Pigeon Peas: An Opportunity for Improving Nutrient Content of Food Consumed among Resource-Poor Households to Ensure Sustainable Health

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Abstract

Pigeon pea is an affordable legume and important source of protein, fibre, vitamins and minerals. Despite its nutritional importance, the crop has not been adequately utilized for human consumption in Tanzania due to limited recipes, knowledge and inadequate agricultural development. This study aimed utilising pigeon peas to enrich the nutrient content of food consumed among resource poor households Laboratory-based experiments and consumer preference tests were conducted in Morogoro and Lindi regions. A total of 452 consumers were involved to collect both qualitative and quantitative data. Analysis of Variance was used to check whether there is a difference between sample means. Tukey test was used to determine differences between the samples at $p<0.05$. Pigeon pea-based noodles, instant porridge, chapatti, biscuits, African doughnut and bread were developed and tested for their sensory attributes at a five-point Likert scale. Developed products had more than 50% of recommended intake of protein, iron, zinc and pro vitamin A. Highest preference scores for colour, aroma and mouthfeel were observed in all pigeon pea-based products with differences between samples. Samples PPBN718 (noodles), PPIPofspr (porridge), PPBS123 (biscuit), PPBC412 (chapatti), PPAD234 (African doughnut) and PPBB917 (bread) were most preferred among others. The Pairwise Comparison counts indicated that 87% of consumers most preferred instant porridge and 58% preferred the bread. The reason for preferences differs significantly among age groups and sex. Incorporate pigeon peas flour into different foods significantly improve the nutrient content of developed foods products. This creates an opportunity of pigeon peas to enrich different foods products.

Keywords: Pigeon pea-based products, dietary improvement, sensory attributes, resource-poor household

Introduction

Pigeon pea is among perennial crops that are grown in semi-arid parts of the world including Asia, Africa, Latin America and the Caribbean (Sharma *et al.,* 2011). It is a legume that can be grown in area that receive minimal rainfall (400mm) and is grown as an intercrop with maize in different areas of Sub-Saharan Africa (Mponda *et al.,* 2014; Abate *et al.,* 2012; Simtowe *et al.,* 2010; Shiferaw *et al.,* 2007). Pigeon pea was chosen because it is one of the most drought-tolerant legumes (Shiferaw *et al.,* 2007; Sharma *et al.,* 2011). It is ranked the third most important legume after beans and groundnuts in Tanzania (Simtowe *et al.,* 2011). It is used as food as well as a source of income. It is also among legumes that are affordable and important sources of protein, vitamins and minerals for most households that can help in improving nutrition security among resource-poor households (Abebe, 2022; Miano *et al.,* 2020; Cheboi *et al.,* 2019). India and Myanmar are the main producers of pigeon peas in Asia (Sharma *et al.,* 2011), whereas, in sub-Saharan Africa, the main producers are Malawi, Kenya, Uganda, Tanzania and Mozambique (Abate *et al.,* 2012). It is among the legumes that contribute towards food and nutrition security most significantly, hence contributing greatly to food sustainability in Sub-Saharan Africa.

The prevalence of undernourishment persists to be high in the world. About 735 people in the world were undernourished (FAO, IFAD, UNICEF, WFP & WHO, 2023).

Among them 281.6 million are form Africa, 262 million from Sub Saharan Africa and 14.9 million were from Tanzania. In Tanzania, about 30% of children are stunted and only 19% of children aged 6–23 months met the minimum dietary diversity (MoH *et al.,* 2022). Among stunted children, 64% were from resource-poor households. About 7.3% of women aged 15-49 years were underweight and 29% were anaemic. Insufficient dietary macro and micronutrient consumption are among the challenges in the growth and development of the individual (FAO, IFAD & UNICEF, 2022). The situation can be due to low per capita consumption, economic slowdown, and adverse climate events (IFPRI, 2016).

A typical diet of resource-poor households in Tanzania is mainly cereal-based foods (Minja *et al.,* 2021; Ochieng *et al.,* 2017) such as a large portion of stiff porridge with little or no protein relish. This kind of diet is monotonous and less diversified with little or no protein sources, vegetables and fruits. The main source of protein for resource-poor households is obtained from legumes (Mfikwa & Kilima, 2014) that are affordable and widely grown in their area. Prolonged consumption of cereal-based foods with little protein or less diversified, results in inadequate intake of daily nutritional requirements responsible to support growth and development. This can lead to Macro and Micronutrient deficiencies. It was hypothesised that addition of pigeon peas significantly, increase protein, iron, zinc and vitamin A content of developed pigeon pea-based noodles, biscuits, instant porridge flour, bread, African doughnuts and biscuits. Therefore, to address these challenges, this study aimed at utilising a nutrient-dense legume (pigeon peas in this study) to enrich different foods products to improve nutrient content of food consumed in the household.

Therefore, the study aimed to utilize pigeon peas flour to improve dietary quality for sustainable health. Specifically, the study (i) identified the best combination of ingredients to develop pigeon pea-based noodles, instant porridge, chapatti, biscuits, African doughnut, and bread (ii) developed the pigeon pea-based noodles, instant porridge, chapatti, biscuits, African doughnut, bread (iii) determined the most preferred sample and attributes of the developed pea-based products

Materials and Methods

Study Location, Size and Population

The study was conducted in Morogoro Municipality, Nachingwea and Ruangwa district councils. In Morogoro Municipality the study was conducted at the Magadu ward which was purposively chosen because it is closer to Sokoine University of Agriculture where the product was developed. The study was also conducted in Mibure village in Ruangwa and Mitumbati village in Nachingwea District. The two district councils and villages were chosen because they are among the leading producers of pigeon peas in the two districts.

The study involved different consumers age group (9-14 years, 15-24 years, 25-60 years) to capture preference variations. Fisher's formula was used to calculate desired sample size. The prevalence of anemia (58%) among children (MoHCDGEC *et al.,* 2016), effect size of 0.05, confidence interval of 95 and attrition rate of 10% was used for sample size calculation.

A total of 412 consumers were randomly selected after stratification in terms of their age, sex and area of residence. A list of all adults (25-60 years), youth (15-24 years) and school children (9-14 years) in the selected villages was established to determine the total number in strata. Then random selection was done proportionate to the number of consumers in each stratum. More adults aged between 25-60 years were involved that other age groups due to higher proportion. Random selection was done using the Excel Random number function RAND after the identification of the required sample in each stratum.

Study Design and Data Collection

Laboratory-based experiments and consumer survey was conducted in a different phase. Laboratory-based experiments were conducted during product development after the identification of all ingredients required. Linear programming simplex method was used to determine best combination of the ingredients and amount of nutrient in each formulation.

Objective function, decision variables and constraint were cost of ingredients in 1000g, nutrients content in 100g of dry matter of the ingredients and Recommended Nutrient contents for adults and children respectively. Tanzania food composition table and Kenya food composition table was used to determine the nutrient content of each ingredient used in the formulation. Recommended Nutrient Intake (RNI) of protein, iron, zinc and pro vitamin A for children aged 1-3 years was used as decision variables for the instant porridge flour (FAO & WHO, 2004; IOM, 2002) and RNI for adults aged 19-60 years was used during formulation of noodles, chapatti, bread, biscuits and African donut (FAO & WHO, 2004; IOM, 2002). The equation for calculation and optimisation process was described elsewhere (Majili *et al.,* 2023; Sheibani *et al.,* 2018; Briend *et al.,* 2003; Briend *et al.,* 2001). Six pigeon pea-based products were developed (noodles (PPBN), chapatti (PPBC), biscuits (PPBS), African doughnut (PPAD), instant porridge (PPIP), and bread (PPBB)) following the procedure describe in Figure 1. Four sample per product were formulated and developed to increase choice preference. All products were formulated and developed with roasted pigeon peas except for instant porridge flour whereas two samples were made with blanched pigeon peas flour.

A consumer survey was conducted to assess the preferences for the sensory attributes (aroma, colour, mouthfeel, softness and overall liking) of the developed products. A structured questionnaire was used to collect socio-demographic characteristics and preference ratings of the developed products. All consumers were asked to fill in their socio-demographic characteristics before assigning the samples for testing. A Complete Randomised Block Design (CRBD) was used during the preference test. Four samples of each product developed were served at a time. Consumers were asked to test the sample one at a time and rate colour, aroma, mouthfeel, saltiness, softness and overall liking on a five-point scale (1 = extremely not preferred, 5 extremely preferred). The testing was done in triplicates for each sample of the developed products. A total of 10 panellist per test were involved. During the test consumers were asked to rinse the mouth with clean safe water. Testing of the pigeon pea-based products was done on different 5 days (one product per day) to reduce confusion of the culinary attributes among consumers. All developed pigeon peas-based products (noodles, instant porridge, African doughnuts, bread, biscuit and chapatti) were well-cooked before serving (Fig. 1). All samples to be tested were packed into different containers with three-digit unique numbers to avoid biases. The samples were randomly assigned to consumers (10 consumers per test) during the testing exercise.

All preferred samples in each product were identified and taken to the consumer for comparison and prioritization. The Garret Henry techniques and Pairwise comparison (PC) method was used during the prioritization of preferred developed and tested pigeon pea-based products. Each consumer was asked to rank in order of preference all pigeon peas products using the Garret Henry techniques as described earlier (Majili *et al.,* 2022). Thereafter, each age group were asked to discuss in a group and conduct a binary comparison of the developed pigeon pea-based product using a Pairwise comparison (PC) matrix table as described by Majili *et al.* (2022).

Data Analysis

R software version (3.6.2 version) was used to summarise the preference data whereas mean and standard deviations were calculated to summarise the preference scores. Analysis of variance (ANOVA) was computed to establish mean differences among the samples. The dependent variable was product attributes (colour, aroma, mouthfeel, softness and overall liking) were considered as a dependent variable which was tested against sample formulations and panellists (consumers). Statistical significance was considered at $p\text{-value} < 0.05$. The Tukey pairwise test was used to determine the differences between the sample means. The Garrett ranking conversion table was used to standardize individual ranking scores before calculating the Garrett mean (GM) score. Rank command in Excel software Version 2016 was used to rank hierarchically the most preferred pigeon pea-based products. Further,

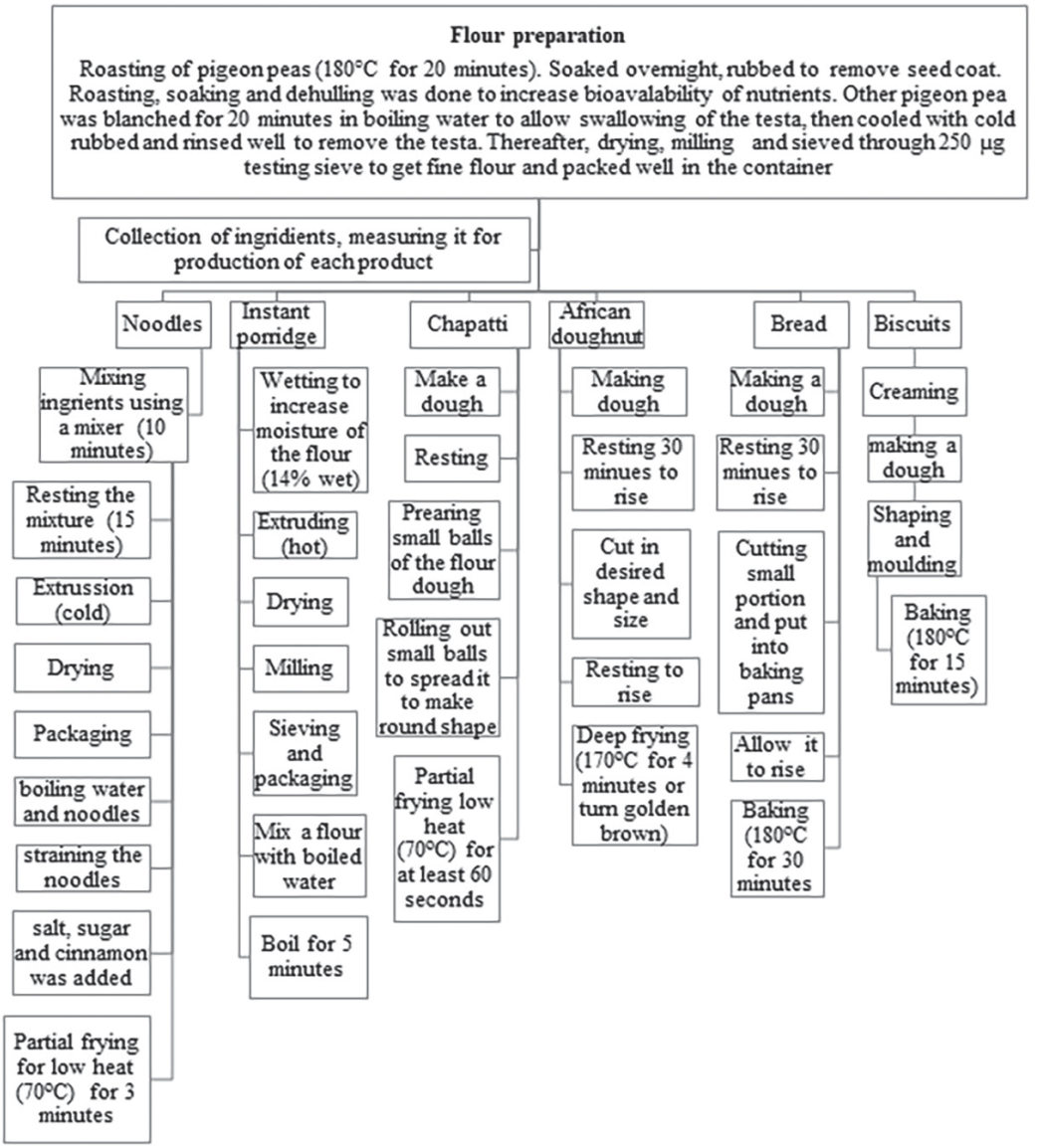

Figure 1: Preparation and production process of each pigeon pea-based product

the Rank command was used to rank the PC counts obtained after summing up the binary comparison of the pigeon peas products in the PC matrix. Logistic regression analysis was performed to determine predictors that influence consumers' preference for developed products. Preference scores were set as outcome variables and explanatory variables were consumers' characteristics (age, sex, education level, consumption of pigeon peas and their frequencies)

Results

Sociodemographic characteristics of the consumers

Table 2 shows the sociodemographic characteristics of consumers who participated in the preference test. A total of 452 consumers were involved in this study among them 43% were aged between 25 and 60 years. About 59% were females, 53% of consumers had primary and 56 % reported to consume pigeon peas.

Table 2: Sociodemographic characteristics of the consumers

Categories	All (n=412) %	Ruangwa (n=124) %	Nachingwea (n=86) %	Morogoro (n=202) %
Sex				
Female	59	62	58	53
Male	41	38	42	47
Age groups				
9-14 years	20	25	27	16
15-24 years	37	33	33	42
25-60 years	43	42	40	42
Education				
No formal education	2	2	3	1
Primary school	53	71	77	34
In school	20	19	16	18
Secondary school	25	9	3	46
Consumption of pigeon peas				
No	43	1	2	84
Yes	56	99	98	16
Consumption frequency				
Daily	2	2	1	0
Once/week	23	9	12	31
Once/month	21	3	3	54
More than once/week	55	68	65	0
Occasionally	35	18	19	16

Amount of Ingredients in each Developed Pigeon Pea-based Products

Table 1 indicate amount of each ingredient in each formulation of instant porridge, noodles, African doughnuts, bread, chapatti and biscuits. The amount of ingredients differs in each formulation in order to have different qualities that can increase consumer choices. Also, the formulation considered RNI for individual. In all formulation the RNI was set at least to meet 50% of RNI for protein, iron, zinc and vitamin A.

Nutrient Composition of Preferred Developed Products

All samples developed had protein, iron, zinc and pro vitamin A content more than 50% of RNI and the amount of these nutrients differ between samples in each pigeon pea-based product developed (Table 3). The highest amount of protein (14/100g of dry matter), iron (8 mg/100g of dry matter) and pro-vitamin A (305 g RE/100g) was observed in sample PPIPofspr of instant porridge flour. Sample PPBN718 for noodles had higher amount of protein (51/100g of dry matter), iron (24 mg/100g of dry matter), zinc (12 mg/100g of dry matter) and pro-vitamin A (920 µg RE/100g dry matter). Samples PPAD234/PPBC234/PPBB917 had higher amount of protein (48/100g of dry matter), iron content of 21 mg/100gdry matter, 11 mg/100g dry matter and 626 µg RE/100g. a biscuit sample PPBS624 had protein content of 37g/100g dry matter, iron (16 mg/100g of dry matter and zinc 11 mg/100g dry matter.

Preference Scores for Different Samples of the Developed Pigeon Pea-based Products

The overall liking of the developed pigeon pea-based products differs significantly among

Table 1: Amount of ingredients in each formulation

Pigeon pea-based product	Maize (g)	Pigeon peas (g)	¹OFSP/²PF/³BB (g)	Wheat flour (g)
$PPIP_{pf}^{b}$	65	50	402	-
$PPIP_{pf}^{r}$	65	50	402	-
$PPIP_{ofsp}^{r}$	65	50	201	-
$PPIP_{ofsp}^{b}$	65	50	201	-
PPBN193	-	160	451	130
PPBN718	-	160	451	240
PPBN193	-	80	451	130
PPBN517	-	130	451	80
PPAD234/PPBC234/PPBB917	-	175	251	130
PPAD674/PPBC4126/PPBB523	-	130	251	250
PPAD149/PPBC516/PPBB723	-	130	251	130
PPAD124/PPBC234/PPBB354	-	130	251	175
PPBS624	-	150	1503	100
PPBS234	-	100	1503	150
PPBS123	-	100	1503	100
PPBS452	-	150	1503	50

PPIP - pigeon pea-based instant porridge, PPBN = pigeon pea-based noodles, PPAD= pigeon pea-based African doughnuts, PPBC = pigeon pea-based chapatti, PPBB = pigeon pea-based bread, PPBS = pigeon pea-based biscuits,

the samples (Table 4). Sample PPBN718 for noodles has higher mean intensity scores for colour (4.7±1.87), aroma (4.8±1.99a), mouthfeel (4.6±2.00), softness (4.7±1.94) and liking (4.9±0.74). Sample PPBS123 for biscuits had a higher mean of overall liking (4.9±1.12). Similar sample PPIPofspr for porridge differ significantly from other samples of porridge (PPIPofspb, PPIPpfr and PPIPpfb) in terms of colour (4.9±0.29), mouthfeel (4.9± 0.35) and softness (4.9±0.35). Sample PPBC234 for chapatti had higher mean liking scores for colour (4.1±0.66), aroma (4.6±1.74), mouthfeel (4.1±0.83a) and overall liking (4.7±2.26). For African doughnut and bread samples, PPAD234 and PPBB917 respectively had higher overall liking scores and sample PPAD149 and PPBB523 had lowest overall liking scores.

3.5 Prioritization of Developed Pigeon Pea-based Product

Overall highest Garrett mean score was 35.28 for instant porridge flour, while the least overall score was 25.87 for bread. However, products score varied between regions, while instant porridge flour was highly scored in Ruangwa and Nachingwea, chapatti was highly scored in Morogoro. Nonetheless, this variation between districts was statistically significant at p value 0.002. Moreover, variation in product ranking was also observed between age groups and sex of consumers. The age group between 9-14 years ranked biscuits highest, while the 15-24 years cohort ranked chapatti highest, and similarly group age between 25-60 years ranked instant porridge flour highest (Table 5). This ranking variation between age groups was found to be statistically significant (p = 0.002). In terms of sex, female ranked instant porridge flour highest whereas male ranked chapatti highest.

The Pairwise Comparison (PC) counts indicated that 87% of consumers preferred instant porridge flour, and 86% of consumers preferred biscuits (Table 6). There were significant differences in PC counts among consumers' areas of residence (p=0.000), sex (p=0.007), and age (p=0.041). About 98% and

Table 3: Nutrient content of developed pigeon pea-based products in 100g of the dry matter of the mixture and percent contribution in RNI

Pigeon pea-based product	Protein g (%)	Iron mg (%)	Zinc mg (%)	Vitamin A µg RE (%)
$PPIP_{pf}^{b}$	12(98)	5(42)	5(60)	242(60)
$PPIP_{pf}^{r}$	13(106)	6(57)	5(60)	242(60)
$PPIP_{ofsp}^{r}$	14(109)	8(73)	4(48)	305(76)
$PPIP_{ofsp}^{b}$	13(102)	6(58)	3(36)	305(76)
RNI (Children)	13	11	8.3	400
PPBN193	40(71)	18(100)	10(71)	818 (91)
PPBN718	51(93)	24(135)	12(86)	920(102)
PPBN193	32(58)	18(100)	7(50)	856(95)
PPBN517	30(53)	14(79)	8(57)	765(85)
PPAD234/PPBC234/PPBB917	48(89)	21(119)	11(77)	629(70)
PPAD674/PPBC4126/PPBB523	41(74)	16(90)	10(71)	528(59)
PPAD149/PPBC516/PPBB723	34(62)	15(82)	8(57)	518(58)
PPAD124/PPBC234/PPBB354	39(70)	17(94)	9(64)	555(62)
PPBS624	37(66)	16(88)	11(78)	1356(151)
PPBS234	34(61)	15(84)	9(64)	1391(155)
PPBS123	29(51)	13(70)	8(57)	1359(151)
PPBS452	32(56)	13(72)	10(71)	1309(146)
RNI (Adults)	56	18	14	900

PPIP - pigeon pea-based instant porridge, PPBN = pigeon pea-based noodles, PPAD= pigeon pea-based African doughnuts, PPBC= pigeon pea-based chapatti, PPBB = pigeon pea-based bread, PPBS= pigeon pea-based biscuits, RNI= Recommended Nutrient Intake

Note: all PPIP sample were formulated based on the children recommended intake.

95% of consumers in Ruangwa and Nachingwea respective ranked highest instant porridge flour and 58% ranked lowest the bread. The highest PC counts for chapatti was observed in Morogoro (98%). The lowest PC counts was observed in bread in all districts. Male consumers' (97%) mostly preferred chapatti and less prefer instant porridge flour. For female the most preferred pigeon pea-based product was instant porridge flour (96%) and the less preferred was bread (47%). Consumers age between 9 -14 years (97%) and 15-24 (99%) years preferred biscuits than African donut and bread respectively. Consumers aged between and 25-60 years preferred instant porridge flour (96%) than bread (53%)

Predictors for preferences of developed pigeon pea-based products

Age, sex and experiences on consumption of pigeon peas significantly predicted preferences of pigeon pea-based products at p=0.021, p=0.027 and p=0.015 respectively (Table 7). The coefficient of determination (R^2) explained 18% of variability of preference scores of the developed pigeon pea-based products.

Discussion

Composition of Ingredients and Nutrient Content of the Developed Pigeon Pea-Based Products

Pigeon peas and wheat flour were the main ingredients for developed noodles, chapatti, biscuits, African doughnut, and bread. For

Table 4: Preference scores for different samples of developed pigeon pea-based products

Food	Sample	Colour	Aroma	Mouth feel	Softness	Overall liking
Noodles	PPBN193	4.5±1.99 ac	4.6±2.06 c	4.3±2.15 c	4.4±1.88 c	4.3±2.17 c
	PPBN718	4.7±1.87 a	4.8±1.99 a	4.6±2.00 a	4.7±1.94 a	4.9±0.74 a
	PPBN193	4.6±2.31 b	4.6±1.89 a	4.4±2.07 ab	4.6±1.68 ab	4.7±2.17 bc
	PPBN517	4.4±1.84 ac	4.4±1.95 b	4.3±1.88 b	4.6±1.98 b c	4.3±1.92 c
	P value	0.023	0.046	0.019	0.010	0.018
Biscuits	PPBS624	4.3±1.23 c	4.0±1.88 c	4.3±1.82 b	4.2±1.99 a b	4.1±1.07 bc
	PPBS234	4.0±0.97 b	4.3±0.08 b	4.4±2.23 b	4.3±2.17 b	4.7±1.13 c
	PPBS123	4.7±0.67 a	4.7±1.50 a	4.8±0.99 a	4.9±0.90 a	4.9±1.12 a
	PPBS452	4.7±0.49 a	4.3±1.02 b	4.7±0.84 ab	4.6±0.76 a	4.8±0.23 ab
	P value	0.013	0.020	0.036	0.011	0.029
Porridge	PPIPpfb	4.5±0.82 b	4.2±1.22b	4.1±1.30 c	3.9±1.56 bc	4.3±0.25 b
	PPIPpfr	4.7±0.91 a b	4.5±0.98ab	4.5±0.95 ab	4.7±0.70 b	3.7±0.94 C
	PPIPofspr	4.9±0.29 a	4.8± 0.42a	4.9± 0.35 a	4.9±0.35 a	4.9±0.29 b
	PPIPofspb	4.8±0.69 a b	4.8± 0.41a	4.8± 0.49 b	4.8±0.48 ab	4.5±0.85 a
	P value	0.036	0.003	0.017	0.012	0.040
Chapatti	PPBC412	4.0±0.72 b	4.1±1.25 b	4.0±1.16a b	4.8±1.74a	4.5±2.48
	PPBC328	3.1±0.83 c	3.8±1.66 c	3.9±0.94 b	4.0±1.75bc	4.1±2.55
	PPBC516	3.4±1.73 b c	3.8±2.04 c	4.0±1.04 a b	3.8±1.86 b c	3.6±2.42
	PPBC234	4.1±0.66 a	4.6±1.74 a	4.1±0.83a	4.9±1.91 a b	4.7±2.26
	P value	0.013	0.036	0.002	0.007	0.019
African doughnut	PPAD124	3.9±1.53 b c	4.2±1.10 a	4.1±1.47 a b	3.8±1.55 c d	4.1±1.98 ab
	PPAD234	4.0±1.02 a	4.7±1.46 a	4.5±1.06 a	4.0±0.76 a b	4.7±2.08 a
	PPAD674	4.0±0.74 a	4.7±1.91 a	4.1±0.98 a b	4.0±1.00 a b	4.2±2.06 ab
	PPAD149	3.7±1.53 b c	4.7±1.93 a	4.3±1.81 a b	3.3±1.06 b c	3.8±2.56 c
	P value	0.040	0.011	0.018	0.046	0.006
Bread	PPBB917	4.6±1.83a	4.5±2.13 b	4.2±2.03	4.7±1.79 b c	4.6±1.02 b c
	PPBB523	4.6±1.70a	4.6±1.84 a	4.6±1.83	4.0±1.71 a b c	4.0±0.75 a b
	PPBB354	3.1±1.88a b	3.9±2.03 ab	3.8±1.91	4.1±1.84 a b	4.1±2.11 c d
	PPBB723	3.2±1.87a b	3.9±1.72 ab	3.2±1.96	3.5±1.90 b c	4.1±1.14 a
	P value	0.002	0.030	0.029	0.003	0.015

The mean values with different superscripts within a column are significantly different at p value < 0.05). PPIP- pigeon pea-based instant porridge, PPBN = pigeon pea-based noodles, PPAD= pigeon pea-based African doughnuts, PPBC= pigeon pea-based chapatti, PPBB = pigeon pea-based bread, PPBS= pigeon pea-based biscuits,

instant porridge, the main ingredients were pigeon peas and maize flour. Traditionally, existing noodles, chapatti, biscuits, African doughnut, and bread in the market are made with wheat flour, which is deficient in lysine (Lande *et al.,* 2017; Mogra & Midha, 2013) and low in protein content (Lukmanji *et al.,* 2008). Hence, complementing pigeon peas which contain a reasonable amount of protein and lysine complement each other. The protein content of developed pigeon peas-based products is more than three times of bread, biscuits, chapatti, African donut, spaghetti and maize porridge flour reported in Tanzania food composition table (Lukmanji *et al.,* 2008). The observed amount of protein content in the developed pigeon peas-based products contributed at least 50% of daily nutritional requirements. Pigeon

peas are also rich in tryptophan and methionine which complement lysine and consequently improve the quality of noodles, chapatti, biscuits, African doughnut and bread. Similarly, maize flour which is commonly used in preparing children's porridge is inadequate in protein, thus mixing it with pigeon pea increase the protein content and make it suitable for the growth development of children. Adequate protein intake among children provides essential amino acids such as lysine and tryptophan which are essential for growth and cognitive development (Endrinikapoulos *et.al.,* 2023; Maulidiana & Sutjiati, 2021) Also, adequate protein intake is important for repairing muscles and bones as well as responsible for the functioning of hormones and enzymes among adults (Putra, 2021; Carbone & Pasiakos, 2019).

Similarly, it is estimated that the developed products contributed at least 45% of the daily iron requirement however, this value does not consider the bioavailability. To increase bioavailability roasting, soaking and dehulling of pigeon pea was done. These processing techniques reduce phytates and tannins that are known to interfere with nutrient absorption (Prodanov *et al.,* 2004). Pigeon pea-based biscuits and noodles had the highest amount of iron than other pigeon peas products (chapatti, African doughnut, bread). This can be due to the reasonable amount of pigeon peas added to the flour blend which is 30 % of the total ingredients used.

Adding pigeon pea flour into developed

Table 5: Prioritization of developed pigeon pea-based products among consumer characteristics based on Garrett mean scores

	GM scores and ranks	Pigeon pea-based products						
		African doughnuts	Bread	Biscuits	Instant porridge flour	Chapatti	Noodles	P value
All								
	GM score	60.32	45.87	61.09	65.28	56.48	60.36	
	Rank	4	6	2	1	5	3	
Residence								
Nachingwea	GM score	26.08	26.51	30.43	35.11	30.43	33.09	0.002
	Rank	5	4	2	1	2	3	
Ruangwa	GM score	30.32	25.87	31.09	35.28	26.48	30.36	
	Rank	4	6	2	1	5	3	
Morogoro	GM score	28.04	27.42	24.60	21.69	30.30	19.67	
	Rank	2	3	4	5	1	6	
Sex								
Male	GM score	32.09	28.76	23.55	21.41	35.36	28.76	0.001
	Rank	2	3	5	6	1	3	
Female	GM score	20.51	24.48	27.28	36.93	25.09	34.32	
	Rank	6	5	3	1	4	2	
Age groups								
9-14 years	GM score	35.28	25.87	37.09	30.36	30.32	31.09	0.02
	Rank	2	6	1	4	5	3	
15-24 years	GM score	25.32	25.93	33.06	23.07	35.55	31.45	
	Rank	5	4	2	6	1	3	
25-60 years	GM score	32.11	23.67	22.97	36.42	25.32	27.48	
	Rank	2	5	6	1	4	3	

products increases the zinc content of developed, noodles, chapatti, African doughnut, bread, biscuits and instant porridge. It contributed at least 30% of daily requirement. Similar to iron, a reasonable amount of pigeon peas added contributed to an increase in zinc content. Existing noodles in the market contain 0.1 mg of zinc, chapatti (0.4 mg), biscuit (0.8 mg), African doughnut (0.4 mg), bread (0.9 mg) and 1.8 mg of zinc in maize flour (Lukmanji *et al.,* 2008). These amounts are lower compared to develop products which is attributed with addition of roasted pigeon peas. Liomba and colleagues reported that roasted pigeon pea flour has zinc content 7.5 mg/100g (Liomba *et al.,* 2018). This amount is higher than that of wheat flour

Table 6: Prioritization of developed pigeon pea-based products among consumer characteristics based on PC counts

	Pigeon pea-based products						
	African doughnuts	**Bread**	**Biscuits**	**Instant porridge flour**	**Chapatti**	**Noodles**	
	PC counts (%)	PC counts (%)	PC counts (%)	PC counts (%)	PC counts (%)	PC counts (%)	P value
All (n=412)	344 (85)	225(58)	348(86)	352(87)	339(83)	339(83)	
Ruangwa (n=124)	99(80)	76 (61)	89(72)	121(98)	89(72)	117(94)	0.000
Nachingwea (n=86)	65(76)	52(60)	68(79)	82(95)	78(91)	79(92)	
Morogoro (n=202)	170(84)	109(54)	186(92)	166(82)	172(85)	143(71)	
Sex							
Male (n=169)	159(94)	98(58)	145(86)	90(53)	153(91)	94(56)	0.007
Female (n=273)	185(67)	127(47)	203(74)	262(96)	186(68)	245(90)	
Age group							
9-14 years (n=87)	53(31)	45(52)	84(97)	67(77)	83(95)	72(83)	
15-24 years (n=153)	131(86)	89(58)	136(99)	120(78)	144(94)	115(75)	0.041
25-60 years (n=172)	162(94)	91(53)	128(74)	165(96)	112(65)	152(88)	

Table 7: Multiple linear regression model predicts preferences of pigeon pea-based product

Factors	**B**	**t**	**Sig.**	**Lower Bound**	**Upper Bound**
(Constant)	4.651	7.061	0.000	3.356	5.945
Village	-0.120	-0.702	0.483	-0.458	0.217
Age	0.010	1.552	0.021*	-0.678	0.024
Sex	-0.406	-2.219	0.027*	-0.765	-0.046
Education	-0.167	-1.179	0.239	-0.446	0.112
Pigeon pea consumption experiences	0.435	1.580	0.015*	-0.646	0.977
Color	-0.042	-0.336	0.737	-0.290	0.205
Aroma	0.038	0.352	0.725	-0.173	0.248
Mouthfeel	-0.043	-0.353	0.724	-0.283	0.197
Saltiness	0.028	0.218	0.828	-0.222	0.277
Softness	-0.033	-0.283	0.777	-0.265	0.198
Overall liking	-0.100	-1.432	0.153	-0.237	0.037

**Significance at p <0.05*

0.87 mg/100g (FAO/GOK, 2018). Therefore, blending pigeon pea into these products increase zinc content which is important in the immune system and the senses of taste and smell (Mozaffar *et al.,* 2023).

Addition of orange flesh sweet potatoes flour in developed products increase significant amount of pro-vitamin A content in developed products which contributes more than 58% of RNI. A hundred grams of orange flesh sweet potatoes contained 1467 µg RE of pro-vitamin A (Lukmanji *et al.,* 2008) and pumpkin flour contained 575 µg RE of pro-vitamin A (Pereira *et al.,* 2020) . These amount is higher and make it suitable to blend with low amount of pro-vitamin A wheat (FAO/GOK, 2018) and maize flour (Lukmanji *et al.,* 2008) in development of pigeon pea-based products.

Preferences for the Developed Pigeon Pea-Based Products

The majority of consumers preferred the colour, aroma and mouthfeel of the developed pigeon pea-based products. This was due to the best combination of the ingredients that did not change the sensory attribute of the developed pigeon pea-based products compared to that existed in the market. The overall liking of the developed pigeon pea-based products differs significantly among the samples. Sample PPBN718 for noodles, PPIPofspr for porridge, PPBS123 for biscuit, PPBC234 for chapatti, PPAD234 for African doughnut and PPBB917 for bread whereas the most preferred sample as had higher overall liking scores. This was due to the good composition of the ingredients that did not alter the sensory qualities of the developed pigeon pea-based products compared to existing products in the market. The addition of roasted pigeon peas flours also contributed to the overall liking of the developed products. The Maillard reaction that occurs during the roasting of pigeon peas resulted in a chocolate/coffee aroma and taste feel. It was reported that taste and aroma are among the sensory attributes that influence the overall preference for food (Liem & Russell, 2019, Starowicz & Zieliński, 2019).

Prioritization of the Developed Pigeon Pea-Based Products

Pigeon pea-based flour had the highest rank among the six products developed. This was due to the importance of porridge as the main meal of children during complementary feeding as well as child experience with porridge consumption. Also, porridge has been used as a morning meal in resource poor household and in schools hence, being familiar to them. According to the Theory of Reasoned Action (TRA), experience is among the key drivers for consumption preferences (Ajzen & Fishbein, 2005).

There were significant differences in Garrett's Mean score and PC counts among consumers' area of residence, sex, and age. Consumers in the Ruangwa and Nachingwea ranked porridge highest because the majority reported it to be important in their daily meals, especially for children. In Morogoro, the highest Garrett Mean score and PC counts were observed in chapatti and African doughnut as the main snack during breakfast. In terms of age, children aged 9 -14 years ranked biscuits highest, whereas youth aged 15 - 24 years ranked highest chapatti and instant porridge flour rank highest among adults (25 – 60 years). This could be due to differences in preferences and values that are determined by several interdepending attributes associated with food products, individual perception and the environment (Gorton & Barjolle, 2013). Children preferred biscuits because of the sweet taste and availability in most areas they live in at the cheapest price. Youth preferred chapatti as it is convenient for them and available in most places where they spend most of their time. Youth spend a lot of time outside the home or in different activities for earning income. This is the reason for them to consume foods available to street food vendors whereas chapatti is among the food product sold at reasonable prices compared to size. Adults always think about household foods and mostly considered children's preferences. This is the reason for the highest rank observed for instant porridge flour and African doughnut. These kinds of foods are mostly consumed during morning meals. African doughnut was available in most places in the study area for a price of TZS 100 compared to chapatti and bread.

Prioritization of pigeon peas-based products differ among male and female consumers. Chapatti and African donuts ranked highest among male consumers whereas female consumers ranked highest instant porridge flour and noodles. This could be due to differences in activities. male consumers are less likely to have breakfast at home due to their activities which force them to be away from home early in the morning. This makes them to have breakfast around their work places to different food vendors whereas chapatti and African donuts are among products sold by them. This is different for female consumers as they always think about family needs and which food will be suitable to them. This could be a reason for prioritizing instant porridge flour as could serve as breakfast meal and complementary foods for under five children. They also prioritize noodles as can be made for a family meal during their breakfast but also as a main meal.

Conclusion

Pigeon peas can be mixed with other ingredients to improve palatability as well as for nutrient optimization. The use of pigeon peas to enrich noodles, biscuits, bread, African donut, chapatti and instant porridge increases nutrient content of it that can contribute to at least 50% of Recommended Nutrient Intake (RNI) for protein, iron and vitamin A and at least 30% of RNI for zinc. Instant porridge flour ranked highest among consumers with difference in terms of age, sex and area of residence. Colour, aroma and mouthfeel are among sensory attributes preferred by consumers. The preferred attributes are due to good composition of the ingredients in the product mix and the use of roasted pigeon pea flour which has good aroma and mouthfeel. The preference scores indicated product were preferred by majority and emphasizing the use pigeon peas in enriching different foods products as an opportunity to increase to increase nutrient content and diversification of pigeon peas recipes. This will contribute on improve the well-being of household members. Different stakeholders should consider pigeon peas among approaches to increase nutrient content of food consumed among resource-poor households.

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