Journal of Food Security, 2017, Vol. 5, No. 5, 169-175
Available online at http://pubs.sciepub.com/jfs/5/5/3

DOI:10.12691/jfs-5-5-3

Neglected and Underutilized Legumes (NULs): Exposure Assessment, Habitual Cooking and Eating Habits and Consumers' Characteristics

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Abstract Many people usually consume neglected and underutilized legumes (NULs) as stop gap diets, making the legumes a critical food security resource. In order to ensure their sustainability, a survey was designed to study the characteristics of 534 respondents towards NULs processing and consumption. The survey questions covered habitual thermal processing times of NULs seeds, the quantities of NULs dishes consumed and the number of times they were consumed per week. Other questions covered consumer characteristics such as age, body weight, educational background, occupation, marital status and household numbers. The statistical analysis used Palisade @Risk software to fit each study item to the most adequate probabilistic distribution, based on their Akaike information criterion. Subsequently, the central tendency characteristics of the studied items together with their variations and uncertainties were recorded. The results showed quantified exposure assessment of each NUL, obtained as an integration of the product of the amount of NULs dishes consumed and the exposure frequency of each NULs dishes consumed per body weights of consumers. Similarly, the output of consumer characteristics were recorded along the statistical distributions of each specific NUL's consumption. These were linked to the ages of individuals consuming it, the household numbers of consumers, the educational levels, marital status and the occupation of the respondents.

Keywords: *lectins, neglected and underutilized legumes, exposure assessment, probabilistic distribution*

Cite This Article: I.W. Ofosu, W.O. Ellis, K. Nsiah, and I.N. Oduro, "Neglected and Underutilized Legumes (NULs): Exposure Assessment, Habitual Cooking and Eating Habits and Consumers' Characteristics." *Journal of Food Security*, vol. 5, no. 5 (2017): 169-175. doi: 10.12691/jfs-5-5-3.

1. Introduction

Neglected and Underutilized Legumes (NULs) are crops which have been ignored by research, technology, marketing systems and conservation, although their cultivation and consumption serve as the livelihood options for the poor [1,2]. Though a large number of people make a living on them, there is scarcity of information on the NULs, such as nutritional and toxicological profiles. It is particularly conjectured that the neglect of these legumes might lead to a build-up of adaptive features, possibly, the production of secondary metabolite phytochemicals, which they require to survive the environment in which they live [3].

However, across the sub-regions of Africa and the world, there are evidences of the stature of NULs as food security crops [4,5,6]. In spite of this, little information on NULs consumption is available. It is these gaps that warrant consumption studies of NULs [5,7]. Acquiring NULs consumption database is important in many ways. It would serve as information resource for researchers such as epidemiologists, dieticians and food systems professionals [8]. In particular, NULs consumption data is the foundation for the exposure assessment and consumers' risks towards ingestion of hazards [9]. Exposure assessment of hazards, which involves the evaluation of the likelihood of intake of hazard by consumers may be determined according to standard methods [10] as;

$$\text{Dietary exposure} = \frac{\sum\begin{pmatrix}\text{Concentration of hazard in food}\\ \times\text{Food consumption}\end{pmatrix}}{\text{Body weight}(kg)}.$$

It has been explained that depending on the length of time of food consumption, two approaches are available for their determination; average daily dose of hazards and chronic daily dose of hazards [11]. While average daily dose is used to evaluate the ingestion of hazard in a relatively short period of time, the chronic daily dose evaluates the ingestion of dose over a life time. It is the life time ingestion that demand the input of exposure frequency of food consumed within a year, in the dietary exposure formula. In order to determine this particular information, consumers are often asked to indicate the number of times of intake of food per week (7 days), which can then be easily transformed to exposure per month (30 days). This is reasonable since it might be too difficult for consumers to recollect NULs dishes ingested per month. Thus, exposure per month may easily be transformed subsequently into exposure per year (365¼ days).

A review of available data shows that the protocols used for food consumption data, such as dietary recalls, diet histories, diet diaries and food frequency questionnaire, are usually not consistent across many studies [9]. For instance, studies have shown that the instructional content of questionnaires of 25 European countries in food consumption survey, had only 15 that were comparable based on the adult consumers [12]. This shows that there is the need for the harmonization of the survey methods. However, harmonization of the survey procedures is complex and demand collaborations among many stakeholders [9]. However, since cataloguing NULs consumption data is warranted, a standard or a harmonized survey protocol must be found. While we wait for the harmonization of collection protocols, the persistent problems of uncertainty in food consumption data collection demand immediate attention [13]. Central tendency values such as mean, median and mode are used to represent huge food consumption data. Such approaches, that use crunched or point estimates, lead to inaccurate conclusions.

It has been recommended that probabilistic analysis must be used to ensure that such a large data is fitted to distributions that quantify both the variabilities and uncertainties [14]. Thus, any collection protocol that is used to gather data should have the quality of data preserved so that it truly reflects the consumption characteristics of the population. The use of the probabilistic approach, comes in handy as it reflects a better representation of the outcome distributions compared to point estimates [15]. The reliability of data relating to NULs consumption patterns and cooking practices has the potential of addressing not only cultural attitudes but barriers that impede the harnessing of the full potential of the NULs. Thus, the study was aimed at determining NULs dishes exposure assessment, time of cooking NULs and characteristics of its consumers in the Mid-West belt of Ghana.

2. Methods

2.1. Study Area and Period for the Study

The survey was conducted in the Mid-West belt of Ghana (Figure 1). The study area included Amantin-Atebubu District, bordering the northern part. The Jaman-South District bordered the far west, where Drobo, a major town is situated. The Ejura-Sekyedumasi, Mampong and Techiman districts were the central study area. Mampong, Techiman and Ejura are major markets. The mid-west study area covered Offinso-North District, where Abofour, a major trading town, is located. Within these districts, there are several towns and villages that feed into these major centers of trading especially during market days.

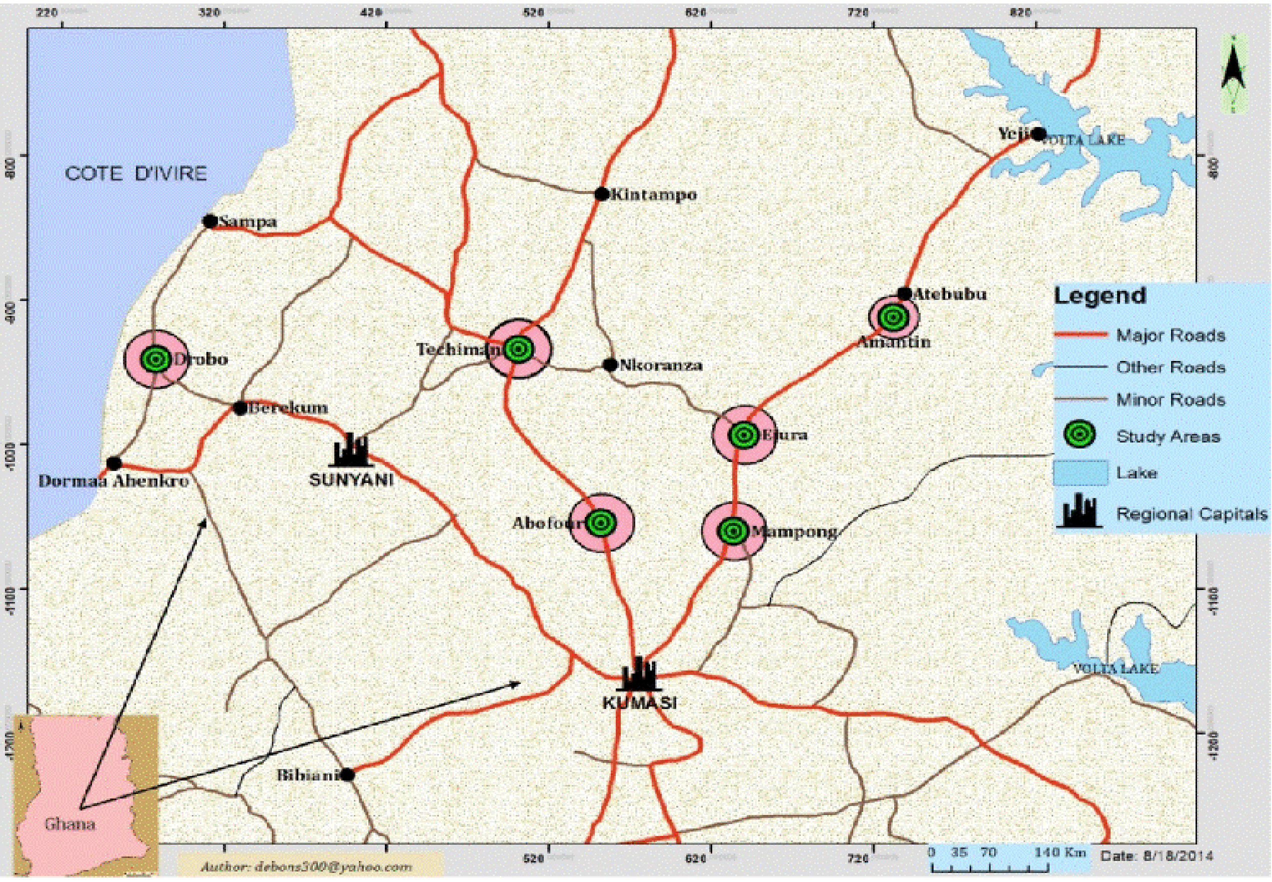

Figure 1. Locations of the surveyed towns in the mid-west of Ghana

The survey was conducted between 5th and 20th May, 2014 during market days which are known to attract a cross-section of the population, involving women, men and children. It was expected that the chosen days would provide the opportunity to recruit a large number of respondents within a short period, from a study area which is sparsely populated.

2.2. Design of Questionnaire/Interview Schedule

A structured questionnaire, which covered factors such as NULs seeds processing times, types of dishes and amount of dish consumed were used. Others factors on the questionnaire were gender, age, weight, level of education, occupation, marital status and household numbers. On thermal processing, the questionnaire was used find out about the variations of cooking times known or used by the respondents. The exposure frequency assessed the quantities of NULs dishes consumed by the respondents and expressed as per month. Some of the dishes were soup, stew, *"Tubani"*, "*Koose*", bean porridge (beans composited with cereals) and boiled beans. The questionnaire was first pre-tested with about 50 respondents in the study area, and based on the feedback, the requisite modifications were made prior to the actual survey.

2.3. Survey

Three assistants, experienced in questionnaire administration were recruited and further trained for the data collection from respondents for the survey. During the training of the interviewers, working definitions both in English and the local dialect were established for some key words. These included "*Tubani*", "*Koose*", bean porridge, boiled bean, consumption rates, exposure frequencies and the names of the NULs in the local dialect. The area of study had predominantly Akan speaking respondents. Though other migrants had settled in the communities, they also understood and spoke the Akan language fairly well. Thus, the Akan language was used to give the flexibility needed to overcome possible barriers to communications. Prior to administration of the questionnaires, the consent of the respondents was sought. It was those who gave informed consent who were interviewed. In the consent seeking process, first, the essence of the study was carefully explained to the respondents.

The data collection was random and individuals were asked questions within the precincts of the market centers, including traders of NULs inside the markets. Every market center was visited twice in order to increase the quality of data collected. Survey was carried out during the market days, which run from about 8:00 am to 5:00 pm. Each interview schedule took an average of 15 min. The five NULs listed on the questionnaire were; *Canavalia sp.*, *Cajanus sp.*, *Mucuna sp.*, *Phaseolus sp.* and *Vigna sp.* However, the quantities of the five types of NULs were not evenly spread among all the market centers. Some market centers had predominantly higher quantities of one or the other type of NULs.

2.4. Data Analysis

Each NULs data was first captured into excel and tallies were made according to gender, age, level of education, occupation, marital status, household numbers, time used in cooking NULs, amount of dish consumed per day and number of times of eating dish per week. Body weights and ages were originally captured in groups of 10 kg or 10 years ranges. Palisade @Risk [16], a Microsoft Excel add-in, was then used to fit statistical distributions for each factor. The fitted distributions were automatically ranked according to *Akaike Information Criterion* (AIC), based on the least loss of actual data and robustness during fitting [17]. The best fitted distributions subsequently gave information such as the central tendencies; minimum, maximum, mean, mode, median and standard deviation. Body weights and ages were iterated (10,000) and their simulated 5th, 50th and 95th percentiles, recorded.

3. Results and Discussion

3.1. Characteristics of Consumers

A total of 534 consumers of NULs aged between 10 and 100 years, made up of 59 men and 475 women in the precincts of the commercial area on the market days, took part in the survey. The consumers were predominantly non-formally educated (373) but some level of basic education (119) were recorded among the consumers. The remaining consumers (38) had either secondary, post-secondary or tertiary education. The consumers were predominantly traders (413), but others were non-skilled workers (51) or farmers (51). There were also artisans (8), civil servants (3) and public servants (8), though such type of workers were marginal. Consumers who were married (398) were similarly predominantly greater than singles (108) and widows (28).

3.2. Central Tendency Metrics

The structure of the study survey were specially designed purposely to facilitate a reliable database for the evaluation of risk assessment of NULs consumption in particular, in a later study. Traditionally, data gathering in a survey or in a laboratory-based work, has been characterized with the use of the measures of central tendency terms; mean, median, mode, minimum, maximum and standard deviation. These terms describe "the statistical measure that identifies a single value as representative of an entire distribution" [18]. In decision making, such as in the evaluation of nutrient quality or in the risk assessment, it is proper to define NULs consumption individually from experimentally determined database. However, for many years, many field experiments have hardly itemized types of legumes and consumption patterns because very often all of them are clustered and referred to as either beans or pulses [19]. To make matters worse, crunched, central tendency values such as the mean is often used to represent large data of clustered pulse consumption. It is therefore misleading to draw general conclusions using such central tendency values. To butress this point, Manikandan [20] has outlined statistical evidence that show that the mean is sensitive. Dawson & Trapp [21] had already shown that the mean is influenced by outliers especially when the sample size is small. But descriptive statistics does not give a complete description of the entire data gathered, because the crunched central tendency values cannot effectively represent the huge data [20] hence the use of probabilistic approach is preferred. Citing heterogeneous consumption population habits as reasons, [22] reinforced the choice of the probabilistic model as the best method to process data obtained from individuals in a population study. When dataset is obtained in a localized sub-population it could provide very useful information on the variabilities or uncertainties among legumes. This would help rank legumes that depend on the edaphic, agricultural and cultural practises to fruit and processed for consumption.

3.3. Exposure Assessment Metrics

One of the aims of this study was to specifically gather data that could help establish the elements for the evaluation of the exposure assessment of the ingestion of possible hazards from NULs. In the evaluation of exposure assessment, the parameters to be obtained from consumers include exposure frequency of hazard, mass of food (NULs) consumed and body weight of consumers [10]. It was found that a minimum mass of NULs consumed in gram, ranged from 160 per day (in *Phaseolus sp.*, *Mucuna sp* and *Canavalia sp.*) through an amount of 250 g per day (*Cajanus sp*.) to 300 g per day (in *Vigna sp.*) The maximum mass of NULs consumption rather ranged from 650 g per day through 800 g per day to 900 g per day respectively. The mean consumption ranged from about 380 g per day in *Phaseolus sp.* to 600 g per day in *Vigna sp.* Since central tendencies are not so robust and are prone to outliers, the true nature of the mass of NULs dish consumption data could be appropriately represented by their respective probability distribution as shown (Table 1). It has been reported by WHO Global Environmental Monitoring System [19], that pulse consumption rate in Ghana is 237.0 g per person compared to what were obtained for specific NULs in this study. This value is deterministic and thus, carry uncertainties as well. For instance, the type of pulse is not known, neither is the type of dishes they were used to prepare them known. Also, lack of the probability distribution associated with it, makes the true nature of the amount of pulse consumed in Ghana unreliable.

Another parameter required in the evaluation of exposure assessment is exposure frequency. From Table 1, the weakness of the central tendency metrics are shown once again. For all the NULs consumed, the central tendencies; minimum, maximum and mode, showed the same exposure frequencies as 1, 24 and 1 respectively. The mean also showed a range of the least exposure frequency (3 per month) of *Mucuna sp.* consumption, but the rest of the NULs showed an high exposure frequency (4 per month) of NULs consumption.

While the probability distributions obtained in this study could adequately describe the nature of the spread of the exposure frequency and increase the reliability of the data, it is difficult to discuss the exposure frequencies of the NULs any further. The difficulty stems from paucity of data in NULs consumption or any related pulse previously studied. By expressing the amount of NULs dishes eaten as food consumption per body weight, ingestion of hazards are harmonized [10]. Therefore, body weights of the consumers is another key parameter required for the evaluation of the exposure assessment. Table 1 shows a minimum body weight of different NULs consumers ranging between 31 and 41 kg, but a maximum of 100 kg was recorded for all of them. The mean weight of consumers rather ranged between 63 kg for those consuming *Vigna sp.* to those 78 kg for those consuming *Cajanus sp*. with those consuming *Mucuna sp*., *Canavalia sp*. and *Phaseolus sp.* within the limits of 63 and 78 kg. Thus, the average body weight of 70 kg adult [11,23], usually used for nutritional and toxicological impact assessments would not be reliable, if the probabilistic distributions of body weights of consumers were used for the evaluations of nutrient or hazard ingestions in food systems and cultural diets.

Table 1. Central tendencies and probability distributions of the elements for the evaluation of exposure assessment of NULs consumption in the study area

NULs	Variables	Probability Distributions	Central tendencies					
			Min	Max	Mean	Mode	Median	Std
	NULs consumed/ gram	Uniform (250,800)	250.000	800.000	525.000	434.250	524.960	158.780
Cajanus sp.	Exposure Frequency/ month	Expon (5.0536,0.95488)	1.000	24.000	6.054	4.000	4.000	6.009
	Weight of consumers/ kg	Histogram (41, 100)	41.040	100.000	78.051	83.235	83.235	11.730
	NULs consumed/ gram	Laplace (400, 114.7084)	160.000	650.000	407.780	400.000	400.000	136.590
Canavalia sp.	Exposure Frequency/ month	Pareto (0.90521,1)	1.000	24.000	4.833	3.400	3.400	5.172
	Weight of consumers/ kg	Histogram (41,100)	41.000	100.000	66.901	66.047	66.047	13.593
	NULs consumed/ gram	Uniform (294.29,905.71)	300,000	900.000	600.000	600.000	600.000	196.520
Vigna sp.	Exposure Frequency/ month	Triang (1,1,26.675)	1.000	24.000	8.849	8.000	8.000	6.554
	Weight of consumers/ kg	Histogram (31,100)	31.000	100.000	63.082	60.978	60.978	13.074
	NULs consumed/ gram	Laplace (400,120.1367)	160.000	650.000	400.910	400.000	400.000	141.020
Mucuna sp.	Exposure Frequency/ month	Pareto (0.68858,1)	1.000	24.000	7.570	3.000	3.000	7.209
	Weight of consumers/ kg	Histogram (41,100)	41.001	100.000	66.190	65.880	65.880	12.903
	NULs consumed/ gram	Laplace (400,119.501)	160.000	650.000	382.170	400.000	400.000	138.460
Phaseolus sp.	Exposure Frequency/ month	Expon (5.725, 0.95229)	1.000	24.000	6.725	4.000	4.000	6.072
	Weight of consumers/ kg	Histogram (0.016, 100)	31.000	100.000	65.095	64.982	64.832	12.397

3.4. Thermal Processing Times

There are reports of different sensitivities of lectin (glycoprotein) toxicities in legumes and other crops to man and animals [24]. However, it is reported that food proteins denature when cooked at moderate temperatures of between 60-90°C for a couple of minutes to 1 h. Therefore, many believe that when lectin is heated at a high temperature for relatively long period of time, their toxicities would be lost [25]. It is in this light that the survey was carried out, to evaluate the cooking times of NULs and evaluate their safety in a subsequent study.

From Table 2, it is seen that the minimum cooking time of all the NULs ranged between 1 and 2 h. However, *Cajanus sp.* seeds were the exception because some consumers reported of cooking times of this legumes running up to 5 h. But the mean, gave two ranges of cooking times and this divided the NULs under study into two groups. One group, made up of *Mucuna sp*., *Canavalia sp.* and *Phaseolus sp*., presented cooking times of between 1.11 - 1.18 h, whereas in the other group, cooking times of 1.69 h and 1.88 h were recorded for *Vigna sp*. and *Cajanus sp*. respectively. To make matters more complicated, the modal (most likely) cooking time of 1 h was recorded for all the NULs. This, once more, brings into focus the need to factor probability distribution of parameters into inherent risk evaluations, in order to quantify uncertainties about them and also give a better outlook of cooking times among the consumers.

Other studies have reported different cooking times for some NULs far less than what consumers reported in this study. For instance, Antunes & Sgarbieri [26] reported of a cooking time of 25 min for soaked *Phaseolus vulgaris* seeds at 97°C which eliminated lectins. Bender [27] also reported of eliminating completely, lectins from *Phaseolus vulgaris* seeds at 100°C for only 10 min. An observation of potentiation (unexpected increase in activity) of lectin activities at a lower temperature (80°C) was also made. This suggest that incomplete elimination of lectin toxicity poses risk to consumers. In this study however, longer cooking times of above 1 h (Table 2) were reported. Thus, it is suggested that risk of lectin toxicity could be low, provided cooking temperature was close to 100°C [27].

3.5. Educational Background

A number of studies have presented NULs consumption as food for the economically poor [28,29,30]. However, economically poor consumers are not necessarily people who have no formal education though there might be linkages.

The results obtained from this study (Table 3) showed that people with no formal education ate more NULs dishes relative to people with some level of literacy. It is seen (Table 3) that over 60 to 80 % of NULs dishes consumption were patronized by people who had no formal education. On the other hand, consumers with high school to tertiary education, patronized NULs dish consumption at between 14 to 26 %. This finding supports the observation that among the Mexican adolescents, the consumption of NULs was higher in individuals with low socioeconomic status as defined by education and economic status [31]. This observation may be linked to the contemporary food consumption trends [32] probably learnt from schools.

3.6. Gender

It was not surprising that over 80 % of the respondents in the study were females. Generally, market activities are dominated by females and since this study was carried out in predominantly market vicinities it might have contributed to the results obtained. However, in a NULs consumption survey, Mexican male adolescents, were found to consume higher quantities of legumes than females [31]. The contrast may probably be attributed to differences in cultural settings or even the study design as well as the area of study.

Table 2. Central tendencies and probability distributions of the age, household numbers and processing temperatures of NULs seeds in the study area

NULs	Variables	Probability Distributions	Central tendencies					
			Min	Max	Mean	Mode	Median	Std
	Age of Consumers/year	Histogram (10,100)	10.003	100.000	55.682	50.361	55.555	20.450
Cajan sp.	Thermal processing time/h	Laplace (2,0.24595)	1.000	5.000	1.878	1.000	2.000	0.447
	Household numbers	Triang (1.793,6,6)	2.000	6.000	5.125	2.000	6.000	1.224
	Age of consumers/year	Histogram (10,100)	10.050	100.000	50.508	49.650	51.326	16.324
Canavalia sp.`	Thermal processing time/h	Pareto (7.7845,1)	1.000	2.000	1.178	1.000	1.000	0.354
	Household numbers	Triang (1.914,6,6)	2.000	6.000	5.267	3.000	4.803	1.111
	Age of consumers/year	Histogram (10,100)	10.001	100.000	40.809	44.795	39.998	18.213
Vigna sp.	Thermal processing time/h	Uniform (0.99038, 2.0096)	1.000	2.000	1.686	1.000	2.000	0.461
	Household numbers	Triang (1.9452,6,6)	2.000	6.000	5.476	3.000	6.000	0.982
	Age of consumers/year	Histogram (10,100)	10.033	100.000	53.727	55.503	54.670	16.356
Mucuna sp.	Thermal processing time/h	Pareto (12.476,1)	1.000	2.000	1.109	1.000	1.000	0.279
	Household numbers	Triang (2.7383,6,6)	3.000	6.000	5.320	3.000	6.000	0.920
	Age of consumers/year	Histogram (10,100)	10.006	100.000	51.867	54.190	52.998	16.579
Phaseolus sp.	Thermal processing time/h	Pareto (12.476,1)	1.000	2.000	1.154	1.000	1.000	0.342
	Household numbers	Triang (0.94735,6,6)	1.000	6.000	5.370	6.000	6.000	0.982

Table 3. Distribution of marital status, gender, occupation and levels of education of NULs consumers (n=534)

Characteristics of consumers	*Cajanus sp.*	*Canavalia sp.*	*Mucuna sp.*	*Phaseolus sp.*	*Vigna sp.*
Marital status					
Single	17	8	20	16	25
Married	76	85	74	71	72
Widowed	7	7	6	5	3
	100	100	100	100	100
Gender					
Male	5	9	17	3	22
Female	95	91	83	97	88
	100	100	100	100	100
Occupation					
Non-skilled	7	10	5	6	16
Farmer	14	6	7	10	12
Civil servants	0	1	0	0	0
Artisans	2	0	2	1	3
Trader	77	82	81	83	69
Public servant	2	1	5	0	0
	100	100	100	100	100
Education					
JSS	14	19	29	22	26
SSS	2	2	8	4	3
PSSS	3	5	1	3	1
Tertiary	1	1	1	1	1
Non-formal	80	73	61	70	69
	100	100	100	100	100

3.7. Household Numbers of Consumers

It was found that the minimum household numbers (Table 3) were between 1 to 3 but on the other hand, the maximum household numbers was 6 for all the NULs studied. Again, the modal household numbers were between 1 and 2 but the mean was 5. However, the average household number has been reported to be between 5 to 6 according to the recent census [33]. The observation suggest the use of probability distribution to give the true nature of household numbers in the study area. The link between household numbers and NULs consumption stems from the fact that, NULs are relatively less expensive and easily accessible [33]. Therefore, the reported low per capita family income (GHS 182.5) within the Atebubu-Amantin study area [33] suggest that many families would probably consume NULs dishes as part of the family diets.

3.8. Age of Consumers

With respect to age, the overall consumers of all NULs dishes in the study area showed a mean, mode and median ages of 49.21, 58.64 and 50.48 years respectively. There were also variations of ages of consumers among the specific NULs consumption (Table 2). The least mean age (40.81 years) was recorded for *Vigna sp.* consumers and the highest (56.68 years) was recorded for *Cajanus sp.* consumers.

Once again the disparities between the overall mean age on one hand and the specific mean age of consumption of specific NULs on the other explains why it is important to catalogue NULs consumptions along specific type of NULs. Overall, the results show that the 5th percentile group of consumers of NULs dishes was less than 20 years of age. This means the consumption of NULs was generally very low among teens. It is important to document this, since nutritional or risk assessment can the tailored to specific age groups. These findings are similar to what was observed in a study on the psychosocial factors which influence young adults' intentions to consume legumes [34]. Even though legumes are nutrient-dense [35] and inexpensive [5]), the findings show that teens consumed little of it. However, the overall sudden decline of NULs consumption among the 95th percentile group, who were over 78 years old is confounding. It may partly be explained that they are less active in the market centres and thus, were not captured in the vicinity of the commercial areas.

4. Conclusion

Key parameters for the exposure assessment of NULs consumption have been evaluated specifically for the five NULs and the uncertainties associated with them have been quantified. Alongside the exposure assessment, amount of specific NULs seeds/dish consumed, exposure frequencies per month and the body weights of respondents consuming them have been evaluated and the uncertainties quantified. With the establishment of the exposure assessment of NULs, the first step of probabilistic estimate of intake assessment of hazards in each NULs is set. Also, the exposure assessments of NULs can effectively be linked to the ages of the individuals consuming it, together with their characteristics such as household numbers, marital status, their educational background and occupation.

Competing Interests

The authors have no competing interests.

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