Suitability of Pigeon Pea and Soybean Flours as Extenders and Binders in Restructured Meat Product (Sausage)

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Abstract

The suitability of pigeon pea and soybean flours as an alternative to chemical binders and extenders in meat restructuring technology was investigated in this study. Pigeon pea flour (PPF) and soybean flour (SBF) were separately developed, assessed for their protein contents and each was used for sausage preparation at 2, 4, and 6% with plain (CB) and chemical phosphate binder (PhB) sausages serving as control samples. The processed sausages were then subjected to texture profile, water solubility index (WSI), sensory profile, and consumer acceptability analyses to assess the flours' performance. Soybean flour had a significantly (p<0.05) higher protein content (31% DM) than pigeon pea flour (22-24% DM). Texture profile parameters differed significantly(p<0.05) between samples with the highest hardness value observed inCB(424.0±1.53g) and lowest values in SBFs (277±1.11-332±1.5 g). The PhB and 4 and 6% SBFs samples had higher cohesiveness (0.46±0.02-0.54±0.03g), adhesiveness (9.0±0.10-10.9±0.25g) and WSI (2.8-3.0%) than respective lower values of 0.29± 0.04-0.42±0.04, 2.5±0.10-6.0±0.66and 1-2.4% in plain control and PPFs samples. The sensory analysis results revealed that PhB samples had significantly (p<0.05) higher colour (8.2±1.30), saltiness (5.8±1.56), and mouthfeel (6.9±1.20) intensities than other samples. Furthermore, the PhB, and 4 and 6% SBFssamples had significantly (p<0.05) higher moistness (0.46±0.02-0.54±0.03g), consumer acceptability (7.1±1.67-7.3±1.88) and preference (125-177)as well as lower hardness intensity (5.9±2.54-6.0±2.82) than other samples. In conclusion, soybean is richer in protein than pigeon pea and its incorporation of up to 6% in sausage produces a more acceptable product than plain control samples but with WSI, texture, and sensory profiles comparable to chemical binder samples. However, further studies to establish appropriate pigeon pea flour levels that will produce acceptable products with similar physical and sensory properties to chemical binder is recommended.

Keywords: Pigeon pea, soybean, sausages; Binder, sensory profiles; water solubility index

Introduction

Legume seeds are important staple foods and are one of the richest and cheapest sources of proteins for the majority of people living in developing countries (Maphosa and Jideani, 2017). The most commonly consumed are pigeon pea, common beans, kidney beans, black gram, chickpeas, green gram, and lentils (Singhali *et al.,* 2014). Pigeon pea (*Cajanu scajan*), is an erect perennial legume shrub belonging to Family Fabaceae originated in the Indian subcontinent and is currently grown in subtropical and tropical regions of several countries (Odeny, 2017). Tanzania is the 4thworld producer of pigeon pea with an annual production of 271 210 tons (FAOSTAT, 2017) after India (4 870000 tons), Burma (798 689 tons), and Malawi (470 630 tons). The key production regions in Tanzania are Arusha, Dodoma, Manyara, Lindi, and Mtwara (Mponda *et al.,* 2014).

Pigeon pea is a good source of crude protein (22 - 27%), fiber, vitamins especially riboflavin, thiamine, choline and niacin, and antioxidants

(Olagunju *et al.,* 2018; Talari and Shakappa, 2018). The health benefits due to the presence of these components have widely been reported and they include regulation of blood pressure, growth, and development, prevention of anemia as well as boosting the immune system (Olagunju *et al.,* 2018). Talari and Shakappa (2018) further associated bioactive compounds present in pigeon pea with modulation of natural microbiota present in the gut hence reduce inflammation.

However, despite its nutritional and health benefits, pigeon pea is still an underutilized crop and its utilization is lowered to low-income families (Fasoyiro *et al.,* 2010).The long cooking time and the presence of antinutrients are among the factors that limit its utilization (Ahmed and El-Tabey, 1992). Furthermore, the crop has received little attention from research and development to unlock its potential contribution as an important food ingredient in industrial applications in the country. Due to its high protein content, pigeon pea can be processed into flour and be used in the food industry as an ingredient for various food products like biscuits, noodles, and pasta (Keshav, 2015). Besides, the flour can be processed into an extender or binders in meat restructuring technology the same way as soybean protein is used (Mora and Andres, 2015). The technology enables the production of value-added meat products from low-quality cuts and trimmings by improving water holding capacity, tenderness, fat content, binding strength, and shape of meat products (Xue *et al.,* 2016). Protein in the meat facilitates water molecules to be bound by polar groups of proteins which is necessary for them to retain their spatial structure and remain intact (Pospiech and Montowska, 2011). Salt and phosphates are among the traditional binders that are in use in the food industry facilitating the extraction of myofibrillar proteins and enhance cohesion and binding of meat particles (Teye and Teye, 2011). They also increase the protein solubility as well as expose hydrophobic groups leading to a better product. However, their applications have been impeded by causing discoloration, rancidity, and harmful residues (toxins) (Teye and Teye, 2011) with consequent health problems (Inetianbor *et al,* 2015).

Soybean protein has widely been used in the food industry as an alternative to chemical extenders and binders in restructured meat products (Badpa and Saghir, 2014). Nevertheless, soy is among the eight (8) most significant food allergens (Solomon *et al.,* 2017) and hence suggesting another protein source such as pigeon pea. Gomezulu (2020) developed pigeon pea binder for sausage which produced a good quality product at 6%, however, its production costs and the overall final sausage cost seemed to be high and probably unaffordable by the majority of people especially low-income earners. Thus, the development and application of the protein-rich pigeon pea flour seem to be a very suggestive and good alternative. The aim is not only to reduce high dependency on chemical binders in the food industry, some of which are linked to health issues but also to produce relatively cheaper restructured meat products. These products will increase overall consumption, marketability, farmer's income as well as positive nutrition and health outcomes of consumers in the country. Despite adequate literature review information on the application of pigeon pea flour alone or its comparison with soybean flour as an extender or binders in the restructuring technology is limited. This study was conducted to assess protein contents of the flours, texture and sensory profiles and consumer acceptability of the sausages prepared by chemical and flour binders.

Materials and Methods

Study area

The study was conducted at Sokoine University of Agriculture (SUA) and the Nelson Mandela African Institute of Science and Technology (NM-AIST).Sausage preparation, sensory evaluation, and texture profile analyses were done at the Department of Food Technology, Nutrition and Consumer Sciences (DFTNCS), SUA while protein analysis and water solubility index analyses were conducted at the NM-AIST laboratory.

Materials and their sources

Two varieties of pigeon pea (improved and local varieties) were purchased from farmers in Lindi region. Ultrafiltration tubes for protein extraction were purchased from Dableen General Suppliers Company - Arusha, Tanzania. Fresh meat, sausage spices, phosphate binder, and sausage lamb casing were purchased from a local market and butcher in Morogoro Municipality.

Chemicals and reagents

Analytical grade chemicals and reagents for protein profile analysis were obtained from NM-AIST and SUA laboratories. These included hydrochloric acid (HCl), potassium iodide (KI) solution, ethanol, sodium hydroxide (NaOH), distilled water (H_2O), concentrated sulphuric acid (H_2SO_4), acetic acid, sodium carbonate (Na_2CO_3) solution, tannic acid solution, Folin-Dennis reagent and concentratedammonium hydroxide (NH_4OH).

Methods

Research designs

A completely randomized design (CRD) was used in this study. The principal factors were binder types (chemical and flours). The effect of this factor on flour protein content, product texture profile, and water holding capacities were determined and compared. The designed mathematical model is depicted in Equation 1.

$$Y_{ij} = \mu + \alpha_i + \varepsilon_{ij} \quad (1)$$

Where μ is the overall (grand) mean, αi is the effect due to the ith treatmenteffect (variety and binder type) and εij is the error term.

Balanced incomplete block design (BIB) was used in sensory analysis. The BIB design (ISO 29842, 2011) is applied to sensory tests in which the total number of samples is greater than the number that can be evaluated, before sensory and psychological fatigue set in. Hence, each assessor evaluates only a subset of the total number of samples in a single session randomly. The principal factors were assessors and sausage formulated from different binders. The effects of these factors on sensory profile of sausages and consumer acceptability and preferences were determined and compared. The mathematical expression is depicted in Equation 2.

$$Y_{ij} = \mu + \tau_i + \beta_j + \varepsilon_{ij} \quad (2)$$

Where μ is the overall mean, τi is the ith treatment effect (binder type), β_j is the jth block effect (assessors) and εij is the random effect.

Flour preparation

Flour preparation was done based on the method described by Adenekan *et al.* (2017) with slight modifications. Soybean and pigeon pea were washed and soaked in water (1 kg pigeon pea: 3 liters of water) for 24 hours at room temperature (22°C). It was then dehulled and oven-dried at 60°C for 24 hours followed by milling (Bunn G2 Black Model 875 miller, USA) into a fine powder then stored in a desiccator (Desiccator; Stainless steel, Tempered Glass Windows, Series 100, USA).

Sausage formulation

Sausage samples were formulated using methods described by Dzudie *et al.* (2002) and Teye and Teye, (2011) with slight modifications. Three formulations consisted of soybean flour (SBF) and pigeon pea flour (PPF) each at 2, 4, and 6% were prepared as depicted in Table 1. The sausage with no flour and/or chemical phosphate binder (0.5% per kg of meat) served as control samples.

Sausage preparation

Sausage samples were prepared using methods as described by Dzudie *et al.* (2002) and Teye and Teye, (2011). Meat muscles were removed from the meat carcass after 24 hours chilling at 4°C, trimmed of visible fat and connective tissues, and ground through a 3 mm plate using a meat grinder. The ground meat was sealed in 8×12 cm polyethylene zipper bags (500g package) and stored at -18°C for 24 hours. Before processing, thestored meat was thawed at 4°C for 16 hours.To each formulation (presented in Table 2.1), a constant amount of 20g salt, 300g water, 1 g ground black pepper, 1 g ground white pepper, and 4g of ground coriander (basic ingredients) were added. The sausage batters were processed by replacing beef with binders at levels of 2, 4, and 6% (Dzudie *et al.,* 2002; Teye and Teye, 2011) of the weight of the meat. The whole mixture (a batter)and 1/3 of the total water (10°C) were chopped in a Stephan UMC 5-12 Electronic cutter (Marne-la-Vallee, UK) for 3 minutes. Binders and the remaining water

Table 1: Beef sausage formulations with chemical binders and different proportions of flours

Sample	Proportions (%)/kg of meat		
	Phosphate	**Soybean flour**	**Pigeon pea flour**
Control (CB)	0	0	0
Phosphate binder (PhB)	0.5	0	0
SBF1	0	2	0
SBF2	0	4	0
SBF3	0	6	0
PPF1	0	0	2
PPF2	0	0	4
PPF3	0	0	6

(2/3) were added and the mix was chopped for 10 minutes and the final chopping temperature did not exceed 15°C. The sausage batters were stuffed into 22 mm lamb casings using a hand-operated stuffer (VLA 13 - France) and formed into links of 15 cm in length.

The sausages were cooked at 85-90°C in a water bath (PURATM Series 30, UK) for about 45 minutes to an internal temperature of 72°C. They were then rapidly chilled to 15-20°C with cold water for 10 minutes and stored in polyethylene bags in a refrigerator at 4°C for 48 hours before sensory analysis.

Determination of protein content

The protein content of the samples was determined by the CHNS/O analyzer method as described in method 44.4.04 by AOAC (2005). The samples were combusted and the produced gases were carried by Helium flow to a second reactor filled with Copper.The gases were then swept through CO_2 and H_2O traps through a gas chromatography(GC) column (Series 4060, UK) and finally detected by a thermal conductivity detector (TCD Detector, Teledyne Series 100, Model 2020, USA). A complete report was automatically generated by software that automatically converts the nitrogen content into protein content. For this case, a specific protein factor of 6.25 was used.

Texture profile analysis

The textural properties (hardness, cohesiveness, adhesiveness, and springiness) were determined using a texture analyzer (Genway Universal Testing Machine, Japan). After peeling off the casing, a texture profile was performed using the central cores from three slices of each cooked sausage (Jung *et al.,* 2012). All measurements were performed in triplicate.

Determination of Water solubility index (WSI)

The WSI of sausages was measured as expressible moisture (EM%) by centrifugation, according to the modified method of Menegassi *et al.* (2011). Approximately 1.5 g of each cooked sausage was wrapped with dried filter paper (Whatman no. 3) and weighed. After centrifugation (in an 800-1 Centrifuge, China) at 3000 rotations per minute (rpm) for 15 minutes, the expressible moisture (EM %) was calculated as the weight difference between the sample weight before centrifugation and sample weight after centrifugation.

Sensory analysis

Quantitative descriptive analysis (QDA)

A quantitative descriptive analysis test was conducted at the DFTNCS laboratory at SUA involving a trained panel of 9 assessors comprising of 7 male and 2 females with age ranging from 22 to 28 years according to the method described by Lawless and Heyman (2010). The assessors were selected and trained for three (3) days according to ISO 8586 (2012). During training, panelists developed descriptors describing differences between samples and they agreed on the following attributes; color, saltiness, mouthfeel, moistness, compactness, and hardness (Table 2). They also developed and agreed on an unstructured 9-line scale for rating the intensity of an attribute. The left side of the scale corresponded to the lowest intensity of each attribute (value 1) and the right side corresponding to the highest intensity (value 9). The samples were coded with 3-digit random numbers and were served to each panelist in a randomized order using BIB design. The obtained average responses were used in the univariate and multivariate analyses. Both pre-trial test and panel performance assessment was done to ascertain the agreement of panelist in discriminating samples and their reproducibility.

Table 2: Definitions of sensory attributes used in descriptive sensory analyses

Attribute	Description	Reference	Scale ranges(1-9)
Color	Characteristic of visual perception described through color categories	Himalaya color	1- Pale Himalaya 9- Himalaya
Saltiness	The quality of being salty	Table salt (NaCl)	1- Less salty 2- Very salty
Mouthfeel	The spread of particles while chewing	Beef Vienna Sausage	1- Loose particles 2- Dense particles
Moistness	Moisture experienced by the finger feel	Beef Vienna Sausage	1- Not moist 2- Very moist
Compactness	The denseness of meat particles in the sausage as perceived by the eye	Beef Vienna Sausage	1- Not compact 2- Very compact
Hardness	Characteristic of the product as perceived for the first teeth bite	Beef Vienna Sausage	1- Not hard 2- Very hard

Source: Study QDA Panel (2020)

Consumer Test

Hedonic test

The hedonic test was conducted at the Department of Food Technology Nutrition and Consumer Sciences (DFTNCS) by 59 untrained consumers of both sexes aged between 20 - 45 years using a 9-point hedonic scale as described by Lawless and Heyman (2010). The sausages were thawed and warmed in an oven (Turbofan 3000, Blue seal, UK), sliced into uniform sizes (about 2 cm in length) then served on white disposable plates which were randomly coded with 3-digit numbers. Then the plates were served to the panelists in a randomized order on the day of evaluation using BIB design. They were then asked to evaluate and express their degree of liking for sausage product attributes on appearance, color, aroma, taste, softness, moistness and finally expressing judgment on overall acceptability using a 9-point hedonic scale (where 1 = dislike extremely and 9 = like extremely). Good sensory practices such as blind labeling and mouth rinsing between tastes were observed.

Preference test

The preference test was conducted at the DFTNCS by 59 untrained consumers of both sexes between 20 - 45 years using a 5-point ranking scale described by Lawless and Heyman (2010). The sausages were thawed and warmed in an oven (Turbofan, Blue seal, UK), sliced into uniform sizes (about 2 cm in length) then served on white disposable plates which were randomly coded with 3-digit numbers. The samples were then served to the panelists in a randomized order on the day of evaluation using a BIB design and panelists were asked to test and rank the sample according to their preference using a scale provided (where 1 = most preferred and 5 = least preferred).

Statistical Data analysis

Data were analyzed by using the R statistical package (R Development Core Team, Version 3.0.0 Vienna, Austria) for analysis of variance (ANOVA). Mean were separated using

Tukey's honest significant differencetest (HSD) at p<0.05. Also, principal component analysis (PCA) was used to determine the systematic variations between a sensory profile and texture characteristics in sausage formulations. Results were presented as an arithmetic mean and standard deviation in tables and PCA biplot.

Results and Discussion

Protein contents of flours

The protein contents of soybean and the two pigeon pea varieties (local and improved) are shown in Table 3.The contents differed significantly between soybean with 38.7 g/ 100 g DM and pigeon pea flour with 22.1-24.9 g/ 100g DM. The variation among varieties was also significant with an improved variety having higher values than the local variety.

Table 3: Protein contents of soybean flour and pigeon pea varieties flours

Flour	Protein (% DM)
Soybean	38.7 ± 0.2a
Local Variety	22.1 ± 0.1c
Improved Variety	24.9 ± 0.4b

Values are expressed as Mean ±SD (n=3). Mean values with different superscript letters are significantly different at p<0.05

serve as a good dietary source of protein and an important ingredient in meat restructuring technology. Protein in restructured meat facilitates water molecules to be bound by polar groups of proteins which is necessary for them to retain their spatial structure and remain intact (Pospiech and Montowska, 2011). This enhances bind strength, physical and sensory properties necessary for consumer acceptability. Similar protein contents in local and improved varieties ranging from 21.1 to 28.1%, were also reported by Aruna and Devindra (2016). The relatively high protein content in the improved pigeon pea varieties suggests its superiority to local ones and its suitability for industrial application to enhance physical, chemical, and sensory qualities of restructured meat products such as sausages (Pazmiño *et al.,* 2018).

Texture profile of the sausage samples

Table 4 shows the results of texture profile parameters which varied significantly between and among sausage formulations. Application of binder and flour reduced hardness but increased other parameters in both crops flour except springinesswith soybean flour higher effects than its pigeon pea counterpart. Similar effects were observed within each crop as the level of its flour in the formulation increased.

Table 4: Texture profile parameters of sausage samples

Formulation	Hardness (g)	Cohesiveness (g)	Adhesiveness (mm)	Springiness (mj)
CB	424.0 ± 1.53^{a}	0.29 ± 0.04^{d}	2.5 ± 0.10^{e}	14.0 ± 0.35^{b}
PhB	361.3 ± 4.35^{ab}	0.54 ± 0.03^{a}	10.6 ± 0.57^{a}	14.3 ± 0.11^{ab}
PPF1(2%)	359.0 ± 8.19^{ab}	0.33 ± 0.01^{c}	4.1 ± 0.56^{d}	14.5 ± 0.17^{ab}
PPF2 (4%)	348.0 ± 1.67^{b}	0.37 ± 0.07^{c}	5.9 ± 0.31^{c}	14.5 ± 0.29^{ab}
PPF3 (6%)	344.7 ± 2.88^{bc}	0.42 ± 0.04^{bc}	6.0 ± 0.66^{bc}	14.6 ± 0.17^{ab}
SBF1 (2%)	332 ± 1.50^{c}	0.46 ± 0.02^{b}	7.3 ± 0.25^{b}	14.7 ± 0.17^{a}
SBF2 (4%)	300e ±1.09^{d}	0.48 ± 0.03^{ab}	9.0 ± 0.10^{ab}	14.8 ± 0.11^{a}
SBF3 (6%)	277 ± 1.11^{e}	0.49 ± 0.04^{ab}	10.9 ± 0.25^{a}	14.8 ± 0.10^{a}

Values are expressed as mean ± SD (n = 3). Mean values with different superscript letters are significantly different at p<0.05. Key: CB - Control sausage, PhB is the phosphate binder, PPF is the pigeon pea flour, SBF is the Soybean flour

The findings revealed that both crop flours are rich in protein contents but soybean contains a substantial amount compared to pigeon pea as previously reported (Adeola *et al.,* 2011). This suggests that both crops may

Systematic variation of sausage samples and their associated texture parameters are further shown in the principal component analysis bi-plot of multivariate analysis (Fig 1). PC 1 accounts for 82.9% of the total variability and it is a contrast between phosphate binder, soybean flour, and 6% pigeon pea flour associated with all texture parameters on one side and control and remaining 2 and 4% pigeon pea flours associated with high hardness intensity on the other side. PC2 accounts for 10% of the variability and it's a contrast between flours on one side and control and binder on the other side.

ions in phosphate binder tend to increase sausage hardness in non-fat meat.

Increase protein contents in the formulation also tends to increase cohesiveness, which is the degree of difficulty in breaking down the internal structure of the sausage (Abdolghafour and Saghir, 2014). Previously, Syuhairah *et al.* (2016) reported similar observation that an

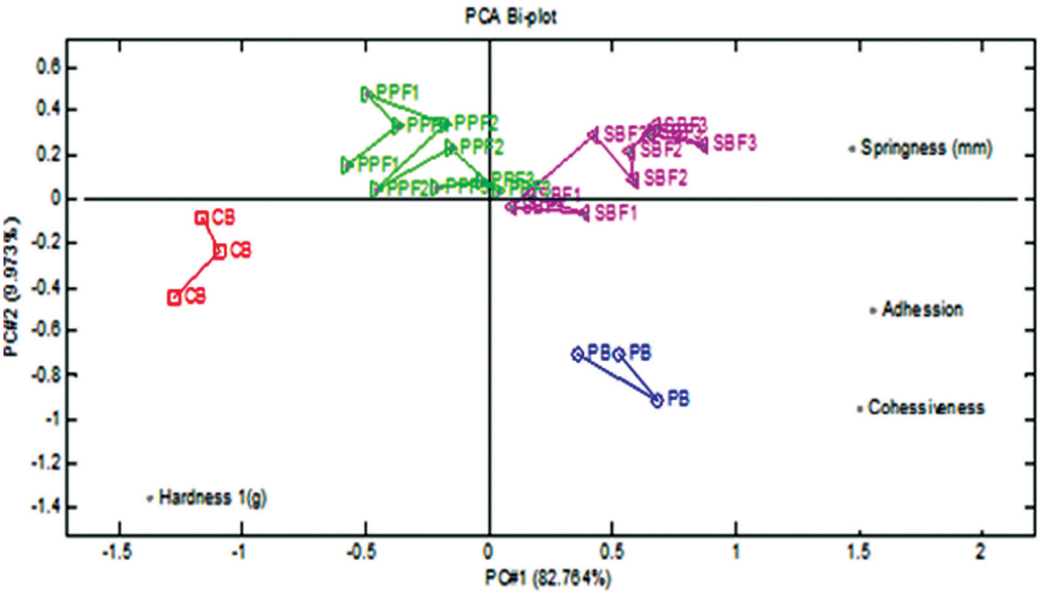

Figure 1: PCA bi-plot showing systemic variations between sausage samples and their associated sensory profiles

increase in non-meat ingredients resulted in a slightly higher degree of cohesiveness while Shand (2000) reported low cohesiveness in control samples compared to meat products treated with potato starch, waxy barley, and wheat flour meal. Adhesiveness is the necessary work required to overcome the forces of attraction between the food surface and the surface of other materials in contact with the food (Wambui *et al.,* 2017). This too could be linked to the presence and level of protein in the formulation and explains why the control samples with no protein had significantly low adhesion values compared to other samples (Syuhairah *et al.,* 2016). Springiness is the sample's ability to recover its original form after the force of deformation is removed. In our study, springiness mostly increased with the addition of flours (especially SBFs). This could be associated with increased protein contents

A decrease in sausage hardness with increasing levels of flours in the formulation could be associated withthe increase in protein in the flours. According to Abdolghafour and Saghir (2014) protein improves water holding capacity and binding strength of the meat particles leading to a tender final product. The absence of protein in the control sample results in water separation from the protein matrix caused by destabilization of meat structure (Hidayat *et al.,* 2018.) thus increasing meat hardness. A similar high hardness value in the control sample was also observed by Syuhairah *et al.* (2016). Low hardness values in phosphate samples may be explained by the fact that phosphates facilitate extraction of myofibrillar proteins and enhanced binding of meat particles resulting in a decrease in meat hardness (Wang *et al.,* 2009). Contrarily, Hemung and Chin (2015) observed that the presence of phosphate similar to the observation in beef sausage by Wambui *et al.* (2017. However, these results contradict those of Syuhairah *et al.* (2016) who reported that the control chicken meat sample (with no binder) had the highest springiness score compared to formulations with binders.

Water solubility index (WSI)

The 6% soybean flour, phosphate binder, and 4% soybean flour samples had the significantly highest water-binding index (2.7-3.0%) while CB and PPF1 had the lowest values of 1 % (Fig. 2). In each flour type, there was a significant and progressive increase in WSI as the proportion of flour increased.

shows pigeon pea flour, at increased levels, may be used in the food industry for the preparation of restructured meat products like sausage. The observed results in this research are similar to the results of several studies where the addition of protein-rich materials like bean flour and gelatin increased WSI in sausages (Dzudie *et al.,* 2002; Lee and Chin, 2016; Souissi *et al.,* 2016)

Sensory analysis

Quantitative descriptive analysis

Table 5 shows the mean intensity scores of sensory attributes of sausage samples. Phosphate binder samples differed significantly in all

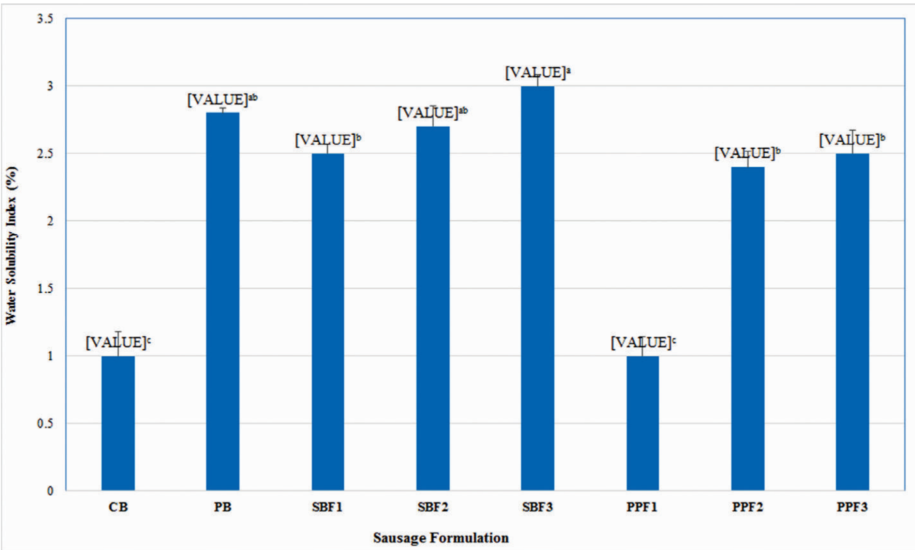

Figure 2: Water solubility index of sausage samples

Water solubility index (WSI) is the ability of meat to retain and hold moisture including any fluids added during the processing of the meat and moisture initially present in the meat muscle (Abdolghafour and Saghir, 2014). The highest water holding capacity in 4 and 6% soybean samples (Fig. 2) compared to all other samples could be ascribed to the presence of a high level of soluble protein which influences water holding capacity (Reddy *et al.,* 2015). Protein facilitates water molecules to be bound by polar groups of proteins and retain their spatial structure and remain intact (Pospiech and Montowska, 2011).Similar WSI between 4 and 6% pigeon pea flours and phosphate binder

sensory attributes intensities with control and phosphate binder samples having the highest colour score followed by soybean flour and lowest intensity in pigeon pea flour. Furthermore, chemical phosphate binder samples had the highest saltiness, mouth feel and compactness intensities compared to all other samples. On the other hand, 4 and 6% soybean flour had the lowest hardness intensity and highest similar moistness intensity to phosphate binder samples

Furthermore, the principal component analysis bi-plot (Fig. 3) of multivariate analysis shows that principal component 1 (PC 1) accounts for 44.3% and it shows clearly sample treatment separation. It groups and separates control and pigeon pea flour samples and their associated high hardness intensity on one side and soybean flour and phosphate binder samples associated high intensities of the remaining sensory attributes on the other side. PC 2 accounts for 26.9% of the variability and it is a contrast between both control and low levels (2%) samples and high level (4 - 6%) samples. The findings further support the Table 3 results that hardness, aroma, and colour decreased while moistness increasing within each flour with their increasing levels of flour in the formulations

The observed high color intensity score in phosphate binder samples (Fig. 3) could be due to the impact of phosphate addition which increases buffering capacity of meat with resulting pH change and stable colour (Long *et al.,* 2011). Stable colour is among the main physical characteristics that determine the acceptability of sausage by consumers and is a parameter that can easily be altered by the proportion of non-meat ingredients in the formulation (Syuhairah *et al.,* 2016) as observed in flour samples. However, nevertheless, the addition of soybean resulted in less colour

Table 5. Mean intensity scores of sausage samples with different binders

Sample	Color	Saltiness	Aroma	Mouthfeel	Moistness	Compactness	Hardness
CB	8.2 ± 1.09^{a}	5.0 ± 1.87^{b}	7.7 ± 1.11^{ab}	4.7 ± 1.40^{c}	5.1 ± 1.96^{e}	4.3 ± 2.40^{c}	6.8 ± 2.71^{a}
PhB	8.2 ± 1.30^{a}	5.8 ± 1.56^{a}	7.8 ± 1.09^{ab}	6.9 ± 1.20^{a}	7.6 ± 1.23^{a}	6.4 ± 1.81^{a}	6.0 ± 2.82^{c}
PPF1	7.1 ± 1.56^{c}	5.1 ± 1.67^{a}	7.4 ± 1.59^{b}	5.4 ± 1.54^{b}	6.0 ± 2.34^{d}	4.2 ± 2.11^{c}	6.4 ± 2.51^{b}
PPF2	7.1 ± 2.15^{c}	5.0 ± 1.73^{b}	7.9 ± 1.54^{a}	5.9 ± 2.14^{b}	6.3 ± 1.92^{c}	4.2 ± 2.22^{c}	6.1 ± 3.00^{c}
PPF3	7.0 ± 2.40^{c}	5.1 ± 1.83^{b}	7.8 ± 1.30^{a}	5.7 ± 2.22^{b}	6.9 ± 3.21^{b}	4.2 ± 1.88^{c}	6.0 ± 2.54^{c}
SBF1	8.1 ± 1.51^{a}	5.2 ± 1.62^{b}	8.0 ± 1.42^{a}	4.0 ± 2.09^{d}	7.3 ± 1.11^{ab}	4.6 ± 2.33^{b}	6.3 ± 2.06^{a}
SBF2	7.5 ± 1.79^{b}	5.2 ± 1.83^{b}	7.9 ± 1.41^{a}	4.1 ± 2.09^{d}	7.5 ± 2.00^{a}	4.6 ± 2.28^{b}	6.0 ± 2.83^{ab}
SBF33	7.6 ± 1.00^{b}	5.1 ± 1.66^{b}	7.6 ± 1.88^{ab}	4.6 ± 1.94^{c}	7.7 ± 3.00^{a}	4.7 ± 2.22^{b}	5.9 ± 2.54^{b}

Values are expressed as mean ± SD(n = 3). Mean values with different superscript letters along the columns are significantly different at p<0.05. Key: CB is the Control sample, PhB is the phosphate binder, PPF is the pigeon pea flour and SB is the soybean

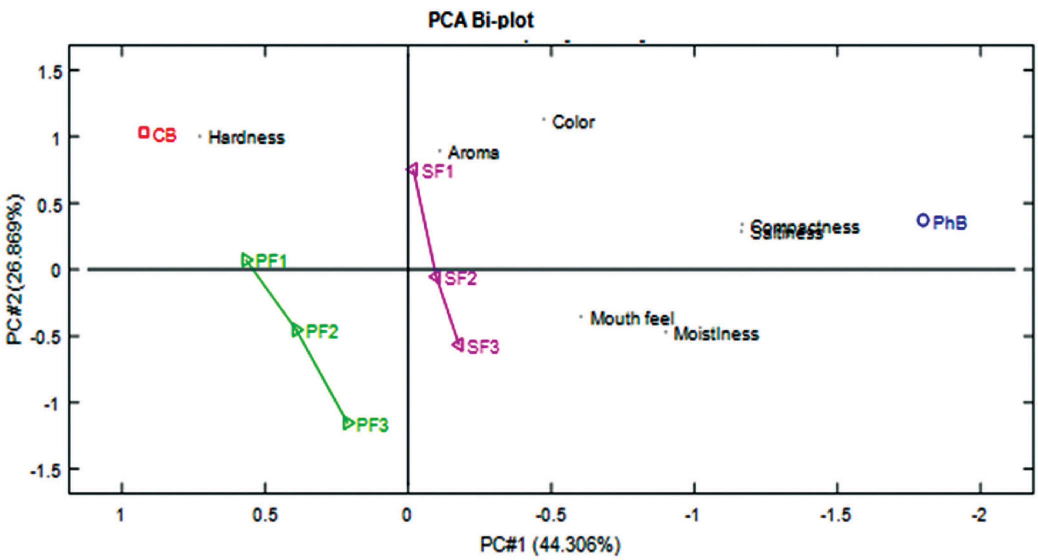

Figure 3: PCA biplot showing systematic variation in sausage samples with their associated sensory attribute intensities

reduction compared to pigeon pea flour. Similar colour increased in the sausage due to legume proteins were reported by Hidayat *et al.* (2018) and Babatunde *et al.* (2013). The high saltiness intensity in phosphates binder samples could be due to the salt nature of the binder (Glorieux *et al.,* 2017). Furthermore, the addition of phosphate improves the compactness and mouth feel of the sausage by holding the water molecules together (Long *et al.,* 2017; Peng *et al.,* 2009;). High moistness and lower harness in 4 and 6% soybean flour samples could be due to increased protein contents in the formulations. The protein interacts with water and myofibrillar protein in meat forming a stable hydrophobic interaction and increasing water holding capacity, resulting in a compact, moist and tender sausage (Wi *et al.,* 2020). The lower intensities for color, mouthfeel, moistness, compactness, and high hardness in control and pigeon pea flour samplesthan phosphate and soybean flour could be to an inadequate amount of protein present in the flours. Lack of binder in the control samples could be responsible for their high hardinessintensity and other low sensory attributes as similarly reported by Teye and Teye (2011) and Babatunde *et al.* (2013)

Consumer test

Table 6 shows the acceptability and preference of different sausage samples by consumers. The phosphate binder was the most acceptable sample (7.3) followed by 6 % soybean flour samples (7.1) and the lowest values in control samples (5.7). It was further observed that acceptability within the flours increased significantly with their increased level in the formulations. Moreover, consumer preference among samples varied significantly (p<0.05) with 4 and 6 % soybean flour samples ranked the most preferred samples with a rank-sum score of 125 on a five-point scale (1 being the most preferred and 5 being the least proffered) followed by phosphate binder samples with a rank sum of 177. The pigeon pea flour samples were the least preferred with a rank sum of 194-228.

By producing sausage samples with high consumer acceptability and preference, it suggests the suitability of using soybean flour up to 6% and greater in sausage and other restructured meat preparation as previously reported by Odiase *et al.* (2013). Protein in the flour could have enhanced physical and sensory properties resulting in an increased influence on consumer overall acceptability and preference of the sausage samples. Oluwaseun (2019) and Syuhairah *et al.* (2016) observed similar findings. In product development, consumer testing is considered to be one of the most important tests and its primary purpose is to assess the personal response by current and potential customers of a product or specific product characteristics (Soma, 2013). The observed low performance

Table 6: Hedonic scores and Friedman rank sum test of the sausage samples of sausage samples

	Acceptability[1]	Preference[2]	
Sample	**Mean hedonic**	**Median**	**Rank Sum**
CB	5.7 ± 2.12[ef]	3	181[ab]
PhB	7.3 ± 1.88a	3	177[ab]
PPF1	5.1 ± 2.03[g]	5	228[b]
PPF2	5.5 ± 3.11[f]	4	212[b]
PPF3	5.9 ± 1.11[e]	3	194[ab]
SBF1	6.2 ± 2.11[d]	3	193[a]
SBF2	6.4 ± 1.84[c]	2	153[a]
SBF3	7.1 ± 1.67[b]	2	125[a]

1Values are expressed as mean ± SD (n = 3)1 and Rank sum (n=70)2. 1Mean and 2Rank sum values with different superscript letters along the columns are significantly different at p<0.05.2Friedman chi-squared = 29.683, p-value = 0.0001085, and least significant rank difference (LSRD) is 43.3. Key: CB - Control sausage, PPF - Pigeon pea flour, and SBF is the soybean flour.

of pigeon pea flour as an extender compared to chemical phosphate binder and soybean flour suggests for a study to determine appropriate flour portion with adequate protein content to enhance the binding effect in restructuring meat technology without affecting physicochemical and sensory properties of the final products.

Conclusion and recommendation

In conclusion, soybean has higher protein contents than pigeon pea and its incorporation of up to 6% in sausage produces a more acceptable product than plain control samples but with WSI and texture and sensory profiles comparable to chemical binder samples.

The study has failed to show clearly the suitability of pigeon pea flour upto 6% in restructured sausages, further studies to establish appropriate pigeon pea flour levels that will produce acceptable products with similar physical and sensory properties to chemical binder is highly recommended.

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