CHARCOAL PRODUCTION, ENVIRONMENTAL DEGRADATION AND RURAL-LIVELIHOOD: CRITICAL EVIDENCE FROM COMMUNITY PERCEPTION IN ADAMAWA STATE

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Abstract. Environmental protection in Nigeria and indeed most developing nations has never been a top priority due to the fact that economic losses arisen from environmental degredation especially as a result of charcoal production often occur long after the economic benefits have been realized. Nigeria is among the largest producers and consumers of charcoal worldwide. This has resulted in continued unsustainable harvest of the few remaining trees for charcoal production in Adamawa State, that has led to devastating environmental impacts on the livelihood of the rural poor where most of the inhabitants of these communities relied on this natural resource. Multi stage and purposive sampling techniques were employed in interviewing 172 respondents for this study. Data obtained were analyzed using descriptive and inferential statistics. Results on socio-economic characteristics revealed that majority (62.8%) of the respondents involved in exploiting the trees for charcoal production were males with a mean age of 33 years. Most respondents were married (63.4%) and having a mean household size of 7 individuals and mean annual household income was ₦216,570. Tree species such as Prosopis africana, Anogeisus leiocarpus and Ziziphus mauritiana were frequently exploited having a mean value of 4.7 and 4.6 respectively. The chi-square analysis revealed a significant relationship ($P<0.05$) between the perceived impacts of charcoal production and gender, age, educational level while marital status, household size, occupation and income of the respondents are not significant ($P>0.05$) in the study area. Charcoal production has become a lucrative business and major source of income to support rural livelihood.
Keywords: *charcoal production, environmental degradation, rural-livelihoods, community perception, sustainable energy policy*

Introduction

Charcoal production is an important economic activity that provides a considerable amount of employment and also serves as a source of livelihood for most rural households (Okello et al., 2001). Charcoal is typically derived from wood, a porous carbon material, with a heterogeneous surface and a disorganized pore structure susceptible to change by adequate thermal treatments to be used as absorbent (Pehlivan and Kahraman, 2011). In most tropical developing countries like Nigeria, energy in the form of charcoal is one of the primary source of energy for domestic requirements. Production and sale of charcoal has the potentials in generating employment and sustaining livelihoods for rural poor in addition to contributing to meeting up their energy needs (Ekhuemelo et al., 2023). Nigeria, a geographical space currently with an unprecedented inequality wealth distribution and high population growth with so much wealth in the country, many Nigerians still suffer on a range of issues such as massive use of charcoal, food insecurity, poverty, and most importantly, poor infrastructure and

economic development (Raimi, 2019). The snag, however is that Nigeria and indeed most of the developing world rely on the use of biomass as the only energy source of choice due to unavailability or unaffordable price of other alternatives like Kerosene, Gas and Electricity which may negatively affect livelihood.

Charcoal production trends between 1965 and 2005 show increasing production levels with Africa topping the chart (Onekon and Kipchirchir, 2016) and approximately 1.5 billion people in developing countries drive more 90% of their energy from charcoal for cooking and heating. Charcoal consumption in the majority of many sub-saharan Africa (SSA) is expected to double by 2030 and fuelwood utilization for charcoal production is estimated to be 544.8 million M3 and 46.1 million tons respectively (Kappel and Ishengoma, 2006). Charcoal is also utilized for industrial purpose as reducing agent in smelting process, medicinal and as source of export among others. However, the rapidly demand and urbanization in many developing countries including Nigeria have not seen an increase in alternative energy sources such as kerosene, gas, and electricity supplied over a period, making use of charcoal unavoidable. The perception of environmental impacts associated with charcoal production on the livelihood of rural inhabitants has continued to be increasingly recognized among communities, especially in developing regions where charcoal serves as a primary energy and income sources. Many studies indicate that local populations are aware of detrimental effects of charcoal production on their environment, including deforestation, soil degradation, air pollution among others. A study conducted in Nigeria that majority of respondents perceived charcoal production as a leading cause of deforestation and erosion with 62.7% acknowledging it′s contribution to soil erosion and 62.4% noting the reduction of available trees for future use. These might ultimately affects the peoples' livelihood since farming land may not be productive again.

Accordingly, Nigeria is one of the most deforested countries globally. Most indigenous trees are rampantly exploited for their excellent wood fuels without taking into consideration the slow nature of their regeneration. Nigeria is among the second largest producers of charcoal and also among the largest consumers of charcoal worldwide. Lack of readily available and cheaply affordable alternative fuels in most parts of Nigeria is what prompted many households into using charcoal for domestic cooking. Traditionally, all tree species can be carbonized to yield charcoal but as a matter of preference, some tree species are selected over others because of the high quality and quantity of the charcoal they produce. Most environmentalists agreed and feel that the traditional method of charcoal production should be stopped because of its destructive nature as presently practiced in most nations (Fearnside and Laurance, 2004). However, Arnold and Persson (2003) asserted that both rural and urban residents in developing nations have continued to have strong appetite for charcoal use. Recently in a bid to protect the environment, the Adamawa State government decided to ban charcoal production. However, the unaffordability of alternative energy sources induced by the high cost of cooking fuel such as kerosene and cooking gas, has continued to be a hindrance to achieving complete success of the policy in the state. Therefore, this research intend to bring to limelight the environmental impacts of charcoal production in some selected agrarian communities of Girei Local Government Area of Adamawa State. This is with the view to discourage the continuous unsustainable harvest of our few remaining trees for charcoal production in addition to improving rural livelihoods.

Materials and Methods

Study area

The study was conducted in Girei Local Government Area of Adamawa State. Girei LGA is one of the 21 Local Government Areas of Adamawa State, Nigeria. The area is located at the central part of Adamawa State and lies between latitude 9° 11' to 9° 39' North of the equator and longitude 120° 11' to 120° 49' East of the Greenwich meridian with land mass of 1,848 km2 and a projected population of 194,887 people. The dominant tribe in the area is the Fulbe or Fulani; however a substantial number of Bwatiye also dwell in villages such as Gereng, Tambo and Labondo within the study area. Girei Local Government falls under the Sudan Savannah type of vegetation and it experiences dry and wet seasons with temperature and humidity varying with seasons. The wet or rainy season fall between April to November having an average amount of rainfall (972mm) while the dry season is characterized by dry, dusty and hazy Northern trade wind that blows over the area from Sahara desert (Adebayo, 2020). Temperature are relatively high almost all the year round, temperature of the area ranges from 27°C-45°C. The coldest months are December and January having an average temperature of 34°C while the hottest period occurs between March and April with average tempreture of 44°C (Adebayo, 2020). The soil of the study area is loamy and it drains easily when it rains. The vegetation has a broad variety of tree species among which are; Vitex doniana, Balanite aegyptiaca, Adansonia digitata, Anogeisus leiocarpus, Prosopis africana, Ziziphus mauritiana etc.

Sampling procedure

Multistage and purposive sampling techniques were used in selection of respondents for the study. Three wards namely: Girei I, Modire and Damare out of the ten wards in Girei LGA were purposively chosen for the study. The reason that inform the choice of the areas was due to the concentration of charcoal producers, marketers and consumers (users). Three villages were purposively selected each from the already chosen wards making a total of nine villages (Sabongari, Sangere, Anguwan honna, Batare, Dagri, Niabbore, Damare, Bagale and Lainde). Twenty respondents were selected from each village using snow ball method as adopted to make a total of 180 respondents. A semi structured questionnaire was used to collect data from the respondents in the various localities. Data collected were on socio-economic characteristics, major sources of household domestic energy, methods of charcoal production, and perceived impacts of charcoal production on the environment among others.

Data analysis

Descriptive and inferential statistics such as tables, frequencies, percentage were used to analyze data on socio-economic characteristics of the respondents, tree species preferred and methods of charcoal production on the environment. A 5-point likert scale was used to know the extents to which various tree species were exploited for charcoal production. The results were interpreted using a mean score. A mean score response of between 4.5-5.0 respondents very frequently exploited, 3.5-4.49 represents frequently exploited, 2.5-3.49 represents not frequently exploited, 1.5-2.49 represent seldomly exploited while mean score of range 1.0-1.49 represents not exploited. Chi-square was also used to test whether there exist any significant relationship between perceived

impacts of charcoal production and some socio-economic characteristics of the respondents. The chi-square formula is given as adopted by Adedotun et al. (2023).

$$\chi^2 = \frac{(O-E)^2}{E} \qquad \text{Eq. (1)}$$

Where; O=frequency of respondents perceived impacts of charcoal production; E=frequency of respondents socio-economic characteristics.

Results and Discussion

Socio-economic characteristics of the respondents

One hundred and eighty (180) respondents were interviewed and questionnaires administered to them in the study area, out of which one hundred and seventy two (172) was retrieved. The results from *Table 1* showed the socio-economic characteristics of respondents. Most of the respondents are males (62.8%) while (37.2%) were females (*Table 1*). This shows that fuelwood exploitation activities for charcoal production is prevalent among males than females in the study area and this could be attributed to the fact that the activities is tedious and energy demanding which many women cannot cope. This agree with the findings of Tassie et al. (2021) who reported in a related study that most of the respondents 31 (91%) are males; this is as a result of the tedious nature of charcoal production which requires a lot of energy. The age distribution of the respondents from Table 1 revealed that majority of the respondents (51.7%) were within the age range of 28-37 years having a mean age of 33 years and mostly married (63.4%). This clearly shows that most respondents in the study area were relatively young and energetic. This finding agrees with Ahmed et al. (2021) who reported in a similar study that most charcoal producers are males and within the age range of 28-37 years with majority of the respondents married. Adedotun (2024) also reported that fuelwood exploitation is mostly carried out by youth having a mean age of 40 years because it required a lot of energy. Majority of production and utilization of charcoal is more among the married individuals than other categories in the study area. This is in conformity with the findings of Adedotun (2024) and Tassie et al. (2021) who reported that married people have more responsibilities such as the provision of food, education, health and well-being of their spouses and children and is primary reason for domination of the activities by the married people unlike the case for the singles who may not likely have other people to take care beside themselves. However, findings from this study is in contrast with the report of Alkali (2014) who stated in a similar study that majority of the respondents (63.05%) involve in exploitation of fuelwood for charcoal production are singles. The household size distribution of the respondents showed that majority 47.7% of respondents have a household size of 6-10 individuals, 16.9% have 11-15 individuals while 1.7% of them have individuals ranging from 16-20 and a mean household size of 7 individuals (*Table 1*). This shows that most of the respondents have medium to large household size and this might affect the rate of exploitation of fuelwood for charcoal production, which are used as source of domestic energy. This conforms with the findings of Ahmed et al. (2021) who reported that majority 26.6% of household size have 6-10 persons.

Table 1. *Socio-economic characteristics of the respondents.*

Variable	Category	Frequency	Percentage	Mean
Gender				-
	Male	108	62.8	
	Female	64	37.2	
Age (yrs)				32.7
	18-27	44	25.6	
	28-37	89	51.7	
	38-47	32	18.6	
	48-57	5	2.9	
	58-67	2	1.2	
Marital Status				-
	Single	50	29.1	
	Married	109	63.4	
	Widowed	12	7.0	
	Divorced	1	0.6	
Household Size				7.3
	1-5	58	33.7	
	6-10	82	47.7	
	11-15	29	16.9	
	16-20	3	1.7	
Occupation				-
	Farmers	83	48.3	
	Charcoal producers	48	27.9	
	Charcoal marketers	22	12.8	
	Civil servant	19	11.0	
Educational Level				-
	No formal	11	6.4	
	Primary	43	25.0	
	Secondary	94	54.7	
	Tertiary	24	14.0	
Income Annually (₦)				-
	Less than 250,000	120	69.8	
	250,000-500,000	44	25.6	
	500,001-750,000	5	2.9	
	750,001-1,000,000	3	1.7	

Results from *Table 1* further indicated that farming (48.3%) is the major occupation of the respondents, follow by charcoal producers (27.9%), charcoal marketers (12.85%) while civil servant (11.0%). The inability to produce charcoal all round the year may prevent some of the producers not to take it as primary occupation (Eniola and Odebode, 2018). Shackleton et al. (2007) in a related study noted that those who have farming as their primary income generating activities have the tendency to be involved in charcoal production because they clear lands which provide easy access to wood for charcoal production. The result reveals that there might be a lot of pressure on the trees in the study area due to the high number of charcoal producers and also consumers (including farmers). The findings further revealed that charcoal business in the study area could be a lucrative activity due to the availability of both charcoal marketers and consumers. This indicates that commercial charcoal production is profitable and blooming and might serve as important source of livelihood for the inhabitants of Girei communities. The findings from this study conforms with that of Ahmed et al. (2021) who also reported that majority 53.3% of the respondents occupation is farming and 30.7% are charcoal producers. The educational level of the respondents from *Table 1* indicated that most of the respondents 93.7% in the study area had Primary, Secondary and Tertiary education while 6.4% did not attend conventional education system. It was observed that even though the respondents were mostly educated, they still engage in charcoal production activities. The reason could be due to unemployment and the need to generate more income to support their families. This findings agrees with Ekhuemelo et al. (2023) who reported that majority of the respondents (85.0%) that had formal education in Adoka communities and engaged in charcoal making are unemployed or

underemployed. However, findings from the study is in contrast with that of Tassie et al. (2021) who reported that 45.3% of the respondents involved in charcoal production are illitrate (had no formal education). The study area also stand a better chance of accepting for conservation of trees so that they can continue to benefit from it. Awareness can be created in the study areas on the dangers of over exploitation of fuelwood trees for charcoal production as this might lead to increase in deforestation and atmospheric temperature, erosion, pollution, soil degradation, climate change among others, affecting livelihoods.

Majority of the respondents earned less than ₦250,000 annually. This income class has the highest frequency of 120 (69.8%), followed by those within income class of ₦250,000-₦500,000 annually with the frequency of 44 (25.6%) while those earning above ₦1,000,000 annually have a frequency of 3 (1.7%) (*Table 1*). The mean amount earned by respondents annually is ₦216,570.76. This is in line with a similar study conducted by Eniola and Odebode (2018) who reported that the annual income of respondents in a savannah zone was ₦217,336.4. It was observed from the field survey that majority of the respondents′ earnings in the study area is low and this could be the reason for the high pressure on the exploitation of fuelwood for charcoal production. Some charcoal marketers in the study area said they make a profit of about ₦50,000 to ₦10,000 monthly from the sales of 50 bags of charcoal. According to Reshad et al., (2017) collection and sale of firewood is reported to be important part of livelihood of rural people and charcoal making also help in generating more income (Worku et al., 2014). Most of the inhabitants along the value chain of charcoal business in the study area have witnessed an improved livelihood sustained by means of income earnings payment of school fees, building houses, clothing among others. This agrees with the findings of (Ekhuemelo et al., 2023; Monela et al., 2005) who reported in a related study that most families assessed used income from sales of wood land products including charcoal for the payment of educational costs, which is an indication of the importance of forest resources to the economics of the rural people. Chen et al. (2023) observed that low income communities are often more dependent on natural resources, leading to practices that may exacerbate soil degradation. Traditional economics can easily be referred as a biomass economics and rural livelihoods are intricately linked to the natural environment and this makes the charcoal production problem a complicated one to solve (Alkali, 2014).

Major sources of domestic energy

The major sources of household domestic energy in the study area from *Table 2* revealed that 44.8% of the respondents depends solely on charcoal, 24.4% uses kerosene, 18.0% uses cooking gas while 12.8% uses electricity. It shows that there is a wide utilization of charcoal among households in the study areas. This agrees with the report of Yobe State Ministry of Environment (YSME) that the major (64%) source of domestic energy was firewood and charcoal while electricity is 26%. The wide use of charcoal by most inhabitants could lead to more pressure on the tree species in the areas becoming rare and threatened, all in the quest to produce more charcoal to meet income and energy needs. This findings from this study is in line with that of Mamman et al. (2023) who reported that the high energy need of the people may be responsible for some species evolving into rare and threatened. The preference given to charcoal as a major source of domestic energy to other alternatives such as electricity, kerosene and

cooking gas could be the later are simply not affordable and far beyond the reach of most people living in both rural and urban areas.

***Table 2**. Major source of domestic energy.*

Source	Frequency	Percentage
Charcoal	77	44.8
Electricity	22	12.8
Kerosene	42	24.4
Cooking gas	31	18.0
Total	172	100

Major trees exploited for charcoal production in the study area

The major tree species exploited for the production of charcoal by the respondents were analyzed and presented in *Table 3*. The tree species that were very frequently exploited for charcoal production were Prosopis africana, Anogeisus leiocarpus and Ziziphus mauritiana. Adansonia digitata and Viteleria paradoxa were frequently exploited. Azadiractha indica, Vitex doniana, Balanite aegyptiaca, Tamarindus indica and Parkia biglobosa were not frequently exploited while Khaya senegalensis was not exploited at all. The tree species very frequently exploited for charcoal production could be as a result of high dominance of the trees and their suitability for usage in the study areas. It was further observed from the field survey that the reason why Prosopis africana was mostly exploited for charcoal production is that it is a hardwood, and it gives high charcoal yield (which can lead to more money when sold), burn slowly and takes longer time before turning to ash. This makes it suitable especially for commercial and industrial uses. The findings from this study comforms with Alkali (2014) who reported that Prosopis africana and Acacia senegalensis are the most preferred species for charcoal production. Further findings from this study revealed that Ziziphus mauritiana was frequently exploited this could be because most women prefer it. It is highly inflammable and less stressful during the igniting process. This conforms to the findings of Adedotun (2024) who reported that Ziziphus mauritiana was very frequently exploited in the study area and this could be due to cultural belief where most women prefer to use the species as fuel and its highly inflammable. Salamatu et al. (2021) also reported in a related study that Anogeisus leiocarpus, Prosopis africana are among the most preferred tree species used for charcoal production. The tree species not frequently or not exploited at all could be attributed to low dominance of these trees in the study areas. The low representative might be due to anthropogenic activities, slow growth and regeneration ability of the species which are mostly indigenous. This collaborates with the findings of Zhigila et al. (2016) who reported that low representative of some trees might be due to poor regeneration abilities or anthropogenic activities.

***Table 3**. Major trees exploited for charcoal production in the study area.*

Family	Species	Mean	Remark
Fabaceae	Prosopis africana	4.70	VF
Malvaceae	Adansonia digitata	3.60	F
	Azadiractha indica	2.60	NF
Lamiaceae	Vitex doniana	2.60	NF
Sapotaceae	Viteleria paradoxa	3.50	F
Combretaceae	Anogeisus leiocarpus	4.60	VF
zygophyllaceae	Balanite aegyptiaca	2.50	NF

Fabaceae	Tamarindus indica	2.80	NF
	Parkia biglobosa	2.60	NF
Rhamnaceae	Ziziphus mauritiana	4.60	VF
Meliaceae	Khaya senegalensis	1.30	NE

Note: VF=Very frequent; F=Frequent; NF=Not Frequent; NE=None Exploited.

Methods of charcoal production

The result from *Table 4* showed that most of the respondents (59.3%) in the study area used the traditional earth mound method in the production of charcoal (*Figure 1*, *Figure 2* and *Figure 3*). This agrees with Eniola et al. (2018) who also reported that majority (80%) of the respondents in the savannah zone used the earth mound method in charcoal production. Observation from the production site shows that this method produces a lot of emission into the atmosphere which could lead to pollution that can affect human health, increase in atmospheric temperature and also contributing to climate change hence this method should be stopped. The findings from this study agrees with Ellegård and Nordström (2003) who reported that traditional charcoal production can lead to climate change, deforestation and soil degradation with devastating impacts. It also conform with Amugune (2020) who reported in a related study that the use or ban of charcoal will be mostly inefficient due to the strong appetite for charcoal utilization by both rural and urban residents in developing nations, and traditional charcoal method used for production is capable of causing adverse health effects such as respiratory illness. Charcoal producers should choose a suitable technical methods that are friendly to the environment, rather than the earth mound method commonly used.

Table 4. *Methods of charcoal production.*

Method	Frequency	Percentage
Traditional earth mound	102	59.3
Brick kiln	39	22.7
Metal drum	31	18.0
Total	172	100

Figure 1. *Arranging of tree logs.*

Figure 2. *Burning process(emission released into the atmosphere).*

Figure 3. *A sample of the charcoal produced.*

Perceived environmrntal impacts of charcoal production on the livelihood of inhabitant in the study area

Results from *Table 5* revealed that most respondents (29.1%) agreed that one of the major drivers to deforestation is charcoal production. Also 23.3% of respondents believed that charcoal production can also be lead to soil degradation, 21.5% flooding, 19.2% population while 7.0% climate change. This implies that the respondents perceived that charcoal production could lead to soil degradation which have negative impacts on the fertility of agricultural soil leading to low organic matter and microorganism in the soil affecting crop yield production. Deforestation also slow down the rate at which arable crops can easily get nutrients deep from the soil and the land are easily exposed to flooding. This might wash away all the vital nutrients in the top soil that would enable the crops grow well. Emissions release from charcoal production site also contribute immensely to health challenges faced in the study area in addition to contributing to climate change problem. These perceived impacts of charcoal production have link to the livelihoods of the rural people, they directly or indirectly affects their means of sustenance. Msuya et al. (2011) observed that in most African countries where charcoal production is prevalent, challenges such as deforestation, soil degradation, increased erosion, acceleration of climate change, infertile land, and low crop yield exist and they affects the livelihood of people in the area. The result of Chi-square (*Table 6*) showed significant relationship ($P<0.05$) between the perceived impacts of charcoal production and gender, age, educational levels of the respondents in the study area. This suggested that gender, age and educational interventions might play a critical role in shaping perceptions and attitudes on the respondents in the study area towards charcoal production. Marital status, household size, occupation and income has no significant relationship ($P>0.05$) with perceived impacts of charcoal production by respondents. However, It was further observed that most respondents despite their gender, age and level of education still make use of charcoal daily as source of cheap domestic energy as well as a very lucrative business currently flourishing where earnings from it are used to support their livelihood. The findings of this study agreed with Ahmed et al. (2021) who reported a significant relationship between educational level of respondents and their knowledge on impacts of charcoal production on the environment.

***Table 5**. Perceived Impacts of charcoal Production in the Study Area.*

Perceived impact	Frequency	Percentage
Deforestation	50	29.1
Climate change	12	7.0
Flooding	37	21.5
Pollution	33	19.2
Soil degradation	40	23.3
Total	172	100

***Table 6**. Chi-square test on perceived impacts of charcoal production and socio-economic characteristics of the respondents.*

Socio-economic characteristic		Chi-square	Remark
Gender			
Male	108	χ^2 cal=20.75	*
Female	64	χ^2 tab=9.49	
Age class (yrs)			
18-27	44		
28-37	89		
38-47	32		
48-57	5	χ^2 cal=65.78	*
58-67	2	χ^2 tab=26.30	
Marital status			
Single	50		
Married	109		
Widowed	12	χ^2 cal=14.29	NS
Divorced	1	χ^2 tab=21.03	
Household size			
1-5	58		
6-10	82		
11-15	29	χ^2 cal=7.42	NS
16-20	3	χ^2 tab=21.03	
Occupation			
Farmers	83		
Charcoal Producers	48		
Charcoal Marketers	22	χ^2 cal=9.21	NS
Civil Servant	19	χ^2 tab=21.03	
Educational level			
No formal education	11		
Primary	43		
Secondary	94	χ^2 cal=30.21	*
Tertiary	24	χ^2 tab=21.03	
Income (₦)			
Less than 250,000	120		
250,000-500,000	44		
500,001-750,000	5	χ^2 cal=13.22	NS
750,001-1,000,000	3	χ^2 tab=21.03	

*Note: *=Significant at 5%, N.S.=Not significant at 5%.*

Conclusion

Charcoal production business in Girei LGA is currently a major source of domestic energy and income to the people. Despite the impacts it's production has on livelihood of the rural poor such as deforestation, increase erosion, infertility, low crop yield, acceleration of climate change, pollution among others. The business has continued to flourish even amidst the recent ban by Adamawa state Government on charcoal production. A lot of trees such as Prosopis africana, Ziziphus mauritiana, Anogeisus leiocarpus, Adansonia digitata, Vitelaria paradoxa, Azadiractha indica, Vitex doniana, Balanite aegyptiaca, Tamarindus indica, Parkia biglobosa were used for charcoal production hence the need for government at all levels to be involve in provision of alternative livelihood system for the rural people to reduce dependence on charcoal production as a business, alternative energy sources such as cooking gas, kerosene, electricity should be made available and affordable. The people should also be encourage to carryout afforestation and reforestation in the study area and credit facilities provided for men and women to start business other than charcoal production with irrigation facilities provided to encourage them to go into raising vegetables, tree seedlings among others to support their livelihood.

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Conflict of interest

The authors confirm that there is no conflict of interest involve with any parties in this research study.

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