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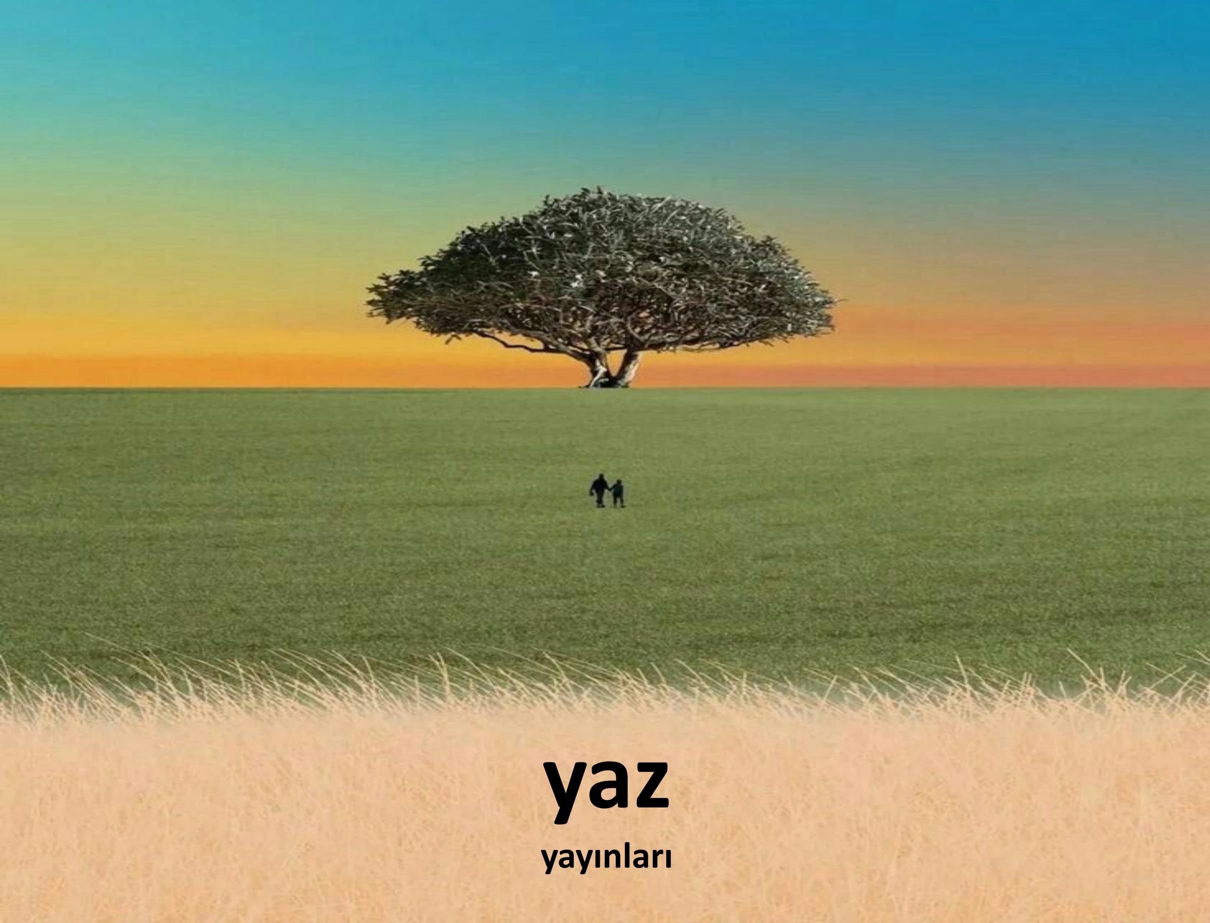

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İÇİNDEKİLER

A REVIEW ON THE DEFINITION, CLASSIFICATION AND SOME TECHNICAL PROPERTIES OF PARTICLE BOARD, AN IMPORTANT FOREST PRODUCT

Orhan KELLECİ[1]

1. INTRODUCTION

Particleboards are one of the most common types of wood-based panels developed after plywood and fiberboards. Today, these panels, which have a large production and usage volume, are widely used especially in the furniture, decoration and construction sectors. Horizontally pressed standard particleboards, OSB (oriented particleboard), okal and cemented types stand out among the most preferred types. In recent years, the consumption of these products has increased in parallel with the growth in the construction sector (Nguyen et al., 2023).

Wood-based panels can be generally classified as veneer panels, particleboards, fiberboards and wood-polymer composite panels. This classification varies according to the type of fibers or additives used in production (Gonçalves et al., 2018). While fiberboards such as MDF and HDF are preferred for interior applications, composite panels such as WPC (wood-polymer composite) provide more durability and resistance to moisture (Pringle et al., 2018).

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Figure 1 . Uncoated (non-laminated) raw particle board

As of 2030, particleboard (Figure 1) production in Europe will account for 42% of total particleboard production. This situation reveals the importance of particleboards in terms of both economic and technical features (Mantanis et al., 2018). In addition, thanks to the environmentally friendly binders developed to reduce formaldehyde emissions, these boards (Figure 2) also provide advantages in terms of environmental sustainability (Antov et al., 2021).

Figure 2. Particle board factory

Particleboards are an important wood-based board obtained by drying wood and other lignocellulosic materials (Figure 3) at a certain moisture level, mixing them with glue and pressing them under heat and pressure. Developed since the 1940s, particleboards are widely used today in both industry and furniture, packaging and construction sectors (Reh et al., 2024). Thanks to their high production capacity and different raw material flexibility, particleboard production has exceeded 100 million m³ worldwide as of 2020 (Nguyen et al., 2023).

Figure 3. Ligno cellulosic raw materials

Particleboards are divided into many subgroups according to the pressing method, structural features, density classification and areas of use. In addition, the resins and binder systems used in production play a critical role in the durability and environmental impacts of the board (Mantanis et al., 2018). Today, the use of recycled wood and forest waste is of great importance, especially in terms of sustainability (Pędzik et al., 2021).

In addition, particleboards produced with agricultural waste and recycled materials contribute to circular economy targets and offer satisfactory results in terms of mechanical performance (Lee et al., 2022). In Türkiye, industrial production started in the 1950s, and the particleboard sector has been developing rapidly with the increasing domestic production capacity in recent years.

Particleboard production in Turkey began in the 1950s and has grown rapidly over time, making the country one of the leading producers in Europe. This success is driven by advantages such as the use of low-quality wood raw materials and forest waste in production, the ability to produce homogeneous and large sizes, and the fact that their surfaces are suitable for decorative coatings (Sugahara et al., 2019).

According to 2020 data, Turkey meets approximately 10% of the total particleboard production in Europe, and the annual production amount exceeds 4.2 million m³ (Kowaluk et al., 2020). Meeting Türkiye's board needs in the domestic market largely through domestic production has reduced external dependency and made the country a net exporter with an export rate exceeding 25% (Istek & Ozlusoylu, 2017).

Kastamonu Entegre A.Ş., which has a total installed capacity of 12,978 m³/day nationwide, Companies such as are leading the growth of the sector with their modern and high-capacity facilities. Similarly, companies such as Yıldız Entegre, Starwood and Orma have expanded their production networks and made Turkey one of the leading countries in the production of MDF, OSB and particle board (Akbulut & Ayrılmış, 2024).

The variety of raw materials used in particle board production is also remarkable. In Turkey, in addition to local species such as poplar, pine and spruce, agricultural resources such as fruit pruning waste have also begun to be used in production (Azambuja et al., 2018; Krumins et al., 2024).

The particle board sector is a rapidly developing area in Türkiye where global competition is intense. As of 2023, the total installed capacity of particle board production facilities in Turkey has reached 16.3 million m³. Many of these facilities operate with a daily production capacity of over 1000 m³ (Azambuja et al., 2018). Although pine and poplar wood are predominantly used in particle board production, the trend towards alternative raw material sources has been increasing in recent years. For example, agricultural wastes such as barley hulls, oat bran and wheat bran have also been evaluated as potential materials (Neitzel et al., 2023).

66% of particle boards produced in Turkey are used in the furniture sector, and this rate is parallel to the European average. While resin and wood particles constitute the largest share in production costs, energy costs cover 11-15% of the total cost (Niemz & Sandberg, 2022). While manufacturers in Europe are turning to resin systems to reduce formaldehyde emissions, steps are being taken in this direction in Türkiye (Mantanis et al., 2018).

Manufacturers looking for more sustainable solutions are using bio-based materials such as hemp scrap instead of industrial wood, reducing swelling rates and environmental impact (Auriga et al., 2022). The increasing export rate in Türkiye shows that these technological developments are being met in international markets.

2. WHAT ARE THE CONTENTS OF PARTICLE BOARD?

The basic raw materials in traditional particleboard production are wood and wood waste; however, in recent years, due to increasing raw material costs, limited forest resources and sustainability goals, interest in alternative ligno-cellulosic resources has increased (Lee et al., 2022).

The amount of wood raw material required for particleboard production in Turkey in 2021 was 12.5 million tons. This amount is met from various sources such as log ends, fine diameter pruning residues, wood waste resulting from furniture and MDF production. According to the TS 1351 standard, fiber-chip sizes that can be used in particleboard production are the basic elements that determine the physical and mechanical properties of the product. In particle boards produced in accordance with these standards, factors such as wood type, fiber length, pH value and density play an important role (Reh et al., 2024).

In order to obtain high-quality boards, mostly coniferous tree species are used. For example, species such as spruce and pine provide advantages in terms of surface smoothness and screw resistance thanks to low fiber curvature and high fiber integrity. However, due to the limited nature of these resources, broad-leaved species such as poplar and eucalyptus are also integrated into production (Iswanto et al., 2017). In addition, by evaluating hybrid species and fast-growing species, production efficiency is increased and pressure on forest resources is reduced.

The use of non-wood resources has great potential, especially in terms of agricultural wastes. Wastes such as barley husk, oat bran and wheat straw are alternative raw materials suitable for panel production thanks to the cellulose and lignin they contain (Neitzel et al., 2023). Studies show that the fiber structure of these wastes is close to industrial chips and can be used in special-purpose applications (Figure 5), especially sound insulation.

Figure 4. Particleboards used for different purposes

Industrial waste is also important for utilization. For example, MDF, chipboard and plywood pieces obtained from construction and demolition waste have been successfully incorporated into particleboard production for use in internal layers (Azambuja et al., 2018). Such applications both improve waste management and contribute to the circular economy by reducing production costs.

An interesting example is the utilization of wastes left after the production of high-quality furniture, such as walnut trees (Juglans regia). In a study, particleboards containing 50% walnut residue provided mechanical strength suitable for load-bearing applications (Pędzik et al., 2022).

It has been proven that annual plant residues such as bamboo, flax, hemp and corn cobs can also be used in particleboard production. In particular, high strength was achieved in boards produced from bamboo with natural binders such as citric acid (Widyorini et al., 2016). This shows that the use of environmentally friendly binder systems and alternative raw materials together is of strategic importance for future particleboard technologies.

3. ADHESIVES IN PARTICLE BOARDS

In particleboard production, glues and additives play a decisive role in terms of durability, water resistance and environmental impacts of the material. The most used glue, urea-formaldehyde (UF) (Figure 5), is preferred due to its low cost and fast curing time. However, it is a controversial adhesive in terms of environmental and health due to its high formaldehyde release (Nuryawan et al., 2017). As a solution to this problem, hybrid structures have been developed with lignocellulosic sources. For example, both formulation stability and low formaldehyde emission have been achieved with nanocellulose and boron-added UF resins (Yildirim et al., 2022).

Melamine-urea-formaldehyde (MUF) and PMDI (polymeric methylene diphenyl diisocyanate) additives are widely used to increase water resistance. In studies, it has been observed that MUF resins supported with PMDI provide up to 23% higher adhesion resistance on laminated surfaces (Rahandi Lubis et al., 2019). These hybrid systems are used in the production of panels that are particularly resistant to outdoor conditions.

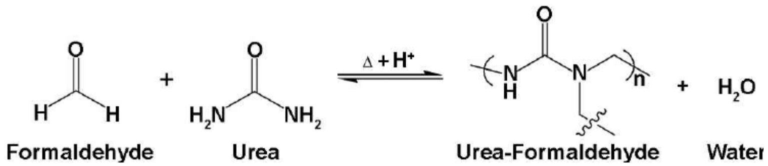

Figure 5. Urea formaldehyde

Bio-based alternatives used as adhesives are also developing. Soy protein-based adhesives in particular are drawing attention in terms of environmental sustainability due to their formaldehyde-free nature (Bacigalupe & Escobar, 2021). However, since such adhesives generally show low water resistance and mechanical performance, they need to be reinforced with different additives.

Paraffin-based hydrophobic additives are also widely used to increase water repellency. It has been shown that a significant reduction in the 24-hour swelling rate is achieved, especially in boards containing 1% paraffin (Baharoğlu et al., 2014). Such additives contribute to the longer life of composite materials such as MDF and particleboard in outdoor applications. Paraffin improves the degree of wettability of particle board. The degree of wettability is given in Figure 6.

Lignin-based adhesives are considered among formaldehyde-free options. Cross-linking ammonium lignosulfonate with pMDI not only offers similar adhesion properties to traditional MUF adhesives, but also reduces formaldehyde release (Hemmilä et al., 2019).

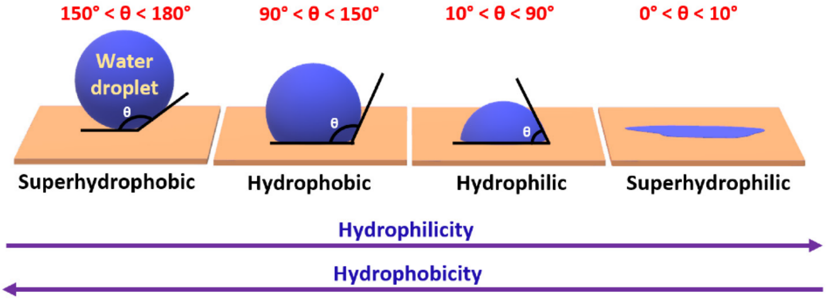

Figure 6. Degree of wettability

4. PARTICLE BOARD PRODUCTION THECHNOLOGIES

The technology and processes used in particleboard production (Figure 7) play a decisive role in terms of both product quality and production efficiency. Today, the wood preparation process, which is one of the first stages of the production line, is of great importance, especially in terms of controlling the raw material properties. Horizontal particleboard production is mostly carried out in three layers, and the machines used in this process are designed to convert the raw material into chips of appropriate size (Nguyen et al., 2023).

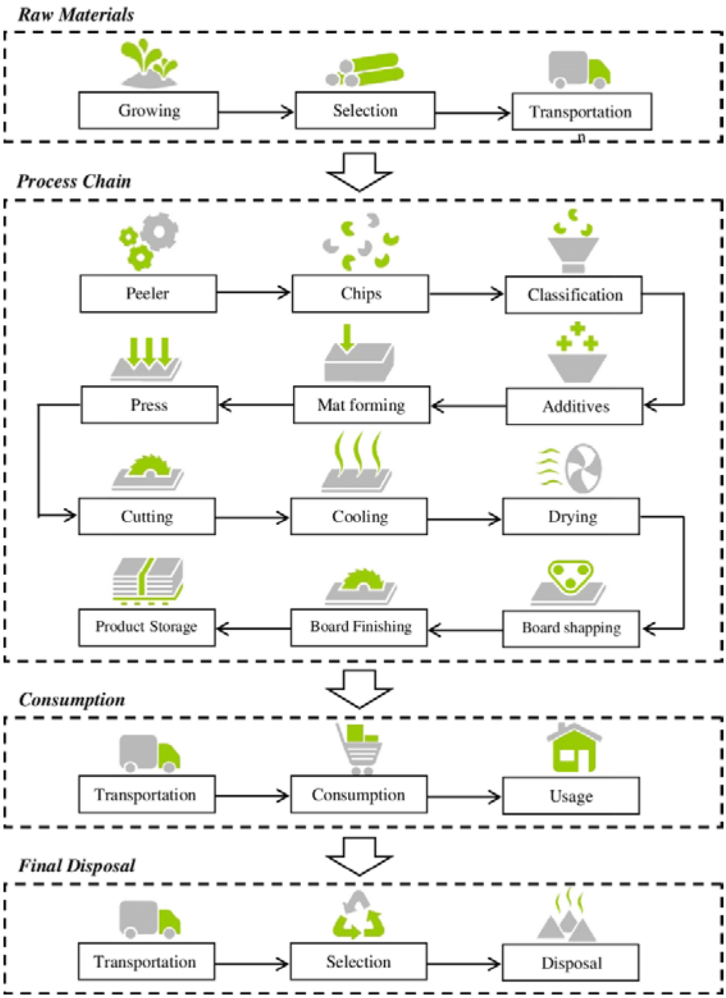

Figure 7. Particle board production process (dos Santos et al., 2014)

Storage conditions can directly affect the physical properties of wood in the particleboard production process. The temperature, humidity and ventilation conditions of the woods kept in the raw material warehouse are the most important parameters affecting the board quality. For example, fibrous woods kept in high humidity conditions for a long time may be exposed to quality-reducing effects such as color change and decay (Aranguren et al., 2012).

The peeling stage is also a critical step in production. It is generally not used in surface layers due to the hardness difference created by the barks on the board surface and the surface defects it causes during pressing. At this stage, cylindrical or drum machines are preferred, and the peeling capacity of the machines per minute varies depending on the wood diameter and engine power (Maksymiuk et al., 2024).

Chipping machines, especially disk and cylindrical models, are used in the conversion of wood into chips. While disk machines are preferred due to their high capacity and precise cutting capabilities; drum machines are suitable for coarser chip production. The number of blades, rotor diameter and feed speed used in these machines directly affect the chip thickness (Spinelli & Marchi, 2021).

The thinning process of the chips is critical for the surface layer production. Grinders such as ring knife mills are used for this process. In these systems, the final chip thickness is determined by factors such as blade diameter, number and feed speed. Especially in facilities where three-layer production is performed, the use of coarse chips for the middle layer and microchips for the surface layers is preferred to increase the physical durability of the board (Neitzel et al., 2023).

The efficiency of chippers is related not only to the technical equipment but also to the type of raw material. For example, low-density woods such as poplar and spruce are preferred because they are easier to shape during pressing, while hard-structured species such as oak require machines with high engine power. Such preferences directly affect the energy costs of the production process and the board quality (Azambuja et al., 2018).

5. RESULTS

Particleboard stands out as a versatile and economically significant wood-based composite panel, with wide-ranging applications in the furniture, construction, and packaging sectors. This review has provided a comprehensive evaluation of its definition, classification, production technologies, and raw material alternatives, particularly in the context of sustainable development and circular economy goals. The increasing use of recycled wood, agricultural residues, and non-wood lignocellulosic sources not only addresses the challenges posed by limited forest resources but also contributes to more environmentally responsible manufacturing practices.

Technological advancements in adhesive systems—especially those aiming to reduce formaldehyde emissions—have significantly improved the environmental performance of particleboards. Formaldehyde-free or bio-based adhesives such as soy protein, lignin-based resins, and citric-acid bonded systems present promising alternatives for future-oriented production. Meanwhile, developments in production technology, such as chip sizing, surface optimization, and moisture control, have enhanced both mechanical strength and dimensional stability of the boards.

In Türkiye, the particleboard industry has demonstrated strong growth, driven by abundant raw material availability, large-scale manufacturing infrastructure, and export potential. The increasing incorporation of waste materials from agriculture and industry positions the country as a regional leader in sustainable particleboard production.

Overall, particleboard production is moving toward a more resource-efficient, low-emission, and high-performance model. With ongoing research and innovation, the industry is well-positioned to meet both global market demands and environmental responsibilities in the coming decades.

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PARTICLE BOARD FINISHING AND QUALITY CONTROL

Suheyla Esin KOKSAL[1]

1. INTRODUCTION

In the particle board industry, surface treatments play a critical role in order to improve the aesthetic and functional properties of the product (Salca et al., 2016). Surface coating and painting processes not only provide a decorative appearance, but also increase the physical and chemical resistance of the board, enabling its long-term use (Weththimuni et al., 2016). In this review, various techniques, material uses and production processes related to particle board surface treatments are discussed in detail.

The main purposes of surface coatings include decorative appearance, increasing physical and mechanical strength, providing chemical and moisture resistance and extending the life of the board (Pan et al., 2023; Wu et al., 2020; Zhu et al., 2016). At this point, the particle boards to be coated must meet certain standards: homogeneous density distribution, sufficient surface hardness, low tolerance thickness differences and low surface absorbency are the basic prerequisites for a successful coating process (Wu et al., 2020). Particle boards are mostly used in furniture production (Figure 1), so it is necessary to cover the surfaces. Thus, both a decorative appearance is given, and their protection is ensured.

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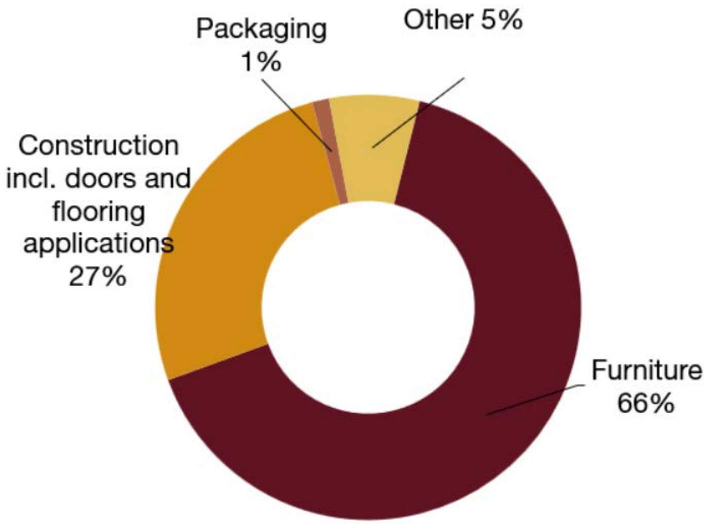

Figure 1. Sectors where particle board is used (European Panel Federation, 2025)

1.1. Surface Coating Materials

Decorative and functional coating materials used on particle board surfaces are quite diverse. These include:

- Liquid and powder paints,
- Decorative foils,
- Heat transfer foils,
- High pressure laminates (HPL),
- Continuous press laminates (CPL),
- Polypropylene films,
- Melamine impregnated papers,
- PVC films and wood coatings.

1.2. Painting Application

1.2.1. Liquid Paint Application

Liquid paint applications are carried out with direct printing technologies and are generally applied on melamine coated boards (Pieters & Mekonnen, 2024). In this method, layers such as primer, intermediate paint and UV varnish are applied with special cylinder roller systems. The process is adjusted precisely according to parameters such as viscosity and temperature, ensuring color homogeneity. For there to be good printability, the wettability properties of the board must be good (Figure 2).

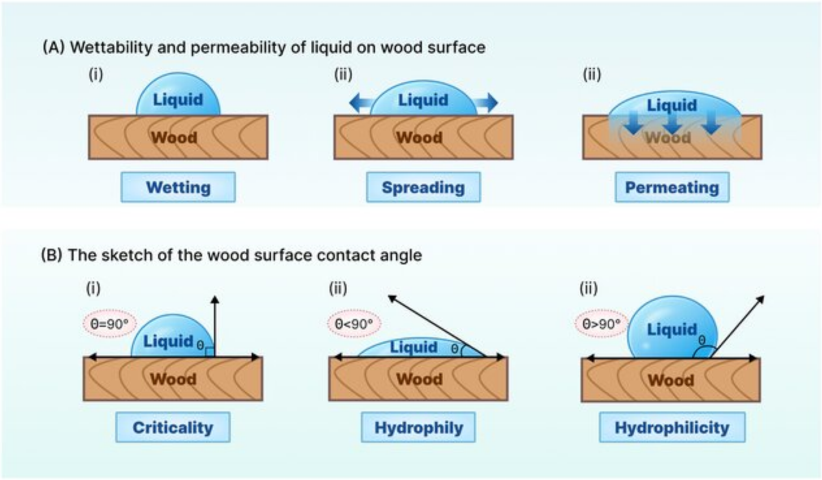

Figure 2. (A) Behavior of liquids spreading and penetrating on wood surfaces; (B) Schematic representation of the contact angle on wood (Hang et al., 2024)

1.2.2. Lacquer Paint Application

Lacquer paint systems are especially preferred on MDF surfaces, but they have also become available for use on particle boards. Lacquer paint usually contains polyurethane resins and cellulosic components, ideal for decorative products such as kitchen cabinets (Lu et al., 2006).

1.2.3. UV Varnish/Lacquer Application

UV lacquer applications create glossy and durable surfaces, especially on MF impregnated papers (Salca et al., 2016). In this system, reactive polyurethane or acrylic-based lacquer materials are cured with UV light (Figure 3) to obtain a high gloss surface (Schwalm, 2006).

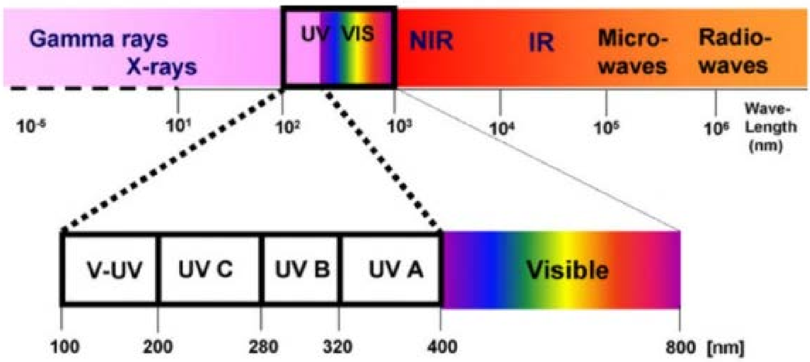

Figure 3. UV spectrum (Schwalm, 2006)

1.3. Powder Coating Application

Powder coating systems are preferred for being environmentally friendly and economical (Weiss, 1997). Electrostatic powder coating provides a solvent-free and reusable system. Pre-drying at 120 °C and baking at 180–200 °C ensures a durable surface.

1.4. Coating with Melamine Coated Papers

Melamine-impregnated papers are widely used in the particle board industry. They are applied using pressure without glue and provide excellent chemical resistance (Liu & Zhu, 2014).

1.5. Coating with High Pressure Laminate (HPL)

HPL coatings are known for their superior mechanical strength and chemical resistance and are used in high-performance environments such as kitchens and laboratories (Ganai et al., 2016).

1.6. Coating with Continuous Press Laminate (CPL)

CPL laminates are applied in continuous processes and are preferred for producing high-gloss surfaces due to their flexibility and production efficiency (Nemli et al., 2003).

Particle board surface treatments increase the added value of products in terms of both functional performance and visual quality. With developing technologies such as UV-cured coatings, powder paints and laminates, manufacturers have a wide range of options to enhance durability and design appeal. Selection of appropriate surface treatment techniques should consider cost, aesthetics, environmental impact, and target application (Nemli et al., 2005).

2. PROCESS CONTROL FOR PARICLE BOARD QUALITY

In the particle board industry, quality control processes consist of a systematic control chain covering all production stages from the entry of raw materials into the factory to the shipment of the final product. Regular control of processes and precise management of parameters both ensure continuity of product quality and increase the competitiveness of the industry by reducing production costs (Esteban et al., 2009).

The quality control process in particle board production begins with the evaluation of the wood raw material. Parameters such as the types, densities and moisture levels of the wood used significantly affect the physical and mechanical properties of the final product (Salgueiro et al., 2010). In order to ensure the homogeneity of the wood raw material received into the factory, the logs are classified according to type, age and moisture levels and mixed in appropriate proportions (Hans et al., 2015). In addition, moisture content is constantly monitored in wood warehouses to prevent possible quality deviations in the raw material (Hans et al., 2015).

The properties of the gluing (Figure 4), another critical component of production, directly determine the strength and durability of the board. Parameters such as the solid content, pH value and viscosity of the glues are monitored daily with laboratory analyses (Zhang et al., 2022). In particular, the solid content of the glue is calculated as a result of drying processes carried out at certain temperatures and its compliance with the determined standard values is ensured. The viscosity of the glue is a critical parameter for the proper mixing of the chips with the glue during the production process and is constantly measured and kept under control (Owodunni et al., 2020). In addition, the amount of free formaldehyde, which is important for human health, is meticulously monitored and controlled with regular analyses so that it does not exceed the specified safety limits (Mantanis et al., 2018).

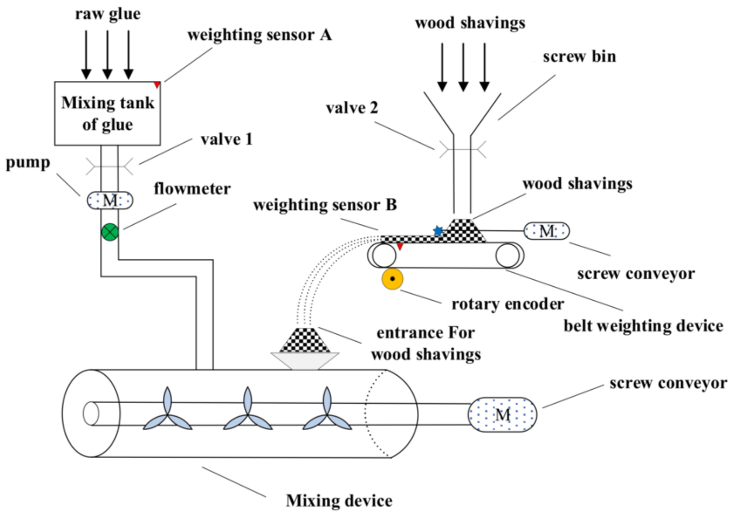

Figure 4. Particle board gluing system

Paraffin emulsion is added to the glue systems to increase the resistance of the board to moisture (Guo et al., 2018). The solid matter content and viscosity of the emulsion are measured at regular intervals to ensure that the desired homogeneous distribution is achieved in production (Xu & Yang, 2019). Control of these parameters is an indispensable part of quality control as it directly affects the effectiveness of the paraffin (J. Jiang et al., 2020).

Metal detectors prevent foreign substances that may be present in the wood raw material used in the production process from damaging the production machines. For this reason, metal parts in the wood are detected and removed from the system thanks to the metal detectors placed in the production line (Liu, 2021). The performance of the chipping machines is also ensured by regular control of the size and thickness distribution of the chips. This control is an important process that directly affects the homogeneity of the boards (de Souza et al., 2022).

During the drying phase, the moisture content of the chips is precisely monitored. The moisture levels of the chips coming out of the dryer are generally controlled within a tolerance range of 2% and the necessary adjustments are made with automatic sensors (Chen et al., 2020). This process is of great importance in terms of preventing quality problems that may arise during the pressing of the board.

In the sieving and sorting processes after drying, the chips are separated according to their sizes. In this process, the size distributions of the chips are verified by sieve analyses performed in a laboratory environment (Zhou et al., 2023). According to the data obtained as a result of the sieve analyses, production parameters are adjusted and non-standard production risks are reduced. This process is considered one of the important components of quality control (Benthien et al., 2018).

During the preparation of the glue solution, the control of parameters such as density and temperature is of critical importance. The dosing of the glue to the production line is carried out with automatic systems and the properties of the solution are constantly monitored for the correct operation of these systems (Yu et al., 2009). Thus, the performance of the glue in the production process is maximized.

In the spreading stations, the homogeneous distribution of the chips on the board surface is ensured. Obtaining a homogeneous structure in the board production minimizes the errors that may occur in the pressing process (Wronka & Kowaluk, 2022). The pressing stage is a critical process that determines the final physical properties of the board. Pressing quality is guaranteed by controlling the pressing time, temperature and pressure parameters without any errors (Lima García et al., 2018). Pressing errors can cause the thickness of the board to vary and the structural integrity to deteriorate.

Sanding the pressed boards is an important production stage that determines the surface quality of the board. During the sanding process, a balanced amount of sawdust is taken from both surfaces, ensuring the homogeneous surface quality and thickness measurements of the board (Liu, 2021). After sanding, the boards are checked with laser sensors or optical systems; during this process, surface errors (stains, cracks, etc.) are detected and product classification is made.

During the storage and shipping processes, it is important to maintain the moisture content of the boards at 9±3%. Temperature and humidity values are constantly monitored in warehouse conditions to prevent the boards from losing quality (Pędzik et al., 2021). In addition, appropriate transportation systems and storage techniques are applied to prevent deformations caused by stacking the boards on top of each other before shipping.

When all these processes are evaluated together, it is seen that quality control in particleboard production is multidimensional and comprehensive. Continuous measurements and analyses throughout the process increase the quality of the final product and support a production structure that meets industrial standards, is sensitive to environmental effects and is economically sustainable (Guo et al., 2018). Thanks to this systematic approach, the particleboard industry gains a competitive advantage by ensuring stability in product quality.

3. CHARACTERIZATION OF PARTICLE BOARD

Various international and national standards have been determined in order to ensure product quality and standardization in the particle board industry. The main purpose of these standards is to ensure that the physical, mechanical and usage properties of the products are within certain limits, thus ensuring consistency in production and consumer safety (Cosereanu & Cerbu, 2019).

Tolerances for the dimensions of the boards are determined by the TS EN 324-1 standard. Thickness tolerances must be between ±0.3 mm for sanded boards and 0.3 mm and +1.7 mm for unsanded boards. Deviations in length and width measurements must not exceed ±5 mm. In addition, according to the TS EN 324-2 standard, the edge straightness tolerance must be 1.5 mm/m and the deviation from the square must not exceed 2 mm/m (Farrokhpayam et al., 2016).

The moisture content of the board must be kept between 5% and 13% according to the TS EN 322 standard (Gul et al., 2020). The tolerance for the average density in the board is ±10%.

In addition, TS EN 120 and EN 717-1 standards are taken as basis for formaldehyde release according to E1 and E2 classes (Simon et al., 2020).

For general purpose boards (Type P1), bending strength and internal bonding resistances were determined according to TS EN 310 and TS EN 319 standards (W. Jiang et al., 2020). As the board thickness increases, the values sought for bending strength and internal bonding resistance gradually decrease. A similar evaluation was made for boards used in applications including furniture (Type P2), and measurements of elasticity modulus in bending, internal bonding resistance and surface durability were standardized. For example, for boards with a thickness of 13–20 mm, the elasticity modulus in bending was determined as 1600 N/mm^2 (Kusumah et al., 2017).

There are many additional standards regarding the classification and testing of particle boards. TS EN 326-1 standard specifies how to take test samples from boards. When taking test samples, it is essential to take more than one sample that differs from the plate dimensions. These samples are usually taken from different directions and in a way that represents the average of the length and width of the plate (Cosereanu & Cerbu, 2019).

The information that should be on the test samples is the test batch identification number, sample serial number and, if possible, information about the length of the plate before cutting. Test samples are taken in standard numbers for the measurement of different properties such as moisture content, density, elasticity modulus in bending and bending resistance, and their placements are determined specifically (Iswanto et al., 2020).

In the measurement of the physical properties of the plate, density determination is of critical importance and the unit volume weight of the plates is made according to the TS EN 323 standard. Density is calculated by dividing the dried mass of the plate by the sample volume (Gul et al., 2020). The swelling ratio to thickness is calculated from the increase in the sample dimensions after immersion in water according to TS EN 317 and shows the resistance of the product to moisture (Ribeiro et al., 2020).

In terms of mechanical properties, bending resistance is measured according to the TS EN 310 standard (W. Jiang et al., 2020). This test determines the behavior of the plate under load and its maximum carrying capacity. The elasticity modulus in bending is also calculated from the part of the deformation under load that is directly proportional to the load (W. Jiang et al., 2020).

The vertical tensile strength of the board surface (internal bonding strength) measures the adhesion between the layers of the boards according to TS EN 319 (Kusumah et al., 2017). The samples are bonded between metal plates and subjected to tensile force. The load of the test sample at the moment of breaking is determined and calculated.

The surface strength determination is carried out according to the TS EN 311 standard. This test determines the surface durability by measuring the amount of particles detached from the board surface (Iswanto et al., 2020). This test is generally of critical importance in terms of surface coating quality in furniture production (Mensah et al., 2024).

Screw holding capacity is carried out according to TS EN 13446. This test measures the resistance of the boards to furniture fasteners. The calculation is made by taking into account the maximum force at the moment of screw withdrawal and the screw diameter (Ribeiro et al., 2020).

Surface absorbency is measured with the TS EN 382-1 standard and determines the liquid absorption ability of the board surface (Ashori et al., 2023). This value directly affects the adhesion quality of surface coatings. Surface roughness is measured with a profilometer device, and the smoothness of the board (Figure 5) surface is one of the basic parameters in quality control processes (Gul et al., 2020).

Figure 5. Laminated particle board surfaces

Thanks to these standards and measurement methods, quality control processes in particleboard production are carried out precisely and systematically, ensuring both the quality of the products and the safety of the end user. The meticulous execution of these processes in industrial applications is one of the basic factors in increasing the international competitiveness of the sector (W. Jiang et al., 2020).

4. RESULTS

The finishing and quality control processes in particleboard production are integral to ensuring both the visual appeal and structural integrity of the final product. Surface treatment techniques, ranging from melamine coatings to UV-cured varnishes and powder applications, not only enhance the decorative quality of boards but also play a vital role in improving their moisture resistance, mechanical strength, and durability. The careful selection of coating materials based on intended applications, cost-effectiveness, and environmental performance contributes to the long-term success of the industry.

Equally important is the quality control chain that spans from raw material intake to final product shipment. Parameters such as wood moisture content, glue viscosity, chip size distribution, pressing temperature, and formaldehyde emissions are meticulously monitored. These checks ensure that the final boards meet international standards such as TS EN 310, 319, 324, and 322, safeguarding performance consistency and user safety.

Advances in characterization techniques and automated control systems have further strengthened the reliability of these processes. The growing adoption of environmentally friendly adhesives and coatings aligns with sustainability goals and regulatory expectations. In this regard, the Turkish particleboard industry demonstrates significant potential by integrating technological innovations and maintaining rigorous control protocols.

In summary, the synergy between advanced finishing technologies and robust quality control systems forms the backbone of high-performance, aesthetically pleasing, and sustainable particleboard production. The continued evolution of these practices will be key to maintaining competitive advantage in both domestic and global markets.

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COMPARATIVE REVIEW OF THE PARTICLE BOARD AND MEDIUM DENSITY FIBERBOARD (MDF)[1]

Birkan ÜMÜT[2]

1. INTRODUCTION

The use of wood materials in human life and especially in the construction sector has maintained its importance from past to present (Figure 1). Traditionally used solid wood is being replaced by plate-based materials that are more economical and functional thanks to technological developments. Medium Density Fiberboard (MDF) and particleboard (chipboard) are the most important of these (ÜMÜT, 2025).

A frequently discussed issue in the construction and furniture sector is under which conditions MDF or particleboard should be preferred. The answer to this question varies according to the area of use, depending on the mechanical and physical properties of the materials as well as economic and environmental factors (ÜMÜT, 2025).

The areas of use of MDF are wider compared to particleboard. Thanks to its homogeneous structure and high density (Figure 2), MDF is frequently preferred in the production of furniture, doors, parquet and decorative products. On the other hand, particleboard is lighter and more economical than MDF due to its low density and voids in its internal structure. Due to these

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features, it is widely used in areas where non-load-bearing furniture components and economic production processes are preferred (Ümüt, 2025).

Figure 1. First wooden tools, wooden plow, ancient digging stick tool, and prehistoric stone hoe (Turbosquid, 2025)

When the mechanical resistances of the materials are examined, it is seen that MDF has superior properties compared to particleboard (Mantanis et al., 2017). MDF has higher bending resistance, screw holding capacity, surface tensile strength and surface durability than chipboard. In addition, MDF offers a more resistant structure to moisture and water (Istek & Ozlusoylu, 2021).

In terms of raw material usage, chipboard is a material that is more suitable for the use of recycled wood waste and provides advantages in terms of environmental sustainability. In MDF production, fiberized wood is generally used, which affects the production process and the amount of energy used (Istek et al., 2010).

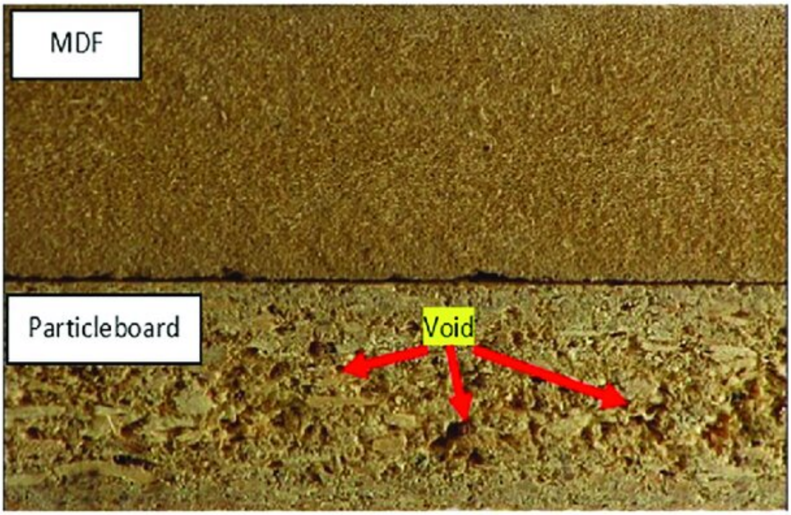

Figure 2. Particle board has more gabs than MDF

The fundamental differences between MDF and chipboard in terms of production processes are striking (ÜMÜT, 2025). In MDF production, wood pieces are first cooked under steam and pressure to become fibers (Figure 3), treated with resin and then dried. In chipboard production, on the other hand, wood pieces are first dried and then resin is applied. In addition, higher temperatures and energy usage are required for the drying process in chipboard production (Muğla, 2010). This can make chipboard more disadvantageous in terms of the complexity of production processes and energy consumption.

As a result, the usage preferences of MDF and chipboard differ according to application areas and performance expectations. The choices made by considering the structural and mechanical properties of the materials are of critical importance in terms of both economic efficiency and usage performance.

Figure 3. Fiber of some different materials

Particleboard and MDF (Medium Density Fiberboard), the two most common wood-based composite materials used in the furniture and construction sector, attract attention with both their physical and mechanical properties. Many factors such as production method, durability, cost and final use area play a role in the selection of these two materials.

Particleboard is a multilayered board produced by mixing wood residues (chips) with synthetic resins and compressing them under a hot press (Mantanis et al., 2017). It usually consists of three layers: the surface layers contain finer chips, while the middle layer is coarser (Engehausen et al., 2024). Particleboards are classified from P1 to P7 according to their intended use (Azambuja et al., 2018).

MDF is a homogeneous density board produced by combining wood fibers under heat and high pressure, usually with urea-formaldehyde-based binders (De Deus et al., 2015). Thanks to its fiber structure, its surface is flat and very suitable for processing. MDF panels are also generally classified as general use (L-MDF), moisture resistant (MR-MDF) and fire resistant (FR-MDF) (Taghiyari et al., 2016).

Particleboard is economical in terms of cost and allows the evaluation of waste materials (Yildirim & Candan, 2021). However, due to its low density and loose internal structure, screw holding resistance and surface roughness are limited (Ergun et al., 2023).

MDF is quite superior in terms of surface quality, millability and coating applications (De Deus et al., 2015). However, due to the dense binders used in its production, the cost is higher and its water resistance is low (Simon et al., 2020).

Particleboard stands out with its low cost, fast production process and suitability for the use of recycled materials (Yang et al., 2024). In addition, formaldehyde emissions are improved with new resin types that can be reduced (Mantanis et al., 2018).

MDF has a more homogeneous structure, high edge processing quality and gives more successful results in CNC applications (Taghiyari et al., 2016). In addition, coating, polishing and painting processes give smoother results (De Deus et al., 2015).

While the processes of drying, bonding and pressing the chips are included in the production of particle board; the refining of the fibers and the shaping processes with higher pressure are carried out in the production of MDF (Owodunni et al., 2020)(Mantanis et al., 2017). This makes the production of MDF more energy-intensive and costly (Iswanto et al., 2022).

MDF is superior to particle board in mechanical properties such as internal bond strength (IB), modulus of elasticity (MOE) and bending resistance (MOR) (Taghiyari et al., 2016); however, the impact resistance of particle board can be higher in some cases (Ergun et al., 2023).

While MDF stands out in terms of surface smoothness and homogeneity (Istek et al., 2017), particle board tends to absorb more water (Yildirim & Candan, 2021).

Particleboard is cheaper than MDF in terms of both raw material and production process (Azambuja et al., 2018). The production of MDF requires more energy and chemical binders, which increases the cost (Kelleci, 2013).

While MDF is widely preferred in interior decoration and surface treatments (De Deus et al., 2015), particleboard is preferred in furniture that offers more economical solutions (Köksal & Kelleci, 2020).

2. ENVIRONMENTAL EFFECT OF MDF AND PARTICLE BOARD PRODUCTİON

In their study, Puettmann and colleagues (2017) examined the environmental impacts of MDF (Medium Density Fiberboard) production using the life cycle assessment (LCA) method. Although the study was based on MDF production in Brazil, the methodology used and the findings obtained will shed light on the environmental analysis of MDF production processes worldwide. The study covered all stages of MDF production from raw material supply to the final product leaving the factory; environmental indicators such as energy consumption, greenhouse gas emissions, acidification and eutrophication potentials were calculated. In particular, the environmental impacts of urea-formaldehyde resins used during production were found to be at a remarkable level. The study offers suggestions such as preferring low-emission binders, using renewable energy sources and increasing process efficiency in order to make MDF production sustainable (Puettmann et al., 2016). In this context, the study reveals the need to restructure MDF production with environmental responsibility not only regionally but also globally.

In the study conducted by Azman et al. (2021), the environmental impacts of particleboard production were analyzed using the life cycle assessment (LCA) method. In this study, the production process was considered within the scope of the "cradle-to-gate" system; in other words, all stages from raw material supply to factory exit were evaluated. In the study, 1 m^3 particleboard production was accepted as the basic functional unit and the materials used, energy consumption and emissions released were analyzed in detail. As a result of FTIR analysis, it was determined that there were various compounds such as aliphatic hydrocarbons, inorganic phosphates and primary aliphatic alcohols in particleboards. The use of formaldehyde-based adhesives in the production process in particular has the potential to cause toxic effects on human health. According to the impact assessment results conducted using the openLCA software, it was determined that the most dominant environmental impact of particleboard was the global warming potential (GWP). It was observed that approximately 57 kg CO_2 equivalent was released in 1 m^3 of production. Apart from this, measurable effects were also detected in environmental impact categories such as acidification, eutrophication and photochemical oxidation. On the other hand, it was emphasized that the effects in the ozone layer depletion, abiotic resource depletion and ecotoxicity categories were minimal. The results of the research revealed that energy consumption (especially electricity and natural gas) and formaldehyde content in particleboard production are direct determinants of environmental impacts. In this context, the use of low formaldehyde or alternative binders and the development of energy efficient production processes are recommended to reduce environmental impacts. As a result, although the environmental impacts of particleboard are limited, it contains elements that should be taken into consideration, especially in terms of climate change (Mohd Azman et al., 2021).

According to the results, the use of electrical energy and resin in the production process stand out as the biggest determinants of environmental impacts. Especially in terms of global warming potential (GWP), the production process produces remarkable CO_2 equivalent emissions due to its dependence on primary energy sources. Significant impacts were also observed in other environmental impact categories — such as acidification, eutrophication and photochemical oxidant formation. It was emphasized that resin production and transportation are also important sources of impact.

Lao & Chang (2023) also revealed that the urea-formaldehyde resins used in the production process play a critical role in terms of both human health and atmospheric emissions. Therefore, it is recommended to evaluate alternative binder systems and diversify energy sources in terms of production optimization. The findings of the research reflect general trends in the environmental sustainability of particleboard production, not only in Spain but also on a European scale (Lao & Chang, 2023).

3. THE ROLE OF QUALITY CONTROL PROCESSES IN PARTICLEBOARD AND MDF PRODUCTION

Various Wood-based composite panels have a wide range of use in today's furniture, construction and decoration sectors. Quality control processes in the production of these panels play a decisive role in terms of the mechanical strength, surface quality, standardization and customer satisfaction of the product. This chapter systematically examines the quality control approaches applied in particleboard and medium density fiberboard (MDF) production and presents a comparative assessment.

Particleboard and MDF are two basic types of fiber panels obtained with different production techniques. While particleboard is produced by pressing large wood chips (Figure 4) with synthetic resin, MDF is obtained by blending smaller fibers with resin in the same way and shaping them under high pressure. Both products must meet certain quality standards; otherwise, performance losses may occur in end-use areas. In this context, quality control applications carried out at every stage of the production process are of great importance in terms of both cost reduction and sustainable production (Bernardy & Scherff, 1997).

In particleboard production, raw material moisture content, chip size, resin viscosity and pressing parameters (temperature, pressure, time) are the main quality control points. These variables directly affect the internal bonding resistance, thickness deviation and surface smoothness of the panel. In MDF production, more sensitive parameters such as fiber quality, resin-fiber homogeneity, moisture content of fibers and surface absorption capacity need to be controlled. These differences enable MDF to offer higher surface quality and processing precision.

In both production processes, the integration of automation systems has strengthened quality control. Moisture meters, laser thickness sensors and automatic resin dosing systems provide instant feedback on the production line and reduce faulty production rates. In addition, final product quality assurance is provided by tests based on standards such as TS EN 319 (internal bonding resistance), TS EN 323 (panel density) and TS EN 311 (surface strength).

Figure 4. Large wood chips

The comparative analysis conducted shows that quality control systems in MDF production are more sensitive, energy intensive and costly; however, more consistent and high-quality products are obtained thanks to this. Although particleboard offers more economical production opportunities, it is more open to quality fluctuations. Digitalization of quality control processes both increases efficiency and reduces the risk of substandard products.

In this context, it is recommended that manufacturing companies develop quality control strategies specific to the type of production, integrate test systems in accordance with international standards, and provide quality training to employees. In the future, it is possible to balance environmental sustainability and quality by combining these processes with life cycle analysis (LCA).

4. RESULTS

This comparative review has highlighted the key differences and performance characteristics of two major engineered wood products: particleboard and medium-density fiberboard (MDF). The selection between these materials is highly application-specific and depends on factors such as mechanical strength, surface quality, cost-effectiveness, and environmental considerations.

MDF offers superior mechanical and physical properties, including higher bending strength, better screw holding capacity, and a smoother surface finish. These characteristics make MDF a preferred material in high-end furniture, interior decoration, and CNC processing applications. However, its production is energy-intensive, costlier, and more reliant on virgin fiber resources and chemical binders.

On the other hand, particleboard stands out with its affordability, low-density structure, and suitability for incorporating recycled wood and agricultural residues. While it generally exhibits lower mechanical strength than MDF, recent advances in adhesive technologies and process optimization have helped improve its performance and reduce environmental impact, particularly in terms of formaldehyde emissions and carbon footprint.

Environmental analyses reveal that both MDF and particleboard production have significant implications, especially regarding energy use and resin-related emissions. Life cycle assessment studies suggest that optimizing adhesive systems, improving energy efficiency, and adopting circular material flows are crucial for making both production systems more sustainable.

Quality control processes play a pivotal role in maintaining product performance across both materials. Integration of real-time monitoring and standardized testing ensures consistency, safety, and customer satisfaction.

In conclusion, a balanced consideration of technical performance, environmental impact, and cost enables more informed decision-making for designers, manufacturers, and end users in the wood-based panel industry.

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