JHER Vol. 31, No. 2, December 2024, pp. 78 – 87

Effect of Textured Vegetable Protein Blends from African Yam Bean (*Sphenostylis stenocarpa*) and Soybean (*Glycine max*) on Nutrient Composition of Beef Patties and Sensory Attributes of Hamburgers

Amadi, Gift A.; China, Mercy A.H.
Department of Home Science and Management,
Rivers State University, Nkpolu-Oroworukwo
Corresponding Author: *giftoprince62@yahoo.com*

Abstract

Effect of textured vegetable protein blends from African yam bean (AYB), soybean (SYB) on the nutrient composition of beef patties and sensory attributes of hamburgers was studied. Patties were produced using beef and textured vegetable protein (curd) from AYB and SYB blends with AYB and SYB and various substitution levels. Proximate and mineral compositions of the patties were determined using standard methods. Data were analysed using means and analysis of variance (ANOVA). Hamburgers were also prepared using the formulated patties and evaluated for their sensory attributes. Proximate analysis of the samples ranged from 21.20-29.80% for moisture, ash (2.61-5.50%), fat (6.08-13.50%), crude protein (23.60-36.80%), crude fibre (0.04-8.33%) and carbohydrate (19.80-25.11%). Supplementation with AYB and SYB curds resulted in a significant ($p<0.05$) increase in the moisture, ash, crude fibre with a decrease in crude protein. Similarly, phosphorus (20.23-100.21 mg/100g), calcium (7.01-16.41 mg/100g) and magnesium (63.70-121.09 mg/100g) content increased significantly ($p<0.05$) as the supplementation with AYB and SYB curds increased. Sensory analysis showed that the control hamburger was generally acceptable.

Keywords: Hamburger, Textured Vegetable Protein, Beef Patties, African Yam Bean, Soybean

Introduction

Hamburger is a popular food items. It normally consists of a cooked patty of ground meat, usually beef, served on a bun or bread roll with different kinds of toppings and condiments. A conventional hamburger generally comprises 70-80 percent beef and 20-30 percent fat (Wordu & Eke-Ejiofor, 2020). This meat product traditionally holds a salt content of approximately 2.2 – 2.4 percent. Additional components beyond beef and fat might be incorporated to enhance the nutritional value and sensory attributes of hamburgers (Adebowale *et al* 2011). The growing demand among consumers for healthier beef sausages has compelled hamburger producers to continuously innovate, creating new and higher-quality products while keeping costs low. This involves minimizing fat content and incorporating health-enhancing ingredients that offer improved functional characteristics, tastiness, and nutritional value. Plant-based proteins are becoming increasingly popular in the production of hamburgers, primarily due to their elevated protein content. These plant proteins are sometimes referred to as meat extenders or substitutes because they effectively rival beef in terms of flavour and texture (Amadi, 2020). They are commonly used as binders in meat products to enhance emulsion stability and serve as a cost-effective alternative to meat (Omwamba *et al* 2014).

Textured plant-based proteins are 'edible plant protein food items. They are distinguished by their structural integrity and recognizable consistency, ensuring that each element withstands hydration during cooking and other food preparation processes (China *et al* 2021). The creation of textured plant-based proteins, particularly from legumes, has been documented by Omohimi *et al* (2013) as a promising solution to address protein malnutrition issues. They serve as excellent substitutes for animal protein in food products. They are also often referred to as meat analogs because they compete effectively with beef in terms of both flavor and chewiness. The production process involves transforming a flour-like substance into one with a meat-like texture (Adedokun *et al* 2017). The resulting protein is known as textured plant-based protein, which contributes to chewiness and fibrous qualities. Soybean flour is the typical primary ingredient utilized for the production of textured plant-based proteins. Nevertheless, the utilization of soybean may be constrained in rural areas due to its scarcity or high cost (China *et al* 2021), necessitating the exploration of other legumes like African yam bean as a substitute for soybean.

African yam bean, scientifically known as *Sphenostylis stenocarpa*, is a tropical climbing legume typically found in lowland regions (Raji *et al* 2014). This legume is considered a minor and underutilized crop but holds significant importance in Western Africa, particularly in Nigeria's Southern, Eastern, and Western regions, where it is a staple food. The seeds of African yam bean boast a high protein content ranging from 21 to 29 percent, accompanied by a carbohydrate content of approximately 50% (Okoye and Onyekwelu, 2018). According to Raji *et al* (2014), the lysine and methionine content of African yam bean seeds is on par with, if not superior to, that of soybeans. However, its widespread utilization has been hindered by the presence of anti-nutritional elements such as phytic acid, oxalate, trypsin inhibitor and tannin, to mention but a few. These compounds can be reduced or eliminated through various processing methods like boiling, soaking, fermentation, and germination. African yam bean tubers and seeds are often prepared and consumed either independently or in combination with vegetables or other dishes (Nwosu *et al* 2014). They are used to create sauces, wrapped in plantain leaves and boiled to make dishes like *okpa*, a delicacy made from bambara nut. Milk can be extracted from its seeds, and the flour derived from its tubers can be used to make moi-moi (Akinyele & Oloruntoba, 2013).

Recently, there is a growing interest in using local, underutilized seeds as alternatives to traditional ones. This approach, particularly in industrialized nations, aims to tap into local resources to meet a growing population's needs. Numerous studies have explored sausage production with various meat extenders like cowpea flour, full-fat soy flour, mung bean powder, and texturized soy protein (Kenawi *et al* 2009; Teye *et al* 2012; Omwamba *et al* 2014; Amadi, 2020). African yam bean, similar to soybean, is a protein-rich seed with untapped potential in sausage production. High meat product costs limit accessibility, and there is a rising demand to reduce costs by using meat extenders without compromising nutrition. Soybean is common due to its cost-effective, high-quality protein, but alternatives like underutilized legumes need exploration. African yam bean is one such option. Efforts are underway to use it as an extender in hamburgers, making this popular food more budget-friendly for all.

Objective of the Study

The study investigated effect of textured vegetable protein (curd) blends from African yam bean (AYB) and soybean (SYB) on the proximate composition, mineral content and sensory attributes of hamburgers.

Specifically, the study determined:

1. proximate composition of the beef patties;
2. mineral composition of the beef patties;
3. sensory properties of beef patties supplemented with AYB and SYB curds

Materials and Methods

Design of the Study: A quasi-experimental design was employed in the study.

Procurement of Materials: African yam bean seed was obtained from Ogbete market in Enugu State, Nigeria. While soybean, hamburgers and other vegetables were purchased from Mile one market and Wilson Bakery at Rivers State University, Port Harcourt. Chemicals and reagents were obtained from the Department of Food Science and Technology Laboratory, Rivers State University, Port Harcourt.

Preparation of Soybean and African Yam Bean Curds: African yam bean and soybean curds were prepared using the method of China *et al* (2021). African yam bean and soybean seeds were sorted, washed and soaked overnight. Thereafter, it was dehulled and wet milled using a milling machine and sieved using chiffon cloth to obtain milk that was used for preparation of curd. 1000 ml of soybean milk was mixed with 1000 ml of African yam bean milk and boiled for 1 hr followed by the addition of 50 ml of lemon juice as coagulant. The coagulant formed was drained using a cheese cloth and it was sliced into square shaped, and thereafter transferred to salted water to eliminate the lemon.

Formulation of Recipe for Hamburger Preparation

Ingredients	Samples				
	A	B	C	D	E
Minced meat (g)	500	-	150	200	250
AYB and SYB curd (g)	-	500	350	300	250
Burger bread (pcs)	2	2	2	2	2
Sliced Lettuce (g)	50	50	50	50	50
Sliced Cucumber (g)	20	20	20	20	20
Mayonnaise (g)	50	50	50	50	50
Egg (pcs)	5	5	5	5	5
Vegetable oil (ml)	20	20	20	20	20
Salt (g)	1	1	1	1	1
Bouillon cube (tbsp)	¼	¼	¼	¼	¼
Dried Pepper (tbsp)	½	½	½	½	½
Onion (g)	50	50	50	50	50

Preparation of Hamburger

- **AYB, SYB, Meat Preparation:** Minced or ground AYB, SYB and meat are mixed, then seasoned with salt, pepper, bouillon cubes and eggs.
- **Patty Formation:** Seasoned minced/ground AYB-SYB-meat mix is shaped into round patties.
- **Cooking:** Patties are fried in vegetable oil on medium – to low heat until golden brown, usually 4-5 minutes per side.
- **Assembling the Burger:** Slather mayonnaise on burger bread. Place cooked patties on the burger bread. Top with sliced lettuce, cucumber and onions.

A total of 26 patties were produced. Six patties were used for proximate and mineral analysis, while 20 were used for preparation of hamburgers which were subjected to evaluation.

***Proximate Analysis*:** The moisture, crude protein, crude fibre, crude fat and total ash contents of samples were analysed using the method described by Association of Official Analytical Chemists (AOAC, 2019). Moisture content determined was obtained gravimetrically after drying to a constant weight at 70^{o}C in a hot air oven (DHG 9140A). Fat was determined using soxhlet extraction method with ethyl ether. Kjeldahl method and a nitrogen conversion factor of 6.25 were used for crude protein determination. Ash content was determined gravimetrically after the incineration of the samples in a muffle Furnace (Model SXL) at 550^{o}C for 2 h. Enzymatic gravimetric method was utilized in the determination of crude fibre. Carbohydrate was calculated by difference {100 - (Crude protein + crude fibre + ash + fat)}.

***Mineral Analysis*:** As described by Gbadamosi *et al* (2021), 1 g of each sample was digested with 10% HNO_3 after ashing. The sample was filtered after digestion and the filtrate was made up to 100 mL of distilled deionized water. Atomic Absorption Spectrometer (Buck Scientific 210 VGP, USA) was used to determine the concentration of Iron, calcium, magnesium and phosphorous.

***Sensory Evaluation*:** A twenty-member semi-trained panellist consisting of students of the Rivers State University, Port Harcourt, Nigeria was used for the sensory evaluation of the samples. Criteria for selection were that panellists are above 18 years of age and regular consumers of burgers. The samples were evaluated for colour, taste, aroma, texture and flavour while overall acceptability was obtained as a mean value of all the other sensory attributes accessed. Each attribute was rated on a 9-point hedonic scale with 1 = disliked extremely while 9 = liked extremely (Iwe, 2010). The panellists were given sensory evaluation forms to rate the samples. The hamburger were served with plates to the panellist while portable water was provided to rinse the mouth between evaluations.

***Statistical Analysis*:** Data were analysed using means, standard deviation and analysis of variance (ANOVA).

Result of the Study

Result of Proximate Composition

Table 1 Proximate Composition (%) of AYB-SYB and Beef Patties

Samples	Moisture (%)	Ash (%)	Fat (%)	Protein (%)	Crude Fibre (%)	CHO (%)
A	29.80^{a}±4.27	3.07^{ab}±0.88	6.08^{c}±1.01	36.80^{a}±0.62	0.04^{d}±0.10	24.21^{b}±0.82
B	27.60^{b}±1.16	3.52^{ab}±0.80	11.84^{b}±0.65	23.60^{e}±2.12	8.33^{a}±2.12	25.11^{a}±0.53
C	21.20^{c}±1.18	2.61^{b}±1.00	13.50^{a}±3.72	35.50^{b}±0.00	6.20^{c}±0.34	20.99^{c}±0.14
D	24.80^{bc}±1.85	3.81^{ab}±1.01	13.00^{a}±5.20	31.70^{c}±0.00	6.50^{c}±0.70	20.19^{c}±0.79
E	26.10^{b}±1.15	5.50^{a}±0.40	12.00^{b}±1.01	28.80^{d}±0.00	7.80^{b}± 0.42	19.80^{d}±0.50

A = 100 % beef patties B = 100% AYB and SYB patties C = 70% beef: 30% AYB and SYB patties D= 60% beef: 40% AYB and SYB patties E= 50% beef: 50% AYB and SYB patties. Mean values are of duplicate determinations. Mean values within a column with different superscripts are significantly different at (p <0.05).

Table 1 shows proximate composition of AYB, SYB and beff patties. Moisture content of the patties ranged from 21.20-29.80 percent with sample B (100% AYB and SYB patties) recording the lowest value (21.20%) while sample A (100% minced meat) had the highest (29.80%). Moisture content of sample A was significantly ($p<0.05$) different from all other samples. Ash content ranged from 3.07 percent in sample A to 5.50% in sample E (70% beef: 30% AYB and SYB patties). Ash content of sample E (50% beef: 50% AYB and SYB patties) was significantly ($p<0.05$) different from that of sample C (70% beef: 30% AYB and SYB patties). Fat content of the samples ranged from 6.08 percent in sample A to 13.50 percent in sample C. Protein content ranged from 23.60-36.80% with sample B recording the lowest value (23.60%) while sample A had the highest (36.80%). There was a significant ($p<0.05$) difference in the crude content of all the samples. Crude fibre content of the samples ranged from 0.04% in sample A to 8.33% in sample B. Crude fibre content of sample B was significantly ($p<0.05$) different from other samples. Carbohydrate content of the samples ranged from 19.80% in sample E (50% beef: 50% AYB and SYB patties) to 25.11% in sample B.

Table 2 Mineral Composition (mg/100g) of Beef, AYB and SYB Patties

Samples	Iron	Phosphorus	Calcium	Magnesium
A	3.43^{a}±0.30	65.00^{b}±1.32	10.32^{c}±0.55	63.70^{d}±1.21
B	4.60^{a}±0.21	20.23^{c}±0.87	16.41^{a}±0.66	76.40^{c}±2.32
C	4.70^{a}±0.04	52.55^{b}±2.93	7.01^{d}±0.24	72.42^{c}±1.43
D	5.15^{a}±0.09	92.65^{a}±3.12	12.23^{b}±0.62	110.12^{b}±3.65
E	4.59^{a}±0.13	100.21^{a}±2.54	15.41^{a}±0.88	121.09^{a}±5.22

A = 100 % beef patties B = 100% AYB and SYB patties C = 70% beef: 30% AYB and SYB patties D= 60% beef: 40% AYB and SYB patties E= 50% beef: 50% AYB and SYB patties. Mean values are of duplicate determinations. Mean values within a column with different superscripts are significantly different at (p <0.05).

Table 2 shows the mineral composition of AYB-SYB and beef patties. Iron content of the patties ranged from 3.43 mg/100g in sample A (100% beef patties) to 5.15 mg/100g in sample D (60% beef: 40% AYB and SYB patties). There was no significant ($p>0.05$) difference in the iron content of the samples. Phosphorus content ranged from 20.23 mg/100g to 100.21 mg/100g with the lowest value found in sample B

(100% AYB and SYB patties) while sample E (50% beef: 50% AYB and SYB patties) had the highest value. Calcium content of the samples ranged from 7.01 mg/100g in sample C (70% beef: 30% AYB and SYB patties) to 16.41 mg/100g in sample B. Magnesium content ranged from 63.70 mg/100g in sample A to 121.09 mg/100g in sample E.

Table 3 Mean Sensory Scores of Hamburgers Produced with African Yam Bean, Soya Bean and Beef Patties

Samples	Colour	Texture	Aroma	Taste	Flavour	Overall Acceptability
A	$7.70^{a}\pm1.03$	$7.65^{a}\pm1.03$	$7.00^{a}\pm0.85$	$7.90^{a}\pm1.29$	$7.25^{a}\pm1.44$	$7.50^{a} \pm 0.78$
B	$6.60^{a}\pm1.50$	$6.05^{b}\pm1.50$	$6.20^{a}\pm1.70$	$5.60^{b}\pm1.72$	$5.50^{b}\pm1.57$	$5.99^{b}\pm0.70$
C	$6.70^{a}\pm1.17$	$6.45^{ab}\pm1.14$	$6.15^{a}\pm1.30$	$6.20^{b}\pm1.67$	$6.30^{ab}\pm1.52$	$6.36^{ab} \pm0.87$
D	$6.70^{a}\pm1.38$	$6.20^{b}\pm1.43$	$6.30^{a}\pm1.21$	$5.80^{b}\pm1.47$	$5.80^{b}\pm1.10$	$6.16^{b}\pm0.69$
E	$6.60^{a}\pm1.60$	$5.85^{b}\pm1.69$	$6.00^{a}\pm1.52$	$6.15^{b}\pm1.84$	$5.90^{b}\pm1.33$	$6.10^{b}\pm0.93$

A = 100 % beef patties B = 100% AYB and SYB patties C = 70% beef: 30% AYB and SYB patties D= 60% beef: 40% AYB and SYB patties E= 50% beef: 50% AYB and SYB patties. Mean values are of duplicate determinations. Mean values within a column with different superscripts are significantly different at (p <0.05).

Table 3 shows the mean sensory scores of hamburgers produced with beef, African yam bean and soybean patties. Colour of the hamburgers ranged from 6.60 in samples B (100% AYB and SYB patties) and E (50% beef: 50% AYB and SYB patties) to 7.70 in sample A (100% beef patties). There was no significant ($p>0.05$) difference in the colour of the hamburgers. Texture of the samples ranged from 6.05-7.65 with sample B as the least preferred while sample A was most liked. Aroma ranged from 6.00-7.00 with sample E as the least preferred while sample A was most preferred. There was no significant ($p>0.05$) difference in the aroma scores of the hamburgers. Taste and flavour of the samples ranged from 5.60-7.90 and 5.50-7.25, respectively with sample B as the least preferred while sample A was most liked. The taste score of sample A was significantly ($p<0.05$) different from other samples. Overall acceptability scores ranged from 5.99 in sample B to 7.50 in sample A.

Discussion

Table 1 shows that replacement of beef with AYB and SYB curds for the preparation of hamburger had varying effects on the crude protein, fat, ash, crude fibre and carbohydrate contents of the patties. Supplementation of beef with AYB and SYB curds led to the reduction in the moisture content of the patties. This can be linked to the increase in the fat content of the samples, and agrees with Eke-Ejiofor *et al* (2023) who reported reduction in the moisture contents of seafood preserved with spice oleoresin, as a result of increase in their fat contents. This trend was also reported by Behailu and Abebe (2020) for beef meat sausage partially substituted with soybean protein and finger millet flours. The moisture content in food is a crucial parameter as it can affect the texture, juiciness, and overall palatability of the product. Moisture content of the patties was lower when compared to 63.77-65.59 percent reported by Amadi (2020) for meat sausages. The low moisture content of the patties from this study indicates a good shelf life for the product, since moisture content affects its stability and overall quality (Folake & Bolanle, 2006).

The ash content of the beef and AYB-SYB patties increased with increase in substitution level of AYB and SYB patties. This increase might be attributed to a concentration effect, as the 100 percent AYB/SYB patties exhibited higher ash content compared to the 100 percent beef patties. This uptick in ash content in AYB/SYB curd formulations indicates their potential as essential mineral sources in hamburger production, as ash content reflects mineral presence (Orisa *et al* 2023). The observed values were consistent with those reported by Amadi (2020), who noted percentages of 3.10-4.24 percent of ash in beef sausage enriched with full-fat soy flour. The ash content of the 100% beef patties (Sample A) obtained in this study (3.07%) aligns with Dharmaveer *et al* (2007) findings for chevon sausage (3.00%).

The fat content of the beef and AYB-SYB patties reduced as AYB and SYB curds were included. The high fat content in patties with AYB and SYB curds when compared with 100 percent beef patties might be attributed to soy flour's strong fat-binding properties (Odiase *et al* 2013), which can be advantageous in meat applications. This increase in fat content was also noted by Omojola et al (2013) in breakfast sausages containing legume flours as binders. The high fat content in patties with AYB and SYB curds suggests their potential as significant energy sources for consumers when used in hamburger production. Conversely, there was a significant ($p<0.05$) decline in the crude protein content of the patties as the substitution with AYB/SYB curds increased. However, the protein content of the patties remained relatively high compared to that reported by Behailu and Abebe (2020) for beef partially substituted with soybean protein and finger millet flours (21.57-25.10%).

On the other hand, there was a significant ($p<0.05$) increase in the crude fibre content of the patties as the substitution with AYB/SYB curds increased. The increase in fibre content may be attributed to the fact that soybean and African yam bean contain vegetable-based fibres, which are a mixture of amylopectins and cellulosic (Odiase e*t al* 2013). This increase in fibre content indicates lower cooking loss, as dietary fibre additions augment bulk and reduce cooking loss in meat products, often without significant changes in textural properties, due to improved water-binding capabilities. This has economic advantages for both consumers and producers (Brewer, 2012). Dietary fibre in meat products also provides health benefits and serves as excellent meat substitutes, owing to their inherent functional and nutritional effects (Biswas *et al* 2011). The inclusion of AYB and SYB curds to the beef patties resulted in a significant ($p<0.05$) reduction in the carbohydrate content of the samples. Sample B (100% AYB and SYB curds) recorded the highest carbohydrate content (25.11%). These curds are sourced from legumes, which are renowned for their carbohydrate-rich composition, including starches and dietary fibres (Obinna-Echem *et al* 2024).

Table 2 shows that the patties supplemented with AYB/SYB curds are a rich source of mineral elements. The results showed an increase in the calcium, phosphorus, iron and magnesium content as the substitution with AYB and SYB curds increased. Similar findings were also reported by Amadi (2020) for beef sausage supplemented with soybean flour. Magnesium content of the patties obtained from this study were higher than that of Schmid *et al* (2009) who recorded that the magnesium content of cooked sausage averaged between 11 and 18 mg/100 g for Swiss sausages. Magnesium helps in the proper functioning of the muscles. It also serves as an activator in many enzymes systems (Okoye and Egbujie, 2018). Calcium content of the beef patties from this study was similar to the values of 11.67-18.74 mg/100g reported by Amadi (2020). Calcium, in conjunction with other minerals and protein, plays a crucial role in facilitating proper bone formation, with calcium serving as the primary contributor. Furthermore, it is vital for essential bodily functions such as blood clotting, muscle contraction, and various metabolic processes (Abulude *et al* 2006). Inclusion AYB and SYB curds to the beef patties increased the iron content as well as the phosphorous content of the samples. The iron content of the patties was similar to iron content of different varieties of *Irvinga gabonesis* reported by Orisa *et al* (2023). The result for phosphorous content were comparable to Amadi (2020) who reported phosphorous content of 83.82-95.77 mg/100g.

Table 3 shows that hamburger produced from 100 percent beef was more acceptable for all sensory parameters studied. Increase in the substitution of beef with AYB and SYB curds resulted in a decrease in the colour, texture, aroma, taste, flavour and overall acceptability of the hamburgers. Substitution with AYB and SYB curds had no significant effect on the colour and aroma of the hamburgers. The result showed that the hamburger containing 100 percent beef did not differ significantly ($p<0.05$) from hamburger containing 30 percent AYB/SYB curds. This suggests that a certain level of substitution (70% AYB/SYB curd: 30% beef) might be acceptable to consumers without a significant loss in sensory quality.

Conclusion

This study observed significant changes in the nutritional composition of hamburger patties when beef was substituted with AYB and SYB curds. Ash content increased, suggesting AYB and SYB curds could serve as a valuable source of minerals. Fat content also increased, which might be attributed to fat-binding properties of AYB and SYB, making it a good energy source. Crude fibre content increased with AYB/SYB curd substitution. The result also showed an increase in the calcium, phosphorus, iron and magnesium content of the beef patties as the supplementation with AYB and SYB curds increased. However, despite these nutritional benefits, sensory evaluations revealed that hamburgers containing 100 percent beef patties were liked best but did not differ significantly ($p<0.05$) from the hamburgers supplemented with 30 percent AYB and SYB curds.

Recommendations

(1) Further research should be conducted with different formulations and processing methods to further optimize the sensory acceptability of hamburgers containing AYB/SYB curds.
(2) Use of plant-base proteins in hamburger production should encouraged.

References

Abulude, F.O., Lqual, L.O., Ehikharmery, G., Adesanya, W.O.&Ashafa, S.L. (2006).Chemical composition and functional properties of some pours from the Coastal Area of Ondo State, Nigeria. *Journal of Environmental, Agriculture and Food Chemistry*, 5, 1235-1240.

Adebowale, B.A., Olubamiwa, Ogunjobi, M.A.K. (2011). Substitution value of sundriedcashew apple bagosse in the diets of *clariasgariefinus. International Research Journal of Agricultural Science and Soil Science*, 1(76), 268-272.

Adedokun, I. I., Onyeneke, E. N., Nwokeke, B. C., Obiloma, A. & Ogbonna, P. C (2017). Proximate composition and sensory properties of meat analogue from blends of plant protein sources of ‛bambara nut and African breadfruit seeds. *Nigerian Journal of Agriculture, Food and Environment*, 13(4), 98-102.

Akinyele, B.J. &Oloruntoba, O.S. (2013). Comparative studies on *Citrullus vulgaris, Citrullus colocynthis* and *Cucumeropsismannii* for Ogiri' production. *British Journal of Microbiology Research*, 3 (1),1-18.

Amadi, A.O. (2020). Nutritional effects of full-fat soy flour as an extender on cooked beef sausage quality. *Asian Food Science Journal*, 17(3),44-53.

Amadi, G.A., China, M.A.H., Ujong, A.E. & Christian, M. (2022). Effect of African Yam Bean Flour as an Extender on the Physicochemical and Sensory Properties of Cooked Beef Sausage. *European Journal of Nutrition and Food Safety*, 14(7), 13-23

AOAC International (2019). Official Methods of Analysis of AOAC Internatioal, 21st ed. Rockville, MD: AOAC International.

Behailu, B. &Abebe, M. (2020). Effect of soybean and finger millet flours on the physicochemical and sensory quality of Beef meat sausage. *Asian Journal of Chemical Sciences*, 7(1),6-14.

Biswas, A., Kumar, V., Bhosle, S., Sahoo, J. &Chatli, M. (2011). Dietary fibers as functional ingredients in meat products and their role in human health. *International Journal of Livestock Production*, 2(4),45-54.

Brewer, M.S. (2012). Reducing the fat content in ground beef without sacrificing quality: A review. *Meat Science*, 91(4),385-395.

China, M.A.H., Olumati, P.N. &Owuno, F. (2021). Utilization of fluted pumpkin (*Telfairiaoccidentalis*) seed milk for the production of textured vegetable protein. *European Journal of Agriculture and Food Sciences*, 3(4),4-9.

Dharmaveer, S., Rajkumar, V. & Mukesh, K.P. (2007). Quality and shelf-life of smoked Chevon sausages packed under vacuum and Stored at 4±I°C. *American Journal of Food Technology,* 2,238-247.

Eke-Ejiofor, J., Albright, A., & Achinewhu, S.C. (2023). Effects of Spice Oleoresin Preservation on the Nutrient content of Selected Shellfish. *Delta Agriculturist*, *15*(1), 21-33.

Folake, O. S. & Bolanle, O. O. (2006) Chemical Analysis and Sensory Evaluation of Ogi Enriched with Soybeans and Crayfish. *Nutrition and Food Science*, 36(4), 214-217.

Gbadamosi, I.T., Obanubi O.T., and Sobowale, A.A. (2021). *In-vitro* antifungal activity of leaf, stem bark and root extracts of *Irvingia gabonensis* against fungi associated with its seed deterioration. *Ife Journal of Science, 23*(2),135-146.

Iwe, M.O. (2010). *Handbook of Sensory Methods and Analysis.* 2nd ed Rojoint Communications services Ltd, Enugu.

Kenawi, M.A., Abdelsalam, R.R. & El-Sherif, S.A. (2009). The effect of mung bean powder, and/or low fat soy flour as meat extender on the chemical, physical and sensory quality of buffalo meat product. *Biotechnology in Animal Husbandry*, 25(5-6), 327- 337

Kumar, P., Kumar, V., and Sharma, S. (2018). Development of vegetable-based patties using different binders. Journal of Food Science, 83(5): S1448-S1456. Doi: 10.1111/1750-3841.14255

Nwosu, J.N., Onuegbu, N.C., Ogueke, C.C., Kabuo, N.O. and Omeire, G.C. (2014). Acceptability of moin-moin produced from blends of African yam bean (*Sphenostylisstenocarpa*) and cowpea (*Vigna unguiculata*). *International Journal of Current*

Microbiology and Applied Sciences, 3(5), 996-1004.

Obinna-Echem, P.C., Amadi, A.O., and Ogan, S.A. (2024). Evaluation of the quality characteristics of cookies produced from blends of tigernut and soybean flour. *IPS Journal of Nutrition and Food Science*, *3*(1), 86–93. https://doi.org/10.54117/ijnfs.v3i1.38.

Odiase, O., Igene, J., Evivie, S. &Ebabhamiegbebho, P. (2013). Determination and sensory evaluation of soy flour-meat combinations in the production of meatballs. *Journal of Applied and Natural Science*, 5(2),482-487.

Okoye, J.I., & Egbujie, A.E. (2018). Nutritional and sensory properties of maize-based complementary foods fortified with soybean and sweet potato flours discourse. *Journal of Agriculture and Food Sciences, 6*(3), 17-24.

Okoye, E.C & Onyekwelu, C.N. (2018). Production and quality evaluation of enriched cookies from wheat, African yam bean and carrot composite flours. *Annals. Food Science and Technology*, 19(1),1-6

Omohimi, C.I., Sobukola, P.O., Sarafadeen, K.O. & Sanni, L.O. (2013). Effect of process parameters on the proximate composition, functional and sensory properties of extruded meat analogue from mucuna bean seed flour. *World Academy of Science, Engineering and Technology*, 76,1-10.

Omojola, A.B., Adetunji, V.A. & Olusola, O.O. (2013). Quality of breakfast sausage containing legume flours as binders. *Journal of Biology and Life Science*, 4(2),310-319.

Omwamba, M., Mahungu, S.M. & Faraj, A.K. (2014). Effect of texturized soy protein on quality characteristics of beef samosas. *International Journal of Food Studies*, 3,74-81.

Orisa, C.A., Amadi, A.O., Achinewhu, S.C. and Owunna, R.N. (2023). Effect of selected spices on the proximate composition, shelf life and sensory properties of cashew nut butter. *Research Journal of Food Science and Nutrition,* 8(3), 40-47. https://doi.org/10.31248/RJFSN2023.162

Osaili, T.M., Al-Nabulsi, A.A. and Al-Holy, M.A. (2017). Microbiological quality of hamburgers served in restaurants. Journal of Food Protection, 80(10): 88(10): 1711-1718. Doi: 10.4315/0362-028X.JFP-17-075

Raji, M.O., Adeleye, O.O., Osuolale, S.A., Ogungbenro, S.D., Ogunbode, A.A., Abegunde, P.T., Mosobalaje, M.A., Oyinlola, O.O., Alimi, I.O. & Habeeb, A.A. (2014). Chemical composition and effect of mechanical processed of African Yam bean on carcass characteristics and organs weight of broiler finisher. *Asian Journal of Plant Science and Research*, 4(2),1-6.

Schmid, A., Ampuero, S., Butikofer, U., Scherrer, D., Badertscher, R. & Hardon, R. (2009). Nutrient composition of Swiss cooked sausages. *Fleischwirtschaft-Frankfurt*, 24(6),61-64.

Teye, G.A., Teye, M. &Boamah, G. (2012). The effect of cowpea (*Vigna unguiculata*) flour as an extender on the physicochemical properties of beef and ham burgers. *African Journal of Food, Agriculture, Nutrition and Development*, 12(7), 7019-7034.

Wordu, G.O. & Eke-Ejiofor, J. (2020). Proximate, mineral and sensory properties of Hamburgers produced from beef and cashew apple pomace. *International Journal of Food Science and Nutrition,* 5(1), 10-15.