Article

Use of Pesticides (Agro-Chemicals) in Treating Pest Infested Cowpea Prior to Human Consumption: A Food Safety Concern

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Use of Pesticides (Agro-Chemicals) in Treating Pest Infested Cowpea Prior to Human Consumption: A Food Safety Concern

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Abstract

Cowpea storage prior to sale by merchants has faced challenges to maintain its safety qualities during post-harvest handling. Poor practices from storage methods, through handling and pesticide usage have been of great concern, leading to the suspension of its exportation into some countries. This study assessed the use of pesticides in treating pests in cowpea during storage. A cross-sectional descriptive study design was adopted for this study in which a face-to-face administered questionnaire was used to collect data from 115 cowpea handlers and business owners in Dawanau market in Kano state, Nigeria. Knowledge, awareness, and practices related to pesticide handling and application were measured. Data were coded numerically, categorized, analysed descriptively and correlation among the variables were determined. In relation to pesticide handling practices, results show that cowpea business owners practice 24-hour aeration (86.72 %), select pesticide dosage based on experience (63.39 %), and apply pesticide indirectly on cowpea. Although there is poor knowledge of pesticide, 42.89 % use dry pesticide powder and discard any pesticide residue based on manufacture's instruction (97.32 %). Storage practices were low, including long periodicity of store cleaning. 54.46 % clean weekly, 44.64 % uses polypropylene woven bags with 33.93 % having their storage structure made up of wood. The inferential statistics show a strong correlation between dosage level and pesticide type ($r= 0.515$, $p<0.01$) and positive correlation between experience and choice of withdrawal time ($r= 0.207$, $p<0.05$). A significant positive correlation was also observed between the age of the respondents and choice of packaging materials ($r=0.267$, $p< 0.01$). This study highlights the need for training and education on pesticide usage amongst cowpea business owners and handlers in Dawanau to ensure the safety of the product for human consumption.

Keywords: cowpea; pesticides; food safety; legumes; crop pest; weevil; postharvest; insecticides; pollutants

1. Introduction

Cowpea (*Vigna unguiculata*) is a versatile and common food legume grown in humid and semi-humid locations globally [1]. It is native to South-Eastern Africa and is now cultivated across the world with its peak consumption and cultivation rates in South and Central America, Middle East, Asia, United States, Southern Europe and Caribbean [2]. Globally, 95% of Cowpea production occurs in West Africa, with Nigeria, Niger, Uganda, Ghana, Burkina Faso, Kenya, Tanzania and Cameroon being among the largest producers in Africa [3,4].

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Cowpea, (Waken suya, as popularly called by native Nigerians), are cultivated in large quantities in the North-west and North-eastern regions of Nigeria, which are known for their low rainfall and sandy soils, producing a total of 1.7 million tonnes of cowpea per annum [5]. Table 1 show cowpea production in Nigeria for the years 2020 and 2021. The crop is consumed daily in Nigeria in different forms such as moi-moi, beans cake, dan-wake, beans soup etc. As observed from Therese et al., cowpea is consumed more frequently due to its nutritional benefits and low cost compared to other protein sources [6]. Annually, the Dawanau International Grain Market, located in Kano State, North-west Nigeria, stock 2.8 million bags of cowpea (each bag weighing 100kg), majority to be exported [7]. Nkomo et al. stated that almost 52% of cowpea production in Africa is used as human food, 13% for animal feed, 10% as planting seeds, 9% for other uses and 16% is lost due to pest damage and other factors [4].

In Nigeria, cowpea production and storage face significant challenges from insect pests, as the pods are dried with minimal care during handling, making them vulnerable to a wide range of bacterial, viral, and fungal diseases [8]. Cowpea weevil, *Callosobruchus maculatus*, is a key challenge that affects cowpea storage, causing 60% postharvest losses due to seed burrowing and physical damage of the crop [9–11]. It is estimated that 30,000 tons of Cowpea seed are damaged annually by bruchids, a common storage pest [12]. Various methods have been used to manage *Callosobruchus maculatus* while in storage, with chemical treatment (pesticide) being the most effective. In addition to the high cost of using synthetic insecticides in food grain storage, it has also shown harmful effects on animal and human health [13]. Additionally, it reduces the beneficial organisms present, resulting in ecological pollution and a loss of biodiversity [14].

It has been observed in the past that cereal farmers and grain merchants often relied on alternative methods, such as applying dried peppers, to protect their products including cowpea, from pest infestation. However, today, the most common preservation method for cowpea involves the use of inorganic chemicals, often applied thoughtlessly, leading to high pesticide residues in many crops, including cowpea [16]. According to Hassan et al., the European Union (EU) provided a favourable market for importing cowpea from Nigeria, as the country is one of the top exporters of cowpea (dry beans) and other leguminous crops, such as melon seed, garlic, soybeans, cotton, and groundnuts [17]. However, in 2013, the European Commission suspended Nigeria's exports of cowpea, and the ban was extended in 2017 due to the persistent presence of pesticides at levels (0.03 mg/kg to 4.6 mg/kg) [17] above EU permitted levels of 0.01 mg/kg [18]. At these levels, pesticides are linked to neurotoxicity and may threaten human health and damage the ecosystem [3]. These concerns involve managing risks related to pests, plant diseases, and pollutants that may threaten human health and the ecosystem [17].

A study on cowpea and moi-moi (a meal made from cowpea) from an open market in Taraba State confirmed the presence of excessive pesticide residues, including carbamates, chlorpyrifos (which is banned in the EU – [19]), organophosphates, and fenitrothion. These residues were the result of either overuse or incorrect application of pesticides and additionally, in Borno State, both rural and urban residents have suffered from cowpea pesticide poisoning and deaths due to improper pesticide use [20].

To preserve cowpea in the market, traders often use synthetic pesticides to protect the seeds from bruchids and ensure the seeds retain their market value. However, Kalayou and Amare expressed concern about the potential negative effects of increased pesticide use on human and environmental health, particularly in countries where pesticide regulations are weak, and users lack proper training in safe application [21]. Adu-Dapaah et. al. emphasized the need to combine improved crop production practices, post-harvest techniques, and better protection methods [22]. Despite the growing demand for high-quality, chemical-free products, the use of pesticides remains widespread.

The aim of the study was to evaluate the pesticide knowledge and handling practices of cowpea merchants in Dawanau International Grain Market, Kano State, North-west Nigeria, with respect to food safety.

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Table 1. Production (MT) output and yield (Ton/Ha) of cowpea in Nigeria for 2020 and 2021.

State	Production ('000) MT			Yield (Ton/Ha)	
	2020	2021	% Change	2020	2021
Gombe	294.55	300.26	1.94	0.93	0.93
Taraba	251.91	257.71	2.3	0.97	0.97
Yobe	216.52	228.90	5.72	2.14	2.08
Adamawa	212.98	217.89	2.3	1.08	1.08
Kwara	202.73	204.91	1.07	0.89	0.88
Jigawa	181.88	185.37	1.92	1.54	1.57
Bauchi	175.59	177.19	0.91	0.91	0.89
Kogi	166.04	170.19	2.5	0.46	0.46
Kano	169.02	169.94	0.54	0.85	0.85
Borno	150.65	159.28	5.73	0.9	0.89
Kaduna	152.25	153.68	0.94	0.85	0.85
Benue	133.46	138.51	3.79	0.95	1.1
FCT	124.45	127.81	2.7	0.9	0.88
Niger	124.49	123.79	-0.56	1.04	1.27
Ondo	115.04	115.81	0.65	0.77	0.78
Katsina	120.15	111.85	-6.91	0.92	0.9
Sokoto	108.85	111.72	2.64	0.79	0.81
Oyo	101.42	101.87	0.45	0.85	0.8
Plateau	96.88	101.35	4.62	0.55	0.56
Ekiti	92.76	96.86	4.42	0.56	0.57
Nasarawa	85.50	90.77	5.79	1.43	1.4
Kebbi	88.92	88.35	-0.64	0.82	0.82
Osun	80.82	87.45	8.21	0.39	0.41
Enugu	78.80	86.36	9.59	0.79	0.82
Zamfara	79.84	71.90	-9.95	0.58	0.56
Imo	65.92	68.37	3.71	0.74	0.7
Anambra	64.01	64.31	0.18	0.54	0.53
Lagos	62.35	62.91	0.9	0.53	0.53
Ogun	55.49	54.10	-2.5	0.63	0.63
Rivers	46.70	47.60	1.92	0.51	0.49
Abia	43.76	47.33	8.16	1.08	1.06
Delta	45.24	45.30	0.13	0.9	0.89
Ebonyi	43.59	43.59	0	0.61	0.61
Akwa-Ibom	42.45	42.50	0.12	1.41	1.4
Bayelsa	28.61	28.42	-0.65	0.92	0.91
C/Rivers	24.00	23.92	-0.33	0.94	0.94
Edo	4.91	5.21	6.19	0.86	0.95

Adopted from: National Agricultural Extension and Research Liaison Services (NAERLS) [15].

2. Materials and Methods

2.1. Study Area

The study was conducted between January and March 2025 at Dawanau International Grain Market located between Latitude 12° 5' 12.38" N, Longitude 8° 26' 27.99" E Altitude 505.055 meters above sea level, with an estimated land size of 5 Km2 situated in Kano State North-west Nigeria. The market is one of the largest for the sale of various food and cash products such as cowpea, Cassa Tora seeds, Hibiscus, millet maize, sorghum and others sourced nationally and from across the borders of Nigeria. Other activities taking place in the market include warehousing, cleaning, milling, and bagging of whole grains. The location was chosen because the market is a central hub for cowpea trading in Nigeria and neighboring countries including Niger, Chad, Benin, Burkina-Faso and Cameroon.

2.2. Questionnaire Design

A structured questionnaire was adopted and administered via Joint Information Systems Committee (JISC – www.jisc.ac.uk) online survey. One hundred and fifteen (115) questionnaires were

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administered through the market association representatives to merchants in the market, 3 had incomplete responses and were excluded in the analysis of the data. The study collected data on sex, age, educational qualification, the merchant's years of experience, techniques and management systems used during pest control treatment of cowpea, structure and capacity of storage, socio-economic attributes, choice of certain brands of pesticides, application methods of pesticides (Direct/Indirectly on cowpea), dosage used and environmental factors influencing safe use pesticides in cowpea for the area under study. Responses were coded from 1-5 (i.e., yes = 1 and No =2, Age 21-30 =1 etc.).

2.3. Participant Recruitment

A gatekeeper letter from market association chairman was approved to allow commencement of the survey exercise. A market focal point helped to identify cowpea merchants, disseminate information about the research in the local language (Hausa), explaining, and giving details to the participants. The activity commenced with respondents reading through the Participant Information Sheet (PIS) and completing the Consent Form.

The Inclusion Criteria include participants above 18 years of age and merchants who have been in this business for at least three (3) years and above. Merchants who have not been in the business for up to three (3) years were excluded in survey.

Ethical approval for the study was obtained prior to the data collection from the Manchester Metropolitan University's ethics committee (Ethos ID 75293).

2.4. Statistical Analysis

Prior to the statistical analysis responses were coded from 1-5 (i.e., yes = 1 and No =2, Age 21- 30 =1 etc.). The data collected from the questionnaire was rated (scored) into numerical values before input into Statistical Package for Social Science (IBM SPSS Version 27) software for further analysis. The results were presented in descriptive statistics (means were calculated as an average value of the specified responses) as well as the inferential statistics using bivariate spearman correlation method (spearman rho correlation coefficient) at $p < 0.05$ or < 0.01.

3. Results

3.1. Demographic Information of the Respondents

A total of 115 questionnaires were administered and 112 completed whilst 3 were rejected due to incomplete responses. The demographic information of the respondents is presented in Table 2. The results show that 96.43 % of the respondents were males whilst only 3.57 % were females. 41.96 % of the respondents are within the age of 31 – 40, 28.57 % were within 21-30 years, 10.72 % were within 41-50 years and 9.82 % were within the range of 18-20 years. The oldest category who are above 50 years of age amount to 8.93 % of the respondents. 40.18 % of the respondents were in cowpea business for 7-8 years, 27.68 % were in for 5-6 years and 12.50 % were in the cowpea business for 3-4 years, 9.82 % of the respondents' population were in the business for 9-10 and above 10 years equally. The level of education of the respondents was 55.35 % with senior secondary school certificate (SSCE), 33.93 % have first school leaving certificate (FLSC), 8.93 % have a graduate degree and only 1.72 % have a postgraduate degree. The business capacity of the respondents shows that about 66 % of the respondents have a cowpea business capacity up to 101-200 metric tons, whilst 29 % have 1-100 metric tons capacity. Only 16 % of the population have a capacity above 201 metric tons.

Table 2. Demographic information of the respondents.

Question	Response	Frequency	Percentage (%)
Sex	Male	108	96.43
	Female	4	3.57
Age	18-20	11	9.82

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Years of experience in cowpea business	21-30	32	28.57
	31-40	47	41.96
	41-50	12	10.72
	Above 50	10	8.93
	3-4	14	12.50
	5-6	31	27.68
	7-8	45	40.18
	9-10	11	9.82
	Above 10	11	9.82
Level of education	FLSC	38	33.93
	SSCE	62	55.35
	Graduate degree	10	8.93
	Postgraduate degree	2	1.79

3.2. Pesticide Handling Practices

The result of pesticide handling practice among cowpea business owners is presented in Table 3. The pesticide practices identified shows that highest percentage of the respondents applied pesticide indirectly (53.57 %) on cowpea with a mean value of 1.54, the withdrawal method was 3-4 days (44.64 %) and about 86.72 % agree to allow the recommended 24 hours aeration time (mean value 1.13). The selection of dosage level for pesticide was mostly based on personal experience (63.39 %, mean value 1.37). The type of chemical pesticide used was Insecticide (45.54 %, mean = 1.96) followed by fumigant (29.46 %) and the pesticide residue and discarding were mostly carried out according to the manufacturer's guidelines (97.32 %, mean= 1.03). Less than half (about 46.43 %) of the cowpea business owners apply insecticide directly on the cowpea seed. The pesticide used is mostly in dry (powdered) form (42.89 %), followed by liquid (28.57 %) with 28.57 % using both forms of the pesticide on cowpea.

Table 3. Pesticide handling practices among cowpea business owners.

Question	Responses	Frequency	Percentage	Mean ± Std. Dev
What method of pesticide application procedure is adhered to?	Direct on cowpea	52	46.43	1.54 ± 0.501
	Indirect on cowpea	60	53.57	
Appropriate Pesticide withdrawal time on pest infested cowpea	1-2 days	11	9.82	2.54 ± 0.909
	3-4 days	50	44.64	
	5-7 days	30	26.79	
	As recommended by manufacturer	21	16.07	
Do you aerate for 24hours after cowpea treatment	Yes	98	86.72	1.13 ± 0.332
	No	15	13.28	
Dosage of pesticide is applied based on	Knowledge from experience	71	63.39	1.37 ± 0.484
	Recommended from licensed professional	41	36.61	
Are pesticide residues retrieved and discarded per manufacturer's instructions?	Yes	109	97.32	1.03 ± 0.162
	No	3	2.68	
What class of pesticide do you use?	Fumigant	33	29.46	1.96 ± 0.758
	Insecticide	51	45.54	
	Rodenticide	27	24.11	
	Others	1	0.89	
What type of pesticide do you use?	Liquid	32	28.57	2.00 ± 0.759
	Dry	48	42.89	
	Both	32	28.57	

3.3. Influence of Knowledge and Experience on Pesticide Handling Practices

As shown in Table 4, the result shows that there is significant correlation ($r = 0.207$, $p<0.05$) between the respondents' years of experience in cowpea business with the pesticide withdrawal time. The experience of the respondents did not affect other practices such as the method of pesticide

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application, dosage level, and the type of pesticide used. The education level shows significant correlation with method of pesticide application (r=0.209, p<0.05), pesticide withdrawal (r=0.191, p<0.05), aeration practices(r=0.280, p<0.01), dosage level of the pesticide (r=0.242, p<0.05), pesticide discarding procedure (r=0.217, p<0.05) and the type of pesticide used (r=0.228, p<0.05). This signifies the importance of education on food safety. The results also revealed the impact of formal education on cowpea postharvest activities. Based on other practices, the dosage level of pesticide used is strongly correlated to the type of the pesticide used (r =0.515, p<0.01) and similar relationship was observed for aeration practices and the pesticide discarding method (r =0.272, p<0.01) (Table 4). Knowledge developed through experience in the cowpea business and the level of education attained has no relationship with aeration practices used. However, the choice of dosage level for pesticide was shown to have a no corelation with aeration practices (r = -0.063).

Table 4. Result of correlation between education level, experience and pesticide handling practices.

	Handling practices	1	2	3	4	5	6	7	8	9
1	Years of experience	1								
2	Level of education:	.077	1							
3	Method of pesticide application	.129	.209*	1						
4	Pesticide withdrawal time	.207*	.191*	.204*	1					
5	Aeration practices	.006	.280**	.027	.130	1				
6	Dosage basis	.160	.242*	.187*	.505**	-.063	1			
7	Pesticide Discard	-.065	.217*	-.067	.083	.272**	-.011	1		
8	Class of pesticide use	-.128	.003	-.020	-.194*	-.054	-.087	.154	1	
9	Type of pesticide use	.118	.228*	.166	.248**	-.036	.515**	.073	-.047	1

*There is significant correlation at p<0.05; **There is significant correlation at p<0.01.

3.4. Storage Practices in Cowpea Business

Storage practices used in the cowpea business are presented in Table 5. The result of cleaning frequency of the cowpea stores shows that most respondents clean their stores weekly (mean score 2.12). The individual frequencies show 54.46 % of respondents carry out weekly cleaning, 25.89 % monthly, 17.86 % daily and 1.72 % rarely. More than 44 % of the respondents use polypropylene (PP) bags for cowpea storage (mean value 2.29), 30.36 % use jute bags, 16.96 % use drums and only 8.04 % of cowpea business owners use bottles for cowpea storage. Related to storage structure, 30.35 % of the respondents have a concrete storage structure, whilst 33.93 % use wood, 27.68 % employed metal and only 8.04 % used open space for cowpea storage (Table 5).

Table 5. Storage practices among cowpea business owners.

Questions	Response prompt	Frequency	Percentage	Mean± Std. Dev.
How often do you clean your facility.	Daily	20	17.86	2.12 ± 0.707
	Weekly	61	54.46	
	Monthly	29	25.89	
	Rarely	2	1.79	
Type of packaging material.	Dums	19	16.96	2.29 ± 0.845
	Woven PP	50	44.64	
	Jute bags	34	30.36	
	Bottles	9	8.04	
The structure for your storage is made up of	Concrete	34	30.35	2.13 ± 0.944
	Wood	38	33.93	
	Metal	31	27.68	
	Open space	9	8.04	

3.5. Relationship Between Age and Experience on Sustainable Storage Practices

The relationship between experience and age in storage practices shows that there is significant, correlation between age of the respondents and the choice of storage material (r = 0.281, p<0.01). Cleaning of storage facilities is positively related to the years of experience in cowpea business;

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however, this is not significant (r =0.161). The choice of packaging material is significantly corelated to the frequency of cleaning of storage structure (r =0.259, p<0.01), but there is significant relationship between the choice of packaging material used and the storage structure in cowpea business. The years of experience in cowpea business is significantly correlated to cowpea business size (r =0.394, p<0.01), signifying the longer the experience, the larger the business size (Table 6).

Table 6. Correlation between age, years of experience and cowpea storage practices.

	Variables for storage practices	1	2	3	4	5	6
1	Age	1					
2	How often do you clean my facility.	.079	1				
3	Packaging material used in cowpea storage.	.267**	.259**	1			
4	Cowpea business size	.256**	.147	.072	1		
5	The structure for your storage is made up of	-.281**	-.023	-.163	-.144	1	
6	Years of experience in cowpea Business	.701**	.161	.170	.394**	-.246**	1

*There is significant correlation at p<0.05; **There is significant correlation at p<0.01.

3.6. Activities During Pesticide Usage

Integrated pesticide management (IPM) has recently attracted attention due to its potential to promote sustainability in pest management. IPM generally involves knowledge of pest and their control strategy in a controlled or uncontrolled storage and has been encourage for its adoption in postharvest storage of cowpea. Therefore, knowledge of IPM is important and integral to cowpea business sustainability. Based on the findings of the current study, 91.07% of the respondents are aware of integrated pest management (IPM) practices (Table 7). 41.07% of cowpea business owners used a licensed pest control service provider to fumigate infested cowpea seeds while 33.93% applied the pesticide themselves. Only 25% used both methods. On choosing pesticide brand, quantity (31.25 %) motivates business owners in procuring pesticide more than just brand name (mean value 2.44), 56.25 % were motivated by the effectiveness of the brands, none of the respondent engaged specialty of licensed service provider in making choice of pesticide brand and only 12.5 % of the respondents choose pesticide brand based on its cheapness.

Table 7. Activities in pesticide usage.

Question/prompt	Responses	Frequency	Percentage of respondents	Mean ± Std. Dev.
Awareness of Integrated Pest Management (IPM)?	Yes	102	91.07	1.09 ± 0.286
	No	10	8.93	
Who applies pesticides on pest infested cowpea?	Self	38	33.93	1.91 ± 0.766
	Licensed pest control	46	41.07	
	Both	28	25.00	
What factors do you consider in procuring brand of pesticide?	Cheapness	14	12.5	2.44 ± 0.708
	Quantity	35	31.25	
	Effectiveness	63	56.25	
	Based on recommendation	0	0.00	
Do you use Personal Protective Equipment (PPE)?	Yes	96	85.71	1.14 ± 0.351
	No	16	14.29	
How often do you apply pesticides in the space of 6 months before sales.	1-2 times	19	16.96	2.37 ± 0.880
	3-4 times	44	39.29	
	5-6 times	38	33.93	
	Above 6 times	11	9.82	
At the end of application, are pesticides residue retrieved and discarded appropriately as per manufacturer's instruction after withdrawal?	Yes	109	97.32	1.03 ± 0.162
	No	3	2.68	

3.7. Relationship Between Pesticide Knowledge and the Activities Engaged in During Pesticide Usage

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The relationship between knowledge of integrated pest management practices and the choice of who applies the pesticide is significant but negatively corelated (r= -0.251, p<0.01) (Table 8). There is also a significant, strong relationship between awareness of integrated pesticide management and the usage of personal protective equipment (PPE) during pesticide application (r=0.677, p<0.01). The choice of who applies the pesticide is significantly corelated to the factor considered in brand selection (r=0.355, p<0.01) indicating the possible influence of service providers or contractors. Conversely, the usage of PPE has a negative relationship with the pesticide service provider or contractor chosen.

Table 8. Correlation between knowledge and activities in pesticide usage.

	Variables for pesticide activities	1	2	3	4	5	6
1	Awareness of Integrated Pest Management?	1					
2	Who applies pesticides	-.251**	1				
3	Factor considered in procuring brand of pesticide.	-.194*	.355**	1			
4	Usage of Personal Protective Equipment (PPE)	.677**	-.253**	-.109	1		
5	Frequency of pesticides application	.084	.049	.059	.121	1	
6	Retrieval and discarding of pesticides residue after withdrawal?	.142	.092	-.025	.090	-.069	1

*There is significant correlation at p<0.05; **There is significant correlation at p<0.01.

4. Discussion

The demographic information shows that most of the cowpea business owners in Dawanau were male adults mostly between 31-40 years old with 7-8 years' experience and have an average cowpea business capacity up to 101-200 metric tons. This agrees with the findings of Osei-Asibey *et al*. who reported that cowpea business and production has been dominated mostly by married males [23]. This was attributed to the high-labor input requirements during production and postharvest handling [24,25], which can only be provided by such age group and experience level as reported by Akpalu *et al.* and Ntow *et al.* [26,27]. The respondents' literacy was also found to be similar to that reported in other studies where a high literacy rate was observed among Ghanaian smallholder cowpea farmers [23,26,27]. However, Shehu *et al*. reported lower literacy levels among cowpea producers in Borno state, Nigeria, and lower age levels between 20 and 50 years [28]. Location may be the cause of this statistical discrepancy; it is commonly thought that literacy rates among Nigerians decline as one moves from the southern region of the country to the far north, which is more of a rural economy.

According to the results of this study, cowpea business owners often ignore the recommendations of licensed pest control professionals when choosing dosage level (36.61 %). Instead, they rely on their personal experience (63.39 %) when deciding upon the amount of pesticide to use for a specified amount of cowpea. This practice is detrimental as the dosage level of pesticide is a key factor in determining the amount of residual contamination after withdrawal and can affect the cooking time and taste of the cowpea during processing. This is especially true when pesticides are applied directly on to the cowpea seeds, often resulting in malodors, decreasing cookability, contact burn and ill health if consumed. Findings of this study, indicates poor pesticide practices among cowpea business owners in Dawanau, especially poor withdrawal time after pesticide application, which is generally 3-4 days (44.64 %). Poor knowledge of pesticide among the respondents, as most of them cannot differentiate classes of pesticide chemical. 45.54 % agreed to use insecticide in cowpea, 24.11 % uses rodenticide which is unrelated and 29.46% uses fumigant. This malpractice may be linked to poor adherence to the manufacturer's guidelines, even though these detailed guidelines are often written on the pesticide packs/container labels, and a lack of consultation with relevant pesticide professionals. This agrees with the findings of Shehu *et al*. who reported that the majority (82.6 %) of cowpea seed handlers do not read the manufacturers guidelines while procuring the relevant pesticide with only 17.4 % of the cowpea handlers being reported to accurately read the manufacturers guidelines before use [28]. This extreme negligence in following

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the manufacturer's guidelines is critical to food and consumer safety and may be linked to the low formal education level of most respondents, 55.35 % with Senior School Certificate (SSCE) and 33.93 % with First School Leaving Certificate. This indicates the prudent need for education in the study area especially because these practices have high environmental, health, climate and economic effect. Additionally, the result of the current study contradicts those of other reports where it is believed that grain producers and retailers knew enough about how to use conventional pesticides [29]. However, this could also be related to manufacturers' unclear labelling of guidelines, as reported by Illiassa and Matthews *et al.* [30,31]. Their analyses of certain formulations revealed the presence of some active ingredients that the manufacturer had not included on the label. For instance, lindane was discovered in the malathion formulation "Poudrox" and the pirimiphos-methyl formulation "Actellic." To ensure food safety, coordinated efforts are essential to address the presence of hazardous pesticide metabolites pesticide formulation and development of dietary recommendations. Fortunately, domestic food processing methods can reduce or eliminate pesticide residues, thereby making grains safer for consumption. However, Subramani et al. reported that even after five months of storage, grains still retained considerable levels of pesticide residues, including their metabolites [32]. Similarly, another study reported residues of dieldrin, endrin, and endosulfan in beans sold in Oyo State, Nigeria [33]. In contrast, Oguntade *et al.* observed that samples of maize, millet, and brown beans collected in Ilorin, Kwara State, contained no synthetic or conventional pesticide residues [34]. Instead, their analysis revealed the presence of bioactive compounds, notably methyl esters and hexadecanoic acid.

Although some food processing techniques have been proposed to reduce pesticide residues, specific methods have shown varying levels of effectiveness [29]. For instance, blanching has been found to decrease organophosphate compounds, while dehulling and soaking prior to cooking significantly lowered concentrations of organochlorine compounds such as chlorothalonil, o,p-DDE, and heptachlor epoxide. This reduction may be attributed to the removal of the seed coat during dehulling. Subramani *et al.* reported that soaking and germination of grain seeds nearly eliminated all detectable pesticide residues [32]. Interestingly, even though certain residues were absent in raw samples, the processed grains exhibited elevated levels of some compounds, which may be due to the degradation of parent pesticides into more potent metabolites [35].

These metabolites, in some cases, may pose greater toxicity than the original compounds. It is also noted that organochlorine pesticides (OCPs) contributed to the decline of beneficial soil fungi and bacteria, raising concerns about similar impacts on human microbiota [35]. Moreover, Adarkwah et al. observed that individuals with high levels of pesticide residues—specifically alpha- and beta-endosulfan—in their blood exhibited altered enzyme activity [36]. In another instance, washing cowpea seeds with tap water prior to cooking led to a notable reduction in alpha-BHC, chlorothalonil, and o,p-DDE levels.

According to Yigit and Velioglu and Bajwa and Sandhu, the effectiveness of washing in removing pesticide residues depends on several factors, including the type of pesticide, its location within the food matrix, and the temperature of the water [37,38]. Under optimal conditions, washing can remove up to 100% of pesticide residues. Similarly, Omeroglu *et al*. reported that washing reduced pesticide residues in oranges by approximately 26% to 84% [39]. In a related study, most respondents (45.54%) correctly identified insecticide as the appropriate pesticide for cowpea, compared to fumigants (29.46%), which are a subclass of insecticides. However, a concerning proportion (28.57%) believed that cowpea should be treated with liquid pesticides—a practice that is undesirable, as such formulations may penetrate the germ layer of seeds, increasing the likelihood of pesticide absorption and retention even after withdrawal.

It was further observed that, pesticide residues with low water solubility were less likely to be reduced by washing, suggesting limitations in the effectiveness of water-based decontamination methods [39]. These findings imply a significant knowledge gap among respondents regarding the harmful effects of pesticide misuse. Although many of the respondents were literate, they often struggled to understand technical terminology on pesticide labels and rarely sought clarification or

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guidance from agricultural extension officers. This aligns with findings in other report where it was found that 66.2% of pesticide users do not read product labels before application, and among those who do, most fail to comprehend the information provided [40]. This was attributed the unsafe use and poor regulation of pesticides largely to a lack of adequate education and awareness [41].

Cleaning and other storage operations are crucial, particularly when it comes to bug infestation, as insects tend to flourish in unclean environments. Nonetheless, most research participants reported cleaning their stores sporadically, typically once a week. When managing cowpeas, aeration and cleaning are crucial storage procedures. Even though they applied pesticides too frequently—three to four times in six months—the largest number of respondents (86.72 %) did not use adequate aeration after pesticide treatment. The rapid cycle of pesticide application combined with the great negligence of cleaning and aeration poses a risk to consumers. This is consistent with the findings of a study where it was observed that farmers are not well-informed on the risks involved with using agrochemicals [42]. Similarly, Owusu-Boateng and Amuzu found 87.0% of Ghanaian farmers lack sufficient awareness and information about the health risks associated to the handling and application of pesticides [43]. According to their findings, most cowpea producers in northern Ghana treated their crops with insecticides prior to storage. This supported the claim indicating that cowpea producers store their grains using dangerous synthetic chemicals, even though there are more environmentally friendly preservation methods available, like using ash powder, which is more readily available and cost-free in most homes [23,25]. However, the use of ash powder is time-consuming and labor-intensive, especially when storing large amounts of grain, and therefore its use may be limited. Ash is commonly used for seed storage since it requires a 1:1 volume ratio of ash to cowpea mix for good preservation [44].

According to Osei-Asibey *et al.* almost two-fifths of cowpea producers utilize Purdue Improved Cowpea Storage (PICS) bags for cowpea storage, whilst roughly half of the respondents (44.64 %) use woven polypropylene (PP) bags [23]. Other studies have reported similar material usage for storage in Niger and other West African nations [45,46]. Most of the respondents thought that PP bags were the best way to store cowpea, and they preferred to use them. Given that PP bags were also the most widely utilized cowpea storage container, this shows how culturally acceptable it is to use bags for protecting and storing grains. As observed in other sub-Saharan African nations, farmers favored PP bags, but availability posed a problem in rural regions [47,48]. Additionally, it was found that whilst one fifth of farmers utilized PP bags, few knew how to use them correctly to store cowpea.

In other households, cowpeas were preserved in other hermetic storage vessels such as plastic bottles and jerrycans, though they might also be used to fetch or store water. Although these alternative hermetic containers were more readily available and less costly, cowpea business owners thought they were the least effective. This perception of ineffectiveness runs counter to research' findings that cowpeas can be effectively preserved using hermetic storage techniques, such as jerrycans [10,49]. These findings collaborate with those reported by Utono and Claire, who discovered that hardly 20 % of farmers stored grain in without storage preservatives [50]. Packaging materials other than PP bags were thought to be accessible, affordable, and efficient. Nonetheless, research has demonstrated that the use of PP bags in combination with synthetic insecticides are more effective than using pesticide chemicals alone [1,51]. In addition to inadequate pesticide application and storage management techniques, most respondents agreed that pesticide remnants should be disposed of in accordance with the manufacturer's instructions, however, there was evidence of widespread inadequate management techniques.

The rise in concern about the safety and quality of food, coupled with the increase in awareness on environmental and climate change have led to the need for sustainable agricultural practices that will not negatively affect health and the environment. The major goal of these practices is to reduce chemical inputs in agriculture. Integrated pest management (IPM) system is one of the most talked about methods for reducing chemical input in agriculture and food handling. In Nigeria an average of 23,000 tons of pesticide are reported to be used annually costing $120 million [52]. As the misuse of pesticide is high this has resulted in damage to the environment and the health of the population.

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Integrated Pest Management (IPM) is believed to be the only solution especially in a developing nation like Nigeria, hence knowledge of IPM among cowpea business owners is paramount. IPM is identified as a sustainable approach to managing pests by combining biological, cultural, physical and chemical tools in a way that minimizes economic, health and environmental risks [53]. It is indicated to encourage natural control of pest population by anticipating pest problems and preventing pests from reaching an economically damaging level by employing the techniques of natural enemies, planting pest resistance crop varieties and using appropriate pesticide judiciously reducing their adverse effects [52]. The result of this study shows that cowpea business owners are aware of Integrated Pest Management (91.07 %) compared to 8.93 % who claimed to be unaware of IPM, this disagrees with the report of Kughur *et al.* who reported awareness of IPM among farmers in Benue state, Nigeria [52]. Knowledge of IPM systems is indicated to result in an increase in the use of plant-based insecticides (PBIs) such as neem extract in rice, cassava and cowpea [54]. Although cowpea business owners are aware of IPM, their implementation of IPM practices is insufficient and negatively influences their activities on pesticide handling, as indicated by a negative correlation with the choice of pesticide service provide. Their awareness of IPM, however, has positive influence ($r = 0.677$, $p<0.001$) on their use of personal protective equipment while applying the pesticide, which might be due to the increase in campaigns on the dangers of pesticide exposure as well as their toxicity.

IPM is very important in cowpea business because they provide alternative to synthetic chemicals as well as equip cowpea handlers with knowledge on approaches to managing pest resistance pesticide. To reduce pesticide resistance amongst pests, the use or hence misuse of synthetic pesticides, there is a greater need for implementing IPM. In order to do this effectively, farmers need to be educated on the correct application of IPM.

5. Conclusions

The findings of this study revealed harmful practices among cowpea business owners in Dawanau, with potential implications for consumer health and safety. The results indicated that most of the business owners operate at a moderate business level, handling up to 200 metric tons, and possess some knowledge of integrated pesticide management. Although they utilize the services of licensed pesticide contractors, their choices regarding pesticide brands, classes, types, and dosages often pose risks to both consumers and the environment, highlighting the need for improvement in decision-making and regulatory compliance. Furthermore, the study uncovered a generally poor understanding of pesticide use and storage practices among cowpea traders. Many were unable to distinguish between pesticides and fumigants and demonstrated inadequate storage management practices, such as infrequent cleaning, lack of grain aeration, improper handling of pesticides, and failure to observe recommended withdrawal periods. These failings significantly increase the risk of pesticide contamination, threatening both human and environmental health. The study concluded that most respondents in the study area exhibited limited awareness of pesticide safety. Many could not interpret label instructions, were confused by technical terminology, and failed to seek guidance from agricultural extension officers. This lack of knowledge contributes to improper pesticide application and poor post-harvest management. Whilst there are some farmers who utilized IPM and correctly manage and apply pesticide, they were found to be in the minority amongst the population sampled. Consequently, improvements are urgently needed in storage practices, pesticide selection, and user education to promote food safety and environmental sustainability.

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Abbreviations

The following abbreviations are used in this manuscript:

MT	Metric Ton
Ha	Hectare
PIS	Participant Information Sheet
SSCE	Senior Secondary School Certificate
FLSC	First School Leaving Certificate
PP	Polypropylene
IPM	Integrated pesticide management
PPE	Personal Protective Equipment
OCPs	Organochlorine Pesticides
PICS	Purdue Improved Cowpea Storage

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