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Optimization of material yield in the sawing process in wood transformation industries

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ABSTRACT: Processing units, particularly in wood sawing, face challenges related to material yield that can impact a company's objectives. This study aims to improve material yield at the Société de Transformation de Bois (STB) by diagnosing the processing of three species: Ayous (*Triplochiton scleroxylon*), Ilomba (*Pycnanthus angolensis*), and Onzabili (*Antrocaryon nannanii*). The results indicate that Ayous (10.52%), Ilomba (9.21%), and Onzabili (9.21%) are the main species processed, with 50% of wood being hardwoods. Onzabili has the highest initial volume (87.21 m³) and volume after sawing (32.34 m³). However, Ayous has the highest material yield at 49.11%, followed by Ilomba (39.40%) and Onzabili (37.07%). The average yield at STB is 46% and is influenced by natural factors, technical factors, and employee skills. To improve yield, STB should demand better quality logs and implement strategies such as process optimization, staff training, quality monitoring, and effective waste management.

KEY WORDS: Material yield, sawing, optimization, wood processing, Cameroon.

I. INTRODUCTION

Unrolling is the operation that produces a veneer strip from the periphery of a log while it rotates. The knife moves in a translational manner [1], completely removing defective parts to achieve the desired width. This operation allows for the production of veneer sheets either continuously (cylindrical unrolling) or discontinuously (eccentric unrolling), with marketed thicknesses ranging from 0.5 to 3.5 millimeters [2]. The veneer sheets produced can have various uses, including the manufacture of matches, plywood panels, and packaging [3, 4]. Depending on the application, specific quality or decorative effects may be sought. Unfortunately, wood processing companies often experience significant losses in raw materials due to waste and wood scraps, leading to decreased yield and economic revenues [2, 5].

A low material yield rate can jeopardize a processing company's viability; thus, some authors argue that the second major issue for sawmills is maximizing "material yield" from all parts of the log after transport by logging trucks [6]. According to Laprise [7], material yield is the ratio of outgoing wood quantity to incoming wood quantity, expressed as a percentage. Generally, the sawing/unrolling yield is about 50–55%. In Gabon, for example, the material yield of unrolling and plywood units is 60% [8], while in Cameroon, it varies between 29% and 40% [9, 10]. Given that wood resources are limited and exhaustible over time and space, efficient and effective utilization is essential for sustainability [11, 12]. Optimizing material yield has become a major challenge for wood processing companies like the Société de Transformation de Bois (STB), where the average material yield ranges from 45% to 63% depending on the species.

Several factors contribute to low material yield rates in processing units (UTs): (1) Poor management of raw materials, which can result from inadequate planning or stock management, leading to shortages or overstocking that affect overall yield; (2) Inefficient production processes, including obsolete or poorly optimized methods, which can cause raw material loss or transformation errors; (3) Defects or technical problems, such as defective machines or unforeseen issues that lead to production stoppages and raw material losses; (4) Lack of training or skills among personnel, resulting in errors during the transformation process and raw material loss; (5) Waste and losses during the transformation process, which may occur during transport, handling, cutting operations, or due to non-recyclable waste; (6) Environmental constraints, where strict regulations may limit the use of certain materials or impose restrictions on transformation processes; (7) Insufficient understanding of the physicochemical characteristics of tropical species, as many wood species have not yet been adequately described.

In light of these challenges and threats to STB's objectives, it is crucial to diagnose its transformation chain to understand the evolution of material yield over time and identify the causes of fluctuations. This study aims to improve the material

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yield of unrolling at STB SA. Specifically, we will focus on: (i) Describing the material circuit of unrolling in the company; (ii) Determining the material yield of three target species: Ayous, Ilomba, and Onzabili; and (iii) Identifying the factors contributing to a low material yield rate.

II. MATERIALS AND METHODS

A. Presentation of the study area

The Société de Transformation de Bois (STB) factory is located in the city of Yaounde, the capital of the Central region and the capital of the Mfoundi department, in the Yaounde 3 district, Ahala neighborhood, 200 meters from the Blessing station heading towards Mbankomo (Figure 1). Its main activities in wood processing are peeling and the manufacturing of plywood. These products are primarily: peeled veneers and backer sheets.

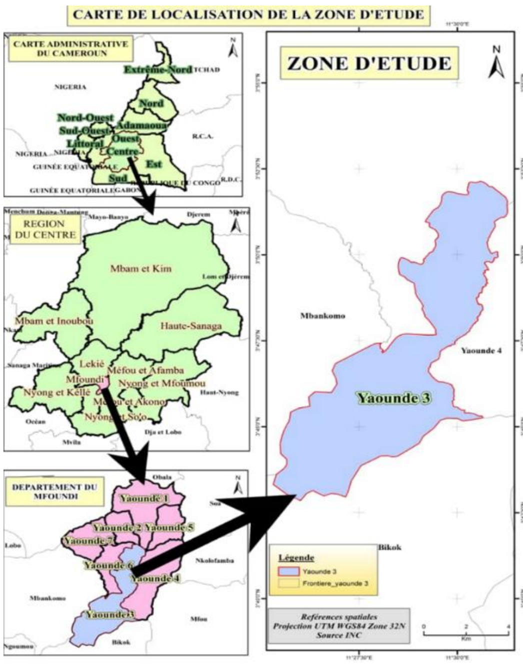

Figure 1.1 Location of the study area.

B. Data collection and analysis

To carry out this research, we conducted online research to exploit existing documents (theses, books, articles, and reports), observe, and consult stakeholders (targets) in the STB. The data collected are of two types: primary data and secondary data. STB SA processes several types of wood; however, after a preliminary assessment, we realized that three types account for nearly 70% of the material processed at STB because they are highly sought after by customers. These are Ayous, Ilumba, and Onzabili, and for this reason, these species were selected to determine the material yield of STB. The determination of material yield was achieved through measurements (length and diameter of logs; length, width, and thickness of pieces) of the logs before and after peeling using a tape measure and a decameter. To identify the factors that contribute to a low material yield at STB, interviews were conducted focusing on the skills of workers, the sharpening method of the peeling blades (knives) used, machine adjustments, observation of defects on the logs, and the production chain.

Calculation of the initial volume with sapwood (VAA) and the volume (VD) after debarking.

The calculation of the initial volume with sapwood (VAA) of each log was done before their debarking using equation 1 for cubing used in Cameroon, which is:

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$$\mathbf{VAA = (\pi Dm^2 / 4) \times L} \quad (1)$$

With L = Length of the log; D = Average diameter of the different ends. The determination of the volume (VD) of each piece resulting from the unrolling of each one:

$$\mathbf{VD = L \times l \times e \times N} \quad (2)$$

With L = Length of the piece, l= Width of the piece; e = Thickness of the piece; N= number of veneer sheets.

Calculation of material yield per log and percentage of defects

It was carried out using the formula (3),

$$\mathbf{r = (VD / VAA) \times 100}, \quad (3)$$

With r = Material yield of the unrolling unit expressed in %. We used the following formula to determine the percentage of defects allocated obtained from the formula below.

$$\mathbf{P(\%) = (longueur\ du\ défaut / longueur\ de\ la\ bille) \times 100} \quad (4)$$

Figure 2 shows the sketch of the measurement points.

$$\mathbf{Dm(cm) = [(d_1 + d_2 + d_3 + d_4)] / 4}, \quad (5)$$

Diameters were measured with sapwood and without sapwood to determine the diameter with sapwood (DAA) and without sapwood (DSA).

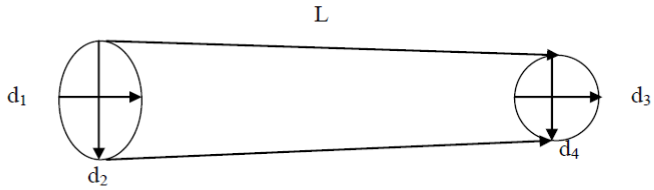

Figure 2. Sketch of measurements taken on a log.

The volume with sapwood (VAA) and without sapwood (VSA) were calculated using the respective formulas:

$$\mathbf{VAA(m^3) = [(\pi / 4)(DAA)^2] \times L}, \quad (6)$$

$$\mathbf{VSA(m^3) = [(\pi / 4)(DSA)^2] \times L}, \quad (7)$$

This volume represents the estimated or measured amount of wood contained in a log, a trunk, a barrel, or a tree, usually expressed in m³. The difference between VAA and VSA gives the sapwood volume. The expression (8) gives the percentage of the sapwood volume relative to the volume of the trunk.

$$\mathbf{[(VAA - VSA) / VAA] \times 100}, \quad (8)$$

For the products of sawing or unrolling a trunk, measurements of length, width, and thickness were taken, as well as counting the number of pieces by length, width, and thickness. The cubing was determined using the following formula for both sawn and unrolled products:

$$\mathbf{V(m^3) = N \times L \times l \times e}, \quad (9)$$

Where N= number of pieces; L= length (m); l= width and e= thickness.

The analysis of yield in sawing and unrolling was done for each log or billet of these species, the transformation was monitored, and the sawn and unrolled volumes were measured to calculate daily and for the entire study period (12 days) the average yield in sawing and unrolling of each species. The yields (Rdt) and for unrolling were found using the following formulas respectively:

$$\mathbf{Rdt(\%) = (volume\ scié / VAA) \times 100}, \quad (10)$$

$$\mathbf{Rdt(\%) = (volume\ déroulé / VAA) \times 100}, \quad (11)$$

The software Microsoft Excel 2016 and Statistix 8.0 allowed us to highlight the proportions of skilled or regularly trained workers and the adjustment mode of the various tools and equipment related to the processes, and Solidwork to establish a new scheme aimed at restructuring the said unit by incorporating new equipment deemed necessary.

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III. RESULTS AND DISCUSSIONS

A. Description of the raw material processing circuit and the resource exploited

The logs arrive at the Société de Transformation de Bois (STB), are received, and stored in the log yard. After receiving an order, the relevant wood species are scaled, cubed, cut, and debarked according to the specified clauses. The billets are then sent to the peeling unit. At the peeling machines, they are centered and peeled into a continuous strip called veneer sheet. After peeling, the veneer sheets are rolled up and sent to the cross-cutting machine, the dryer, sorting, and finally the products are classified for export or for the manufacture of plywood [3]. Table 1 presents the species exploited by STB. Ayous (10.52%), Padouk (10.52%), Ilomba (9.21%), and Onzabili (9.21%) are the major species processed by the company. STB has a preference for hardwoods (50%) compared to softwoods (29%) and semi-hardwoods (21%) (Table 1). However, the hardwoods do not undergo any prior thermal treatment, which is important for softening the wood, making it easier to peel, and limiting losses. According to Adhikari, Quesada [13], cross-laminated timber (CLT) manufacturing reveals both opportunities and complexities associated with integrating hardwood lumber, especially as mass timber emerges as a formidable alternative for sustainable construction.

Table 1. Percentage of wood species processed at STB

Common names	Scientific names	Nature of essence	Percentage (%)
Ayous	*Triplochiton scleroxylon*	Soft	10.52
Padouk	*Pterocarpus soyauxii*	Hard	10.52
Ilomba	*Pycnanthus angolensis*	Soft	9.21
Onzabili	*Antrocaryon nannanii*	Soft	9.21
Acajou	*Swietenia macrophylla*	Hard	7.89
Epicéa	*Picea abies*	Hard	7.89
Bubinga	*Guibourtia tessmannii*	Hard	7.89
Bilinga	*Nauclea diderrichii*	Medium-hard	7.89
Iroko	*Milicia excelsa*	Hard	6.57
Moabi	*Baillonella toxisperma*	Medium-hard	6.57
Movingui	*Distemonanthus benthamianus*	Medium-hard	5.26
Wenge	*Millettia laurentii De Wild*	Hard	3.94
Kosipo	*Entandrophragma candollei*	Medium-hard	3.94
Frake	*Terminalia superba*	Soft	2.63

Within this milieu, STB's targeted selection aligns with an industry-wide shift toward resilient and ethically sourced materials that meet rigorous sustainability standards while enhancing structural integrity. The utilization of hardwoods like Ayous and Padouk not only meets the criteria for durability and aesthetic appeal but also signifies compliance with emerging ecological mandates, which are becoming paramount in competitive market landscapes [14, 15]. This adherence to principles of eco-consciousness ensures STB's alignment with global efforts to curtail environmental degradation through responsible resource management.

B. Determination of the material yield of Ayous, Ilomba, and Onzabili species

Data analysis shows that the initial volume with sapwood (VAA) is higher for Onzabili (87.21 m^3) compared to Ilomba (71.81 m^3) and Ayous (62.63 m^3) (Figure 3a). The volume after peeling (VD) is higher for Onzabili (32.34 m^3) and lower for Ilomba (23.29 m^3). Regarding yield, Ayous has the highest material yield (49.11%), followed by Ilomba (39.40%) and finally Onzabili (37.07%) (Figure 3a).

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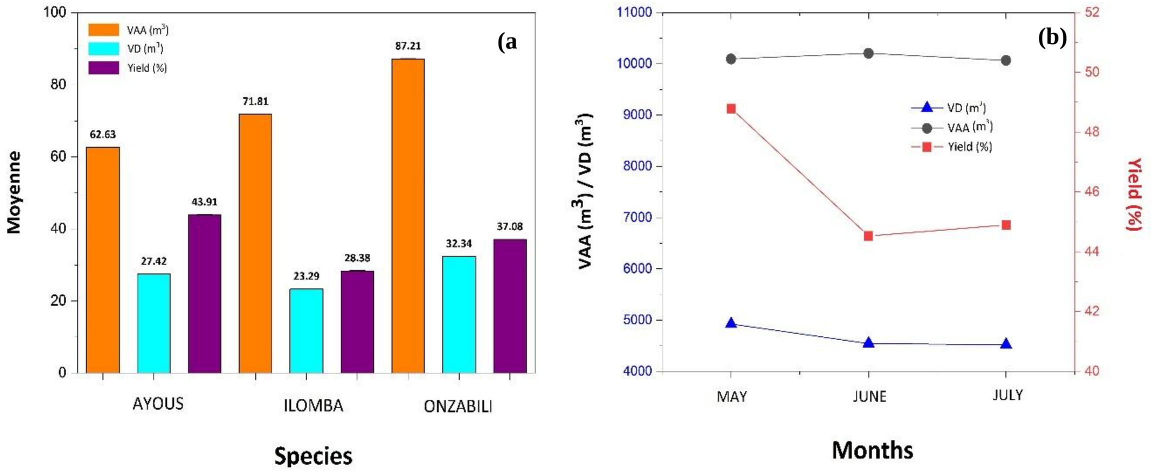

Figure 3. Volumes and material yield during the unrolling of Ayous, Ilomba, and Onzabili from STB during the 3rd quarter of 2022. Initial volume with sapwood (VAA), volume after unrolling (VD).

Material yield varies according to several factors related to the intrinsic characteristics of the wood. The reasons for yield differences include: (i) cell composition; (ii) moisture content; (iii) the presence of knots and defects; and (iv) the hardness and resistance of the wood. Our results are similar to those of Kambogo [16], who indicated that slicing/peeling yield varies between 43-50%. Moisture content remains a pivotal element, as Atik and Yılmaz [17] assert that improper levels lead to significant challenges in processing and long-term dimensional stability. Additionally, their study underscores the pivotal role of knots and defects, which introduce variability in both aesthetic appeal and structural soundness elements critical in ensuring consistency in high-quality wood products.

The resistance and hardness attributes further dictate the selection criteria for wood utilized in heavy-duty applications, emphasizing the necessity for rigorous quality control measures during harvesting and processing stages. Moreover, the duo's analysis reiterates the significant role of knots and defects which not only compromise structural soundness but also affect market value due to their impact on aesthetic uniformity [18]. Hardness and resistance remain pivotal, as they dictate suitability for specific applications requiring heightened durability, reinforcing the necessity for stringent selection criteria and processing protocols to ensure high-quality outputs. The transformation circuit of STB appears to be more efficient than that of the Company Dino et Fils (JDF) with a lower material yield in Ayous (41.31%) [19]. Moreover, the average yield of STB (46%) is higher than that of SEFAC (39%) and SIM (37%) [20].

C. Factors influencing the low material yield rate

C.1. Natural factors (related to raw material)

During peeling, imperfections such as knots or cracks lead to material losses. The behavior of cutting tools depends on the hardness of the species, influencing the cutting speed. The yield of hardwoods is generally low, with the lowest yield observed for Ilomba (28.38%). In the log yard, the woods exhibit numerous defects due to prolonged exposure to the elements and soil quality. Losses caused by defects are classified into structural defects (cracks at 26.66%) and conformity defects (tapering at 36.66%) (Table 2). Other defects such as cracks and knots negatively impact yield. The amplitude of deformations increases oversizing and results in low material yield [21].

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Table 2. Default rates recorded during the study period.

Defects	Weight (kg)	Percentage (%)
Structural defects		
Fracture	4	15.23
Rollers	6	22.85
Rot	5.25	20
Cracks	7	26.66
Knots and Bosses	4	15.23
Conformation defects		
Misshapen	5	33.33
Conicity	5.5	36.66
Curvature	3	20
Flat Face	1.5	10

C.2. Technical factors

The cutting into thin sheets influences material yield. Poor planning can lead to excessive waste. Results show that 36% of the peeling steps are not operational in the STB transformation circuit. Missing steps include the absence of a breaking yard and a steaming station. Adhering to the confidence intervals of parameters and geometric angles is essential for the success of the process. Peeling machines must be precise and well-maintained to minimize losses [22, 23]. The characteristics of the machines are presented in Table 3.

Table 3. Parameters for the operation of the STB machines.

Parameters	Results
Pressure bar	10% compression rate
Wear step	The pitch is set at 2.7 for 3 mm thick pieces and at 4.5 for 5 mm thick pieces
Blade thickness	1.3 mm
Average duration of use	2 hours
Bevel angle	It is 20°
Clearance angle	Variable
Rake angle	Variable
Vertical side	The vertical side is set at 0.7 mm for e = 3 mm and at 0.9 mm for e = 5 mm
Horizontal Side	
Placage thickness	Commonly used thicknesses are: 3 mm for hardwoods and 5 mm for softwoods
	Variable (depending on the quality of the wood)
Feed speed	A = 60 x 3 = 180 tr/mn for 3 mm thick pieces:
	A = 60 x 5 = 300 tr/mn for 5 mm thick pieces
Cutting speed	25 m/s
Log rotation speed	It is set at 60 tr/mn

The sharpening of blades must be precise. Currently, the blades are sharpened dry, which can lead to overheating and premature wear. The use of a wet sharpening method is recommended to keep the whetstone clean and slow down wear.

C.3. Human Factor

The skills of the employed staff are one of the important factors that influence performance. Indeed, workers must be proficient in the use of machines. Following the survey conducted within the company, data analysis reveals that out of

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500 recruited employees, only 125 employees at STB have undergone training in the primary processing of wood, 145 in the peeling field, and 230 have received no specific training in the wood sector (Figure 4). Such disparities underscore the necessity for structured skill enhancement initiatives that align with organizational objectives and enhance productivity metrics [24]. In an environment where technological advancements continuously reshape operational demands, the lack of adequately trained workers not only hinders process optimization but also curtails innovation potential within the organization [25]. This skills gap results in higher error frequencies and substandard output quality, jeopardizing the company's competitive positioning.

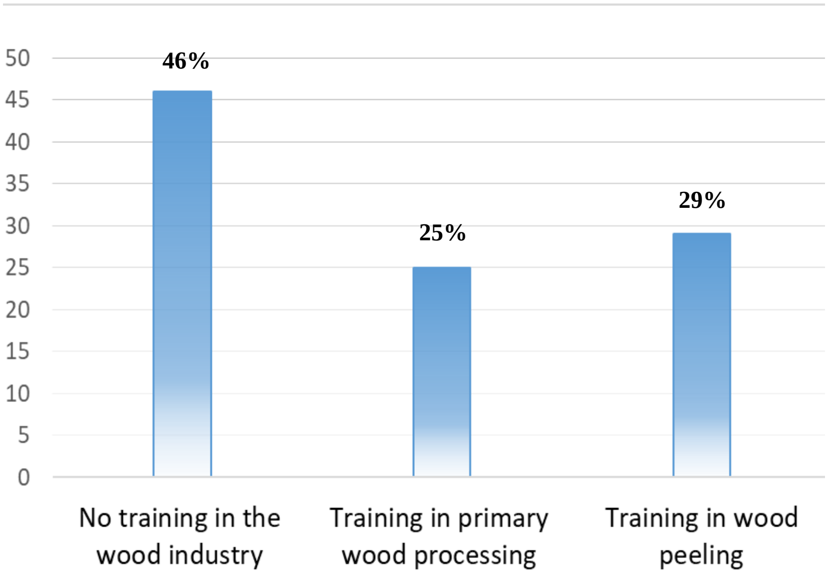

Figure 4. Professional status of STB employees.

C.4. Implications for Improving Material Yield at STB

With the aim of continuously and sustainably improving material yield, STB must enhance (i) production management and (ii) restructure the transformation circuit. Stock management is included in the production chain, which begins with suppliers and ends with intermediate or final customers (Table 4). In light of all these challenges, it is clear that STB needs to readjust its transformation circuit. Effective production management entails integrating Total Quality Management (TQM) practices that prioritize both customer satisfaction and a centralized production process [26].

Table 4. Proposals for a strategy to optimize STB yield.

Actions to take
Supply
- Identify reliable partners who can supply the primary raw material (crumb rubber) in a timely manner to avoid supply shortages; - Have a breakage area to store usable crumbs in case of supply difficulties due to poor road conditions during the rainy season; - Emphasize quality by obtaining crumbs from a reputable source to ensure good quality placement.
Production
- Have all necessary stages for shredding; - Implement a reorganization of the production chain to allow fluidity in the placement production operations;

- Acquire new machines and equipment that are actually suitable for the properties and characteristics required, as well as more precise and specific machines and equipment for essential processes;
- Define a revision planning schedule for machines and equipment to detect and/or prevent any existing or potential malfunction;
- Proceed with regular sharpening of different blades and cutting tools according to standards and requirements;
- Assign qualified workers to key positions to maximize the chances of producing quality exigencies;
- Proceed regularly with training and seminar sessions to refine staff skills;
- Proportionally motivate workers at the top of their work and inspire them with commitment and motivation through bonuses, rewards.

This approach emphasizes the significance of maintaining continuous improvements in stock management through structured feedback loops across all nodes of the supply chain [27]. Moreover, previous studies have demonstrated that optimizing throughput through a permanent adjustment of the machining cycle is a key point in improving yield. Therefore, designing a peeling unit to realize a new machining circuit will be beneficial to the company and must include new equipment. Consequently, the steps of this design are as follows: design of the various constitutive parts; choice of the plan and creation of sketches; dimensioning and creation of a material volume. The sub-assembly of parts: switch to the assembly tab, insertion of different parts and constitutive elements, and insertion of constraints. The assembly: This step is marked by the grouping of all machines and assembled equipment into a single plan.

IV. CONCLUSION

The study conducted at STB aimed to contribute to improving the material yield of the company after analyzing it. Our goal was to determine the material yield of the wood processed by the company (Ayous, Ilomba, and Onzabili), describe the material circuit of the company, identify the parameters that influence material yield, and propose means to increase it. To achieve this, we conducted a documentary search and a survey within the company, through interviews and semi-directive interviews. We also carried out daily monitoring of production for a month. Analysis of the company's production reveals a yield per species of: 49.11% for Ayous, 39.40% for Ilomba, and 37.07% for Onzabili; resulting in an average yield of 41.12%. We also identified some factors explaining why this yield is not optimal. We present them in two groups: natural factors (species nature, defects in the wood) and technical factors (human resources, precision of machines). To improve the company's production, we designed and created a model of a formal peeling circuit that was proposed to STB. Special emphasis should be placed on the following points: the supply of raw materials (quality logs); stock management (establishment of a break park); and the human resources and equipment used.

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