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COMPARATIVE STUDY OF WOOD WASTE GENERATIONS ON SAWMILLING INDUSTRIES IN OYO STATE, NIGERIA

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ABSTRACTS
This study investigated various wood waste generation on sawmilling industries in Oyo State, Nigeria. Three sawmills (Ajah, Alomaja and Forestry Research Institute of Nigeria (FRIN) Ibadan) were selected for this study. Five different species were selected for wood waste generation (Gmelina arborea, Milicia excelsa, Lophira alata, Entandrophragma utile and Triplochiton scleroxelem). Twenty 20 logs diameter were taken from the five wood species and the volume of round log, volume of sawn log, volume of waste generated were determined and percentage of waste generated were calculated. Result revealed that Gmelina arborea was highest (26.99%) in abundant in the sawmills due to its utilization for various construction purpose and the lowest (21.432%) wood species was Melicia excelsa. However, these study reveals that wood waste generated from sawmilling operations in various sawmill are high and should be encouraged to enhanced in the utilization for energy production and other value-added product for wealth creation and environmental sustainability.

Keywords: Wood Waste, Sawmilling, Industries, Log volume Waste utilization, Lumbers**.**
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INTRODUCTION

Wood waste generation in Nigeria is constantly on the increase as a result of low average percentage timber recovery both in the forests and wood processing industries and increased demand for wood and its products in the country. Being perceived as mere useless materials to be discarded, wood waste has become a menace to public health and the environment in Nigeria due to its indiscriminate disposal practices (Akhator *et al.,* 2016). However, as the demand for wood products rises in a quest to meet the developmental drive of the society, the generated wood waste also increases and this increase overwhelms its present utility as a result, there is growing concern about fulfilling the need for timber products without deteriorating the world forest resources (FIM, 2017).

Wood wastes is a category of wastes that includes discarded wood products from different sources such as wood packaging, demolition and construction, wood processing industry, and others such as private households and railway construction (Van *et al.*, 2007). This waste can be a secondary source of raw material for energy production and production of a range of new potential product such as chemical, biofuel and other lignocellulosic materials (Packalen *et al.*,2017). Wood bark, for example, contains lipophilic and hydrophilic extractives that can be turned into high-value products like cosmetic chemicals or pharmaceutical products (Routa *et al.*,2017).
Also, preventing wood waste could assist the timber business in reducing environmental impact while also meeting the rising demand

for wood without further harming the world's forests (Eshun *et al.*,2012).
Therefore, reducing, recovering and enhancing the utilization of wood waste from harvesting and processing of wood should be the strategy of forest-based industries. Wood waste and byproducts from wood-based industrial operations can be used to make a wide range of useful industrial products. For every 1000 board feet of lumber produced, 1 ton of sawdust, shavings, slabs, and edgings is gathered in sawmills; approximately 75% of this useless material is wood content, and 25% is bark (Saal *et al.*,2019). This can be converted into energy and non-energy applications. The use of wood waste for energy generation includes form combustion, cogeneration, pellet and briquette while non-energy uses include the production of composite boards, surfacing product, composting, and cement board (Sudip, 2022).

The increase in the quantity of unutilized wood wastes have over the years impacted negatively on the environment while crude management techniques have posed health hazards in addition to air and water pollution. Hence, enhancing insight is required into ways of improving the efficiency of timber production process, reducing wood wastage and helping the timber sector to address growing environmental challenges (Eshun *et al.*, 2012). A huge volume of wood residue is generated annually from timber processing activities around sawmills, plank markets, and furniture making factories in cities within Nigeria. Wood wastes are generated from human operation in process of wood conversion which started from the forest to the last stage of processing before reaching the consumer. Through these processing activities, large quantities of wood wastes are generated which prompted further research in reutilizing the wood wastes for the benefits of mankind (Ogunjobi *et al.*,2018).

Wood wastes generation is a phenomenon in wood utilization, which cannot be over-emphasized. The process of wood conversion leads to generation of wood residues (wastes) which used to be adequately and properly utilized to ensure high wood recovery rate in other to maximize wood utilization (Ogbonnaya, 2001). Studies have shown that the conversion efficiency by sawmills in Nigeria is in the range of 40-56%. This implies that 44 – 60% of the logs inputs end up as residues. These residues are in the form of sawdust (5-12%), edgings, trimmings and slabs (30-40%). Sawmilling industry originated in Nigeria with the establishment of the first pit-sawing facility (Lucas, 1982). The small sawmills generate considerably higher wastes than the large mills because of low level of technological process adopted by the owners of the mills, poor machines maintenance and inadequate training of the operators (Ogunsawa, 2010).

The rate of wood wastage in sawmills differ from one sawmill to another. This may be caused by poor saw doctoring, inability of operators to handle the machines – band saw and ripping machine (Oyinloye, 2004). There is therefore, need for effective and efficient utilization of our forest resources. The problem facing the forest service is therefore how to meet the wood requirement of the growing population on sustainable bases (NISER, 1972). It is common knowledge that wood is the most multipurpose raw material the world has ever known. People have always relied on wood for their various needs, farming tools, building materials, fuel, weapons for hunting and warfare, until the last half of the 19th century, wood has been virtually the most principal material used for construction and energy generation (Ogunbode *et al.*,2013; Ogunvvusi, 2014). They are many useful products and uses that these generated wood wastes can be put into; which are particle board production, fibreboards, compost, fuel, pulp and paper production, poles. The study aimed at quantify the abundance of wood wastes for wealth creation and determination of the source wood waste are generated. This necessitates the need for environmentally friendly technologies for the recycling of wood wastes (Croan, 2000).

MATERIALS AND METHODS

Study area

The study was carried out in Forestry Research Institute of Nigeria (FRIN) Ibadan, Oyo State, Department of Forest Product Development and Utilization. FRIN is located on Latitude 7°23' 7°39' North and Longitude 3°51' 3°86' East with elevation of 122m above sea level. Rainfall of about 1250mm and 1800mm with temperature ranges between 27°C and 32°C with a relative humidity of about 75% to 90% (National Bureau of Statistics,2009).

Sample Collection
Data was collected at the sawmill industries in Ajao village, Alomaja Ibadan and Forestry Research Institute of Nigeria FRIN in Ibadan, Oyo State. Data were collected from three different sawmill on five different wood species (*Gmelina arborea. Milicia excelsa*, *Lophira alata*, *Entandrophragma utile* and *Triplochiton scleroxelem*),10 logs samples of different wood species making a total 0f 50 logs in each sawmill site, 20 logs were randomly selected on each of the wood sample to estimate the volume of wood waste generated at the sawmill, the diameter of the 20 logs from different wood species were measured using the basal part and upper part of the log to measure the circumferences. The circumference of the logs measured was converted into diameter using the appropriate formula (McGraw, 1994). The data obtained from this study were presented as descriptive statistical method analysis.

Determination of Log Volume
The round log volume over bark was calculated using the Smalian's formula. The Smalian's formula was used to calculate the volume of the logs (McGraw, 1994; Lucas,1982).
Smalian's Cubic Volume = (B + b) L/2 …… (i)
$V = (A_B + A_b) L/2$ …... (ii)
Where V = Volume of log (m^3); A_B = Cross-sectional area at large end of log (m^2); A_b = Cross-sectional area at small end of log (m^2)
L = Log length (m); A_B or A_b was calculated using the formula:(McGraw, 1994).
$A = \pi d^2/4$……. (iii)
Where A = Cross-sectional Area of the log (m^2)
π = 22/7 or 3.142d = Diameter of the log (m).

Determination of volume of processed lumber
The sawn lumbers are cut into different dimensions in sawmills according to specification of the customer and the volume/size of the log (Table 1).

Table 1: Common sizes of products produced based on market standard

S/N	Market Measurement Value	Conversion Value
1	1″ x 2″ x 12ft	0.0254 x 0.3048 x 3.66(m)
2	2″ x 12″ x 12ft	0.0508 x 0.3048 x 3.66(m)
3	2″ x 6″ x 12ft	0.0508 x 0.1524 x 3.66(m)
4	2″ x 4″ x 12ft	0.0508 x 0.1016 x 3.66(m)
5	2″ x 3″ x 12ft	0.0508 x 0.0762 x 3.66(m)
6	3″ x 4″ x 12ft	0.0762 x 0.1016 x 3.66(m)
7	2″ x 2″ x 12ft	0.0508 x 0.0508 x 3.66(m)

The first value on table 1 represents the thickness of the pieces of sawn boards, the middle value represents the width while the third value represents the length in the dimension. The volume of the marketable lumber pieces recovered for the log after sawing were estimated by taking measurements of the lengths, width and thickness. Sawn lumber volume produced from a log can be calculated using the formula:

Vs = T x W x L x N ………………………. (iv)

Where
Vs = volume of processed lumber
T = thickness,
W = width,
L = length,
N = number of sawn lumbers

Determination of total volume of wood wastes generated
The total volume of wood wastes generated in the mill was calculated using the simple mathematical formular of subtracting the final volume (volume of processed lumber from log) from the initial volume (volume of round log).

Vw = V – Vs ……………………………… (v)
Where
Vw = volume of wood wastes,
V = volume of round log,
Vs = total volume of sawn lumber produced

Determination of wood wastes percentage
The percentage of wood wastes was calculated using the formula; (Okigbo, 1964).
% of wood wastes = V -Vs x 100/V ……... (vi)
Where V = Volume of round log.Vs = Total volume of sawn lumber produced

RESULTS

The result in table 2; percentage volume of wood waste generated form *Gmelina arborea* reveals highest at log 2(38.01%) and lowest in log 11(10.10%), the mean percentage of waste generated was 26.992%, the high level of waste generated from this species accounts for its high level of utilization in construction work and other value-added products. The result in Table 3; percentage volume of wood waste generated form *Milicia excelsa*(Iroko) reveals highest at log 16(35.27%) and lowest in log 7(11.44), the mean percentage of waste generated was 21.34%. The result in table 4; percentage volume of wood waste generated form *Lophira alata* reveals highest at log 16(36.09%) and lowest in log 15(10.10%), the mean percentage of waste generated was 22.46%.

Table 2: Percentage volume of wood waste generated from *Gmelina arborea*

Logs S/N	Volume of round log (m^3)	Volume of sawn lumbers from log (m^3)	Volume of waste generated (m^3)	Percentage of waste generated (%)
1	1.2132	0.808	0.4052	33.39
2	1.6632	1.031	0.6322	38.01
3	1.1880	0.780	0.4080	34.34
4	2.1024	1.338	0.7644	36.36
5	1.4688	1.003	0.4658	31.71
6	0.4518	0.334	0.1178	35.27
7	0.3978	0.307	0.0908	22.83
8	0.3042	0.223	0.0812	26.69
9	0.5544	0.446	0.1084	19.55
10	0.1710	0.139	0.0320	18.71
11	0.4338	0.390	0.0438	10.10
12	0.4176	0.390	0.0276	36.09
13	0.4158	0.362	0.0538	22.94
14	0.2880	0.278	0.0100	34.72
15	0.8064	0.641	0.1654	20.51
16	0.8064	0.641	0.1654	20.51
17	0.4248	0.307	0.1178	27.73
18	0.4626	0.307	0.1556	33.64
19	0.6228	0.557	0.0658	10.57
20	0.4158	0.307	0.1088	26.17
Total	**14.6088**	**10.589**	**4.0198**	**539.84**
Mean	**0.73044**	**0.52945**	**0.20099**	**26.992**

Table 3: Percentage volume of wood waste generated from *Milicia excela*

Logs	Volume of round log (m^3)	Volume of sawn lumbers from log (m^3)	Volume of waste generated (m^3)	Percentage of waste generated (%)
1	0.9378	0.697	0.2408	25.68
2	0.6660	0.529	0.1370	20.68
3	0.1674	0.139	0.0284	16.97
4	0.7758	0.613	0.1628	20.98
5	0.4680	0.390	0.0780	16.67
6	0.4680	0.335	0.0718	17.65
7	0.7272	0.644	0.0832	11.44
8	0.4518	0.362	0.0898	19.88
9	0.7128	0.613	0.0998	14.00
10	0.3222	0.251	0.0712	22.10
11	0.4842	0.362	0.1222	25.24
12	0.5202	0.390	0.1302	25.03
13	0.5184	0.362	0.1564	30.17
14	0.4086	0.307	0.1016	24.87
15	0.5526	0.474	0.0786	14.24
16	0.4518	0.334	0.1178	35.27
17	0.3978	0.307	0.0908	22.83
18	0.3042	0.223	0.0812	26.69
19	0.5544	0.446	0.1084	19.55
20	0.1710	0.139	0.0320	18.71
Total	**10.0602**	**7.917**	**2.082**	**428.65**
Mean	**0.50301**	**0.39585**	**0.1041**	**21.4325**

The result in table 4; percentage volume of wood waste generated form *Lophira alata* reveals highest at log 16(36.09%) and lowest in log 15(10.10%), the mean percentage of waste generated was 22.46%.

Table 4: Percentage volume of wood waste generated from *Lophira alata*

Logs	Volume of round log (m^3)	Volume of sawn lumbers from log (m^3)	Volume of waste generated (m^3)	Percentage of waste generated (%)
1	0.8064	0.641	0.1654	20.51
2	0.4248	0.307	0.1178	27.73
3	0.4626	0.307	0.1556	33.64
4	0.6228	0.557	0.0658	10.57
5	0.4158	0.307	0.1088	26.17
6	0.5562	0.418	0.1382	24.85
7	0.1800	0.167	0.0130	17.40
8	0.5310	0.390	0.1410	26.55
9	0.4662	0.390	0.0762	16.35
10	1.0836	1.059	0.0246	22.70
11	0.3978	0.307	0.0908	22.83
12	0.3042	0.223	0.0812	26.69
13	0.5544	0.446	0.1084	19.55
14	0.1710	0.139	0.0320	18.71
15	0.4338	0.390	0.0438	10.10
16	0.4176	0.390	0.0276	36.09
17	0.4158	0.362	0.0538	12.94
18	0.2880	0.278	0.0100	34.72
19	0.8064	0.641	0.1654	20.51
20	0.8064	0.641	0.1654	20.51
Total	**10.1448**	**8.36**	**1.7848**	**449.12**
Mean	**0.50724**	**0.418**	**0.08924**	**22.456**

The result in table 5; percentage volume of wood waste generated form *Entandrophragma utile* reveals highest at log 4(66.09%) and lowest in log 2(9.51%), the mean percentage of waste generated was 24.73%.

Table 5: Percentage of wood waste generated from *Entandrophragma Utile*.

Logs	Volume of round log (m^3)	Volume of sawn lumbers from log (m^3)	Volume of waste generated (m^3)	Percentage of waste generated (%)
1	0.6336	0.502	0.1316	20.77
2	0.5238	0.474	0.0498	9.51
3	0.4338	0.390	0.0438	10.10
4	0.4176	0.390	0.0276	66.09
5	0.4158	0.362	0.0538	12.94
6	0.2880	0.278	0.0100	34.72
7	0.8064	0.641	0.1654	20.51
8	0.4626	0.279	0.1836	39.69
9	0.5566	0.334	0.2222	39.95
10	0.5310	0.390	0.1410	26.56
11	0.6228	0.557	0.0658	10.57
12	0.4158	0.307	0.1088	26.17
13	0.5562	0.418	0.1382	24.85
14	0.1800	0.167	0.0130	17.40
15	0.5310	0.390	0.1410	26.55
16	0.4662	0.390	0.0762	16.35
17	1.0836	1.059	0.0246	22.70
18	0.3978	0.307	0.0908	22.83
19	0.3042	0.223	0.0812	26.69
20	0.5544	0.446	0.1084	19.55
Total	**10.1812**	**8.304**	**1.8768**	**494.5**
Mean	**0.50906**	**0.4152**	**0.09384**	**24.725**

The result in table 6; percentage volume of wood waste generated form *Triplochiton scleroxylom* reveals highest at log 6&18(30.17%) and lowest in log 12(11.44%), the mean percentage of waste generated was 21.67%. Table 7 shows the summary mean of all the wood species, volume of round log, volume of sawn lumbers from log, volume of waste generated, percentage of waste generated (%) of *Gmelina arborea, Melcia excelsa, Enthadrophragma utile, Lophira alata, Triplochiton scleroxylom*. From the results *Gmelina arborea* had the highest volume of round of 0.73044 and highest in percentage of waste generation (26.992%). *Melicia excelsa* had the lowest volume of round log of 0.50301 and lowest in percentage of waste generation (21.4325). The low level of waste generated from this species accounts for its high level of utilization in value added products for wealth creation. Result on the mean summary of the wood waste generated from wood species reveals that volume of round log were highly significant at $P \leq 0.05$.

Result on figure 1 reveals that variation in rate of percentage of wood waste species generation, these reveals that *Gmelina arborea* and *Entandrophragm utile* was high at 26.99% &25.73% respectively and the lowest percentage waste generation was observed in *Melicia excelsa* and *Triplochiton scleroxylom* at value 21.43% &21.67% respectively.

Table 6: Percentage volume of wood waste generated from *Triplochiton scleroxylom*

Logs	Volume of round log (m^3)	Volume of sawn lumbers from log (m^3)	Volume of waste generated (m^3)	Percentage of waste generated (%)
1	0.4518	0.363	0.0888	19.65
2	0.7128	0.557	0.1558	21.86
3	0.3222	0.251	0.0712	22.09
4	0.4842	0.362	0.1222	25.24
5	0.5202	0.390	0.1302	25.03
6	0.5184	0.362	0.1564	30.17
7	0.4086	0.307	0.1016	24.87
8	0.5526	0.474	0.0786	14.24
9	0.6552	0.474	0.1812	27.66
10	0.6102	0.501	0.1092	17.89
11	0.4680	0.335	0.0718	17.65
12	0.7272	0.644	0.0832	11.44
13	0.4518	0.362	0.0898	19.88
14	0.7128	0.613	0.0998	14.00
15	0.3222	0.251	0.0712	22.10
16	0.4842	0.362	0.1222	25.24
17	0.5202	0.390	0.1302	25.03
18	0.5184	0.362	0.1564	30.17
19	0.4086	0.307	0.1016	24.87
20	0.5526	0.474	0.0786	14.24
TOTAL	**10.4022**	**8.141**	**2.2**	**433.32**
MEAN	**0.52011**	**0.40705**	**0.11**	**21.666**

Table 7: Mean summary of wood waste generated from wood species in selected sawmills

Wood Species	Vol of Round log (m^3)	Vol of sawn lumbers from log (m^3)	Vol of waste Gent (m^3)	Percentage of Waste generated (%)
Gmelina arborea	0.73044^{a}	0.52945^{b}	0.20099^{c}	26.992
Milicia excelsa	0.50301^{b}	0.39585^{bc}	0.1041^{d}	21.4325
Lophira alata	0.50724^{b}	0.418^{c}	0.08924^{d}	22.456
Entandrophragm utile	0.50906^{b}	0.4152^{c}	0.09384^{d}	24.725
Triplochiton scleroxylom	0.52011^{b}	0.40705^{c}	0.11^{cd}	21.666
Mean	0.55±0.04^{b}	0.43±0.024^{c}	0.120±0.021^{cd}	23.45±1.06
P≤0.05	0.12^{a}	0.068^{b}	0.0573^{c}	2.93

a,b,c,d = means with different superscript across the rows are significantly different (p< 0.05)

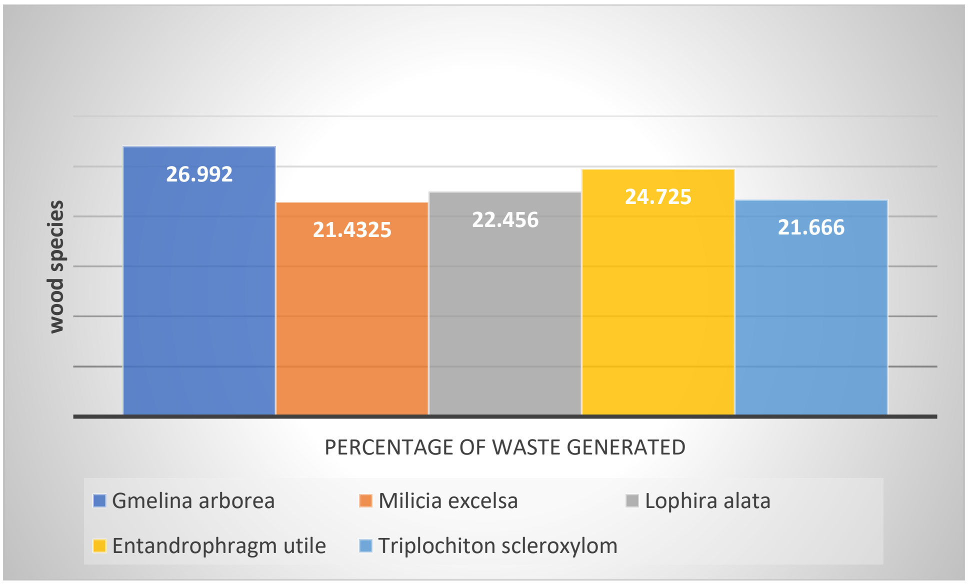

Figure 1: Species variation with percentage of waste genereation

DISCUSSION

Result on the study reveals high significant difference on the various wood species indicating that gmelina arborea and *Entandrophragma utile* percentage waste generation was high at 26.92% &24.73% respectively. Some of the factors that responsible for high wood generation may vary from one sawmill to the other and years of skill experience could have influenced its generation. These confirmed the report of Smith and Jeo, (2006) who reported that skill and year of experience of machine operators plays a major role in deciding wood waste generation from various wood species. The result in table 2; percentage volume of wood waste generated form *Gmelina arborea* reveals highest at the mean percentage of waste generated was 26.992%, the high level of waste generated from this species accounts for its high level of utilization in construction work and other value-added products, the result on *Melicia excelsa* could be attributed that wood is highly valued commercial timber in Nigeria, for which its demand is high. It is used for all sort of constructional work such as ship building and marine carpentry, sleepers, framework, trucks, structural uses etc (due to its resistant to acids and bases). Logs from this tree species are usually straight and cylindrical, which accounts for the high level of utilization of wood wastes arising from this wood. The average percentage volume of wood waste evaluated was 22.46%. *E. utile* is an excellent timber in strength with a high specific gravity which indicates its usage in high constructional work and furniture. The average percentage volume of wood waste evaluated was 24.73%.

T. scleroxylom known as Obeche is a tropical tree of Africa specialized for its highly proficient construction works. The average percentage volume of wood waste evaluated was 21.67%. The study reveals that highest percentage of wood waste were generated in from *G. arborea* 26.992% and least generation from *M. excels (Iroko)* (21.4325%) respectively. However, these values were affected by shape and size of the logs. This is similar to report of Aina (2006). He found that the diameter of logs and power supply greatly affect the average number of round logs converted per day. According to study by Kukogho *et al.* (2011), the highest percentage of lumber recovery in the mills studied was 80.23% due to the fact that most of the selected logs were fairly large in girth while the lowest lumber recovery was 70.09% due to the fact that most of the selected logs where fairly small in girth and of different forms. The result agreed with the observation of Ogunsanwo (2010) who observed logs size and shape to have direct impact on lumber recovery.

Furthermore, based on the number of sawn pieces of lumber cut into different dimensions in sawmills according to specification of customers and the volume/size of the log, the volume of *G. arborea, M. excelsa, L. alata, E. utile* and *T. scleroxylom* after conversion were 0.5295m^3, 0.3959m^3, 0.4180m^3, 0.4152m^3 and 0.4070m^3 respectively on the average of 20 logs each. This agrees with the findings of *Egbewole et al*. (2011) which revealed that wood species, technology and headrig process machine used and operators have direct significant impact on the conversion efficiency obtained during log processing and consequently, the volume of wood waste generated. Studies has shown that the conversion efficiency by sawmills in Nigeria is in the range of 40-56%. This implies that 44-60% of logs inputs end up as wastes. These wastes are in the form of sawdust (5-12%), edgings, trimmings and slabs (30-40%) (Ogunvvusi, 2014).

From the results, it was observed that higher dimensional timbers had lower percentages of wood wastes volume while smaller dimensional timber had the higher percentages of wood waste volume. This is in agreement with the findings of Magin, (2001) that the volume of wood wastes generated depends and varied within the dimensional sizes. Smaller dimensions produced higher volumes of wood wastes since they required more cutting. The above result also indicated that the percentage volume of wood wastes generated in the sawmill industries varied from 15-30%. This is also in line with the findings of Scotland (2002). He observed that during the conversion of logs into lumber at the sawmill, vast quantities of wood wastes can be produced with the final product in some cases accounting for 20-30% of the input log. However, this is more often 40-50% depending on the feedstock, equipment and end product (Scotland, 2002). Results also reviewed position of Ogunbode et al. (2013) who noted that the quality of the input log affects the amount of wood wastes generated when the log is sawn. Low quality logs produce large volume of wastes when sawn. Logs with fewer defects produce fewer wastes when sawn (Ogunjobi *et al.*,2018).

CONCLUSION AND RECOMMENDATIONS

Results of the study revealed high wood waste generated from *Gmelina arborea which account* average percentage volume of wood waste 26.992% accounts for its availability, high level of utilization in construction work as light weight wood and some strength properties and other value-added products, the wood waste generation maybe due to its high request for construction purposes and its quest for demand and is a hard wood which is not easy to generate waste during conversion process and the least wood waste generation was in *Melicia excelsa* (Iroko) with mean value 21.433%, Other wood species may be influenced by the skill operators and years of experiences in sawmill operation in various locations. The result also revealed that the volume of round log was significant at $p \leq 0.05$ at the value of $0.12m^{3.}$ Therefore, maintenance of the machine operator and trained skill operators would influence the reduction in wood waste generation, furthermore, abundance and availability of these wood waste generated should be put into efficient and effective re-utilization for fuel wood production such as charcoal and briquette production, particle board productions, fibre boards, oriented-strand board etc and other value-added products for wealth creation and sustainable environmental management.

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