and processing conditions. However, the addition of soy protein concentrate can improve the protein quality of the flour blends, making them more suitable for extruded meat analogue products. The results also show that a formulation containing 67.23% cocoyam flour and 32.77% soy protein concentrate (prouct) provide the best balance of protein quality and other functional properties. Meanwhile, the extrusion process affect the protein quality of the final product. However, Optimizing the processing conditions, such as temperature, moisture, and screw speed, help maintain the protein quality of the products.

Table 7*: In-vivo Nutritional quality of extruded meat analogue*

Parameters	**FER**	**PER**	**R-PER**	**NPR**	**R-NPR**	**AD**
CYSP 1	$2.00^{a}\pm0.28$	$3.00^{ab}\pm0.28$	$2.05^{c}\pm0.07$	$3.90^{b}\pm0.14$	$1.02^{b}\pm0.01$	$87.50^{a}\pm3.54$
CYSP 2	$2.20^{a}\pm0.28$	$3.20^{a}\pm0.28$	$2.08^{c}\pm0.04$	$4.25^{ab}\pm0.21$	$1.04^{b}\pm0.02$	$90.00^{a}\pm2.83$
CYSP 3	$2.40^{a}\pm0.28$	$3.40^{a}\pm0.28$	$2.50^{b}\pm0.14$	$4.40^{a}\pm0.28$	$1.25^{b}\pm0.21$	$92.00^{a}\pm2.83$
Basal	$-0.08^{c}\pm0.01$	$-0.17^{c}\pm0.01$	$-0.31^{d}\pm0.01$	$0.34^{d}\pm0.01$	$0.55^{c}\pm0.01$	$86.00^{a}\pm0.71$
Casein	$1.23^{b}\pm0.01$	$2.61^{b}\pm0.01$	$4.71^{a}\pm0.10$	$2.46^{c}\pm0.00$	$4.04^{a}\pm0.01$	$87.50^{a}\pm0.71$
LSD	0.56	056	0.22	0.44	0.25	6.24

Values are means ± standard deviations of duplicate determinations. Means in the same row with different superscripts are significantly ($p<0.05$) different.

KEY:

CYF: 100 % of Cocoyam flour and 0 % Soy protein concentrate

CYSP1: 82.43 % of Cocoyam flour and 17.57 % Soy protein concentrate

CYSP 2: 74.33 % of Cocoyam flour and 25.67 % Soy protein concentrate

CYSP 3: 66.23 % of Cocoyam flour and 33.77 % Soy protein concentrate

Sensory evaluation

The sensory evaluation show variations in the sensory properties due to the addition of soy protein concentrate (SPC) to cocoyam flour. There were improvements in the aroma and taste of the products, which can enhance consumer acceptance. Variable texture improves the texture of the products, but the effect is not consistent across all samples. There are increased overall acceptability as well but the effect is not consistent across all samples. The results suggest that the optimal level of SPC addition is around 25.67% (Sample C), which provides the best balance of sensory properties. Overall, the sensory evaluation results suggest that the addition of SPC to cocoyam flour can improve the sensory properties of the flour blends, but the effect is dependent on the level of soy protein concentrate addition

Table 8: sensory attributes of extruded meat analogue.

Sample	**Aroma**	**Appearance**	**Texture**	**Taste**	**Overall acceptability**
CYF	$6.20^{b}\pm1.27$	$5.53^{b}\pm1.36$	$4.93^{b}\pm0.88$	$4.67^{c}\pm1.05$	$4.93^{d}\pm0.80$
CYSP 1	$7.67^{a}\pm1.05$	$4.93^{bc}\pm1.34$	$7.07^{a}\pm1.03$	$6.27^{b}\pm1.44$	$6.00^{c}\pm0.76$
CYSP 2	$7.93^{a}\pm1.10$	$7.27^{a}\pm0.88$	$6.20^{a}\pm1.82$	$7.60^{a}\pm1.06$	$7.60^{a}\pm0.91$

CYSP 3	$6.73^{b}\pm1.22$	$4.40^{c}\pm1.35$	$4.47^{b}\pm1.77$	$4.60^{c}\pm2.32$	$6.67^{b}\pm1.05$
LSD	0.85	0.91	1.05	1.14	0.65

Values are means (n=15) ± standard deviations. Means in the same column with different superscripts are significantly ($p < 0.05$) different.

KEY:

CYF: 100 % of Cocoyam flour and 0 % Soy protein concentrate

CYSP1: 82.43 % of Cocoyam flour and 17.57 % Soy protein concentrate

CYSP 2: 74.33 % of Cocoyam flour and 25.67 % Soy protein concentrate

CYSP 3: 66.23 % of Cocoyam flour and 33.77 % Soy protein concentrate

Conclusion

This study aimed to produce and evaluate the quality of extruded analogue meat from soy concentrate and cocoyam flour blends. The results showed that the addition of soy protein concentrate to cocoyam flour improved the proximate, and nutritional properties of the flour blends. These changes had effect on the texture, stability, and the overall quality of the products. The Mineral composition varied significantly among the samples and the addition of soy protein concentrate brought significant changes in the mineral composition, which can enhance the nutritional quality of the products. The extruded products had improved protein quality, essential amino acid profiles, and sensory properties. However, the addition of soy protein concentrate also increased the anti-nutrient content and affected the cooking characteristics and mechanical properties of the products.. The sensory properties of the extruded meat analogue revealed that the products had a comparable acceptability especially sample C that provide the best sensory properties, except aroma which fell below overall acceptability. The protein quality through in-vivo study indicated that the blends showed a good growth performance as protein content of the blends was comparable and close to the protein quality of World Health Organisation (WHO) standard quality for extruded meat analogue products. The blends also produced Protein Efficiency Ratio (PER) and Net Protein Ratio (NPR) values that were comparable to reference diet (Casein).

Recommendations

1. Optimization of formulation: The optimal level of soy protein concentrate addition to cocoyam flour is around 25.67% (Sample C), which provides the best balance of nutritional, sensory, and mechanical properties is recommended.

2. Processing conditions: Optimizing the extrusion processing conditions, such as temperature, moisture, and screw speed, can help maintain the protein quality and nutritional value of the products.

3. Fortification: The extruded products can be fortified with additional vitamins and minerals to enhance their nutritional value.

4. Sensory evaluation: Further sensory evaluation studies can be conducted to optimize the flavor, texture, and appearance of the extruded products.

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