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Analysis of the Wood Processing Chain and Improvement of Material Yield for Sapelli, Frake and Azobe: The Case of Interbois Company of Cameroon, Littoral Region

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Abstract

This study was carried out between February and June 2024 at the Société Interbois du Cameroun (SIBC), located in Douala 5ème. Its objective was to contribute to the analysis of the processing chain for the three timber species - Sapelli (Entandrophragma cylindricum), Frake (Terminalia superba) and Azobe (Lophira alata) - at SIBC, with a view to improving material yield. The methodological approach initially involved measuring a total of 196 logs for the three species studied: 92 for Azobé, 54 for Frake and 50 for Sapelli. These logs were selected using rational stratified sampling based on production flows over a five-month period, in accordance with ATIBT standards. Subsequently, each log was tracked; to prevent loss of traceability during cross-cutting and sorting operations, each log was individually marked at both ends with indelible paint. Dendrometric measurements were taken with the bark intact, in accordance with ATIBT volume measurement rules, in order to obtain the actual timber volume and enable an objective comparison of material yields by species. Diameter was measured using a forestry caliper in a cross-pattern (two perpendicular measurements were taken) to average out ovalisation. Finally, individual interviews were conducted with the managers of the various processing units using a semi-structured questionnaire. The results showed that the timber processing cycle at SIBC is as follows: procurement of roundwood stock, transfer of roundwood stock to the log yard, feeding of the head saw, processing of roundwood into sawn timber, inspection, storage and recording of batches of intermediate products, drying, planing and removal of batches from stock. The company has a specific yield by timber species of 33.12 per cent for Sapelli, 41.54 per cent for Frake and 38.67 per cent for Azobé, resulting in an overall material yield of 37.64 per cent with a standard deviation of

(±4.33), indicating moderate variability. This variation can be explained by the differences in the technological behaviour of the different timber species: (Sapelli is a high-density, cross-grain species with the lowest yield, whilst Frake is a homogeneous species). The range of [33.31 per cent - 41.97 per cent] shows that Interbois remains below the break-even threshold set by the ATIBT standard (45 per cent). In light of these results, the development of a sawing system that takes into account log shapes and variations in the cutting line depending on the timber species could increase machine yield. Furthermore, alternative uses could also assist SIBC in the production of various items (furniture, panelling, charcoal, etc.).

Keywords

Processing Chain, Timber, Improvement, Material Yield, Interbois Company Cameroon

1. Introduction

The African continent is home to a wide variety of ecosystems; its forests cover 645 million hectares, representing 21.4% of the total land area (Barney, 2018). The forests of the Congo Basin constitute the world's second-largest tropical forest massif after the Amazon (FAO, 2009) and span six countries: Cameroon (11%), the Central African Republic (3.4%), the Republic of the Congo (12.4%), Equatorial Guinea (1.3%), Gabon (17.7%), the Democratic Republic of the Congo (54.2%) (African Development Bank, 2018). They have a total estimated area of 268 million hectares, representing approximately 6% of the world's total forest area (CIFOR, 2015). They represent an exceptional reservoir of carbon and biodiversity for the countries concerned and for the entire planet. These forests provide livelihoods for 60 million people and help to feed a further 40 million in nearby urban centres (CIFOR, 2022). Today, 31 million hectares are allocated as forest concessions, representing 51.3% of the major forest areas identified in these countries. Around 20 million hectares are under management, of which 4.4 million are certified as 'sustainably managed' by the FSC (Forest Stewardship Council) (French Development Agency, 2012). The logging and timber industry sectors depend on this and have undergone major changes over the last two decades. The predominant activity in this logging sector is primary processing, with low material yield in most countries of the Congo Basin, particularly Cameroon (FAO & Vendahaute, 2013).

A study conducted by the Centre for Environment and Development (2019) showed that Cameroon loses around 60 billion francs each year by exporting timber in the form of logs, of which 10 billion represents taxes and duties; hence the need to focus on the local processing of wood products. Nevertheless, Cameroon already has a fairly diverse range of timber processing facilities. However, several factors influence sawmill operations, notably the performance of the machinery used, the skills of the sawmill operators (sawyers) and the sawing technique employed (Nguenang & Ngo Badjeck, 2013). Furthermore, Cameroon's forestry in-

dustry is characterised by numerous dilapidated facilities, which affect its competitiveness in both the local and international markets in terms of product quality and costs (French Development Agency, 2010). Hence the need to focus on the timber processing chain in Cameroon's timber processing units (UTBs).

Interbois company Cameroon (SIBC), having obtained its licence on 25 November 1993, has since made the sustainable management of its forests one of its core principles. Among the species most commonly harvested by this organisation are *Lophira alata, Terminalia superba and Entandrophragma cylindricum*, which actively contribute to the company's material yield. However, there is a low level of utilisation of wood waste within this company, which has a considerable impact on material yield; hence the main objective of this research is to analyse the processing chain of the three selected species at SIBC with a view to contributing to the improvement of material yield in sawmills.

2. Methodology

2.1. Description of the Study Area

The InterBois company of Cameroon (SIBC) is located in Cameroon in the district of Douala 5th Littoral Region, Wouri Department (Figure 1). This district was created by Presidential Decree of 25 November 1993, splitting off from the district of Douala 3. It is situated 30 km from the Atlantic coast, at the head of the Gulf of Guinea. The Douala 5th district, which covers an area of approximately 210 km^2, is both urban and rural. The district of Douala 5th is situated between 4˚05'47" north latitude and 9˚45'06" east longitude and is bordered:

- To the north by the municipality of Dibombari;
- To the south by the municipality of Douala 3;
- To the east by the municipality of Yabassi;
- To the west by the district municipality of Douala 1.

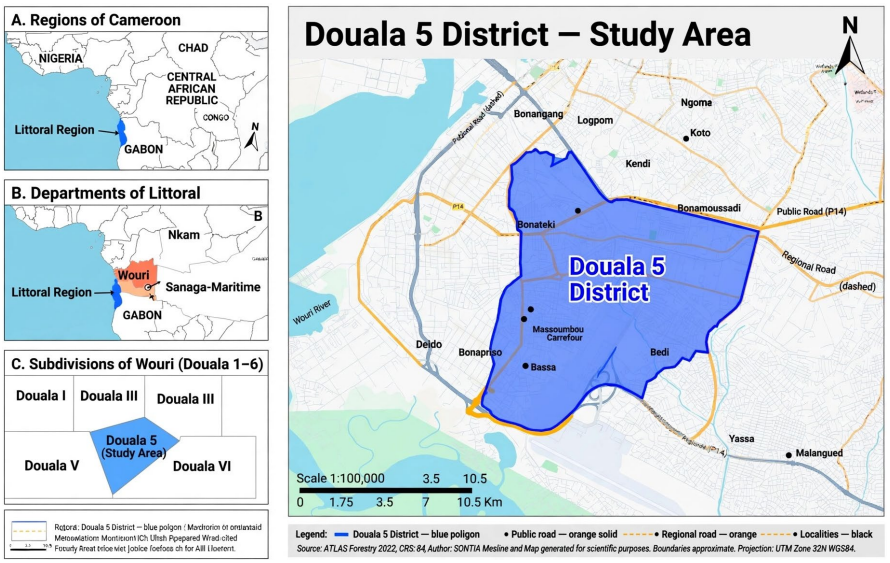


Figure 1. Map showing the location of the study area.

2.2. Data Collection

The data were collected through quantitative surveys and observations carried out at the InterBois company of Cameroon (SIBC). The information gathered focused on describing the timber processing chain and the material yield of three timber species: Sapelli, Fraké and Azobé at the SIBC production sawmill.

2.2.1. Description of the Timber Processing Chain at InterBois Company of Cameroon (SIBC)

Using observations made within SIBC, combined with semi-structured interviews with SIBC staff (heads of the sawing, drying, planing and quality control workshops), a map of the SIBC timber processing chain was drawn up. This map took into account all stages of the timber processing cycle. At each stage of the process, the unit manager was interviewed in order to gain a better understanding of the various links in the wood processing chain.

2.2.2. Yield Rates for Sapelli, Fraké and Azobé at the SIBC Production Sawmill

The yield was determined by measuring the various logs and log sections prior to sawing and then assessing the sawn timber obtained at each stage of the sawing process. The methodological approach initially involved measuring a total of 196 logs for the three timber species studied: 92 for Azobé, 54 for Frake and 50 for Sapelli. These logs were selected using rational stratified sampling based on production flows over a five-month period, in accordance with ATIBT standards. Subsequently, each log was tracked; to prevent loss of traceability during cross-cutting and sorting operations, each log was individually marked at both ends with indelible paint. Dendrometric measurements were taken with the bark intact, in accordance with ATIBT volume calculation rules, in order to determine the actual timber volume and enable an objective comparison of material yields by species. The diameter was measured using a forestry caliper in a cross-pattern (two perpendicular measurements were taken) to account for ovality. Finally, individual interviews were conducted with the managers of the various processing units using a semi-structured questionnaire. The information gathered focused on dendrometric measurements, including the names of tree species, the cross-sectional diameters of logs with sapwood at both the thick end and the thin end, and the length of each log. These data were collected regularly at the factory entrance. Following the processing operation, the length, width and thickness of the sawn timber were recorded, as were the types of waste generated during machining. With regard to cross-cuts, the boards from the same log retained the log's parent number, supplemented by an alphabetical character, and the volumes were totalled. The sawn timber products were separated by batch and marked with chalk, then their volumes were recorded separately on a tracking sheet. No grouping of sawn timber from different logs was permitted prior to volume measurement, in order to ensure that the individual timber yield could be calculated per log and per species. The timber yield for these species was assessed on the basis of initial estimates

of log volume and the volumes of sawn timber. The dimensions of the logs and sawn timber were measured using a metre and a decametre.

2.3. Data Processing and Analysis

The data was first organised manually, then entered and cleaned in Excel. The information collected made it possible, in particular, to describe the wood processing chain of Interbois company Cameroon and to calculate the volume of logs prior to sawing and that of sawn timber. The machining yield and the volume lost as waste, as well as that of the sapwood, were assessed using the following formulas:

- Determination of log volume

$$V = 1/4\,\pi D2L \tag{1}$$

where:

L = Log length;

D = Average diameter of the different ends.

- Determination of the volume (Vp) of each piece produced by sawing

$$Vp = L \times l \times e \tag{2}$$

where:

L = Length of the piece;

l = Width of the workpiece;

e = Thickness of the piece.

- Calculation of material yield for Sapelli, Fraké and Azobé

$$r = VpV \times 100$$

where:

r = Sawmill yield

Subsequently, data was organised into pivot tables using Excel to generate the sawn timber volumes for each processed species and the sawing yield.

Smalian's formula for calculating the volume of regular and tapered logs (Frake) and the volume by log bundles for irregular logs (Sapelli) has helped to limit the overestimation of volume.

In the case of tapered logs (as with Frake), Smalian's formula was adopted:

$$V = \left(\left(Sg + Sp\right)/2\right) \times L\,,$$

where:

Sg = Area of the thick end = π × $Dg^2/4$;

Sp = Area of the small end = π × $Dp^2/4$;

L = Log length.

For the calculation of volume by sections for irregular logs, Newton's method, which involves truncating the log, was adopted:

$$\text{Total}V = V_1 + V_2 + V_3 + V_4 + \cdots + V_n\,;$$

$$V = \left(A_1 + 4A_m + A_2\right) \div 6 \times L\,;$$

A_1: Area at large end; A_m: Area at midpoint; A_2: Area at small end; L: Length.

2.4. Results

2.4.1. Description of the Wood Processing Chain at Interbois Company Cameroon

The wood processing chain at Interbois company Cameroon mainly covers the first and second stages of processing, ranging from log procurement to packaging and storage. The wood processing chain at Interbois company Cameroon is structured as follows (Figure 2):

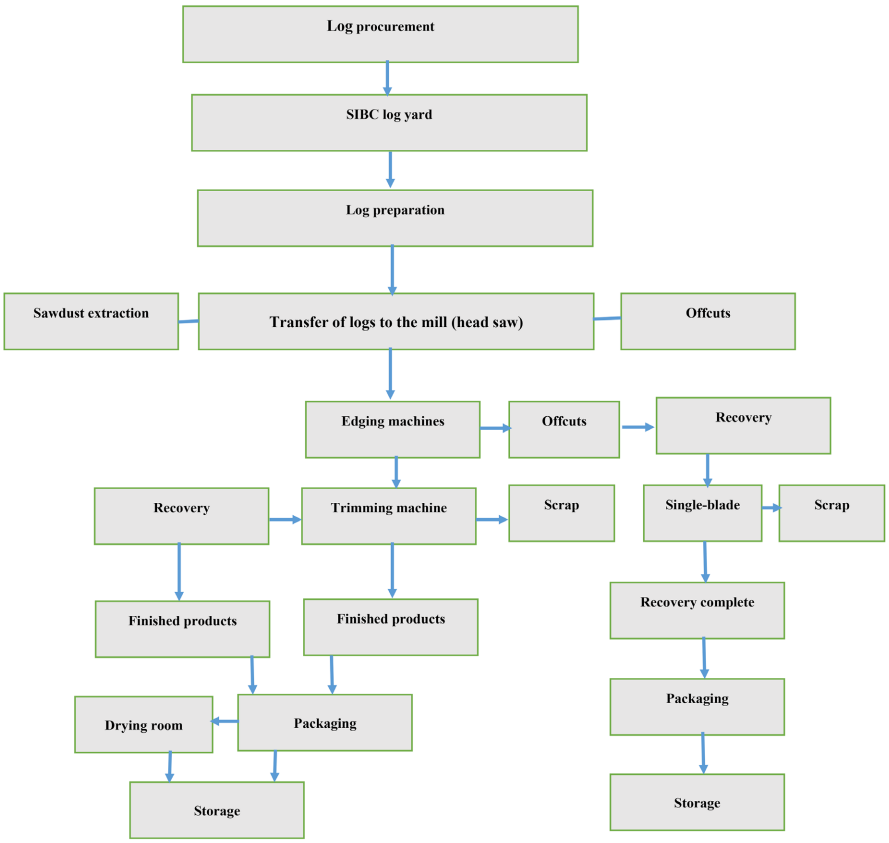


Figure 2. Sawing process at the Interbois company Cameroon timber processing unit.

✓ **Supply of log stock:**

The receiving log measurers record the logs that have been delivered to the log yard on the forms. They check the information on the consignment note and carry out a measurement check. Once the forms have been completed, they are signed by the log measurer at the end of the receiving process. A stock intake report is drawn up by the logistics department; this is printed and submitted to the log yard measurers for approval, who sign it with their names. Finally, the approved report is filed in the log book at the log yard office.

✓ **Transfer of roundwood stock to log stock**

The log sorter responsible for cross-cutting selects and marks the logs in accordance with the sawmill's orders, using the contract sheets provided by the production managers. The cross-cutter cuts according to the markings. The cross-cutter then measures the length of the logs and records their dimensions on the

log sheets, along with the date of cross-cutting. Once cross-cutting is complete, the list of cross-cut logs is sent to the logistics department for the cross-cutting details to be entered.

The marker clearly paints the internal number on both sides of all the logs. The log stock manager then enters all the data listed on the cut log sheet into the log management application. The logs in question are reclassified from whole logs to logs. The daily entry report is then printed and submitted to the log measurer for checking. The records are then sorted by number at the log measurers' office.

✓ **Feeding the head saw**

Before starting production, the plant manager checks the order book and informs the team leaders. The team leaders update the noticeboard with the list of current contracts and add to the production schedule any other contracts that could potentially be sawn during the same production run. At each head saw, the operator records the internal numbers of the logs on the trolley during their shift in a duplicate consumption logbook. A copy of this record is sent to the log sizing office. The log stock manager enters the new data from the consumption sheets into the stock management system. The logs in question are removed from the log stock and the raw material stock. The daily log consumption report is printed. This report is submitted to the log measurer for verification; the measurer signs it with their name and files it in a chronological file at the log yard office.

✓ **Processing of logs into sawn timber within sawmills**

As the factory operates on a just-in-time basis, there is no stock held during production. The packages produced are either intermediate packages or finished packages. However, waste is also generated during the production of these packages and can be recycled to produce reclaimed packages.

✓ **Inspection, storage and recording of intermediate product packages**

The picker, acting on instructions, identifies the packages that are to be sent to intermediate production. They mark the details of each package using white industrial chalk. For these intermediate packages, the picker draws up an intermediate production report, noting the date and all the package details. The packages are transported to the intermediate products area. The packer then forwards the intermediate production reports to the cut-to-order operations department. The intermediate products stock manager enters the information from the report into the cut-to-order management system and prints a copy, which must be checked and signed by the packer.

✓ **Planing**

The processing department specifies which contracts are to be sent to the planing mill. Packages received at the planing mill are recorded on a receipt form. The cubing operator sends a copy to the team leader for package tracking and another to the debited operations tracking department. Using this information, the debited stock manager updates the planing mill entry details, prints a report and sends it to the cubing operator for correction and approval. The final report is archived in the debited operations tracking department. Planed packages are recorded on

finished production forms. For each package recorded, the contract number, package number and timber species are specified. This report is signed off and forwarded to the debarked operations monitoring department. Once the package is complete, the measurer proceeds to measure the new packages produced and assigns them a new package number. The contract number and label remain the same as for the main contract. The marker then applies this information using paint, depending on the type of label.

✓ **Clearance sale**

The parcels to be picked are selected according to the specifications of the contract to which they will be allocated. The information on the parcel is updated and the parcel proceeds through the processing workflow if necessary. The order picker draws up a stock removal report corresponding to the allocation of the package to a contract. This report is forwarded to the debited operations monitoring department for updating the debited operations management application. The manager responsible for monitoring the debited operation updates the application and prints the various reports for checking, validation and archiving.

2.4.2. Yield of the Three Selected Timber Species (Sapelli, Fraké and Azobé) at Interbois Company Cameroon

1) Yield of Azobé

Figure 3 shows that the volume of offcuts decreases as the processing progresses, with the main stage being the edger, which produces 33.24 m^3 of waste, compared to the head saw, which produces 26.34 m^3 and the cross-cut saw, which produces less waste at 18.71 m^3. These results can be explained, amongst other things, by the incompetence of the machine operators and the poor quality of the timber, which has defects (warping, frost damage). Figure 4 shows the sawn yield of azobé at each stage of the processing process.

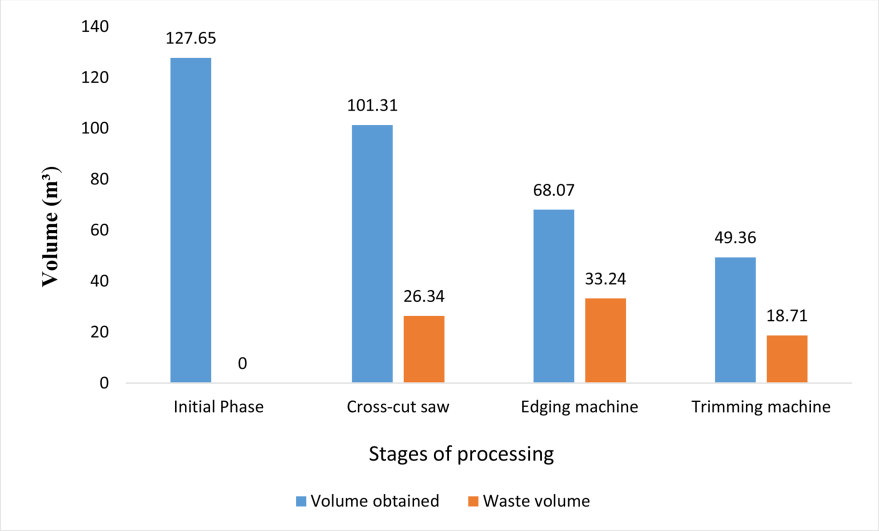


Figure 3. Volume of Azobé offcuts and waste produced.

Figure 4 shows the overall material yield of Azobé, estimated at 38.67% and

broken down by stage as follows: 79.36% at the head saw, 67.19% at the edger and 72.51% at the cross-cut saw. As Azobé is a naturally hard wood, it has a low yield percentage due to the poor quality of the logs, which contain defects (rot).

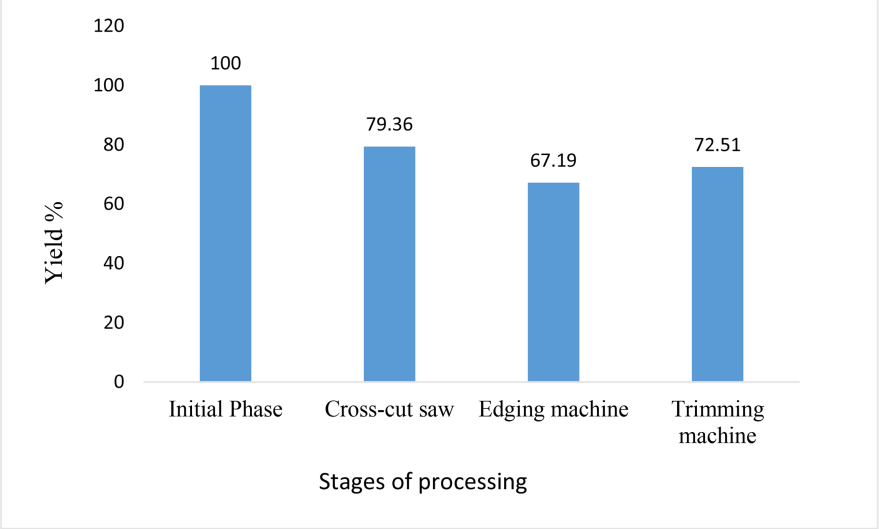


Figure 4. Azobé yield by stage.

2) Material yield of Frake

The results for the Fraké's material yield (Figure 5) show that the volume of sawn timber decreases as the processing progresses, with the head saw representing the main source of loss at 21.1 m^3. These results can be attributed, amongst other things, to the operators' lack of expertise in timber processing.

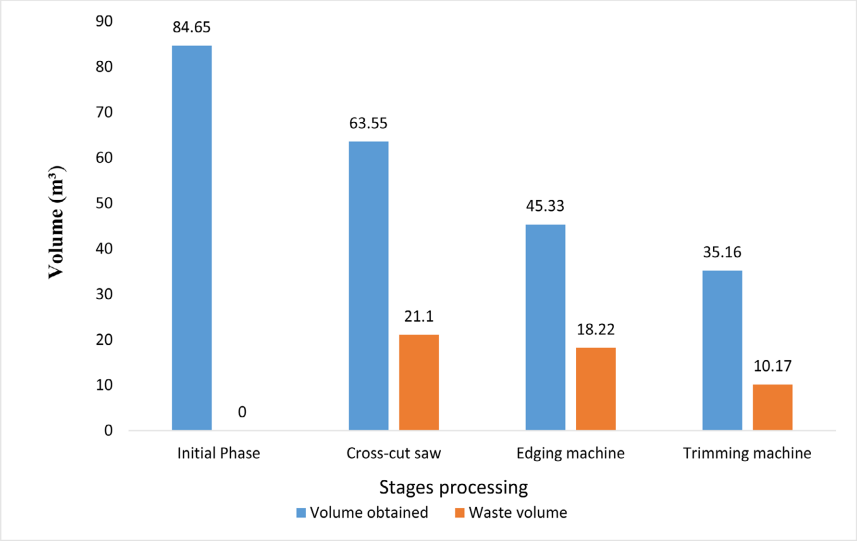


Figure 5. Volume of sawn timber and waste produced by Fraké.

The overall material yield for Fraké is 41.54%, distributed across the various stages as follows: 75.08% at the head saw, 71.33% at the edger and 77.56% at the

cross-cut saw. However, as Fraké is a softwood, a loss is observed at the edger stage due to the poor quality of the wood (Figure 6).

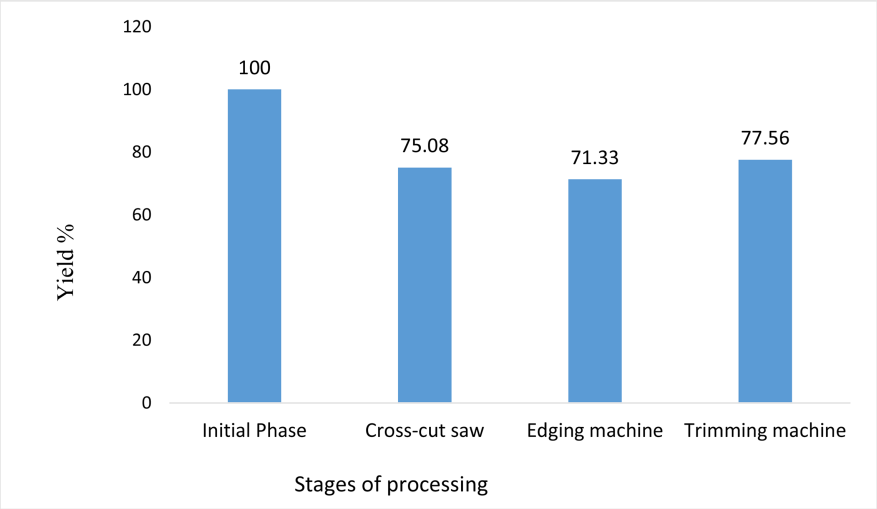


Figure 6. Fraké yield rates from one stage to the next.

3) Sapelli material yield

The material yield of Sapelli shows that the volume of sawn timber decreases as processing progresses, with the main stage of loss being the head saw at 28.52 m^3 (Figure 7). These results can be explained, among other things, by the incompetence of the machine operators and the poor quality of the timber, which exhibits rot defects in the sapwood.

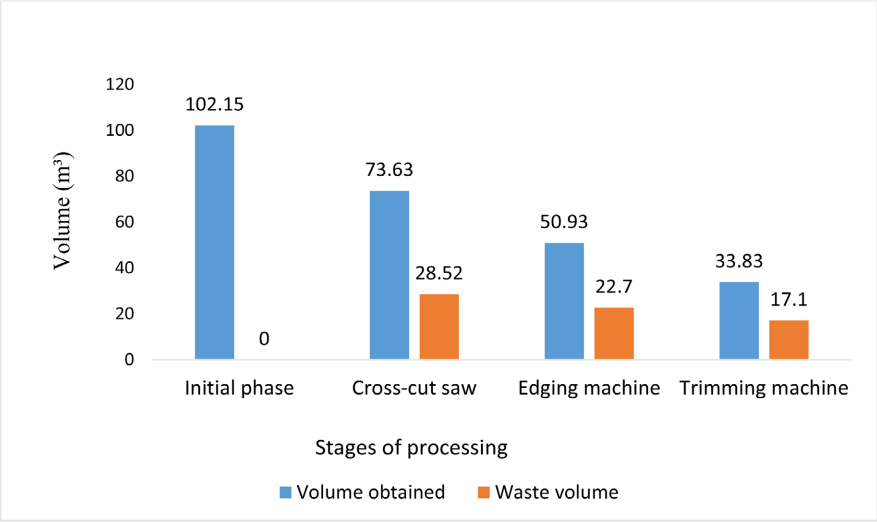


Figure 7. Volume of sawn timber and Sapelli waste produced.

The overall material yield for Sapelli is 33.12%, distributed across the various stages as follows: 72.08% at the head saw, 69.17% at the edger and 66.43% at the cross-cut saw (Figure 8). As sapelli is a medium-hard wood by nature, it has a

very low yield percentage compared to hardwoods and softwoods. This is due to the presence of sapwood, which is cut below the sapwood line.

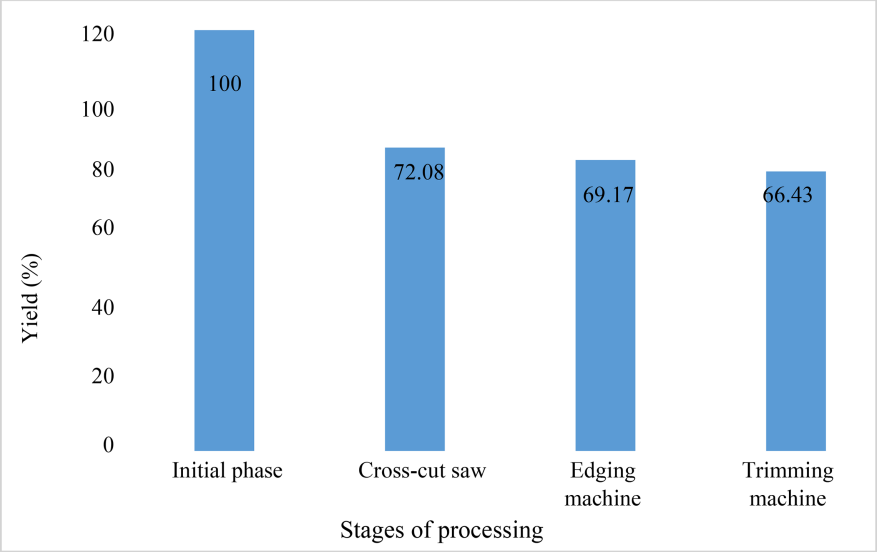


Figure 8. Sapelli yield from one stage to the next.

2.5. Overall Material Yield for the Three Species at Interbois Company of Cameroon

The volume of sawn timber decreases as processing progresses, with the main stage of loss being the head saw at 75.96 m^3 (Figure 9). In general, the overall material yield of the species studied at the SIBC sawmill is shown in Figure 10.

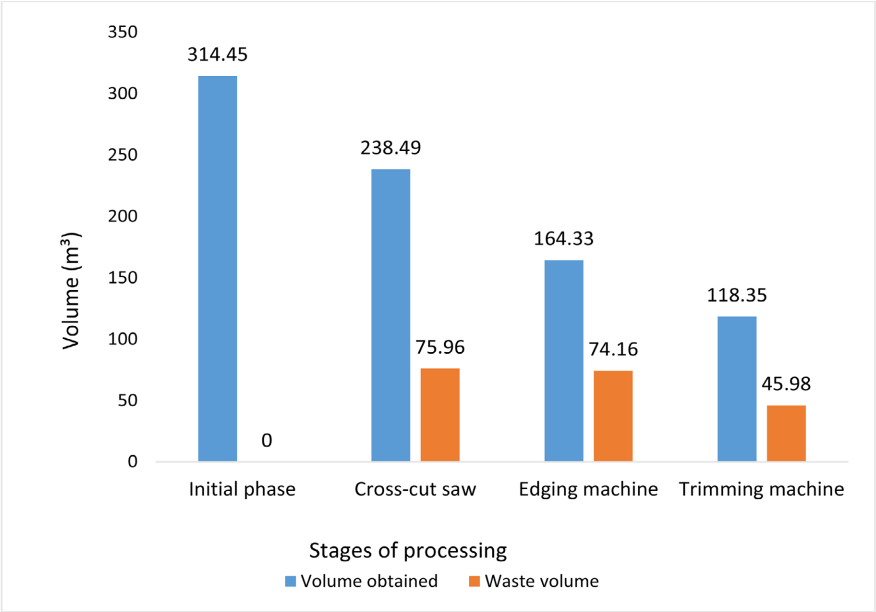


Figure 9. Volume of sawn timber and waste produced.

The overall material yield for the selected species is 37.64%, distributed across

the various stages as follows: 75.84% at the head saw, 68.90% at the edger and 72.02% at the cross-cut saw (Figure 10).

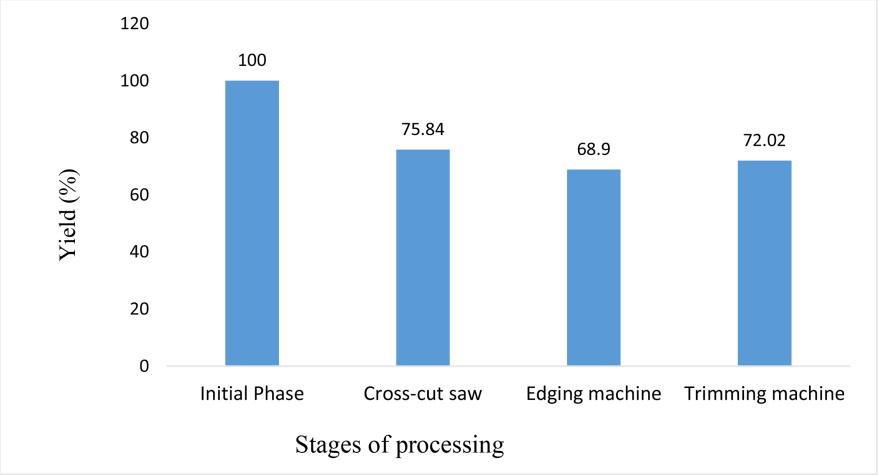


Figure 10. Overall sawn yields from one stage to the next.

3. Discussion

3.1. Description of the Processing Chain

The SIBC processing cycle involves the procurement of roundwood stock, the transfer of roundwood stock to the log yard, feeding the head saw, the conversion of roundwood into sawn timber, the inspection, storage and recording of batches of intermediate products, drying, planing and the removal of batches from stock. This is similar to the description provided by Owono (2020), which is defined as the sawmill log yard, preparation of logs for sawing, transfer of logs to the head saw, processing of logs into sawn timber, packaging and storage.

3.2. Material Yield

SIBC's material yield is 75.84% at the head saw, 68.90% at the edger and 72.02% at the cross-cut saw; these results therefore give an overall yield of 37.64% with a standard deviation of (±4.33) indicating moderate variability. This variation can be explained by the differences in the technological behaviour of the different timber species: (Sapelli is a high-density, cross-grain species with the lowest yield, whilst Frake is a homogeneous species). This result differs from that obtained by Nimpa (2019), which was 46.7%; from that obtained by Owono (2020), which was 67.77%, and from that obtained by Ansah et al. (2023), which was 57%. This is due to the fact that Dino et Fils and the Industrial Society of Mbang utilize part of their wood waste. However, the results obtained in this study are close to those predicted by the forestry administration (Ministry of Forests and Wildlife, 2013), which is 40%. The material yield based on wood hardness is 38.67% for hardwoods (Azobé), 33.12% for medium-hard woods (Sapelli) and 41.54% for softwoods (Frake). This is close to the figure obtained by Nimpa (2019) for softwood (Ayous), which was 41.31%, but differs from that for hardwood (Iroko) and medium-

hardwood (Sapelli), which were 23.70% and 37.11% respectively. This timber processing unit produced 196.1 m^3 of waste from an initial volume of 314.45 m^3 broken down as follows: 75.96 m^3 from the head saw, 74.16 m^3 from the edger and 45.98 m^3 from the cross-cut saw.

4. Conclusion

Having reached the conclusion of this study, which aimed to contribute to the analysis of the processing chain for the three timber species selected by the SIBC, with a view to helping improve material yield in sawmills. To carry out this study, information was gathered through data collection via direct interviews with key informants at the UTB and through direct observations. The results of the study show, albeit with some ambiguity, that the company has a specific yield per species of 33.12% for Sapelli, 41.54% for Frake and 38.67% for Azobé, resulting in an overall yield of 37.64% (±4.33). To help optimize material yield in Cameroon's wood processing units, and in particular at SIBC, measures must be taken to minimize the amount of wood waste produced in these units by prioritising the recovery of wood offcuts. To minimize losses, SIBC should establish contractual partnerships with companies for the recycling of wood waste; organize staff training workshops on wood processing and methods for reusing wood waste; install a system in the log yard to treat logs with preservatives upon receipt in order to protect the wood against abiotic and biotic pathogens; create a covered storage area to reduce losses due to adverse weather conditions.

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Author Contributions

Christelle DADEM: Supervision and Revision; Jean Baurel ATCHOMBOU: Research, Revision, Editing; Mesmine Sheilla SONTIA KENFACK: Conceptualisation.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this article.

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