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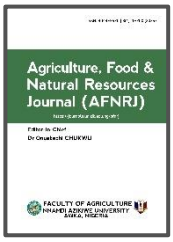

Original Article

Determinants of post-harvest losses of rice in north-east Nigeria

OPEN ACCESS

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ABSTRACT

Post-harvest losses, particularly along the rice value chain, have been identified as a source of food insecurity and reduction in income among the value chain actors. It is therefore necessary to determine the factors that influence post-harvest losses in the study area and also to assess the level of post-harvest losses so as to be able to provide a reliable policy stand that can help reduce these losses. Gombe, Taraba and Yobe States were purposively selected from the northeast in Nigeria because they are the major producers of rice in the zone. Data were collected through the use of a questionnaire from 107 farmers, 106 processors, and 106 traders. Descriptive statistics, correlation, and machine learning were used to analyze the data. The result revealed that loss was highest for farmers at 189.22 kg/ha of paddy rice (₦112,500.00 at ₦643.00/kg) (1 naira = $0.00066), processors (10.22 kg/bag at ₦1100/kg), and marketers (3.22 kg/bag at ₦1100/kg) of milled rice. The household size, educational level, and farm size significantly affected post-harvest losses for farmers, while experience and access to credit significantly affected post-harvest losses for processors, and only distance significantly influenced post-harvest losses for marketers. It was therefore recommended that the government should intensify efforts and investment in rural infrastructure facilities such as good roads, stable electricity, and storage facilities in addition to providing adequate training to the value chain actors.

KEYWORDS: *Actors, Effect, Influence, Value-chain*

INTRODUCTION

Nigeria is a country with high levels of food insecurity, the number of food insecure Nigerians increased significantly, from 66.2 million in Q_1 2023 to 100 million in Q_1 2024 Nigerian Economic Summit Group (NESG, 2024), with 18.6 million facing acute hunger and 43.7 million showing crisis-level or above crisis- level hunger coping strategies, this demands an immediate action.

Rice is a staple food in Nigeria and is consumed by a large proportion of the population; however, post-harvest losses in rice production can lead to food shortages and contribute to food insecurity. Rice is an important cash crop in Nigeria and a significant source of income for farmers, traders, and processors.

Post-harvest losses can occur during any of the stages in the postharvest operations. Whatever the source, post-harvest

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losses represent more than just a loss of food as it ripples through the factors (including land, water, labor, seeds, time and fertilizer). Post-harvest losses of rice can be quantitative or qualitative. Quantitative losses lead to a reduction in weight or volume of the final usable product from the potential yield or harvestable paddy, while qualitative losses lead to a reduction in value of usable product due to physical and chemical changes in the rice, which diminish the grain size, cause poor appearance, bad taste and foul aroma. The wastes indicate that post-harvest food loss translates not just into human hunger and minimizing the revenue of farmers, but into tremendous environmental waste as well (Babatunde *et, al*, 2019).

To close the gap between domestic rice production and imported rice, Care must be taken at each post-harvest stage to reduce losses and increase supply.

According to Manful and Fofona (2010), qualitative losses could be as high as 50% in some developing countries. More so, reducing postharvest losses could help in reducing rice imports with its accompanied economic losses. For effective reduction in losses, it is therefore important to estimate the losses, identify the determinant of the losses, and the stages at which they occur. However, empirical information on the determinants of post-harvest losses that occur at each stage of the value chain need to be emphasize in literature. This study therefore aimed at identifying the determinants of postharvest losses that occur in the rice production in North East Nigeria using Taraba, Gombe and Yobe State as a case study.

However, post-harvest losses can increase the level of food insecurity and reduce the income of these stakeholders and limit the economic development of the region.

MATERIAL AND METHODS

Study area

This study was conducted in north-eastern part of Nigeria. The area lies between the vast arid expanse of the Sahara and the dense tropical rain forest along the Guinea Coast. Sharing boundaries with the study area were Cameroon on the east, Niger and Chad republics on the north, North-Central Nigeria on the west, and South-Eastern Nigeria on the south. This geographical area constitutes the largest zone in Nigeria (Soltan *et., al.* 2017) and comprises of Adamawa, Bauchi, Borno, Gombe, Taraba and Yobe State. The area is located between 6^0 26 - 13^0 45N and longitude 8^0 42 - 14^0 39 E. It covers an area of 262578 km^2 (Soltan *et., al.* 2017). The soil type in Northeast Nigeria was mainly ferruginous tropical soils, which are characterized by high iron content; there are also alluvial soils, which are found along river banks, and clay soils, which are found in areas with high precipitation (Opara-Nadi *et al*., 2020). The temperature varies depending on the season. During the dry season (November to February), the temperature can reach as high as 40°C, while in the rainy season (March to October), the temperature drops to around 30°C. Night-time temperatures are usually cooler, averaging around 20°C, the zone is predominantly covered by savannah grasslands, which are characterized by tall grasses and scattered trees (Ogolo *et al*.,2016). However, there are also areas of woodland and forest in the region, particularly in the southern parts of Adamawa and Taraba states. The vegetation in the region is adapted to the semi-arid conditions, with many plants having long taproots to reach underground water sources (Ogolo *et al*., 2016).

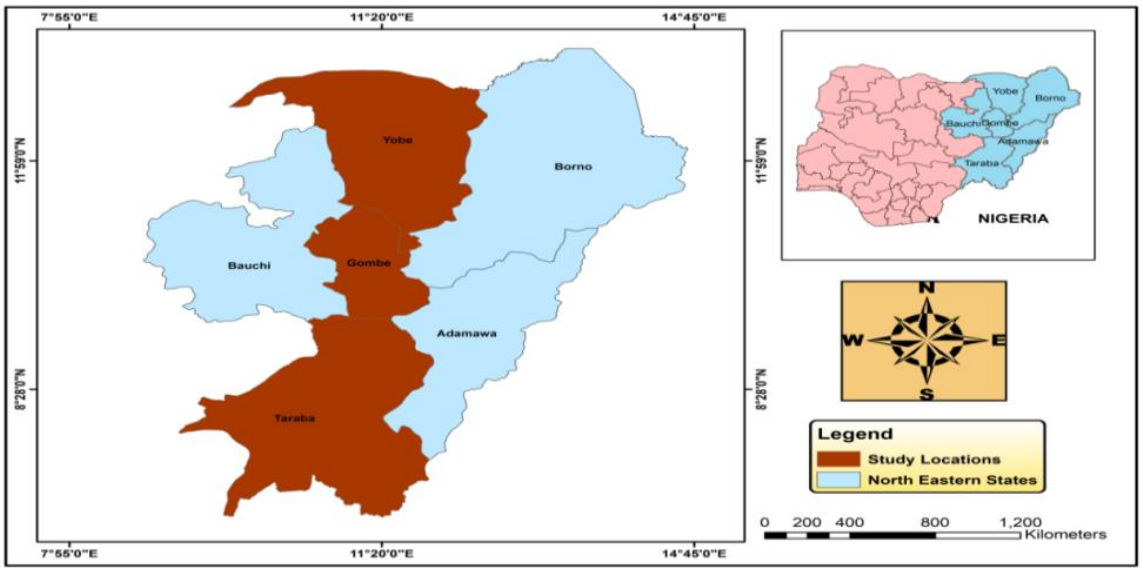

Figure 1. Map of Nigeria showing the study area.

Sampling Techniques:

A multistage sampling procedure was used for the study. In the first stage; Three States out of the six states in the zone has been purposively selected for the study, namely Gombe, Yobe and Taraba State which are the most highly rice producing states in the zone. In the second stage a purposive sampling procedure is used to select three local government areas (LGAs) from Gombe and Yobe State respectively while four LGAs were selected in Taraba State being the largest producer of rice in the zone. In the third stage, sample size online calculator was used to determine the sample size of the study, where by the calculator was set at an error margin of 8%, a confidence level of 90%, and a population of 98700, 24450 and 8414 for farmers, processors and marketers respectively and a response distribution of 50% that give a total sample size of 319 as shown in table 1 below (Calculator.net, 2023)

Table 1: Sampling frame for the study

State	Farmers	Processors	Marketers	Total sample size
Taraba	48	41	43	
Gombe	29	26	31	
Yobe	30	39	32	
Total	107	106	106	319

Source: Field Survey data, 2023

Methods of data analysis

In this study, descriptive statistics such as frequency distribution, tables, mean, and percentage, minimum, maximum, and radar graphs were used, furthermore, inferential statistics such as Pearson correlation and machine learning were also used to analyze the data.

RESULTS AND DISCUSSIONS

The socioeconomic distribution of the rice value chain actors in the study area revealed that 36.45% and 32.71% of rice farmers in the study area were within the active age of 21-35 and 36-45 years. While 62.26% processors and 49.05% marketers fell within the active age of 21-35 years. Meanwhile, farmers, processors and marketers had a mean age of 42, 34 and 37 respectively. With the above background therefore, one can conclude that good number of the value chain actors are within the active working age (Table 2).

The table also presented distribution of respondents according to gender, it shows that 98.1%, 90.6%, and 57.5% farmers, processors, and marketers were male, this is contrary to (Babatunde *et al*, 2019) who showed that rice processing such as parboiling, milling, drying, among others are predominantly done by women. This might be due to the differences in culture and faith.

On the marital status of the respondents, it was shown that 69.2%, 45.3% and 51.9% of farmers, processors and marketers were married. The marital status of a respondent is an indirect indicator of how responsible the respondent is and it is also a measure of the ability to shoulder socio-economic responsibility in the society (Sambo,2023).

The distribution of respondents based on household size revealed that 79.25%, 63.21% and 48.59% processors, marketers and farmers had between 1 – 5 household sizes. Moreover 1.87% farmers and 0.94% marketers had household size of between 16 – 20 persons. However, farmers, processors and marketers had a mean household size of 7, 4 and 5. This implies that, the value chain actors in the study area had relatively large household sizes. The larger the household size the higher the need and expenses of the family (Opeyemi *et al.*, 2013).

The educational levels of the value chain actors in the study area showed that, about 41.1% farmers, 50% processors and 60.4% marketers had secondary education while 37.4%, 25.5% and 19.8% farmers, processors and marketers have tertiary education. Meanwhile, 7.5%, 5.7%, and 9.4% farmers, processors, and marketers had non-formal education. It was observed that illiteracy militates against adoption of recommended packages of innovation and modern techniques.

However, majority 82.2%, 82.1% and 68.9% of farmers, marketers and processors were not registered with any group or association. This implied that majority of the value chain actors were not registered members and this may be due to unavailability of government and non-governmental interventions in the study area. Respondents who belong to cooperatives are better informed on resources use, training and planning which enables them to utilize resources more efficiently.

Meanwhile, on whether the value chain actors have access to credit facility in the study area. The results revealed that majority 82.2%, 70.8% and 63.2% farmers, processors and marketers respectively didn't have access to credit facilities. Therefore, this shows that there is poor access to credit facilities in the study area which if adequately tackle will help in boosting the activities of the value chain actors in the study area.

Furthermore, it revealed that 80.19%, 78.30% and 64.49% farmers, processors and marketers fall within 1 – 10 years of experiences. Farmers, processors and marketers have 12, 7 and 8 as mean experience. This implied that majority of the value chain actors` had adequate years of experience that will help them to manage risk and make sound decisions to enhance performance in their various activities.

Table 2: Socio-economics characteristics of respondents

Variable	Farmers frequency	Percentage	Processors Frequency	Percentage	Marketers Frequency	Percentage
Age						
21-35	35	32.71	66	62.26	52	49.05
36-45	39	36.45	27	25.47	38	35.84
46-55	22	20.56	12	11.32	15	14.15
56-65	9	8.41	1	0.94	1	0.91
66-75	2	1.87	-		-	-
Mean	41.7850		34.2547		36.7547	
Gender						
Male						
	105	98.1	96	90.6	61	57.5
Female	2	1.9	10	9.4	45	42.5
Marital status						
Married	74	69.2	48	45.3	55	51.9
Single	31	29.0	54	50.9	33	31.1
Divorced	-	-	3	2.8	5	4.7
Widowed	2	1.9	1	.9	13	12.3
Household Size						
1-5	52	48.59	84	79.25	67	63.21
6-10	30	28.03	17	16.04	30	28.30
11-15	20	18.69	5	4.71	8	7.54
16-20	2	1.87	-	-	1	0.94
21-25	3	2.80	-	-	-	-
Mean	6.9813		3.7170		5.0000	
Farmsize (ha)						
0.1-3	60.00	56.07				
3.1-6	31.00	28.97				
6.1-9	10.00	9.35				
9.1-12	5.00	4.67				
12.1-15	1.00	0.93				
Mean	3.88					
Mean	12.04		7.33		7.88	
Education						
Primary	8	7.5	6	5.7	10	9.4
Secondary	44	41.1	53	50.0	64	60.4
Tertiary	40	37.4	27	25.5	21	19.8
Islamic	14	13.1	19	17.9	11	10.4
Non-formal	1	.9	1	.9	-	-
Membership of coopt.						
Yes	19	17.8	33	31.1	19	17.9
No	88	82.2	73	68.9	87	82.1
Access to credit						
Yes	19	17.8	31	29.2	39	36.8
No	88	82.2	75	70.8	67	63.2
Experience						
1-10	69	64.49	85	80.19	83	78.30
11-20	21	19.62	21	19.81	21	19.81
21-30	10	9.35	-	-	2	1.88
31-40	6	5.61	-	-	-	
41-50	1	0.93	-	-	-	
Mean	12.0374		7.3302		7.8774	

Source: *Field survey (2023)*

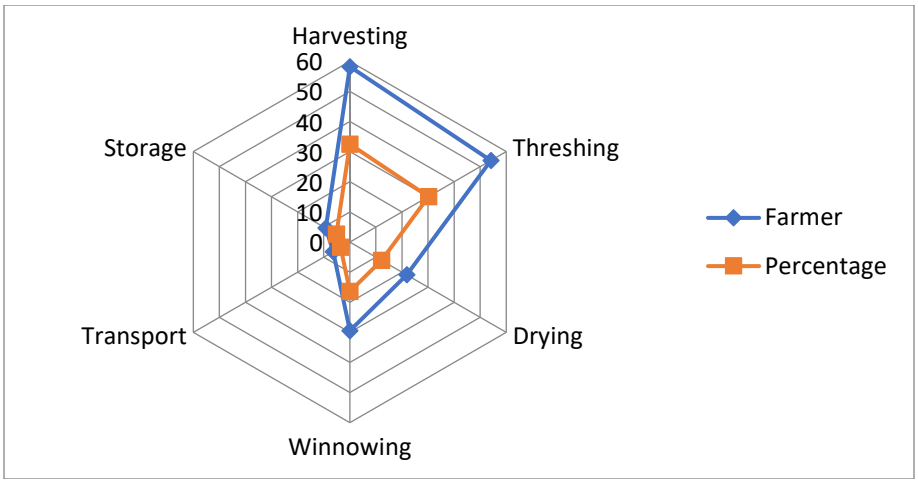

Figure 2: Losses incurred by farmers

Figure 2 presents the pattern of post-harvest losses at various stages on the farm. The losses incurred at the farm level include losses during harvesting, threshing, winnowing, storage, drying and transportation. The figure shows that farmers experienced higher losses of paddy during harvesting. Out of the total losses on the farm, about (32.50%) of paddy was lost during harvesting while (30.18%) of paddy was lost during threshing. Another 16.43% was lost during winnowing, and 12.19% during drying. However 5.14% got lost during storage while only 3.55% was lost during transportation. These losses were explained by the fact that most farmers in the study area used traditional techniques in farming operations except for transportation which were mostly conducted by vehicles transport system with minimal loss compared to that of traditional techniques. On average, about 189.22kg/ha of paddy rice was lost during production equivalent to over 2.5 bags (at 75kg/bag or ₦112,500.00 at ₦45,000.00/bag). This is in line with the finding of Appiah et., al. (2011), where it was acknowledged that losses at harvesting stage is higher when compared with the losses at other stages. These results contradict the findings of Sani et., al. (2022), who found out that farmers experienced higher losses of paddy during storage. This implies that postharvest losses of paddy rice contribute greatly to the reduction in the total quantity produced thereby affecting food security status and reducing the income of the farmers.

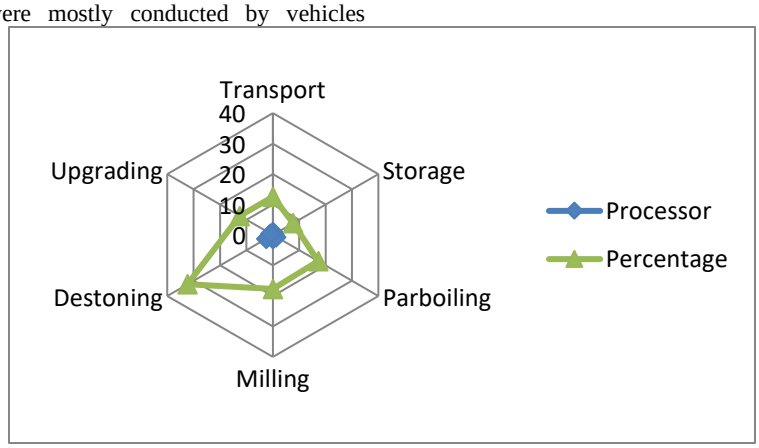

Figure 3: Losses Incurred by processors.

Losses incurred by processors were presented in Figure 3, the Figure shows from the total losses experienced by the processors`, losses during destoning were the highest at 32.32%, followed by milling (17.70%) and parboiling (17.20%) while upgrading (12.53) and transporting (12.52%) were moderate and storage was the least at 7.72%. These findings differ from the 11%, 10%, 9%, and 8% of milling, parboiling, transportation, and storage losses obtained by Coker (2016). The results revealed that destoning contained the highest loss during processing while storage is the least. On the average, about 10.22 kg/bag or ₦11,242 at ₦1100/kg of milled rice got lost during processing. Therefore, it is recommended that credit facilities should be provided to the actors so as to be able to acquire modern destoning and milling machine will go a long way in reducing losses at this stage of the value chain.

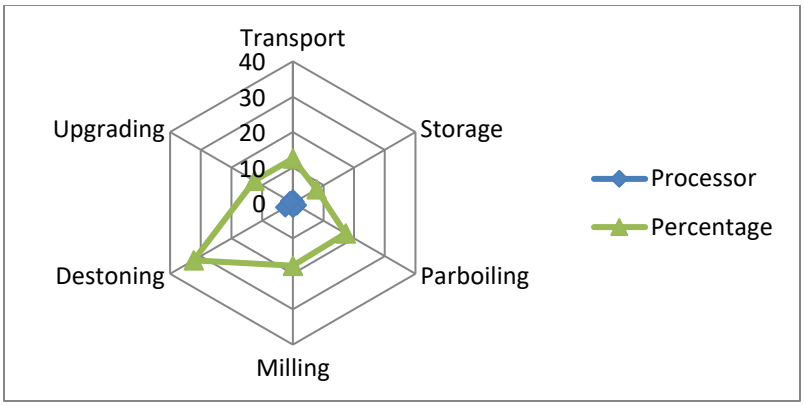

Figure 4: Losses incurred by marketers

The results presented in Figure 4 revealed that out of the total losses incurred by the marketers, measurement losses were 43.95%, storage losses (30.68%) and transportation losses was 25.37%. The result shows that marketers experienced higher losses due to measurement/handling followed by storage losses and lastly losses due to transportation. On average 3.22kg/bag or ₦3,542.00 at ₦1100/kg of milled rice got lost during marketing. This is mostly as a result of the use of poor measurement instrument and poor storage facilities. The use of good storage facilities and standard measurement instrument in addition to good transport facilities should be put in place so as to reduce the level of losses at this stage of the value chain.

Determinants of post-harvest losses among rice value chain actors

Table 3 shows the determinants of post-harvest losses among rice value chain actors in the study area. In this study, Person correlation and machine learning method were used. Household size significantly affects post-harvest losses for farmers` with coefficient of 1.9937 and p-value (0.008). This may be attributed to the fact that farmers with large farm size with many household members would likely employ family members for labour to save cost, however, at time family labours are less skilled in harvesting and other farming operations particularly in rice production which may result in high post-harvest losses. This finding is in line with that of MSME (2009) baseline survey in Kaduna state, Nigeria, where it was affirmed that the complexity of labour needed in rice farming accounts for high postharvest losses. However, educational level is statistically significant with coefficient of -21.89 and (p-value of 0.009). This indicate that for every increase in educational level the dependent variable decreases by 21.89kg on the average.

Moreover, for processors, experiences in processing had the coefficient of (-0.289) and is statistically significant at (p-value-0.003), indicating a negative relationship between experience and the dependent variable. This is to say that as experience increases, the dependent variable tends to decrease by 0.2891kg likewise access to credit has a coefficient of (-1.6760) and is statistically significant at (p-value -0.043), showing a negative relationship with dependent variable. This shows that the higher the access to credit the lower the post-harvest losses. This is logical in the sense that modern processing equipment will be procured and experienced/skilled labour would be employed.

Furthermore, for marketers only distance is significant at (pv-0.001) with coefficient of 0.77 showing that the more the distance the higher the losses.

Table 3: Determinants of post-harvest losses among value chain actors in the study area

Variables	Farmers		Processors		Marketers	
	Coeff	Pv	Coeff	Pv	Coeff	Pv
Gender	43.8187	0.480	-	-	32.561	0.524
Age	1.1861	0.359	0.0517	0.239	0.437	0.379
Household size	-21.8927	0.008**	-	-	11.734	0.672
Educational Level	-21.89	0.009**	0.1059	0.750	2.246	0.936
Variety	14.8082	0.571	-	-	-	
Method of Harvesting	-21.0903	0.604	-	-	-	
Farm size	26.0692	0.151	-	-	-	
Experience	0.4600	0.669	-0.2891	0.003**		
Membership of coop.	11.0370	0.609	-	-	-	
Access to credit	-28.5796	0.197	-1.6760	0.043*	-2.743	0.078
Distance	-		-0.0172	0.439	0.775	0.001***
Marital status	-		-0.7592	0.173	1.374	0.351

***Source**: field survey 2023 ***significant at 1%, ** 5%,* 10%*

Model Performance

In the study, three machine learning methods namely linear regression (LR), Decision tree regression (DTR) and Random Forest regression (RFR) were used to assess rice post-harvest losses in the study area. Parts of the data were used as model training set and test set. The prediction factors were selected from socio-economic factors. As presented in Table 4, the linear regression model had the highest prediction accuracy for farmers with R^2 of 0.61, RMSE 60.25, MAE 57.39 and MAPE 20.47 and processors with R^2 0.37, RMSE 4.12, MAE 2.96 and MAPE 34.05. The prediction performance was better than that of RFR and DTR. However, Random Forest has the highest prediction effect among all the other methods for marketers which R^2 0.20, RMSE 5.24, MAE 3.24 and MAPE 31.32. Meanwhile, R^2 is low which may be due to outliers or omitted variables.

Table 4: Performance of the machine learning models

Actors	Model	RMSE	MAE	MAPE	R^2
Farmers	RFR	72.50	58.75	25.31	0.376
	DTR	90.58	65.27	31.53	0.22
	LR	60.25	57.39	20.47	0.61
Processors	RFR	4.43	3.02	35.47	0.21
	DTR	4.58	3.39	37.04	0.20
	LR	4.12	2.96	34.05	0.37
Marketers	RFR	5.24	3.24	31.32	0.20
	DTR	9.34	7.82	45.34	0.17
	LR	8.45	5.45	33.66	0.18

Source: field survey (2023)

CONCLUSION AND RECOMMENDATION

Based on the findings of the study, it is evident that the postharvest losses in the study area is relatively high at an average of 189.22kg/ha of paddy for farmers, processors (10.22 kg/bag at ₦1100/kg), marketers (3.22kg/bag at ₦1100/kg) of milled rice. However, most of the actors` realize reasonable income. Meanwhile, household size, educational level and farm size significantly affects post-harvest losses for farmers` while experience and access to credit significantly affect post-harvest losses for processors and only distance significantly affect post-harvest losses for marketers. The study recommends training of value chain actors on post-harvest management and handling techniques as well as the provision of farm machineries and good storage facilities, that could help prevents losses especially at the farm level and stakeholders should intensify efforts and invest in providing infrastructural facilities such as good roads, so as to make easy access to market and rice processing mill by the actors. Increased accesses to credit facilities can help the rice farmers hire skilled rice harvesters, and threshers. These will help reduce post-harvest losses along the value chain in the study area.

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Authors` Contributions

Author HA. managed the initiation and design of the research. GEN. managed the data coding and analysis. HU. Edit the whole manuscript and EAE. Managed the research instrument design and guides the data collection.

Ethical statement

Not applicable

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