Farmers' Knowledge and Traditional Processing Practices of Pigeon Peas (*Cajanus cajan*) in Rural Areas in Lindi Region Tanzania: a Quantitative and Qualitative Mixed Study

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Abstract

Pigeon peas (Cajanus cajan) are an important protein source in many parts of tropical and sub-tropical regions of the world. However, their quality and availability may be affected by post-harvest handling and processing practices in use. In the present study, knowledge and practices of pigeon pea growers (PPG) in Lindi Region were evaluated with respect to harvesting, storage, processing and cooking preparation. A sample of 597 randomly selected PPG from two villages, were interviewed and 60 farmers participated in focus group discussions. Majority PPG (83.6%) harvested pigeon peas (PPs) by cutting and putting them in polyethylene sacks while 86.6% had knowledge on only one storage method. Also, majority of PPG (77%) lacked any processing knowledge on mentioned methods such as hulling and solar drying. Results also indicated 75.7% of PPG having no knowledge on cooking preparation methods out of which 94.5% had no knowledge on soaking, 89.6% on use of bicarbonate and 89.9% on methods to increase shelf life of PPs. Overall, 49.4% had little/limited knowledge on harvesting, storage, processing, and cooking preparation practices, with no significant gender difference. All PPG prepared stew using green or dry PPs. A sizeable proportion (45%) of PPG used dry PPs for stew preparation, after traditional hulling. The threshing of peas from pods was carried out manually. Traditional methods in the Lindi Region are laborious and time-consuming; resulting in poorly prepared products thus affecting the appearance of processed PPs. Training farmers on proper postharvest handling and processing can improve food security and market appeal.

Keywords: Pigeon peas, postharvest, knowledge and practices, dhal

Background

The current world population of 7.6 billion is expected to reach 9.8 billion in 2050 (UN, 2017). According to Durst and Bayasgalanbat (2014) there are almost 842 million people (representing 12 percent of the global population) undernourished in terms of dietary energy supply. In 2022, it was reported that among children under five years of age, an estimated 148.1 million (22.3%) were stunted, 45 million (6.8%) were wasted and 37 million (5.6%) were overweight worldwide (FAO *et al.,* 2023). United Nations International Children's Fund (UNICEF) *et al.* (2023) estimated that in 2022, 22.3% children under age 5 worldwide had stunted growth. Globally, Stevens *et al.* (2022), estimated that over half of children under 5 years old and over two-thirds of non-pregnant women of reproductive age are micronutrient deficient. However, putting in place strategies to improve food and nutrition security in Sub-Saharan Africa remains a challenge. In 2010, the rate

of stunting in Tanzania was estimated at 35% among children under 5 years of age (Chirande *et al.,* 2015). It has also been shown that despite improvement of wasting and underweight in Tanzania, stunting has remained persistent and declined to just 30% (from 1991-2016) affecting one in every three children (Sunguya *et al.,* 2019). Gowele *et al.* (2021) reported that more than 42% of children aged 5-10 years in Kilosa and Chamwino Districts were anaemic. Micronutrient malnutrition especially among children is a concern in Tanzania, where 34% of children under 5 years suffer from chronic malnutrition, while 58% suffer from anaemia (IRIS, 2017). A study by Mrimi *et al.* (2022) revealed that 14.0% of children were anaemic, while 23.90%, 12.60%, and 16.20% of school children were stunted, wasted, and underweight, respectively, including those with vitamin A and B12 deficiencies. Lindi Region is among the Regions in Tanzania where food and nutrition insecurity remains a challenge, whereby, stunting of children has been reported to be more than 54% while 76.8% are anaemic. It has also been shown that in Lindi Region 56% of women aged 15-49 are anaemic. A prevalence of 35% of farmers (male and females aged 31-59) in this Region was also reported to be anaemic (Eleraky *et al.,* 2022). Protein malnutrition is also a problem as most people in rural areas cannot access or purchase animal food sources. Pulses contribute 12% of the perennial crops production in Tanzania and important cash crop for small-scale farmers (Molenaar, 2017). Of the pulses, pigeon peas (PPs) (*Cajanus cajan*) is predominantly exported compared to other pulses (Ryze, 2017). Among the legumes, PPs provide essential protein and micronutrients for poor communities (Abebe, 2022; Aruna & Devindra, 2018; Sarkar *et al.,* 2018). However, inappropriate processing of this legume affect it's nutritional, organoleptic and market values (Johnson, 2015; Szczebylo *et al.,* 2020). Attempts to encourage Tanzanians to eat "dhal" (dry split seeds with coat removed and roasted) as a means to improve nutrition seem to have been met with limited success (Mponda *et al.,* 2013). Apart from work reported by the same researcher that dealt with value chain analysis, information on handling and processing of PPs in Tanzania is lacking. In other countries different methods have been used for harvesting, storage, processing and cooking of PPs with the aim of improving availability and nutritional quality (Vasquez *et al.,* 2021; Onwuka, 2006; Rizvi *et al.,* 2022; Vales, 2014; Ayenan *et al.,* 2017; Jeevarathinam & Chelladurai, 2020). Considering the potential of PPs in nutrition, there is a need to understand farmer's knowledge and traditional processing practices to form a basis for any intervention in improving food security and nutrition in Lindi Region. This study aimed to assess knowledge and practices employed by pigeon pea growers, focusing on harvesting, storage, processing and cooking of PPs. The results of this study will form a basis for identifying appropriate intervention such PPs technologies that will contribute to improved food and nutrition in Lindi Region.

Methods

Study design and sampling

A descriptive cross-sectional study was conducted in Lindi Region, covering Nachingwea and Ruangwa Districts of Tanzania, from October 2019 to March 2020. This study on knowledge of traditional processing practices of pigeon peas (PPs) by pigeon pea growers (PPG) was conducted in two villages of Mitumbati (Nachingwea) and Mibure (Ruangwa). The two Districts experience erratic, but adequate, rainfall between December and March. They receive enough rainfall to support the growth of pigeon peas despite this erratic precipitation. Based on data provided by the district agricultural office, the two districts and two villages were chosen due to their market accessibility and as the region's top producers of pigeon peas. The study included males and females from both villages aged 16-82 years who grew PPs on a modest scale (less than 5 acres). Fisher's method (Fisher *et al.,* 1991) was utilized to determine the appropriate sample size, taking into account that 80% of farmers in the study area cultivate PPs. Following the compilation of lists of farming homes, each household was given a unique number using the RAND function and the Microsoft Excel Ranking of numbers (RANK function) to produce values that were used to choose which households would participate in

the study. Selection for household survey was based on the criteria set by the Vegi-Leg project that considered PPGs who had grown PPs in the last three years before July 2019. This covered the period after the PPs export trade ban by India. Microsoft Excel Random number function RAND was used to randomly sample 335 farming households making a total of 670 PPG (males and females) out of which only 597 PPG (326 females and 271 males) participated in the study. From each household both male and females household heads were interviewed and replacements (from other household lists) were made where there was only one household head. The sample distribution by gender was 176 females and 136 males from Mitumbati village and 150 females and 135 males from Mibure village participated in the study. Details of selection criteria are found in Eleraky *et al.* (2022) and Majili *et al.* (2020). A sample size of 60 farmers for focus group discussions (n = 30 from each village) was obtained by using principles outlined in Moser and Korstjens (2018).

Data collection

Data was collected in two stages: The first stage was a household survey of 597 PPG using face-to-face interviews by trained enumerators. A pretested structured questionnaire was employed by using mobile tablets with an open data kit tool (ODK collect ver.4.2). A GPS-enabled Garmin satellite communicator (GPSMAP® 62) was used to add the location of the session. Data on age and education level were collected to evaluate their association with general knowledge on production and processing of PPs. Data on knowledge of harvesting, storage, processing and cooking practices used by PPG were also collected through household survey. The second stage involved collecting qualitative information involving 60 PPG from both villages for focus group discussions.

Survey on knowledge of harvesting and storage, processing and cooking preparation of PPs

The study inquired about the harvesting (A) and storage (B) methods, processing practices (C) and cooking preparation methods (soaking duration: D; use of bicarbonate: E and ways to extend shelf life: F) of PPs as detailed in Table 1. Respondents scored 1 for correct choices and zero for unsolicited responses. A score of 1 signified a higher rank of a correct choice from the questions. The total scores of harvesting and storage (AB) indicator variables for each respondent were combined to determine their total knowledge and the same for cooking preparation practices. The total knowledge of harvesting (A), storage (B), processing (C) and cooking preparation practices (D+E+F) were summed up to make a total score of 20. The total knowledge of PPG was evaluated through cross tabulations and Chi-square tests based on assigned scores.

Qualitative Information

In order to obtain comprehensive information about the preparation and cooking of PPs focus group discussions (FGDs) guided by a checklist, and deductive thematic content analysis were used to gather qualitative information on the traditional processing techniques of PPs and their end products. Six focus group discussions were conducted in both villages (3 in each village), with each village represented by 30 PPG, involving both males (15) and females (15). In each village, the discussions involved three different groups with an average of 10 PPG in each group. The first two groups were gender specific. The third group included both male and female PPG with 2 females and 2 males as key informants on different traditional techniques used in processing PPs. Actively practicing traditionally processing of PPs, selling their end products and in-depth knowledge as identified by village leadership were criteria for selection of the key informants.

Statistical analysis

Socio-demographic data of the farmers were presented as means and prevalence (numbers). Chi-square test was used to compare prevalence and distributions of socio-demographic data and 'knowledge' scores between the villages and male and female farmers. Scores as continuous values were compared among the four gender groups (female and males and both villages) using Kruskal-Wallis test with multiple

Table1: Correct choices for practices for harvesting, storage, processing and cooking preparation of PPs

Indicator variable	Correct choices	Score	Total
Handling of PPs after harvest (A)	Put in constructed shaded area	1	
	Put in sisal sacks	1	
	Put in polyethylene sacks	1	
	Put on open ground mat	1	4
Storage of PPs (B)	Put in polyethylene sacks	1	
	Put in sisal sacks	1	
	Put in silos	1	
	Put in mud pots	1	4
Total Score (A+B)			**8**
Processing of PPs (C)	Open sun drying	1	
	Solar drying	1	
	Boiling	1	
	Hulling	1	
	Sorting	1	
	Winnowing	1	
Total Score (C)			**6**
Soaking of PPs (D)	31min to 1 hour	1	
	15 to 30min	1	
	Less than 15min	0	2
Use of bicarbonate (E)	Soften	1	
	Reduce cooking time	1	
	Enhance taste	0	
	Normal practice (traditionally used to)	0	
	Maintains colour	0	2
Ways to increase shelf-life (F)	Refrigeration	1	
	Reboiling/ reheating	1	
	Hulling	0	2
Total Score (D+E+F)			**6**

pairwise comparisons. All statistical analyses were done using SPSS Version 20 (IBM SPSS STATISTICS, USA); P-values <0.05 were considered as statistically significant. Focus group discussion data were grouped and summarized.

Ethical issues

The permission for the study was approved by the Tanzania National Institute of Medical Research (NIMR) with reference number NIMR/HQ/R.8a/Vol. IX/3040. Written informed consent was obtained from each farmer before carrying out interviews.

Results

Education and age characteristics of pigeon pea growers

The education and age characteristics of pigeon pea growers (PPG) are shown in Table 2. The results indicated that more than the half (54.6%) of the PPG were female. Similarly, majority (65.7%) of the PPG had completed primary education, with Mitumbati

village having more PPG with primary school education (>70%).Results further show that 49.1% of the PPG were adults aged between 36-60 years, with 29.8% below 35 years. Results also show that there is a significant difference ($p < 0.05$) between the four gender groups from both villages and education level.

General knowledge on processing practices of PPs

The general knowledge of farmers on PPs processing is represented in Table 4. Most of the PPG (77.1%) lacked knowledge on processing (scored 0). Only 92 (15%) of 597 PPG had knowledge on one of the processing

Table 2: Education and age characteristics of PPG (%) in Mitumbati and Mibure villages in Lindi Region

Characteristic	Mitumbati village		Mibure village		Total N=597	P value
	Female n=176	Male n=136	Female n=150	Male n=135		
Education level						
No formal education	13.6 (24)	6.6 (9)	28.0 (42)	17.8 (24)	16.6 (99)	0.000*
Incomplete primary education	13.6 (24)	6.6 (9)	17.3 (26)	14.8 (20)	13.2 (79)	
Primary	70.5 (124)	76.5 (104)	52.0 (78)	63.7 (86)	65.7 (392)	
Secondary	1.7 (3)	7.4 (10)	2.7 (4)	3.0 (4)	3.5 (21)	
Diploma	6.0 (1)	0.7 (1)	0.0 (0)	0.7 (1)	0.5 (3)	
Adult education	0.0 (0)	1.5 (2)	0.0 (0)	0.0 (0)	0.3 (2)	
University	0.0 (0)	0.7 (1)	0.0 (0)	0.0 (0)	0.2 (1)	
Age						
<=35	29.2 (52)	26.4 (47)	26.4 (47)	18 (32)	29.8 (178)	
36 -60	28.3 (83)	20.5 (60)	26.3 (77)	24.9 (73)	49.1 (293)	
61+	32.5 (41)	23 (29)	20.6 (26)	23.8 (30)	21.1 (126)	

*Figures in parenthesis indicate number of respondents in each gender group. *Chi-square test of independence is significant at $p < 0.05$ within rows of different PPG gender groups.*

Knowledge and practices of harvesting and storage of PPs

Results of the prevalence of the scores (either 0,1,2 or 3) as described in Table 1 on general knowledge of methods of handling of PPs after harvest and storage are presented in Table 3. Out of 597 PPG, 499 (83.6%) stated one method among the correct choices (score 1) of harvesting PPs while only 8.4% stated used a combination of two harvesting methods (score of 2). In the case of storage, majority (86.8%) of PPG stated one correct method of storage. Two correct choices of harvesting and storage were stated by 445 PPG (74.5%). Most of the PPG from both villages had a median score of 1 in the 'harvesting and storage' and a score 2 when combined.

methods (Table 1). From the results, there was no significant difference among PPG from both villages in processing knowledge ($p = 0.064$).

General knowledge on cooking preparation practices of PPs

Results on the general knowledge of PPs cooking preparation practices including time of soaking, reason for use of bicarbonate in preparation and any other methods that may be used to increase shelf-life are presented in Table 5. The results show clearly that more than 89.6% (range 89.6-94.5%) of PPG did not state having knowledge on cooking preparation practices of soaking, use of bicarbonate and other ways of increasing shelf-life. This resulted in overall median score of zero. There was a significant

Table 3: General knowledge on harvesting (A) and storage (B) of pigeon peas

Score A (harvesting method), % (n)	Mitumbati village		Mibure village		Total N=597	P value
	Female N=176	Male N=136	Female N=150	Male N=135		
0	6.2 (11)	9.6 (13)	7.3 (11)	8.1 (11)	7.7 (46)	0.064
1	80.7 (142)	77.9 (106)	89.3 (134)	86.7 (117)	83.6 (499)	
2	12.5 (22)	11.8 (16)	3.3 (5)	5.2 (7)	8.4 (50)	
3	0.6 (1)	0.7 (1)	0.0 (0)	0.0 (0)	0.3 (2)	
Score A, median (rank)	1 (315)	1 (304)	1 (285)	1 (288)	1	0.055
Score B (storage method), % (n)	N=176	N=136	N=150	N=135	N=597	0.075
0	8.0 (14)	16.2 (22)	7.3 (11)	8.9 (12)	9.9 (59)	
1	88.1 (155)	78.7 (107)	90.7 (136)	88.9 (120)	86.8 (518)	
2	4.0 (7)	5.1 (7)	2.0 (3)	2.2 (3)	3.4 (20)	
Score B, median (rank)	1 (306)	1 (287)	1 (303)	1 (299)	1	0.327
Score AB, % (n)	N=176	136	150	135	597	
0	2.3 (4)	2.9 (4)	3.3 (5)	3.0 (4)	2.8 (17)	0.016*
1	9.7 (17)	19.1 (26)	8.0 (12)	11.1 (15)	11.7 (70)	
2	73.3 (129)	61.8 (84)	83.3 (125)	79.3 (107)	74.5 (445)	
3	12.5 (22)	14.7 (20)	5.3 (8)	5.9 (8)	9.7 (58)	
4	1.7 (3)	1.5 (2)	0.0 (0)	0.7 (1)	1.0 (6)	
5	0.6 (1)	0.0 (0)	0.0 (0)	0.0 (0)	0.2 (1)	
Score AB, median (rank)	2 (316)	2 (294)	2 (293)	2 (289)	2	0.230

*Figures are percentages and total number of total respondents (N) represented in parenthesis. Score A (harvesting means) and Score B (storage means). *Kruskal-Wallis with multiple pairwise comparisons test is significant at $p < 0.05$ within rows of different PPG gender groups.*

Table 4: Scores (%) with frequency (in parenthesis) on processing knowledge (C) PPs in Mitumbati and Mibure villages

Score C (processing knowledge), % (n)	Mitumbati village		Mibure village		Total N=597	P value
	Female N=176	Male N=136	Female N=150	Male N=135		
0	76.7 (135)	76.5 (104)	74.7 (112)	80.7 (109)	77.1 (460)	0.064
1	14.2 (25)	20.6 (28)	16.0 (24)	11.1 (15)	15.4 (92)	
2	8.5 (15)	2.9 (4)	9.3 (14)	8.1 (11)	7.4 (44)	
3	0.6 (1)	0.0 (0)	0.0 (0)	0.0 (0)	0.2 (1)	
ScC, median (rank)	0 (301)	0 (297)	0 (307)	0 (289)	0	0.695

Figures are percentages with total number of total respondents (N) represented in parenthesis. Kruskal-Wallis with multiple pairwise comparisons test is significant at $p < 0.05$ within rows of different PPG gender groups.

difference among PPG on the use of bicarbonate and when the three cooking preparation methods are combined.

show that 50.6% of farmers had a total score of 2 and a median of 2 meaning that most respondents had knowledge on the use/ combination of two

Table 5: General knowledge on cooking preparation practices of: soaking (D), use of bicarbonate (E) and ways of increasing shelf-life (F)

Score D (soaking), % (n)	Mitumbati village		Mibure village		Total N=597	P value
	Female N=176	Male N=136	Female N=150	Male N=135		
0	95.5 (68)	92.6 (126)	94.7 (142)	94.8 (128)	94.5 (564)	0.297
1	4.0 (7)	4.4 (6)	4.7 (7)	5.2 (7)	4.5 (27)	
2	0.6 (1)	2.9 (4)	0.7 (1)	0.0 (0)	1.0 (6)	
Score D, median (rank)	0 (296)	0 (305)	0 (298)	0 (298)	0	0.720
Score E, % (n)	N=176	N=136	N=150	N=135	N=597	0.000*
0	89.2 (157)a	75.7 (103)b	97.3 (146)a	95.6 (129)a	89.6 (535)	
1	7.4 (13)a	15.4 (21)b	1.3 (2)a	1.5 (2)a	6.4 (38)	
2	3.4 (6)a	8.8 (12)b	1.3 (2)a	3.0 (4)a	4.0 (24)	
Score E (), median (rank)	0 (300)a	0 (340)b	0 (276)a	0 (282)a	0	0.000*
Score F (ways of increasing shelf-life) % (n)	N=176	N=136	N=150	N=135	N=597	
0	92.6 (163)	89.0 (121)	88.7 (133)	88.9 (120)	89.9 (537)	
1	7.4 (13)	8.8 (12)	11.3 (17)	10.4 (14)	9.4 (56)	0.190
2	0.0 (0)	2.2 (3)	0.0 (0)	0.7 (1)	0.7 (4)	
Score F, median (rank)	0 (290)	0 (348)	0 (279)	0 (284)	0	0.566
Score DEF, % (n)	N=176	136	150	135	597	
0	78.4 (138)a	60.3 (82) b	82.0 (123)a	80.7 (109)a	75.7 (452)	0.000*
1	17.0 (30) a	26.5 (36) b	16.0 (24)a	15.6 (21) a	18.6 (111)	
2	4.0 (7) a	11.0 (15)b	0.7 (1)a	2.2 (3) a	4.4 (26)	
3	0.6 (1) a	1.5 (2)b	1.3 (2)a	1.5 (2) a	1.2 (7)	
5	0.0 (0) a	0.7 (1) b	0.0 (0)a	0.0 (0) a	0.2 (1)	
Score DEF, median (rank)	0 (290) a	0 (348)b	0 (279)a	0 (284)a	0 a	0.000*

*Figures are percentages with total number of total respondents (N) represented in parenthesis. *Values within a row not sharing a common superscript letter (a,b) are significantly different (p-value <0.05) among different PPG gender groups.*

Total knowledge on harvesting, storage, processing and cooking preparation practices

The total knowledge score on harvesting and storage, processing and cooking preparation practices is presented in Table 6. Results also

practices. Only 4 (0.7%) of 597 PPG showed to possess knowledge on 7 practices. The findings show that there was no significant difference among the PPG gender groups (p =0.076).

Table 6: Total knowledge (ABCDEF) on harvesting (A), storage (B), processing (C) and cooking preparation (soaking: D; use of bicarbonate: E; shelf life extension: F) practices of PPs

	Mitumbati village		Mibure village			
Score (Total knowledge) % (n)	**Female N=176**	**Male N=136**	**Female N=150**	**Male N=135**	**Total N=597**	**P value**
0	0.6 (1)	0.7 (1)	2.0 (3)	2.2 (3)	1.3 (8)	0.076
1	5.1 (9)	10.3 (14)	4.7 (7)	8.1 (11)	6.9 (41)	
2	51.7 (91)	38.2 (52)	56.7 (85)	54.8 (74)	50.6 (302)	
3	24.4 (43)	28.7 (39)	20.7 (31)	20.0 (27)	23.5 (140)	
4	13.1 (23)	13.2 (18)	13.3 (20)	11.9 (16)	12.9 (77)	
5	2.3 (4)	5.1 (7)	2.7 (4)	0.7 (1)	2.7 (16)	
6	2.3 (4)	1.5 (2)	0.0 (0)	2.2 (3)	1.5 (9)	
7	0.6 (1)	2.2 (3)	0.0 (0)	0.0 (0)	0.7 (4)	
ScABCDEF, median (rank)	2 (307)	2 (322)	2 (288)	2 (277)	2	0.084

Figures are percentages with total number of total respondents (N) represented in parenthesis. Kruskal-Wallis with multiple pairwise comparisons test is significant at $p < 0.05$ within rows of different PPG gender groups.

Identified existing traditional processing methods of PPs

Three methods of processing PPs were identified. They were (1) hulling of dry PPs into *"dhal"* for stew making (Fig. 1). Dhal is locally termed as *"balahoa"* in both villages. In Mitumbati village dhal is called *"Chipalasya"* in the Kimwera/Kiyao native languages while in Mibure it is called *"Ikodi"* in Makua native language; (2) drying of PPs for later consumption as stew and; (3) green PPs for immediate consumption as stew. The traditional processing of dry PPs for normal cooking preparation of stew involves manually threshing using sticks which may take 2 days to obtain 100 Kg. Green PPs were hand-peeled to obtain the seeds for immediate cooking. The dry and green PPs are then sorted; dry PPs are boiled for

Table 7: Existing traditional processing methods of PPs from FGD

Theme	Sub-theme	Processing practice method responses from PPG	Response (N=60)
Processing method	Hulled PPs	*"We roast dried PPs in ashes from spent firewood, leave them to cool, grind them by using two stones to remove the seed coats, pound, winnow them and wash them. The washed PPs splits are boiled while continuously removing the foam formed during boiling for 15min. The PPs are finally relished and cooked with salt, tomato, coconut, onions depending on preference".*	27 (45)
	Green PPs	*"We harvest green PPs, thresh them manually by hands to remove husks, then boil with salt and consume as snack or relish them to make a stew".*	60 (100)
	Dried PPs	*"We harvest dry PPs, thresh them manually by beating with sticks to remove husks, sorted, and then store for later use. We consume the stored PPs by relishing them to make a stew when needed".*	60 (100)
End product consumed	Dhal	*"We take sorted hulled dry splits of PPs then relish them (add onions, salt oil) to make a stew".*	45 (75)

1 hour while green ones for 30 min. The boiled PPs are then relished with other ingredients like tomato, onions, peanuts etc. to ones desire to make the stew for consumption. Members in the FGDs from both villages reported processing PPs either as green or as dried PPs for cooking as a stew. Despite the hulling process to produce dhal being more laborious and time consuming, PPG stated that hulled PPs were tastier and preferred when cooked and consumed compared to the unhulled form. All PPG reported preparing green or dry PPs as a stew for consumption. Hulling process to produce dry splits (dhal) was practiced by 45% of pigeon pea growers (Table 7).

study show that PPG possess little knowledge on better harvesting and storage methods. In Lindi Region PPG harvested PPs by hand-picking using polyethylene sacks. Most of the farmers stored their PPs by hanging them in ceilings of their homesteads with some using mud pots for storage. PPs intended for export were stored at village warehouses using polyethylene sacks only. PPG knowledge on better storage methods is still very low. There was no significant difference in knowledge of PPG regarding harvesting or storage methods of PPs except when both methods were combined. The fact that most of PPG had knowledge on one method of harvesting or storage and only 2 and 20

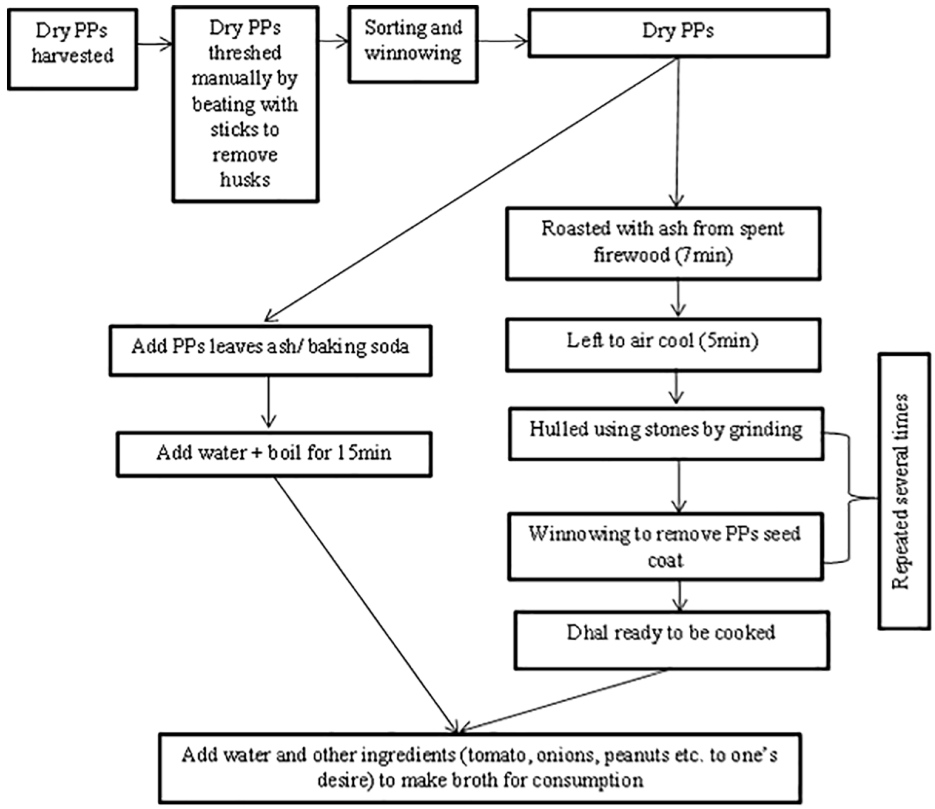

Figure 1: Traditional processing of dhal (dry pigeon pea splits) in Lindi Region

Discussion

Knowledge on harvesting, storage, processing and cooking preparation of PPs

Among legumes, pigeon pea (*Cajanus cajan*) is a staple in rain-fed agriculture and is frequently consumed as dhal. Findings from the

PPG had knowledge on 2 and 3 harvesting and storage methods respectively suggests that all PPG groups in Mitumbati and Mibure villages need training on these aspects. However, when considering training on these aspects due to the observed significant difference among PPG

groups it may be necessary to segregate PPG according knowledge on harvesting and storage methods and give more training on those with knowledge on two or less methods. In India, improved cowpea storage employing purdue improved crop storage bags (PICS bags) for eight months retained germination and seed integrity significantly better than seed stored in traditional gunny bags (Vales, 2014). PICS bags prevented major damage caused by bruchids (*Callosobruchus maculatus* F.) while grain stored in gunny bags suffered severe losses. The techniques available for seed storage are varied and selection of a method largely depends on the effectiveness and cost which include recent developments in using chemical substances for pest-control but are not yet readily available to small-scale farmers (Jaganathan & Liu, 2014). Pigeon pea coated with red soil in India has shown to be an efficient storage method and inexpensive compared to other methods like solar heating of pigeon peas and chick peas (Jaganathan & Liu, 2014). Chick pea and other legume crops growing in the tropics and subtropics have been shown to be a host of Bruchids (*Callosobruchus* spp.) but solar heating method on chick peas has shown to be an efficient storage method in India (Juneja *et al.,* 2023). Most of the PPG (77%) had low knowledge on processing methods like hulling and solar drying. This may be due to the fact knowledge on hulling of PPs was mostly indicated by elders who formed the minority of the PPG. There was no significant difference in knowledge of PPG regarding different processing methods of PPs in Mitumbati and Mibure. The fact that most of PPG in Mitumbati and Mibure villages had no knowledge on any method of processing and only 15% of PPG had knowledge on only one of the methods, training is very much needed on all possible processing methods. Soaking in combination with boiling had shown to reduce anti nutritional factors such phytic acid but also increase nutritive value of PPs (Onwuka, 2006; Rizvi *et al.,* 2022). Few PPG in Lindi Region stated to use bicarbonate to soften PPs and reduce cooking time with Mitumbati village male PPG having more knowledge on its use. The use bicarbonate in PPs processing has shown to improve cooking time (Vasquez *et al.,* 2021). Regarding knowledge on ways of increasing PPs shelf life, 75% of PPG were not aware of ways of improving shelf life. Three quarters of PPG did not have any knowledge on either of the cooking preparation methods. The fact that most of PPG had no knowledge on soaking and ways of increasing shelf life and only 4% and 9% PPG had knowledge only 1 method respectively suggests that all PPG groups in Mitumbati and Mibure villages need training on these knowledge gaps. However, PPG groups where significantly different in the knowledge on use bicarbonate being attributed to Mitumbati males having more knowledge than other PPG groups on the use of bicarbonate. Therefore there is a need for training PPG on cooking preparation methods such soaking and bicarbonate. Since there was no significant difference in the combined aspects of harvesting, storage, processing and cooking preparation methods of PPs training on these aspects is strongly recommended for PPG in Lindi Region. Fasoyiro *et al.* (2019) showed that the participants increased food processing understanding and showed interest in processing products when educated. The majority of PPG had primary education which offers potential for training on post-harvest and processing methods. It has been found that focus on export market involving unprocessed PPs and lack of pigeon pea processing facilities in Tanzania for local markets are some of the reasons for low processing knowledge (Majili *et al.,* 2020; Wangari et al., 2020). Hence, it is important to provide training and extension services to PPG on better processing methods and proper storage practices. Such improvements will add value to the pulse and ensure all year round availability, thereby contributing to improved nutritional value of local diets and food security.

Traditional processing methods of PPs

There is no comprehensive work reported on processing of PPs in Lindi region. Processing of PPs is still at traditional level, with home cooking by boiling being the major transformation practiced by all PPG. Boiled whole dry PPs have also been shown to be the main form of consumption in west Africa and in other various forms such mixed with *"gari"*

(cassava derived product) or maize flour and groundnut/ palm oil (Ayenan *et al.,* 2017). Hulled PPs processing to produce dry splits (dhal) of PPs is traditionally and manually done in Lindi Region. However, the hulling process for cooking preparation of much favoured dhal stew in Lindi Region is time consuming and laborious. The hulling efficiency of enzyme pretreated PPs has been shown to be improved and cooking time reduced in India (Dabhi *et al.,* 2019). According to Jeevarathinam and Chelladurai (2020), pigeon pea should be harvested as bright green pod and processed and stored as dhal. The traditional threshing method that is laborious and time consuming imparts dirt and dust, which affect the shelf-life of PPs by introducing pathogens/insects but also producing products with inconsistent quality. In India, traditionally, sundried PPs after harvest are threshed with suitable thresher or beating with sticks (Dinesh *et al.,* 2019). PPs are mostly consumed as dhal and in India, pre-milling treatments including application of enzymes (e.g. xylanase and pectinase) are generally employed to remove husk without losing the edible portion which improves dhal recovery (Dabhi *et al.,* 2018). Attempts to encourage Tanzanians to eat "dhal" seem to have met with limited success (Mponda *et al.,* 2013). The situation did not improve even after the ban/restriction on importation of PPs by India in 2017 (Ubwani, 2018). Dependence on only one market in India coupled with the India's ban on importation of pigeon pea from 2017 provided a lesson and livelihoods challenge for all actors in the value chain including the farmers. Lyimo (2020) encouraged actions that promote utilization and processing. Improving existing traditional technologies like drying and storage can lead to significant improvements in food security in most regions (Adeyeye, 2017). Similarly, Heuvel (2019) reported that pulse-based products have found an increasingly greater acceptance among consumers beyond traditional consuming regions in the world. Overall, pulses offer a great potential to be incorporated in plant-based food products and align well with changing consumer preferences for healthy diets (Muhammad *et al.,* 2021). According to Rajeev *et al.* (2017), pigeon pea, being a tropical grain legume with low agricultural input requirements like fertilizers and pesticides, is expected to continue to have an important role in providing food and nutritional security in developing countries, including Tanzania.

Conclusion

Despite being a majorly cultivated for export, PPs are important for food security in Lindi Region. This study has shown that knowledge of PPG with regard to harvesting and storage, processing and cooking preparations was still low. The methods traditionally used in threshing and processing 'dhal' are inefficient that could result in nutrient losses and damage to the peas. Combining local PPG knowledge of harvesting, storage, processing and cooking preparation of PPs together with simple innovative technologies like use of hulling and threshing machines would be a suitable intervention to improve food and nutrition situation in this region. Imparting knowledge on improved processing methods will reduce economic and nutrient losses, consequently ensuring the availability of safe and quality PPs for better nutrition. Improved simple processing methods like hulling and threshing have greatest chance of being successfully adopted and bringing about positive change in improving PPG knowledge and sustainability. There is a need to invest in promoting local use of PPs so that farmers can be linked to non-traditional markets (e.g., schools and other institutions) for sustainable marketing and attractive prices.

Author Contributions

A.B.T. countersigned on the design of the study, data collection, and performed the statistical analysis; as well as wrote the first draft of the manuscript. Other authors (B.C., R.M., C.R. and W.S.) critically reviewed and refined the manuscript. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The authors declare no conflicts of interest.

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