Heliyon 8 (2022) e10703

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

Descriptive sensory analysis, consumer acceptability, and conjoint analysis of beef sausages prepared from a pigeon pea protein binder

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ARTICLE INFO

Keywords:
Descriptive analysis
Consumer acceptability
Preference mapping
Conjoint analysis: sausages
Pigeon pea protein
Binder

ABSTRACT

The objective of this study was to assess the sensory profile, consumer acceptance, and internal and extrinsic factors influencing the acceptability of beef sausages made at varying levels of pigeon pea protein (2, 4, and 6% w/w) as a binder. Sausages prepared without binders (CNB) and sausages made with a chemical phosphate binder served as controls (PoB). A panel of 12 trained panelists performed descriptive analysis using the quantitative descriptive analysis (QDA) approach on a 9-point line scale, while 70 consumers participated in a consumer test utilizing a 9-point hedonic scale. Preference mapping was done by linking descriptive sensory and hedonic data using partial least squares regression analysis (PLSR) and the conjoint analysis was conducted by 90 panelists using a 9-point scale. The 6% pea protein sausages had the significantly lowest ($p < 0.05$) mean hardness, aroma, and color intensity but statistically similar ($p > 0.05$) highest moistness intensity to the phosphate sausages. Phosphate sausages had the highest mean color and saltiness intensity ($p < 0.05$) compared to the lowest mean values in 6% pea protein sausages. The phosphate sausages were the most accepted by consumers ($p < 0.05$), followed by the 6% pea protein sausages, with aroma, saltiness, moistness, and firmness being the key drivers in consumer acceptability of sausages. Furthermore, formulation and price had a significant ($p < 0.05$) effect on consumer acceptability. In conclusion, employing pea protein as a binder in sausage formulations improves sensory profiles and increases consumer acceptance, making it a possible food industry alternative. Further studies to determine the optimal amount of pea protein binder that will perform better than phosphate binder are recommended.

1. Introduction

Pigeon pea (*Cajanus cajan*) is a common legume crop grown in tropical and subtropical parts of Asia, Africa, and Latin America (Kaoneka et al., 2016; Maphosa and Jideani, 2017). Worldwide, India and Myanmar are the producer of pigeon peas, which are ranked sixth after peas, broad beans, lentils, chickpeas, and common beans (FAO, 2017; Emefiene et al., 2014). In Africa, Malawi, Tanzania, Kenya, Uganda and Mozambique are the main producers (Fatokimi and Tanimonure, 2021; FAO, 2017). The crop is nutritionally rich in crude protein and contains considerable levels of essential minerals, water-soluble vitamins, and amino acids (Olagunju et al., 2018; Saxena et al., 2010). Smallholder farmers and low-income households in the tropics and subtropics use its products, such as dry grain, green pods, and pod husks, as an inexpensive source of protein in their diets (Mergeai et al., 2001).

However, despite the fact that pigeon pea contains a significant amount of protein, little research has been done to explore its potential use as an active ingredient in food industry product development. Diversifying how pigeon peas are utilized in the food industry could be one way to enhance their production, marketing, and consumption. One of the recommended applications is processing its protein into a binder for meat-based products like sausages (Li, 2019) to replace soybean and chemical phosphate binders, which have been associated with health issues like renal, liver, and allergic reactions (Inetianbor et al., 2015; Ritz et al., 2012). Pea protein appears to be a promising substitute due to its high nutritional protein content and non-allergenic qualities (Lam. et al., 2018). Binder is an important ingredient in restructured meat technology to enhance water holding capacity, binding strength, and rheological properties of the final products (Xue et al., 2016). Gomezulu and Mongi. (2022) developed and tested sausages using extracted pea

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https://doi.org/10.1016/j.heliyon.2022.e10703
Received 7 February 2022; Received in revised form 31 March 2022; Accepted 14 September 2022

Table 1. Product design and variable coding.

Profile	Product level	Price level
1	Control	652
2	Control	652
3	Control	652
4	PoB	700
5	PoB	700
6	PoB	700
7	PPB	853
8	PPB	853
9	PPB	853

The product attribute coding was 1 for control, 0 for PoB and 1 for PPB while the price was 1 for TZS 652/ = , 0 for TZS 700/ = and 1 for TZS 853.

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

Attribute	Description	Reference	Scale ranges(1–9)
Color	Yellow/red to red/blue	Himalaya	1- Pale Himalaya 9- Himalaya
Aroma	Aromatics associated with Vienna beef sausage	Beef Vienna sausage	1-Low aroma 9-High aroma
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
Firmness	The deneseness of meat particles in the sausage as perceived by the eye	Beef Vienna Sausage	1- Not compact 2- Very compact
Hardness	The force required to bite through the sample)	Beef Vienna Sausage	1- Not hard 2- Very hard

Source: Study QDA Panel (2020).

protein as a binder and discovered that they performed similarly to sausages manufactured with a chemical phosphate binder in terms of physical qualities and consumer preferences. However, neither an investigation nor a report was made regarding the sensory profile, consumer acceptance, or factors influencing consumer acceptability for the pea binder-based sausages.

Sensory studies, which use a range of approaches and are based on sense organs, offer details on the nature of a product and the level of consumer acceptability of the product acceptability (Civille and Carr, 2015). Consumer tests determine whether consumers like, accept, or prefer a product over another, while descriptive sensory analysis uses a trained panel to provide quantitative descriptions of a product based on sensory attributes (Lawless and Heymann, 2010). Additionally, preference mapping uses a perceptual map to illustrate the aspects that affect customer preference, demonstrating the connection between descriptive sensory data and consumers' hedonic judgments (Tenenhaus et al., 2005). Consumer acceptability is better understood when extrinsic variables and internal sensory attributes are examined together utilizing conjoint analysis. The conjoint analysis examines how different product characteristics influence consumer acceptance (Gustafsson et al., 2003). The objective of this study was to investigate the sensory profile of beef sausages prepared using an extracted pigeon pea protein and chemical phosphate binders, as well as the intrinsic and extrinsic factors that affect customer acceptability.

2. Materials and methods

2.1. Materials

Two pigeon pea varieties (improved and local) were procured from farmers in Mibure and Mitumbatu villages in the Lindi Region, Southern Tanzania. Ultrafiltration tubes (Merck Millipore AmiconTM-UK) for protein extraction were purchased from Dableen General Suppliers Company in Arusha, Tanzania. Fresh meat and other recipes for making sausage were purchased at a butcher and a local market in the municipality of Morogoro, respectively whereas a chemical phosphate binder was purchased from Meat Pro-Tanzania Company in Arusha, Tanzania.

2.2. Experimental designs

2.2.1. Sensory analysis

This study used a randomized complete block design (RCBD) for sensory analysis, with panelists and sausage formulations as the main factors. The effects of these factors, and their interactions, on the sensory profiles and consumer acceptability of sausages, were investigated and compared. Eq. (1) depicts the mathematical expression of the model.

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

where μ is the overall mean, τ_i is the ith treatment effect (formulations), β_j is the jth block effect (assessors), and ε_{ij} is the random effect.

2.2.2. Conjoint analysis

The conjoint analysis employed a 3 × 2 full factorial design with two extrinsic factors and three types of data sets: product design, consumer traits, and consumer preferences (Næs et al., 2010; Kuznetsova and Brockhoff, 2015). For the product design, only three sausage formulations (control, phosphate, and protein binders, and market-based product prices of TZS 652, 700, and 853/= (1 TZS = USD 2300) were used. These factors were picked as a result of an 8-person focus group discussion, resulting in a total of 9 product profiles depicted in Table 1.

2.3. Determination of protein contents of the pigeon pea varieties and extracted binder

The Micro-Kjeldahl technique 960.52 methods (AOAC, 2005) and a conversion factor of N = 6.02 were used to evaluate the protein contents of the pigeon pea varieties to determine the rich variety for binder development and that of the created binder.

2.4. Pigeon pea binder preparation

The binder was prepared from 5 kg of pigeon peas using a method described by Pazmiño et al. (2018). The peas were sorted, soaked in 3 L of water for 24 h at 22 °C, dehulled, and dried in an oven for 24 h at 60 °C before being ground into a fine powder (Bunn G2 Black Model 875 miller, USA) and stored in a desiccator (Tempered Glass Windows, Series 100, USA). For protein extraction, approximately 800 g of the flour were sieved through a 90-micrometer sieve (GKL-Model KTL, Germany), mixed with water at a ratio of one to 10 (weight/volume), and adjusted for pH to 8.5 using 1N NaOH. The blend was allowed to stand for 30 min, agitated for 5 min to eliminate any foam, and then centrifuged two times for 20 min at 4000 rpm (800-1 Centrifuge, China). The mixture was filtered via 0.45-micrometer ultrafiltration tubes (Merck Millipore AmiconTM-UK) and freeze-dried (BK-FD10S, China) for 48 h at -44 °C and 0.08106 bars to produce a pea protein binder. The obtained protein binder was kept in a desiccator (tempered glass windows, series 100, USA) before being used to make sausage.

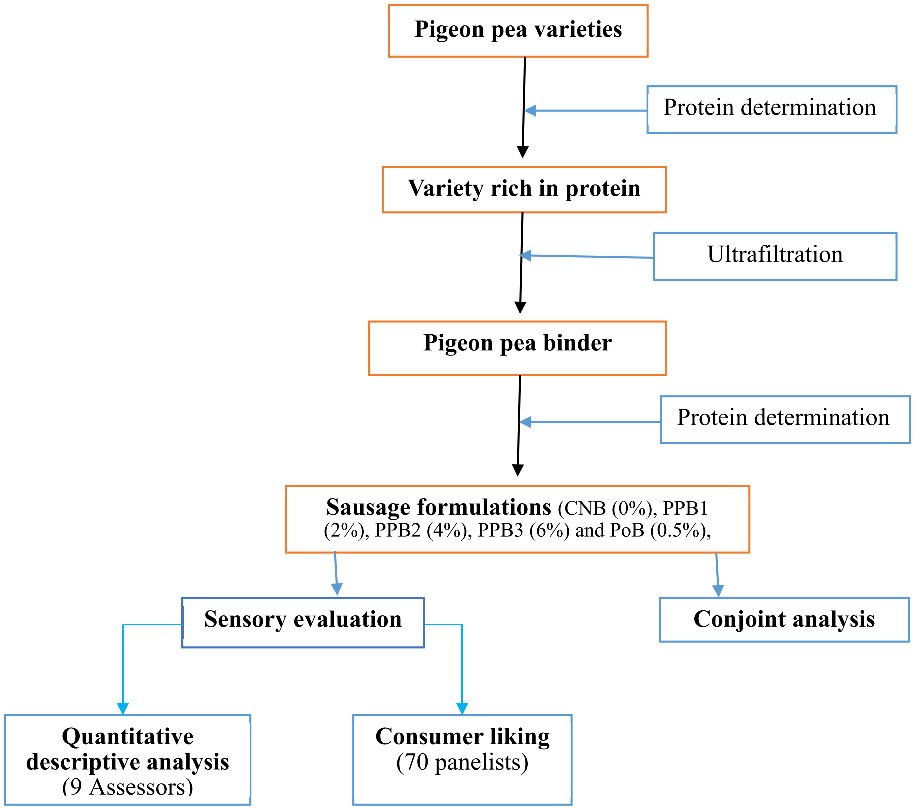

Figure 1. Summarized flow chart of the whole experiment.

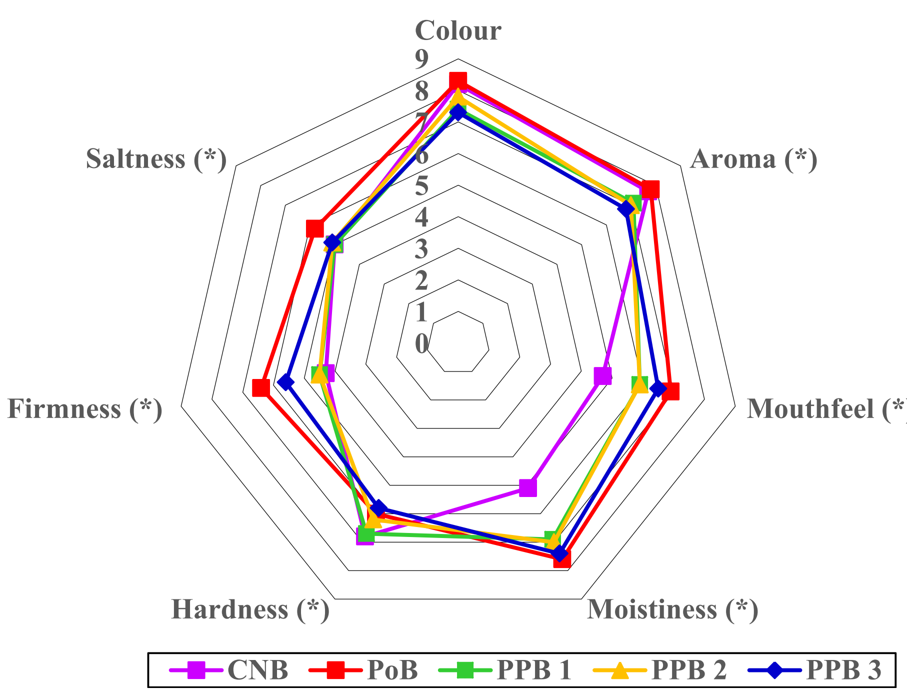

Figure 2. The spider plot depicts the average intensity scores of sausage samples produced with various binders. PPB is a pea protein binder, PoB is a phosphate binder, and CNB is a control sausage without a binder.

2.5. Preparation of sausages

Five sausage formulations one containing no binder (CNB (0%), one containing 0.5 % chemical phosphate binder and three containing 2, 4 and 6 % pigeon pea binders in 1 kg of beef meat were prepared using a method that was previously used by Teye and Teye (2011). The meat and binders were mixed with equal amounts of 300 g water, 1 g ground black pepper, 20 g salt, 1 g ground white pepper, and 4 g ground coriander and cooked at 85–90 °C in a water bath (PURATM Series 30, UK) for 45 min to an inner temperature of 72 °C. The cooked sausages were quickly

Table 3. Mean hedonic scores for overall acceptability of sausage samples.

Formulation	Mean hedonic score
CNB	5.7 ± 0.7^{d}
PoB	7.9 ± 0.9^{b}
PPB1	6.5 ± 0.5^{c}
PPB2	6.8 ± 0.1^{c}
PPB3	7.2 ± 0.8^{a}

Values are expressed as mean ± s.d. (n = 70). Mean values with different superscript letters along the columns are significantly different at $p < 0.05$. CNB is the control sausage without binder, PoB is the phosphate binder and PPB is a pigeon pea protein binder.

cooled to 15–20 °C, packed in polyethylene bags, and maintained at 4 °C in a refrigerator before analysis.

2.6. Sensory analysis

2.6.1. Descriptive sensory analysis

2.6.1.1. Selection and training of panelists. Sensory profiling was conducted with a panel of 9 panelists ranging in age from 23 to 28 years old at the Department of Food Science and Technology, Sokoine University of Agriculture (SUA). Written consent was taken from the panelists for their participation before the start of the test, and ethical clearance was obtained from the ethics committee of the Board of College of Agriculture Studies, Sokoine University of Agriculture (SUA) (MFQ/E/2018/0001/09 on 6th September 2019.

Seventeen (17) panelists were initially selected for the study based on their dedication, motivation, good health, and ability to work in a group (Lawless and Heymann, 2010). They were then subjected to a five-day, 2-h daily training program based on ISO standards 29842 (2011) and 8586 (2012), during which they developed attributes using various items as reference materials, such as beef Vienna sausage, table salt, and Himalayan color. The panelists eventually agreed on color, aroma, saltiness, mouthfeel, firmness, and hardness as the study's attributes (Table 2). In addition, the panelists devised a nine-point quantitative line scale for assessing attribute intensity, with 1 and 9 values representing the lowest and greatest intensities, respectively.

2.6.1.2. Panel performance evaluation. The performance of the panel and individual panelists in terms of their agreement and ability to discriminate between samples and reproducibility was assessed in two sessions using PanelCheck software V.I.4.2 (Tomic et al., 2010a). A small portion of the sausage samples was coded with 3-digit random numbers and provided to each panelist at 11:00 h in randomized order, and they were asked to rate the intensity of the attributes using the line scale provided. Water was provided for rinsing the mouth between the tests during the analysis. Data were subjected to univariate and multivariate analyses for Tucker and pMSE plots, whereby 9 panelists out of 17 total panelists were retained for the final actual test.

2.6.1.3. Actual descriptive test. The final selected nine panelists rated the attribute intensities of the five sausage samples on a questionnaire using a continuous, structured 9 cm line scale (Meilgaard et al., 2006) anchored at the ends by low and very pronounced for most attributes. The samples were coded with three-digit random numbers and served in a randomized order to each panelist. The obtained average responses were used in the univariate and multivariate analyses.

2.6.2. Acceptance test

The acceptance test was conducted secretly (without external information) and voluntarily by 70 untrained consumers of both sexes aged 20–45 years at the Department of Food Technology, Nutrition, and Consumer Sciences using a 9-point hedonic scale as described by Lawless and Heyman (2010). Written consent was taken from the panelists for their participation before the start of the test, and ethical clearance was obtained from the ethics committee of the Board of College of Agriculture Studies, Sokoine University of Agriculture (SUA) (MFQ/E/2018/0001/09 on 6th September 2019. The sausages were thawed and warmed in an oven (Turbofan 3000, Blue Seal, UK), then sliced into uniform 2 cm lengths and presented on white disposable plates with 3-digit numbers randomly assigned. The plates were then presented to the panelists in a randomized order, and they were asked to rate and express their overall acceptability on a nine-point hedonic scale (where 1 equals extremely dislike and 9

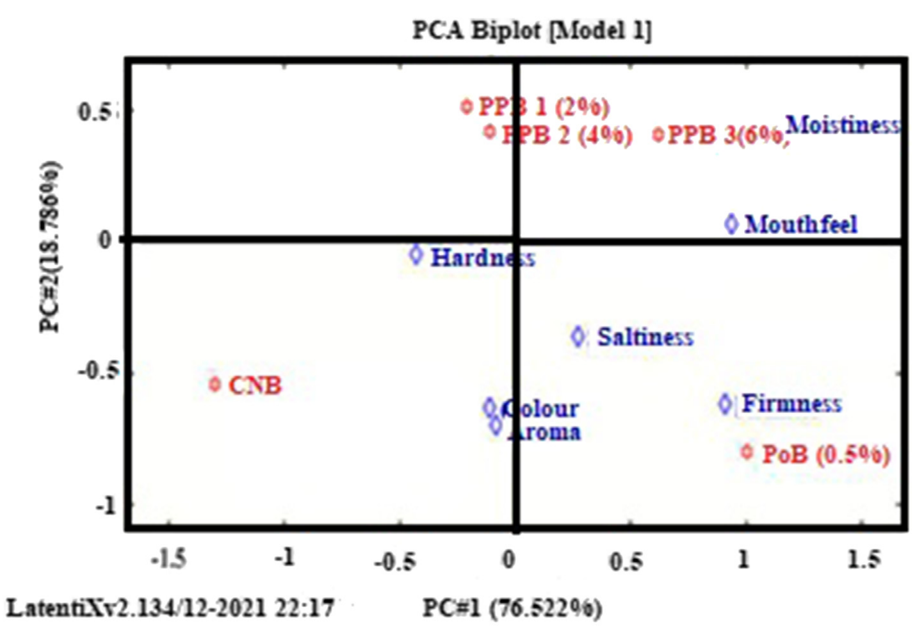

Figure 3. Bi-plot from PCA of descriptive sensory data for sausage samples. CNB is the control sample with no binder, PoB is the phosphate binder and PPB is the pea protein binder.

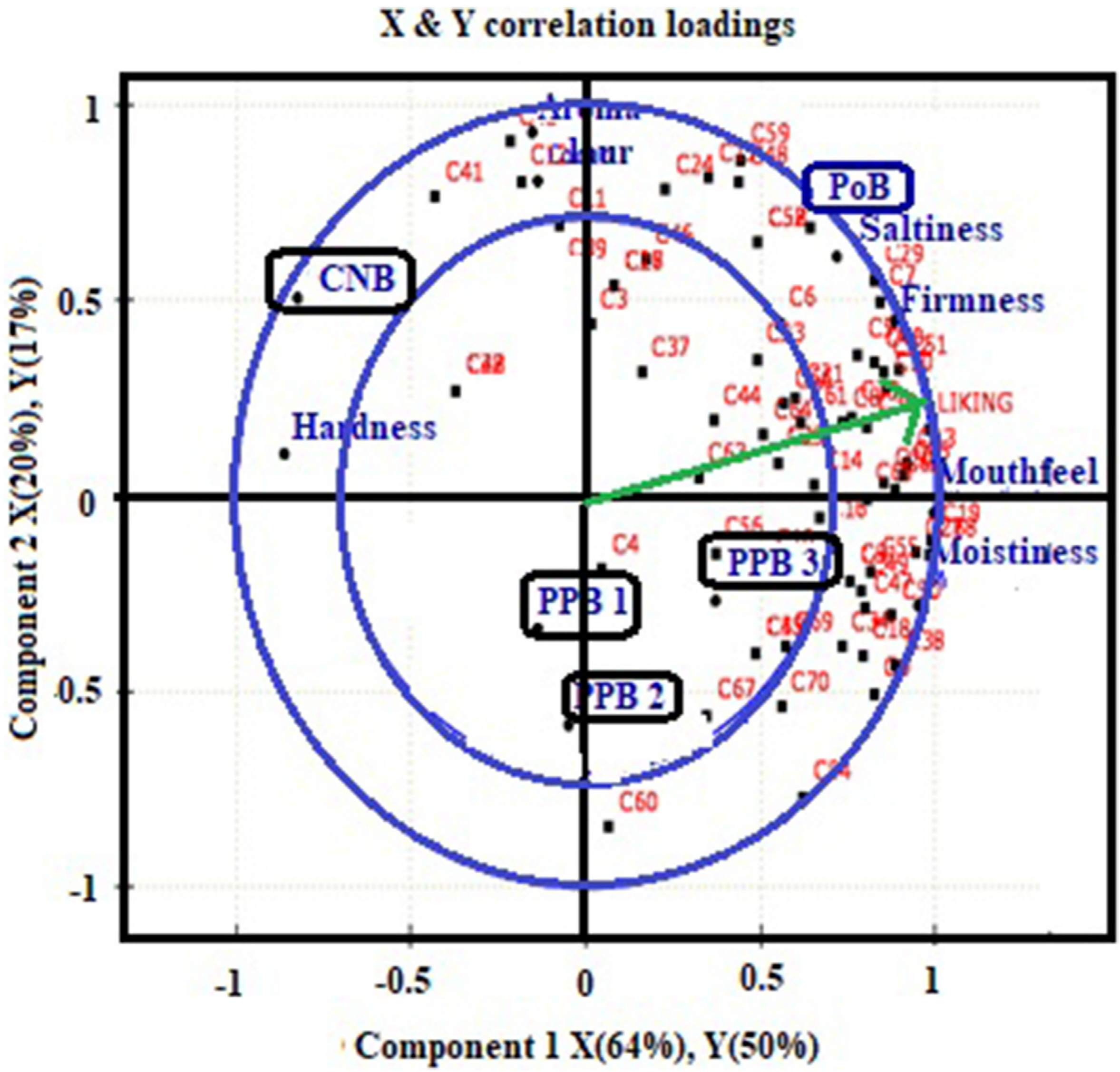

Figure 4. Correlation loadings from a partial least squares regression of sausage samples made from different binders with descriptive data as X variables and hedonic rating as the Y variable.

Table 4. Regression coefficients from PLSR showing the contribution of each sensory attribute to sausage sample preference.

Sensory attribute	Regression coefficient (β)
Colour	0.10
Aroma	0.10
Mouthfeel	0.30
Moistness	0.28
Hardness	−0.15
Firmness	0.40
Saltiness	0.15

equals extremely like). All good sensory practices such as blind labeling and mouth rinse between tastings were observed.

2.6.3. Relationship between descriptive sensory and acceptability data (preference mapping)

Preference mapping to ascertain drivers for consumer liking of the sausage samples was performed by relating descriptive sensory and hedonic data using partial least squares regression analysis (PLSR) as described by Tenenhaus et al. (2005). The descriptive data were regressed onto consumer data.

2.6.4. Conjoint analysis

A consumer test for conjoint analysis was conducted four days after the hedonic test, involving 90 consumers in three sessions. Sausage samples were prepared as in the hedonic test, and each panelist received nine sausage samples according to the factorial design and was asked to rate their liking using a 9-point scale from "dislike extremely" to "like extremely" based on the product's profile. The information on the product profile was provided to each panelist on a separate sheet of paper just before and throughout the test. At the end of each session, consumers filled in a questionnaire about their social-demographic characteristics (age and sex) and sausage consumption frequency. The questionnaire session also included a self-explicated test centered on direct rating (Sattler and Hensel-Börner, 2003). The consumers were asked to evaluate the importance of formulations and price when purchasing sausage on a 5 - point scale anchored at 1 = not important at all and 5 = very important.

Table 5. Mixed model ANOVA on conjoint rating data.

Source of variation	DF	P-value
Fixed effects		
Price	2	<0.001**
Product	2	<0.001**
Age	1	0.885
Frequency	1	0.412
Sex	1	0.341
Price * Product	4	<0.001**
Price * Age	2	0.896
Price * Frequency	2	0.252
Price * Sex	2	0.716
Product * Age	2	0.569
Product * Frequency	2	0.934
Product * Sex	2	0.457
Age * Sex	1	0.025*
Frequency * Sex	1	0.082
Random effects		
Consumer	1	1
Price * Consumer	1	1
Product * Consumer	1	1

2.7. Statistical data analysis

Quantitative descriptive analysis (QDA) and hedonic data were analyzed by using the R statistical package (R Development Core Team, Version 3.0.0, Vienna, Austria) for analysis of variance (ANOVA) using two factors (panelist and sample formulations). Means were separated by Tukey's honest significant difference (THSD) test at $p < 0.05$. Furthermore, principal component analysis (PCA) was used to determine the systematic variations in sensory data using Latentix software (Latentix Apps Team, version 2.12, Frederiksberg, Denmark). A partial least squares regression (PLSR) (Martens and Martens, 2001) was computed to determine the relationship between QDA and hedonic data to ascertain drivers for consumer liking. The QDA dataset matrix had 5 rows of products (CNB, PPB1, PPB2, PPB3) and 7 columns of sensory attributes (Colour, aroma, mouthfeel, moistness, hardness, firmness and saltiness). The consumer liking dataset had 5 rows of products and 70 columns of consumers.

Conjoint analysis data were analyzed using Mixed-effects ANOVA Model (Kuznetsova and Brockhoff, 2015; Næs et al., 2010). The model involved the main effects and two-factor interactions for the design variables plus random effects consisting of consumer effect and interaction between consumer and all fixed effects (both main and interaction ones) as described by Næs et al. (2010). ConsumerCheck software version 3.1.2 (Tomic et al., 2010b) was used to perform the analyses as described by (Kuznetsova and Brockhoff, 2015). The mathematical model is depicted in Eq. (2).

$$\begin{aligned} Y_{ijklmn} = {} & \mu + P_i + R_j + A_k + F_l + S_m + P_i * R_j + P * A_{ij} + P * F_{il} + P * S_{im} \\ & + R * A_{jk} + R * F_{jl} + R * S_{jm} + A * S_{km} + F * S_{lm} + C(A,F,S)_{nklm} \\ & + P * C(A,F,S)_{inklm} + R * C(A*F*S)_{jnklm} + \varepsilon_{ijklm}; \\ & j = 1;...; J; k = 1;...; K; l = 1;...; L; m = 1;...; M; \end{aligned} \tag{2}$$

where ***Yijklm*** is the (ijklm)th observation, μ is the general mean, *Pi, Rj, Ak, Fl and Sm* are the main effects of the five conjoint factors; price, product, age, frequency, and sex, *PiFl - FlSm* are the fixed interaction effects. The Ck represents the main effects of consumers and conjoint design variables and ε_{ijklm} is the random error. The product design dataset matrix had 9 rows of product names and one column with two levels of sausage pricing, whereas the consumer characteristics dataset included a row of consumers and two columns with consumer characteristics (Sex and age). The consumer liking dataset had one column of product names and 90 rows of consumers. The whole study experiment has been summarized in Figure 1.

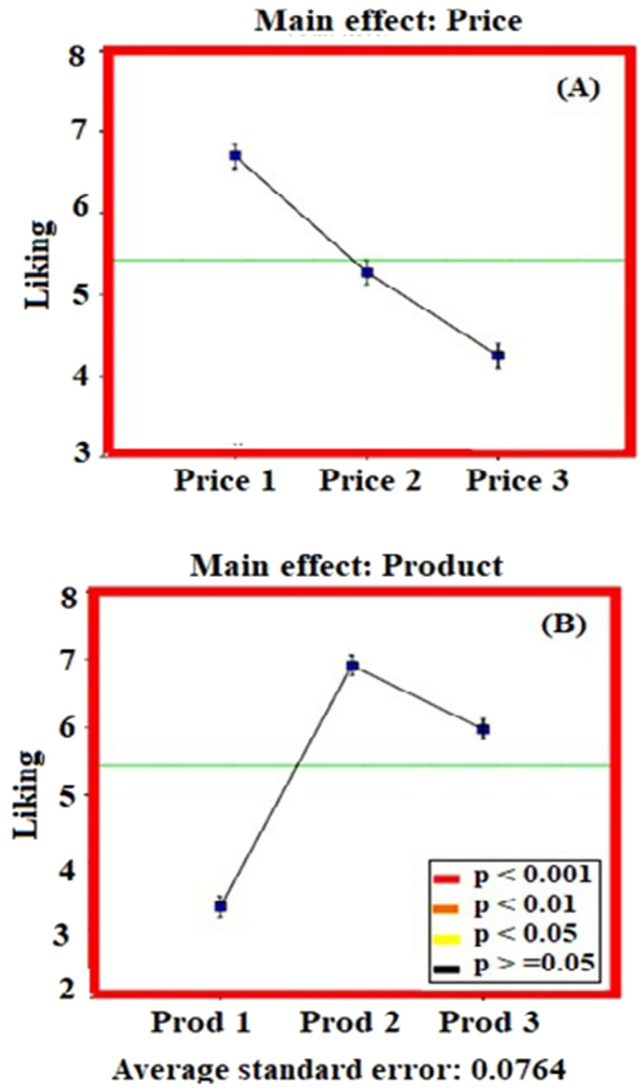

Figure 5. Significant main effects of product and price from conjoint analysis of sausage samples. Price 1 is TZS 652/ = , price 2 is TZS 700/ = , and price 3 is TZS 853/ = . Product 1 is control sausages without a binder (CNB), product 2 is sausages made with phosphate binder (PoB), and product 3 is a sausage made with 6% pigeon pea protein.

3. Results and discussion

3.1. Protein contents of the pigeon pea and the developed binder

A significantly higher protein content of 25 g/100 g was observed in the improved variety than in the local variety with a lower value of 22 g/100 g led to its selection for binder development. Furthermore, the extracted binder had a higher protein content of 32 g/100 g than its flour suggesting its suitability for application in restructured meat products like sausages. The observed high protein contents in pigeon pea were within the value of 20–30 % reported in legumes and which varies depending on a variety, genetic makeup, and environmental factors (Parihar et al., 2016; Meng and Cloutier, 2014). However, the values were less than those reported in other studies Akharume et al., 2021; Kyriakopoulou et al., 2021). This could be explained by the fact that the amount and properties of pea protein components can be influenced by the pea cultivar, the extraction technique, and the actual protein composition (legumin/vicilin ratio) (Cui et al., 2020).

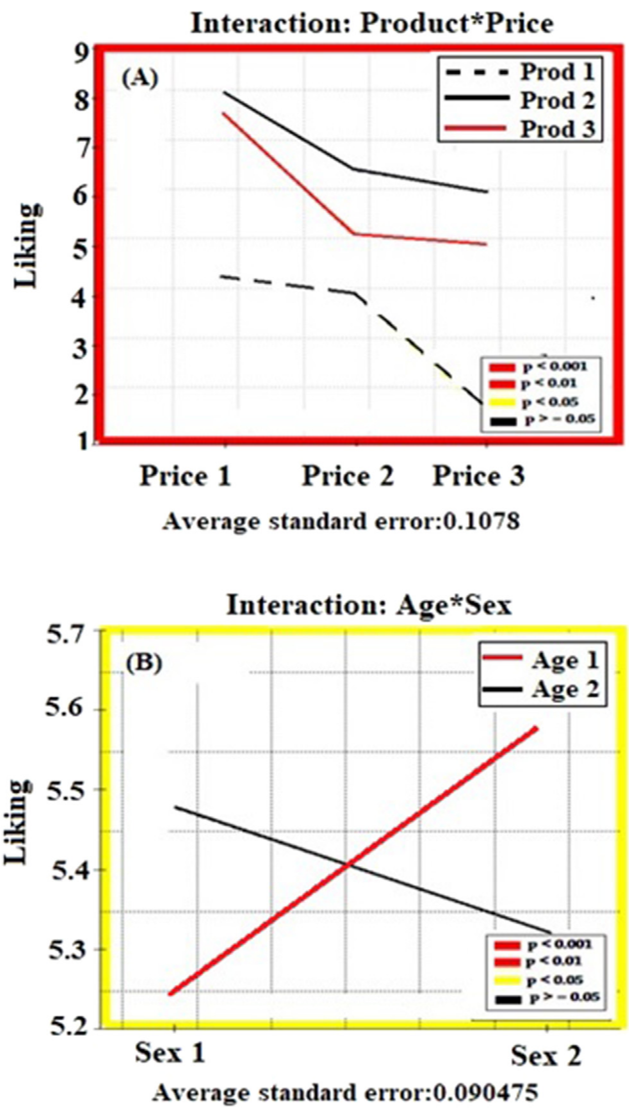

Figure 6. Interaction plots between product and price and age and sex. Price 1 is TZS 652/ =, price 2 is TZS 700/ =, and price 3 is TZS 853/ =. Product 1 is control sausages without a inder (CNB), product 2 is sausages made with phosphate binder (PoB), and product 3 is a sausage made with 6% pigeon pea protein. Sex 1 is male and sex 2 is female, while age 1 is young and age 2 is old.

3.2. Descriptive sensory profile of sausages

The mean intensity scores of sensory attributes between sausage formulations are shown in Figure 2. The 6% pea protein sausages (PPB3) had the significantly ($p < 0.05$) lowest hardness, aroma, and color intensity scores (5.8, 6.8, and 7.3 points) but a statistically similar ($p > 0.05$) moistness intensity score (7.4 points) to phosphate sausages (7.6). Control without a binder (CNB) and phosphate sausages (PoB) had significantly higher (p 0.05) mean color (8.2–8.3 points) and aroma (7.7–7.8 points) intensity scores than 6% pea protein sausages (7.3 and 6.8 points). Moreover, phosphate sausages had significantly ($p < 0.05$) the highest mouthfeel (6.9), hardness (6.4), and saltiness (5.8), followed by 6% pea protein sausages with 6.5, 5.6, and 5.1 points, respectively, and control sausages with the lowest values of all.

Pigeon pea protein had a significant effect on the sensory profile of the sausage samples. The reduced color intensity of 6% pea protein sausages was likely owing to the yellow tone color of pigeon pea protein, which deviated from the sausage's traditional brown hue as the level in the formulation was raised (Coombs et al., 2017). Color is one of the most important physical characteristics that determine a product's acceptance among consumers, and it may be easily changed by modifying the amount of non-meat ingredients in the formulation (Syuhairah et al., 2016). The high amount of protein in the 6% pea protein formulations increased the muscles' ability to hold water, improving physical and sensory attributes like softness and moistness (Long et al., 2017; Peng et al., 2009). Additionally, the meat's water and myofibrillar protein form stable hydrophobic interactions, resulting in a compact and moist sausage (Wi et al., 2020). Other studies (Omojola et al., 2013; Hidayat et al., 2017) have reported similar results. Babatunde et al. (2013) discovered that sausages with more legume proteins had higher moisture content and enhanced physical and sensory features, which was similar to the findings of this study. This suggests that they could be used as binders and functional enhancers.

However, legume proteins have a distinct "beany" flavor that is difficult to mask, which could have decreased the aroma and taste of the pea protein sausages, as well as their customer acceptance, as previously reported (Saint-Eve et al., 2019; Söderberg, 2013; Tárrega et al., 2012). As shown in previous studies (Peng et al., 2009) and Teye and Teye (2011), the lack of a binder in control samples explains their poor sensory characteristics and low customer acceptability (2011). Phosphate had a significant effect on the color of meat by increasing its buffering capacity, which helps the meat keep its fresh, stable color by changing the pH (Long et al., 2011). The observed increase in color and saltiness intensities in phosphate sausages may be due to the salty nature of the extra phosphates in the binder (Glorieux et al., 2017).

3.3. Consumer acceptance of sausages

3.3.1. Consumer panel characteristics

Of the total 70 consumers, 56% were male and 44% were female, with the majority (95%) being undergraduate students. Furthermore, 92% of them were between 20 and 35 years old, while only 5% consumed sausages daily. About 80% of consumers were willing to purchase the sausages when they were introduced to the market.

3.3.2. Overall consumer acceptability

Phosphate sausages were the most ($p < 0.05$) acceptable, followed by 6% pea protein sausages, with control and 2% pea protein samples being the least acceptable (Table 3). There were significant ($p < 0.05$) differences in overall consumer acceptability with the sausage from the phosphate binder being the most acceptable sample followed by sausages prepared from the 6% pea protein binder. The control and PPB (1-2) samples were the least acceptable sample.

The high consumer acceptance of phosphate sausages was likely owing to their strong sensory characteristics, which were important for the end product's quality and acceptance (Mihafu et al., 2019). Although phosphate sausages scored higher than others, the results demonstrate that adding pea protein binder to sausage formulations improves the sensory profile and consumer acceptability. Mokni et al. (2018) and Hidayat et al. (2017) also reported that the addition of protein to sausage significantly improved the acceptability of sausage to consumers.

3.3.3. Relationship between sensory descriptive attributes and acceptance by the PLSR

3.3.3.1. Principal component analysis of quantitative descriptive analysis data. Figure 3 shows a bi-plot with the two significant principal components (PCs) of the average sensory attributes of the sausage samples. Principal component 1 (PC1) accounted for 76.5% of the total variations, while PC2 accounted for 18.8%. Generally, the samples were differentiated into two major groups along with the PC 1; phosphate and 6% pea protein sausages, associated with high loadings of firmness, saltiness, mouthfeel, and moistness attributes; and control without binder and 2-4% pea protein sausages, associated with high loadings of hardness, color, and aroma attributes. The PC 2 was a contrast between the control (CNB and PoB) and the pea protein sausages (PPBs).

3.3.3.2. The relationship between descriptive data and hedonic liking (preference mapping). The relationship between descriptive data and hedonic liking is depicted in Figure 4. The first two key components are responsible for 84% of X changes and 67% of Y variability. Many consumers fall to the right of the vertical Y-axis, beyond the 50% explained circle, which is the direction of sausage liking, where the phosphate sausage sample is highly loaded, followed by the 6% pea protein sausages. The findings demonstrated that consumers liked sausages with a high intensity of saltiness, stiffness, mouthfeel, and moistness attributes. On the other hand, the significant correlation between hardness and low acceptability of the control without binder and 2% pea protein sausages implies consumers' preference for soft sausages.

Furthermore, the effect of each attribute on sausage liking is presented by the PLSR plot (Table 4). Firmness, mouthfeel, moistness and saltiness had a higher positive contribution to the sample acceptability. However, hardness contributed negatively to the acceptance of sausage samples. These results, support the results of consumers' liking (Table 3).

Preference mapping elucidates the intrinsic sensory characteristics that influence consumer acceptance, and the study's findings revealed that firmness, moistness, mouthfeel, and saltiness were the key drivers for consumer acceptability of sausages. This is consistent with earlier studies (Mongi et al., 2013), which show that a product's look, color, texture, and flavor serve as indicators of its intrinsic good quality and have a major impact on customer acceptance, selection, consumption, and satisfaction (Barrett et al., 2010).

3.3.4. Conjoint analysis

3.3.4.1. Consumer panel profile. The consumer panel consisted of 44.9% males and 55.1% females, the majority (91%) of whom were between the ages of 20 and 35. Furthermore, 78.7% were university students, with only 12.4% consuming sausage regularly and 80.9% willing to purchase pea protein sausages if they were available in the market.

3.3.4.2. Mixed ANOVA results. The findings of the ANOVA mixed model for liking with all of the experimental factors are shown in Table 5. The main effects of price and product on liking, as well as their interaction, were significant ($p < 0.01$). However, the effects of the consumer on liking and random interactions between the conjoint factors and the consumer were all statistically insignificant ($p > 0.05$).

Consumers preferred phosphate sausages over the control sausages (Figure 5a). Furthermore, they preferred the lower-cost sausages over the higher-cost sausages (Figure 5b).

The influence of the price and product interaction was similarly significant ($p < 0.001$) (Figure 6a). Phosphate and 6% pea protein sausages received higher consumer ratings of 8.1 and 7.6 points, respectively, at the low price of TZS 652/ =, but declined to around 7.6 and 5 points at the high price of TZS 853/ =. Similarly, control without binder sausages received a lower rating of 4.4 points, which dropped to 1.6 points when the price was increased. The only significant ($p < 0.05$) consumer characteristics interaction was that of sex and age, with older males and young girls preferring sausages over their counterparts (Figure 6b).

3.3.4.3. Self-explicated measures. The self-explicated measures revealed that price was the most important extrinsic factor for sausage liking, followed by the product variable ($t = 8.35$, $p = 0.00024$, $n = 90$), with a mean score of 4.6 against 3.7 points. This shows that extrinsic factors such as product formulations and price, in addition to intrinsic sensory attributes, influence sausage consumer preferences. The increased consumer acceptance of pea protein sausages compared to control samples, but almost equal to phosphate sausages, is most likely due to the protein content of the binder, which improved sensory characteristics and enhanced consumer acceptability. Gomezulu and Mongi. (2022) previously revealed that pigeon pea binder improves the physical qualities of sausages, which, when combined with the findings of this study, suggests that pigeon pea protein binders could be used to produce high-quality and acceptable sausages and other restructured meat products.

The significant effect of price on consumer acceptability and purchase intent could be explained by the fact that in low-income households, price is sometimes the most important factor when choosing food items, regardless of quality or nutritional content (Koen et al., 2018; Veale and Quester, 2006). Most individuals in the study and probably in developing nations do not eat sausage and other meat-based products regularly for various reasons, including cost (Font-I-Furnols and Guerrero, 2014), which may explain why price appeared as the most relevant variable in sausage liking. The first and most crucial factor is to get it for a reasonable price, with further considerations coming later. This indicates that employing pea protein as a binder in the production of high-quality but low-cost sausages will benefit the great majority of people, particularly in low-resource countries. Iop et al. (2006) reported a similar influence of price on consumer acceptability and purchase intent.

4. Conclusion

The 6% pea protein sausages (PPB 3) had the lowest mean hardness, aroma, and color intensity scores, but statistically similar highest moistness intensity score to the phosphate sausages. Phosphate sausages had also the highest mean color, and saltiness intensity compared to the lowest mean values in 6% pea protein sausages. The phosphate sausages were the most acceptable by consumers, followed by the 6% pea protein sausages, with aroma, saltiness moistness, and firmness being the key drivers in consumer acceptability of sausages. Furthermore, formulation and price had a significant effect on liking, with phosphate and lower-cost sausages being the most acceptable by consumers, followed by 6% pea protein sausages. Price was the most influential extrinsic attribute in affecting consumer preference. The findings demonstrated that increasing the amount of pea protein in the sausage formulations leads to improved sensory profiles and enhanced consumer acceptability, hence it is recommended for use in the food industry. However, studies into the optimal amount of pigeon pea protein binder for producing sausage with a greater sensory profile and consumer acceptability than phosphate binder are also recommended.

Declarations

Author contribution statement

Richard Mongi: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Alice Gomezulu: Conceived and designed the experiments; Performed the experiments; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Funding statement

This work was supported by Federal Ministry of Food and Agriculture – BMELMinisteriet for Fø devarer, Landbrug og Fiskeri (Announcement No. 18/16/12).

Data availability statement

The authors do not have permission to share data.

Declaration of interest's statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

Acknowledgements

The authors acknowledge the management of the **Vegi-Leg** Project at Leibniz-Zentrum für Agrarlandschaftsforschung (ZALF), Germany and the Sokoine University of Agriculture (SUA).

References

Akharume, F.U., Rotimi, E., Aluko, R.E., Adedeji, A.A., 2021. Modification of plant proteins for improved functionality: a review wileyonlinelibrary.com/journal/crf3. Comp. Rev. in Food Sci. Food Saf. 20, 198–224.

A.O.A.C., 2005. Official methods of analysis of AOAC international. In: AOAC International Suite, eighteenth Edition 500. OAOC Internation, p. 481. North Frederick Avenue, Gaithersburg. Maryland, USA.

Babatunde, O.A., Ayodeji, A.V., Olufemi, O.O., 2013. Quality of breakfast sausage containing legume flours as binders. J. Biol. Life Sci. 4 (2), 157–164.

Barrett, D.M., Beaulieu, J.C., Shewfelt, R., 2010. Color, flavor, texture, and nutritional quality of fresh-cut fruits and vegetables: desirable levels, instrumental and sensory measurement, and the effects of processing. Crit. Rev. Food Sci. Nutr. 50 (5), 369–389.

Civille, G.V., Carr, B.T., 2015. C. Sensory Evaluation Techniques, Fifth Edition. Taylor & Francis, pp. 1–512.

Coombs, C.E.O., Holman, B.W.B., Friend, M.A., Hopkins, D.L., 2017. Long-term red meat 863 preservation using chilled and frozen storage combinations: a review. Meat Sci. 125, 84–94.

Cui, L., Bandillo, N., Wang, Y., Ohm, J.B., Chen, B., Rao, J., 2020. Functionality and structure of yellow pea protein isolate as affected by cultivars and extraction pH. Food Hydrocoll. 108, 106008.

Emefiene, E., Joshua, V.I., Nwadike, C., Yaroson, A.Y., Zwalnan, N.D.E., 2014. Profitability analysis of pigean pea (Cajanus cajan) production in Riyom LGA of plateau state. Int. Lett. Nat. Sci. 13 (2), 73–88.

FAO Statistics, 2017. Pigeon Producing Countries. Production and Area Harvested Food and Agriculture Organization of the United Nations, Rome.

Fatokimi, F.O., Tanimonure, V.A., 2021. Analysis of the current situation and future outlooks for pigeon pea (Cajanus Cajan) production in Oyo State, Nigeria: a Markov chain model approach. J. Agricul. Food Res. 6, 100218–101543.

Font-I-Furnols, M., Guerrero, L., 2014. Consumer preference, behavior, and perception about meat and meat products: an overview. Meat Sci. 98, 361–371.

Glorieux, S., Goemaere, O., Steen, L., Fraeye, I., 2017. Phosphate reduction in emulsified meat products: impact of phosphate type and dosage on quality characteristics. Food Technol. Biotechnol. 55 (3), 390–397.

Gomezulu, A.D., Mongi, R.J., 2022. Protein content and anti-nutritional factors in pigeon pea and effect of its protein isolate on physical properties and consumer preference of beef sausages. Appl. Food Res. 2 (2022), 100047.

Gustafsson, A., Herrmann, A., Huber, F., 2003. Conjoint Measurement. Methods Andapplications. Springer, Berlin, Germany.

Hidayat, B.T., Wea, A., Andriati, N., 2017. Physicochemical, sensory attributes, and protein profile by SDS-PAGE of beef sausage substituted with texturized vegetable protein. J. Food Res. 2 (1), 20–31.

Inetianbor, J.E., Yakubu, J.M., Ezeonu, S.C., 2015. Effects of food additives and preservatives on Man: a review. Afr. J. Sci. Technol. 6 (2), 1118–1135.

Iop, S.C.F., Teixeira, E., Deliza, R., 2006. Consumer research: extrinsic variables in food studies. Br. Food J. 108 (11), 894–903.

ISO 29842, 2011. Sensory Analysis, Methodology, and Balanced Incomplete Block Designs. https://www.iso.org/standard/64716/html] site visited on 12/07/2020.

ISO 8586, 2012. Sensory analysis: General guidelines for the selection, training, and monitoring of selected assessors and expert sensory acceptors. https://www.iso.org/standard/45352.html.

Kaoneka, E.R., Saxena, R.K., Silim, S.N., Odeny, D.A., Rao, N.V., Shimelis, H.A., Moses, S., Varshney, R.K., 2016. Review Pigeonpea breeding in eastern and southern Africa: challenges and opportunities. Plant Breed. 135, 148–154.

Koen, N., Wentzel-Viljoen, E., Nel, D., Blaauw, R., 2018. Consumer knowledge and use of food and nutrition labeling in South Africa: a cross-sectional descriptive study. Int. J. Consum. 42 (3), 335–346.

Kuznetsova, A., Brockhoff, P.B., 2015. Linear Mixed Models in Sensometrics. Kgs. Lyngby. Technical University of Denmark (DTU) (DTU Compute PHD-2015; No. 374).

Kyriakopoulou, K., Keppler, J.K., van der Goot, A.J., 2021. The functionality of ingredients and additives in plant-based meat analogues. Foods 10, 600.

Lam, A.C.Y., Can Karaca, .A., Tyler, R.T., Nickerson, M.T., 2018. Pea protein isolates structure, extraction, and functionality. Food Rev. Int. 34 (2), 126–147.

Lawless, T.H., Heymann, H., 2010. Sensory Evaluation of Foods: Principles and Practices, second ed. Springer, New York, London, p. 1251.

Li, L., 2019. The effect of soy protein isolate, starch, and salt on qualityof ready-to-eat restructured beef products. Int. J. Food Eng. Technol. 3 (2), 31–44.

Long, N.H.B.S., Gál, R., Buňka, F., 2011. Use of phosphates in meat products. Afr. J. Biotechnol. 10 (86), 19874–19882.

Maphosa, Y., Jideani, V.A., 2017. The role of legumes in Human nutrition. J. Funct.Foods 10, 57–72.

Martens, H., Martens, M., 2001. Multivariate Analysis of Quality; an Introduction. John Wiley & Sons, Leicester, UK, p. 445.

Meilgaard, M.C., Carr, B.T., Civille, G.V., 2006. Sensory Evaluationtechniques, fourth ed. CRC Press, New York.

Meng, Y., Cloutier, S., 2014. Gelatin and other proteins for microencapsulation. microencapsulation in the food industry: A practical implementation guide, pp. 227–239.

Mergeai, G., Kimani, P., Mwang'ombe, A., Olubayo, F., Smith, C., Audi, P., Baudoin, J.P., Le Roi, A., 2001. Survey of Pigeonpea Production Systems, Utilization and Marketing in Semi-arid Lands of Kenya. BASE.

Mihafu, D.F., Issa, Y.J., Kamiyango, W.M., 2019. Implication of sensory evaluation and quality assessment in food product development: a review. Curr. Res. Nutr. Food Sci. 8 (3), 690–702.

Mokni, A., Ben Amira, A., Makhlouf-gafsi, I., Lahiani, M., Bejar, M., Triki, M., Zouari, A., Attia, H., Besbes, S., 2018. Toward the enhancement of sensory profile of sausage "Merguez" with chickpea protein concentrate. Meat Sci. 143.

Mongi, R.J., Ndabikunze, B., Chove, B., Wick, L.T., 2013. Descriptive sensory analysis, consumer liking, and preference mapping for solar dried mango cv dodo. J. Food Qual. 16, 16–23.

Næs, T., Almli, V.L., Bølling Johansen, S., Hersleth, M., 2010. Alternative methods forcombining design variables and consumer preference with information about attitudes and demographics in conjoint analysis. Food Qual. Prefer. 21 (4), 368–378.

Olagunju, A.I., Omoba, O.S., Enujiugha, V.N., Alashi, A.M., Aluko, R.E., 2018. Pigeon pea enzymatic protein hydrolysates and ultrafiltration peptide fractions as potential sources of antioxidant peptides: an in vitro study. LWT – J. Food Sci. Technol. 6 (4), 566–574.

Omojola, A.B., Adentuji, V.A., Olusola, O.O., 2013. Quality of breakfast sausage containing legume flours as binders. J. Biol. Life Sci. 4 (2), 617–623.

Parihar, A.,K., Bohra, A., Dixit, G.P., 2016. Bio-fortification of Food Crops. Nutritional Benefits of winter Pulses with Special Emphasis on Peas and Rajmash. Springer, India, pp. 61–71p.

Pazmiño, A., Vásquez, G., Carrillo, W., 2018. Pigeon pea protein concentrate (Cajanus Cajan) seeds grown in Ecuador functional properties. Asian J. Pharm. Clin. Res. 11 (6), 430–435.

Peng, W., Xu, X., Zhou, G., 2009. Effects of meat and phosphate level on water-holding capacity and texture of emulsion-type sausage during storage. Agric. Sci. China 8 (12), 1475–1481.

Ritz, E., Hahn, K., Ketteler, M., Kuhlmann, M.K., Mann, J., 2012. Phosphate additives in food—a health risk. Deutsches Ärzteblatt Int. 109 (4), 49–55.

Saint Eve, A., Granda, P., Legay, G., Cuvelier, G., Delarue, J., 2019. Consumer acceptance and sensory drivers of liking for high plant protein snacks. J. Sci. Food Agric. 99 (8), 3983–3991.

Sattler, H., Hensel-Börner, S., 2003. A comparison of conjoint measurement with self-explicated approaches. In: Gustafsson, A., Herrmann, A., Huber, F. (Eds.), Conjoint Measurement: Methods and Applications. Springer, Berlin, pp. 147–159.

Saxena, K.B., Kumar, R.V., Sultana, R., 2010. Quality nutrition through pigeon pea-a review. Health 2 (11), 1335–1344.

Söderberg, J., 2013. Functional Properties of Legume Proteins Compared to Egg Proteins and Their Potential as Replacers in Vegans. MSc Dissertation. Sweden University of Agricultural Sciences. https://stud.epsilon.slu.se/6240/7/soderberg_j_131101.pdf.

Syuhairah, A., Huda, N., Syahariza, Z.A., Fazilah, A., 2016. Effects of vegetable incorporation on physical and sensory characteristics of sausages. Asian J. Poultry Sci. 10 (3), 117–125.

Tárrega, A., Ramirez-Sucre, O.M., Vélez-Ruiz, F.J., Costell, E., 2012. Effect of whey and pea protein blends on the rheological and sensory properties of protein-based systems flavoured with cocoa. J. Food Eng. 109 (3), 467–474.

Tenenhaus, M., Pages, J., Ambroisine, L., Guinot, C., 2005. PLS methodology to study relationships between hedonic judgments and product characteristics. J. Food Qual. Pref. 16, 315–325.

Teye, M., Teye, G., 2011. The use of sweet potato (*Ipomoea Batatas*) starch as a binder in beef and pork frankfurter-type sausages. J. Anim. Sci. Adv. 1 (1), 21–27.

Tomic, O., Kuznetsova, A., Brockhoff, P.B., Graff, T., Naes, T., 2010a. ConsumerCheck: software for analysis of sensory and consumer data. J. Stat. Software 5 (2), 1–44.

Tomic, O., Luciano, G., Nielsen, A., Hylding, G., Lorensen, K., Naes, T., 2010b. Analysing sensory panel performance in proficiency tests using the PanelCheck software. Eur. Food Res. Tech. 230, 497–511.

Veale, R., Quester, P., Karunaratna, A., 2006. The Role of Intrinsic (Sensory) Cues and the Extrinsic Cues of the Country of Origin and price on Food Product Evaluation. 3rd International Wine Business and Marketing Research Conference, Montpellier.

Wi, G., Bae, J., Kim, H., Cho, Y., Choi, M., 2020. Evaluation of the physicochemical and structural properties and the sensory characteristics of meat analogues prepared with various non-animal-based liquid additives. Foods 9 (4), 461.

Xue, S., Zou, Y., Chen, X., Yang, H., Xing, T., Xu, X., Zhou, G., 2016. Effects of sodium tri-polyphosphate on functional properties of low-salt single-step high-pressure processed chicken breast sausage. Int. J. Food Sci. 51, 2106–2113.