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Quality Control in Wood Processing

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Abstract

Wood quality is influenced by its characteristics, which can be altered through silvicultural practices such as spacing, thinning, pruning, and fertilization. It has long served as a major source of raw materials for many industries due to its versatility. Wood quality is defined as the attributes that make logs and lumber valuable for a particular end use. Many factors affect the quality of wood which includes density, microfibril angle, juvenile wood, reaction wood and fibre length. This aforementioned affect the resulting products derived from wood during processing for its end use. Wood quality control starts from the stage of planting to the stage of utilization of wood. Wood quality control has a resultant effect on the planned end use of the wood and it determines the properties of the wood. Each wood property can be manipulated by using silvicultural techniques; including: spacing, respacing/thinning, pruning, and fertilization. The level of success in applying each silvicultural technique can vary due to factors such as location and species. Also, wood quality has a very importance influence on the timber for construction, furniture's, pulp, paper board and particle board produced from it. This article discusses the effects of wood characteristics on quality, silviculture and wood quality, control of wood quality during harvesting, processing, and transportation, and methods for improving wood quality, including thermal treatment, chemical modification, and impregnation. Wood quality improvement can be achieved through chemical modification, thermal modification, impregnation and coating. Therefore, wood quality control mechanism is very essential to obtain the desired end use for the wood.

keywords: Juvenile wood, Microfibril angle, Modification, Reaction wood, Wood quality.

Introduction: The quality of wood makes logs and timber valuable for a certain end purpose, the physical and chemical attributes a tree or a section of a tree possesses allow it to meet the requirements for various end products (Ramage, Burridge, Busse-Wicher, Fereday, Reynolds, Shah, …& Allwood, 2017). These requirements are what make different people interpret wood quality differently. Numerous aspects characterize wood quality, which can only be accurately evaluated about a particular application. Foresters consider the size and shape of the trees, timber manufacturers notice huge, straight, and clear logs, and purchasers connect the quality of the wood with other characteristics (Picchi, Sandak, Grigolato, Panzachhi & Tognetti, 2022). Strength, stiffness, and dimensional stability are factors to consider when evaluating wood for structural purposes, whereas certain grain patterns or colors may be necessary for architectural millwork (Olorunishola, 2018). To provide a high-quality result, structural timber manufacturing requires wood with high density, minimal knots, straight grain features, and high bending strength (modulus of elasticity) (Mirski, Dziurka, Chuda-Kowalska, Kawalerczyk, Kuliński, & Łabęda, 2020). The length of the fibres and the amounts of cellulose and lignin may be used in the pulp and paper industry to determine the quality of wood. Low density wood mixed with long fibres produces collapsible, easily bonded fibres that exhibit low porosity and high strength, which is preferred in the production of pulp and paper (Jakob, Mahendran, Gindl-Altmutter, Bliem, Konnerth, Mueller, & Veigel, 2022).

Effects of wood characteristics on quality:
Density: Mass per unit volume is referred to as wood density or specific gravity. It simply means how much fibre is crammed into a given volume of wood. The usefulness of wood as a raw material is frequently closely correlated with its density. Dense wood tends to be more durable, stiffer, better at holding fasteners, and more impactful and wear-resistant. It will contain more wood material and less void space in any given volume than a less dense sample and produce more wood fiber for paper products. In general, for applications requiring a lot of strength, it is good to employ wood with a greater specific gravity (Ramage *et al.*; 2017).

Angle of microfibrils: According to Wang, Zhao, Zhang, Shi, Shan, & Cai, (2024), the Microfibril Angle (MFA) is the angle formed by the cellulose microfibrils and the cell axis. The MFA of the S2 layer cell wall is frequently used for assessment. According to Auty, Moore, Achim, Lyon, Mochan, Gardiner, (2018), MFA is greatest in the innermost rings and diminishes in the rings that are farthest from the pith. Additionally, MFA is larger in the large growth rings of fast-growing trees and decreases for the same ring at higher places inside a tree . According to Petroudy (2017), MFA has a major impact on the qualities of wood and fibre products and has been proven to partially influence the mechanical characteristics of wood cells.

Juvenile wood: Faster rotational growth of trees results in greater proportions of juvenile wood

(Shmulsky & Jones, 2019). Wood properties are constantly changing as the juvenile wood zone matures because different wood qualities mature at different periods and to varying degrees of abruptness, the transition from juvenile to mature wood cannot be precisely mapped to a single annual ring (Bräuning, De Ridder, Zafirov, García-González, Dimitrov, & Gärtner, 2016). Juvenile wood differs from adult wood in that its tracheids are shorter, its cell walls are thinner, and its density, transverse shrinkage, and strength are all lower.

Length of fibre: Fibre length is inversely correlated with ring width and inversely correlated with the age of an annual ring. During times of increased growth, shorter fibre development was seen, whereas longer length development was seen during times of decreasing growth rates. The relationship between fibre length and MFA features is strong, with MFA values decreasing and fibre length values rising to the lowest and maximum values, respectively, at the same yearly ring. For paper that has strong tensile properties for its intended usage, long fibres are preferred (Tham, Fazita, Abdul Khalil, Mahmud Zuhudi, Jaafar, Rizal, & Haafiz, 2019). According to research on fibre length, tear index, bending stiffness, and pulp yield are all strongly and directly influenced by it (Larsson, Lindström, Carlsson, & Fellers, 2018).

Reaction wood: Reaction wood is a type of wood cell that was specifically designed to correct crooked stems and support branches. Broadleaved plants produce tension wood, whereas conifers produce compression wood, a type of reaction wood (Liu, Wang & Hui, 2018). According to their names, compression wood grows on the side of a stem or branch that is being compressed mechanically, and tension wood grows on the stem or branch that is being pulled taut while fulfilling an important purpose inside the tree, reaction wood lowers the quality of wood in most uses. It frequently has a distinct color, not easily machined, and can be challenging to polish. Compared to mature wood, it also tends to be weaker and more prone to shrinking. Wood is not recommended for pulp and paper applications. Knots are challenging for chemicals to penetrate, resulting in insufficient pulping (Liu *et al.*, 2018).

Silviculture and wood quality: The spacing between newly planted trees, which is determined during the first planting, will have a significant impact on the plants' growing environment. It establishes the degree of inter-tree competition. The faster diameter growth that follows from increased spacing is due to reduced inter-tree competition, larger and longer live crowns, and less inter-tree competition (Chai, Zheng, Lei, Yao, Chen, & Zhang, 2023). Spacing has a significant impact on wood's quality. The mechanical characteristics of the wood produced are negatively impacted by an increase in tree spacing. After initial planting, reducing stand density is a silvicultural technique intended to lessen competition amongst trees. It has several ramifications for the type of wood that is produced. At either the pre-commercial or commercial stages of a tree's development, thinning may be used (Reventlow, Nord-Larsen, & Skovsgaard, 2019). For trees that haven't been cut down, thinning strategies encourage quick growth (Marchi, Paletto, Cantiani, Bianchetto, & De Meo, 2018). Thinning is advantageous because it allows for the removal of low-quality wood-producing trees while retaining the strongest, healthiest trees for continued growth. Following thinning, crown growth accelerates and encourages branch growth. Thinning results in greater branch diameters and, thus, larger knots (Erasmus, Kunneke, Drew, M. & Wessels, 2018). According to Hassegawa, Savard, Lenz, Duchateau, Gélinas, Bousquet, & Achim, (2020). thinning has an impact on crown size and is proportionate to the growth of juvenile wood. To control the growth of wood, pruning is done on branches on the lower part of the stem. For the production of clear wood, it is a crucial silvicultural technique. Therefore, increasing the percentage of clean, knot-free stem wood is the most typical purpose of pruning. Crown size manipulation, which forces live crown recession, is another advantage of pruning since it reduces the amount of juvenile wood generated (McGavin, McGrath, Fitzgerald, Kumar, Oliver, & Lindsay, 2021). After pruning, compression wood production can become less likely. It is not quite obvious how pruning affects density, microfibril angle, and fibre length. After pruning, density is typically shown to rise (Erasmus, Kunneke, Drew, & Wessels, 2018). Higher MOE and MOR were discovered in a study of trees pruned for structural timber (Olaoye & Ojo, 2022). As it raises the proportion of higher-grade veneers in comparison to other process, pruning has a positive impact on veneer quality (McGavin *et al.*, 2021).

At different phases of a tree's life, fertilization can be used as a silvicultural strategy to encourage development. It can be used to aid in the development of the tree's root system, reduce nutritional deficits in locations with poor soil conditions, and assist stem development during periods of rapid growth that place a high demand on nutrients (Ameray, Bergeron, Valeria, Montoro Girona, & Cavard, 2021). The amount of fertilization's impact on wood quality is influenced by a variety of factors, including the nutrients utilized, either alone or in combination, the site's state, and the species that were treated. Depending on how competitive the stand is, fertilizing encourages crown growth and depth from height growth as well as potential girth growth (Brandani, Santos, de Oliveira, Bordon, Bheling, Silva, & Gonçalves, 2020). Larger knots occur in the stem; juvenile wood production increases in quantity and duration due to crown enlargement and vigor.

Controlling quality while harvesting, processing, and transporting wood: Due to the consistent trunk diameter of succeeding farmed trees, clear fell harvesting with properly designed harvester heads delivers the highest efficiencies in terms of annual yield. For maximum production, harvesting processes are becoming more mechanized (Lewark, 2022). Customized cutting heads fitted on a harvester truck with hydraulic control are used to harvest round wood mechanically. To ensure successful harvesting and prevent harm to the trees, machine blades must be sharp and correctly adjusted. When creating notches, caution should be given to ensure they are created correctly to avoid splitting upon landing. To avoid mishaps, the landing area should be devoid of people and animals. "Roundwood," or harvested timber, is taken from the forest to a sawmill for additional processing, including removing bark and surface flaws (Heppelmann, Labelle, Wittkopf, & Seeling, 2019). The logs are removed and either skidded or forwarded to the forest roads for onward transit to the mill. To prevent harm to the log, extraction roads are adequately cleared. During the round wood processing. The leftover dust, shavings, and fibre byproducts are commonly used as biomass fuel or as fiber in engineered timber panel products with a market value (Takase, Kipkoech, Kibet., & Mugah, 2023). Approximately 50% is recovered as viable board and plank products. Even among samples of the same species, lumber demonstrates inherent variance because it is a natural product (Ramage *et al*., 2017). Each piece of dimensional lumber must be strength graded per standard to verify that processed timber materials can withstand projected maximum loads as a part of a structure in service (Ettelaei, Taoum & Nolan, 2022).

Control of wood quality during sawmilling: Logs are sorted and stored according to species, diameter, length, and ultimate use upon arrival at the mill's storage yard. Logs can be stored in water or stockpiled and routinely misted with water to ward off attack by bio-deteriorating agents (Loeffler & Anderson, 2018). Sand or dirt that may still adhere to the surface of the logs can be removed with the use of log washers (Fogg, O'Daniel, Poole, Reinhold, & Hyman, 2020). After the head rig, the resaw further breaks down the slabs, flitches, and cants, allowing for the upgrading of the wood by sawing the thick slabs into planks and the flitches and cants into planks and boards. To generate the appropriate standardized widths, the rough round edges of the pieces coming from the head rig and resaws are either removed by a circular saw or chipper edger. Resawing, or edging is done as soon as the logs leaves the headrig, it is cut to standardized lengths, the edges are squared, and any faults are corrected using one or more fixed or mobile trimming saws. After this, the lumber is sorted and graded. Roundwood is transformed into sawn timber using one of the two sawing methods listed below, which results in boards with various qualities and attributes of wood (Sandberg, Fink, Hasener, Kairi, Marhenke, Ross, & Wang, 2023).

To increase its marketability, sawn timber that is not sold green is either air- or kiln-dried. Because the wood is dimensionally stabilized, its strength and color are improved, and the moisture content is reduced to an acceptable level, its value is increased. Additionally, a decrease in weight saves transportation expenses. Before the sawn wood is stacked for storage, it is typically checked for any flaws that may have developed during the drying process, such as broken ends, loose knots, etc., which may be removed by trimming and so increase the wood's value. Depending on the demands of the market, further upgrading may be accomplished by surface smoothing using rotary knife planers or abrasive belts. The wood that is obtained from the sawmill is carefully planned and sized to be used for furniture construction, roofing, flooring, and other purposes. Paints, lacquers, and other furnishings can be used to improve the quality of wood (Dangel, 2016).

Wood quality and plywood production: The purpose of drying the veneer to between 2-10% MC is to facilitate glueing while making plywood. The veneer sheets may be kiln-dried or left out in the open to dry in the air depending on where the plywood mill is located and how advanced it is. When veneer is dried in a kiln, it can be dried in batches or continuously as sheets are automatically moved along a continuous belt or roller system through the dryer. A veneer will dry more uniformly and with less damage in a controlled drying environment with less handling. Even though temperatures for drying between 90 and 160 °C may be regarded as normal, certain species are being dried at temperatures as high as 175 °C (Jayaraman & Gupta, 2020).

Before pressing, the plywood is assembled by joining the thin strips of veneer that are edge-glued to create sheets that are the right size. The inner plies or core are then glued and put between the outer veneers in preparation for bonding. A significant portion of the manual labour used in the production process is dedicated to this task. Although curtain coaters, extruders, spray booths, etc. have all gained popularity as alternatives to hand roller spreaders for the application of glue, each has its fan base (Kūliņš, Meija, Roziņš, Liepa, & Spulle, 2021).

The veneers are fed through hydraulic presses after being assembled into assembly plywood sheets in order to put the veneer in direct touch with the adhesive, where the application of heat cures the glue. Although thermic oil is used when pressing at higher temperatures, hot water or steam are typically used to heat the platens (Marbun, Dwianto, Meliala, Widyorini,, Augustina, & Hiziroglu, 2023). To make the product more marketable, primary finishing, which comprises trimming, sanding, and improving the plywood after pressing, is done. The plywood boards are first cut to the proper size using trimming saws, and then they are sanded using wide-belt or drum sanders to achieve the ideal surface smoothness. Then, manually applied patches and plugs are used to fix any damage or flaws in the face veneers (Hallmann, 2019).

Production of particleboard quality control: Particleboard furniture comes from a variety of sources, and as demand for solid wood and solid wood residues rises, manufacturers are being forced to use low-grade residues like sawdust, planer shavings, hogged mill waste, and other types of wood that they had not previously considered. For the purpose of bonding with liquid resins, the majority of the feed provided to the mill needs to be dried so that the total moisture level of the particles is in the range of three to eight percent. (Monteiro, 2020). The particles are sized on vibrating or gyrating screens or by air classification immediately after drying. In order to avoid using an excessive amount of resin binder and to provide a valuable supply of fuel, it is crucial to screen out the fines and recycle the larger particles for further reduction (Badrun, Abdullah & Ghaffar, 2021). The particle mix is often bound together using adhesives in the forms of urea, phenol, and melamine formaldehyde, with the former being the preferred resin in usage (Badrun *et al*.; 2021). The mats are also transported to the pre-press by being formed on metal plates known as cauls, which are then either manually or mechanically wheeled to the presses.

The boards are automatically or manually removed from the cauls after leaving the hot press using chains or turning devices. The cauls are mechanically moved on a fixed return line or stacked, allowed to cool, and then brought back to the forming station on push carts. To prevent urea resin breakdown, the boards are cooled and conditioned. The boards are reduced to size with trimming saws, and the edge trimmings are either recycled or used as fuel. Knife planers and belt or drum sanders may be combined to achieve predetermined specifications for thickness and surface quality. The boards are cut to size along their length and breadth with a combination of saws after they have been surfaced and treated, under market demands (Badrun *et al.*,2021).

Quality control in the making of pulp and paper: Preparing the raw materials is the first step in the production of pulp (Bajpai, 2018). This covers debarking (when the raw material is wood), chipping, and additional procedures like depithing (for instance, when raw material is bagasse). From the basic components, cellulosic pulp is produced utilizing mechanical and chemical processes. By applying mechanical energy to the wood matrix, mechanical pulping separates fibres from one another by gradually breaking the connections that hold the fibres together and releasing fibre bundles, single fibres, and fibre fragments (Bajpai, 2018). To produce a high yield with appropriate tensile qualities and brightness, the primary component of the lignin must be maintained during the mechanical pulping process. To turn raw stock into finished stock (furnish) for the paper machine, stock preparation is done. The preparation of stocks involves a number of processes that are tailored to one another, such as cleaning, fibre modification, storing, and mixing. Depending on the quality of the needed furnishing and the raw stock used, these systems diverge significantly. Dry pulp is dissolved into water using a pulper to create a slurry. When preparing fibres for papermaking, refining is one of the most crucial processes (Liu *et al.,* 2018). The batch treatment of stock is referred to as "beating." When pulps are constantly run through one or more refiners, whether in series or parallel, the process is referred to as refining. Chemical additives may also be used to treat the furnishings. These include fillers like talc and clay to improve optical qualities, resins to increase the paper's wet strength, dyes and pigments to change the color of the sheet, and sizing agents to reduce liquid penetration and enhance printing properties (Liu *et al.,* 2018).

At the wet end of the paper machine, the slurry is formed into the chosen type of paper once the stock has been prepared. The paper machine's head box receives the pulp via a pump (Bajpai, 2018). The paper is compressed between two revolving wheels as it reaches the press area to remove more water. The machine's design and operating speed have a big impact on how much water is removed from the forming and press sections. The moisture content of the paper sheet is typically around 65% when it leaves the press area. The paper web keeps going through the dryers that are heated by steam, losing moisture along the way. Tonnes of water are evaporated during the process. As established by the mill, the moisture level should be between 4 and 6 percent. The paper could become overly brittle if it is too dry. Paper continues onto a reel at the machine's exit where it is wound to the required roll diameter. When the paper is this diameter, the machine tender cuts it and instantly starts a new reel with the extra paper dropping as an infinite web. The procedure is now finished for paper grades used in the production of corrugated paperboard. Finishing and conversion processes will now be carried out for those papers used for other purposes, often away from the paper mill. Coating, calendaring, super calendaring, and winding are a few examples of these processes (Bajpai, 2018). To improve printing quality, color, smoothness, opacity, or other surface qualities, the paper surface is coated with clay or other pigments and/or adhesives.

Improvement of wood quality: Due to its practicality, thermal treatment is a widely used method in industry to increase wood's dimensional stability and endurance against biodegradation (Calovi, Zanardi, & Rossi, 2024). Heat treatment of timbers alters both their chemical and physical characteristics. Under high temperatures, chemical processes can be triggered within cell walls. Acetyl esters in xylan are hydrolyzed during the heat treatment to produce acetic acid (de Carvalho, Berglund, Marchand, Lindström, Vilaplana, & Sevastyanova, 2019). Under acidic circumstances, hemicelluloses depolymerize into oligomeric and monomeric units before being further dehydrated to aldehydes, resulting in a reduction in hydroxyl groups and a reduction in hygroscopicity. A slight increase in cellulose crystallinity rather than a significant depolymerization of cellulose is the effect of heat treatment on cellulose (Ahmed, 2020). The least active component, lignin, can only be broken down at high temperatures to produce phenolic groups. However, the reactive lignin derivatives that are produced can strengthen the cell wall's cross-linking. As a result, treated timbers have less elastic cell walls and cellulose microfibrils that are less hygroscopic and are less likely to swell, both of which increase dimensional stability and biodegradation resistance (Hill, Altgen & Rautkari, 2021).

Massive amounts of hydroxyl groups (OH) in wood are used in chemical modification to react with other chemical reagents, changing the molecular structure of cellulose, hemicellulose, etc. permanently (Papadopoulos, Bikiaris, Mitropoulos, & Kyzas, 2019). Acetylated wood is a well-known example, where the hydrophilic OH groups are changed by acetylation using acetic anhydride into more hydrophobic acetyl groups. Due to the hydrophobic treatment, the acetylated wood exhibits high resistance to moisture and fungi in addition to good durability and dimensional stability without loss of strength. More importantly, it can be burned for energy recovery without creating additional risks and has the same end-of-life scenarios as untreated wood.

Chemicals are used to treat wood during impregnation, and they either diffuse into the cell walls or lumen. Impregnation is a passive method, as opposed to active strategies like alterations, where an improvement in attributes takes place without changing the chemical makeup of materials. The swelling of wood cells by the impregnates is the main cause of the property change (Augustina, Dwianto, Wahyudi, Syafii, Gérardin, & Marbun, 2023). Timbers become less permeable after impregnation, improving their resistance to moisture and fungus. Additionally, as some mechanical properties are improved, the density of wood rises. Impregnates can be monomers that are subsequently polymerized into bulk and then cured inside of wood cells. Preservatives like creosote and chromated copper arsenate (CCA) can also be used as impregnants. However, due to the usage of arsenic and chromium, the use of CCA and creosote has been discontinued throughout Europe (Vani, Prajwal, Sundararaj, & Dhamodaran, 2022). Wood preservatives nevertheless carry a risk of harm. Potential toxicant leakage into the environment at the end of these goods' useful lives could cause problems during recycling or disposal (Hassan & Saleh, 2022). For many high-value exterior wood end uses, such as window joinery and cladding, a coating or sacrificial layer can be painted on the surface of the wood products, providing a physical barrier against weathering and degradation and presenting the aesthetics of the product as well (Ramage *et al.*; 2017). Coating is typically the last step in the processing of wood because it is a surface treatment rather than a homogeneous cumbersome change.

Conclusion: Wood quality is significantly influenced by its characteristics. By applying silvicultural procedures, including as spacing, respacing/thinning, pruning, and fertilization, each wood property can be changed. Depending on the region and species, different silvicultural techniques may or may not be successful. However, given the correct circumstances, the effectiveness of silviculture applications would probably depend on elements like the timing, intensity, and repetitions/duration of the application. When silvicultural practises are used, the intended final use of the raw material has a significant impact on the quality of the wood produced. Rapidly increasing stem diameters was the silvicultural treatments' most frequently objective. Negative effects on the features and properties of wood were frequently viewed as a concession to faster development. Ignoring how forestry practices affect the qualities of wood could be a bad decision because quantity often comes at the expense of quality.

Recommendations: The optimal characteristics of wood grown for the manufacture of timber are high density, low microfibril angle, and the absence of juvenile wood, compression wood, or knots. To guarantee that healthy and robust trees flourish, trees managed with these aims should have close starting spacing and be regularly respaced. Periodically during growth, pruning should be done in conjunction with fertilization. Pruning and fertilization together may be an efficient way to counteract any potential growth reductions brought on by pruning. Once canopy closure has been established, modest thinning should be carried out. A relatively high stand density will make it easier to maintain crown size. Additionally, trimming will drive crown recession and encourage the growth of transparent wood. The development of juvenile wood during stem formation is reduced by both options. Reducing the amount of juvenile wood and increasing the amount of mature wood efficiently lowers MFA and raises density.

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