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Table Tennis Blade Production and Features

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Review Article

Abstract − Table tennis, which emerged in the late 1800s, has changed and developed with equipment development, as in many sports. In the early days, table tennis was played with parchment-covered long-handled rackets and cork or rubber balls. The game started to change with the invention of the hard rubber-coated racket in the 1930s, and the table tennis racket also changed with the spread of composite materials. A racket blade made of wood can consist of a single layer, or it mostly consists of 3-7 layers. The racket blade is produced 17 cm long and 15 cm wide on average. However, since there is no limitation in shape, size, and weight in their production, players choose racket blades according to their playing style. According to the International Table Tennis Federation (ITTF) regulations, at least 85% of the racket blade thickness must be made of wood, and the surfaces must be smooth and hard. Wood species with high impact absorption energy value are more suitable for table tennis blade production. There is an important relationship between the vibro-acoustic feature when the racket hits the ball and the racket blade. Density, hardness resistances, compressive strength, bending resistance, impact absorption energy, vibro-acoustic properties should be known in determining the suitability of the wood material to be used in the production of table tennis rackets. Various tree species such as Hinoki, Limba, Balsa, Kiri (Paulownia), Ash, Spruce, Linden, and Walnut are widely used in racket blades production.

Keywords − *Table tennis, racket blade, composite, impact absorption energy, vibro-acoustic, production*

Masa Tenisi Raket Tahtası Üretimi ve Özellikleri

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Derleme Makale

Öz − 1800'lü yılların sonlarında ortaya çıkan masa tenisi pek çok spor dalında olduğu gibi ekipmanların gelişimiyle birlikte değişim ve gelişim göstermiştir. İlk zamanlarda parşömen kaplı uzun saplı raketler ile mantar veya kauçuk toplarla oynanmıştır. 1930'larda sert kauçuk kaplı raketin icadıyla oyun değişmeye başlamış ve kompozit malzemelerin yaygınlaşmasıyla masa tenisi raketi de değişmiştir. Ahşaptan üretilen raket tahtası tek katmandan oluşabileceği gibi daha çok 3-7 katmandan oluşmaktadır. Raket tahtası ortalama olarak 17 cm uzunluğunda ve 15 cm genişliğinde üretilmektedir. Ancak üretimlerinde şekil, boyut ve ağırlık yönüyle bir sınırlama olmadığından oyuncular raket tahtalarını oyun tarzlarına göre seçmektedir. Uluslararası Masa Tenisi Federasyonu (ITTF) yönetmeliklerine göre, raket tahtası kalınlığının en az %85'i ahşaptan oluşmalı ve yüzeyler düz-pürüzsüz ve sert olmalıdır. Darbe emilim enerji değeri yüksek olan ağaç türleri masa tenisi raket tahtası üretimine daha uygundur. Raketin topa çarpma anında oluşan vibro-akustik özellik ile raket tahtası arasında önemli bir ilişki bulunmaktadır. Masa tenisi raketi üretiminde kullanılacak ahşap malzemenin uygunluğunun belirlenmesinde yoğunluk, çeşitli sertlik dirençleri, basınç mukavemeti, eğilme direnci, darbe emilim enerjisi ve vibro-akustik özellikleri bilinmelidir. Üretiminde Hinoki, Limba, Balsa, Kiri (Paulownia), Dişbudak, Ladin, Ihlamur, Ceviz gibi çeşitli ağaç türleri yaygın olarak kullanılmaktadır.

Anahtar Kelimeler − *Masa tenisi, raket tahtası, kompozit, darbe emilim enerjisi, vibro-akustik, üretim*

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1. Introduction

The sport of table tennis is a fun and exciting game enjoyed by people of all ages and walks of life. Table tennis is a quite easily accessible sport by everyone and is widely played worldwide. Like many other sports, it is known that table tennis started as a social pastime. It is known that in the last quarter of the 19th century, it was played with improvised equipment among the upper classes of society as an after-dinner parlor game in England. Table tennis co-evolved with the old game of tennis (jeu de paume; real tennis; court tennis or royal tennis), badminton, and outdoor tennis. With outdoor tennis becoming popular in the 1880s, table tennis was also developed (URL1). Major gaming companies such as J. Jacques & Son in the UK and Parker Brothers in the United States have successfully promoted competing versions of the game under names such as ping-pong and table tennis (McAfee 2009). The name ping-pong was in common use before British manufacturer J. Jaques & Son Ltd created its trademark in 1901. Jaques later used ping-pong to describe a game played on costly equipment he manufactured by himself. However, the name "ping-pong" was changed to "table tennis" by the American company after Jacques transferred the naming rights to Parker Brothers (URL2).

A table tennis racket is a hybrid material consisting of gluing a rubber sheet comprised of a dense elastic sponge and a compact rubber layer to a wooden sheet (Rinaldi et al. 2016). In other words, a table tennis racket consists of a wooden blade that is coated on one or both surfaces with rubber (called sandwich racket rubber) (Miyazawa et al. 2020). In the early days, table tennis was played with parchment-covered long-handled rackets and cork or rubber balls. However, the difficulties arising from the equipment used brought along the search and changes for new equipment. With the development of the celluloid ball in the 1920s, the game gradually began to be played fast. The invention of the hard rubber-coated racket in the 1930s contributed significantly to the game's development. The invention of the hard rubber coating changed the bounce and friction between the ball and the racket, two essential features in table tennis. This development has transformed table tennis from an ordinary parlor game into a challenging competitive sport that requires a swift reaction (McAfee 2009; Varenberg & Varenberg 2012). In the 1950s, racket rubber with elastic sponges was developed. The elastic sponge helped provide more spin and speed to the ball during the stroke. Until 1986, players used rubbers of the same color on both sides of the racket so that the opponent would not know which rubber they were the ball hitting. On July 1, 1986, two years before table tennis's entry into the Olympics, the International Table Tennis Federation (ITTF) made it a rule for competition rackets to have black rubber on one side and red rubber on the other. These developments have formed the basis of today's table tennis equipment, game rules, and styles (URL3; McAfee 2009).

In table tennis, the racket blade is an essential criterion in the players' success and affects the player's performance. For this reason, it is a necessity to produce the racket blade at a certain level of satisfaction and to provide the desired features (Arifin et al. 2017). The development of composites and advanced composites has affected nearly every aspect of modern life. Today, the aerospace industry, automobile industry, sporting goods industry, marine applications, construction industry, etc., are widely used in the fields. Composite materials are commonly used in the production of sports equipment due to their ease of processing, high strength, ability to be produced at the desired density, and vibration reduction properties. In the production of racket blades, plywood and reinforced wood composites are used together with solid wood (Buragohain 2017; Wang 2012). It is stated that the shape, weight, thickness, stiffness, and energy absorption of the racket affect the racket blade’s performance. For this reason, it has been emphasized that the material used in the production of table tennis blades should be chosen according to their properties, such as energy absorption, hardness, and lightness. It has been stated that the required features for the table tennis blade; spin (15%), control (25%), speed (25%), shape (10%), and racket handle (25%) (Arifin et al. 2017). However, it has been emphasized that the chemical modification of the wood coatings used in the production of racket blades affects the racket's performance, increases the rebound distance of the ball and the increase is more pronounced in high-speed

hits. In addition, it was determined that the modification process did not change the vibration frequency of the blade but significantly increased the modulus of elasticity and its stiffness (Bao et al. 2015).

The mechanical properties of Kenaf natural fiber/polyester composite structures were evaluated for table tennis blades. Polyester was used as the polymer matrix material, and Kenaf natural fibers were used as the reinforcement material. It has been found that it is appropriate to use these composite structures as the primary material in the production of table tennis blades. In addition, it was emphasized that impact absorption energy is the most important issue to be investigated in the production of table tennis blades (Amin et al. 2017). The factors affecting the table tennis ball's restitution coefficient, spin, and tangential velocity were investigated. It has been noted that the type of racket blade has a significant influence on the restitution coefficient. It has been found that the effects of the solid wood blade (Hinoki) covered with a rubber sheet on one side and the allround blade on the restitution coefficient are close to each other as the strike speed increases. It is stated that the blade with the highest speed feature is the massive Hinoki. It was emphasized that the structure of the ball is a feature that should be considered in developing a blade with high-speed characteristics. At submaximal topspin conditions, wood has been found to have little effect on spin and tangential velocity (Tiefenbacher 1994). It has been stated that the restitution coefficient is closely related to the effect of energy loss, and the racket vibration caused by the impact is one of the main sources of energy loss. In addition, it was emphasized that impact strength and contact time have a strong effect on racket vibration (Kawazoe 1992). It has been stated that the distinctive sound produced when a table tennis ball hits the racket blade is an essential criterion in evaluating the racket. This sound is directly related to the blade vibrations and depends on the structure and layer properties of the blade. The relationship between the paddle blade plywood structure produced with Hinoki, Limba, and Ayous veneers and the vibration behavior was investigated in this context. It has been found that the detailed composition of the plywood can be taken into account in modeling but does not lead to better results than modeling an equivalent layer of homogenized orthotropic wood (Manin et al. 2012a). Manin et al., in a study they conducted, determined the vibro-acoustic feature that occurs when the ball hits the racket. This study showed a relationship between the vibration and acoustic behavior of the racket blade at the time of hitting the ball (Manin et al. 2012b). The relationship between the wood type and layer thickness in the plywood composition used to construct the racket blade and the vibro-acoustic formed when the ball hits the racket was investigated for ten different racket blades. It has been verified that there is a correlation between vibration and acoustics when the ball hits the paddle blade. It is stated that the vibro-acoustic feature of each racket is unique to itself. It was found that the layer thickness more than the wood type was effective on the vibro-acoustic property. In addition, it was stated that the vibro-acoustic frequencies vary linearly with the layer thickness. (Manin et al. 2014). In another study, the relationship between natural frequency and moisture content of Ayous and Cypress species, which are widely used in table tennis blade production, was investigated in accordance with acoustic and vibration theory. It has been emphasized that the natural frequency characteristics of the species used decrease with the increase in moisture content (Lu et al. 2016). Because differences in material structure can result in a wide variety of racket frequencies, the vibratory behavior of the racket can be used by a manufacturer to determine quality control or as a tool to explore various racket materials and construction (Russell 2018).

In this study, table tennis blade features, historical development, production, tree species used in its production, and required features, which play an essential role in the performance and success of the players in table tennis sport, are explained.

2. Racket Blade General Features

While the term "racket" is used by the ITTF in table tennis, the term "bat" is used in England, and the term "paddle" is widely used in the USA and Canada. The wooden part of the racket, often called the racket board, in English "blade," usually ranges from 1-7 layers (URL2). In general, the more layers a racket blade has, the faster it is said to be, but the racket's weight also affects speed. Five-layer blades, which generally contain a

thicker core layer than the outer layers, are preferred in games that give the ball more control and spin. When the wood layers of the racket blade are thicker, they usually offer more flexibility and a lighter feel. Five-ply blades are often associated with the classic, all-wood feel. On the other hand, the seven-ply blade contains thinner layers of wood and, therefore, more glue to join the layers together. This requires more strength and precision, providing greater rigidity and less flexibility. It is generally accepted that seven-ply racket blades are faster than the five-ply blade (URL4).

According to ITTF regulations, at least 85% of the racket blade thickness should be made of natural wood, and the wood surface should be smooth and hard. Today, in the production of racket blades, thickness less than 0,35 mm or 7,5% of the total blade-thickness according to the relevant regulation, fibrous reinforcing materials are allowed to be used between layers. For this purpose, materials such as carbon fiber, glass fiber, or compressed paper fiber adhere between the plywood layers that make up the racket blade, giving the blade hardness and speed. However, the surface of the racket blade is polished to the thickness permitted by ITTF. However, it should not be coated with more than 0,1 mm thick paint or very thick varnish (URL5; Wang et al. 2012). The racket blade can be of any shape (triangle, square, circle, etc.), size or weight, but is on average 17 cm long and 15 cm wide (Heaton 2012; URL2). Although official restrictions only focus on the flatness and stiffness of the paddle blade, these dimensions are ideal for most play styles. In addition, there is no regulation regarding the mass of rackets in the ITTF regulation (URL2; Iino and Kojima 2016). In general, larger paddle blades are preferred by defensive players who want to reduce the chance of bad hitting, while attackers prefer smaller-sized paddle blades because they think they can swing the racket faster when hitting the ball (Iino and Kojima 2016). In general, racket blade can be categorized as follows:

- Defensive game paddle blade (slow),
- Allround game racket blade (for intermediate and beginner players),
- Offensive game racket blade (fast)
- Carbon-infused racket blade (quite fast)
- Hardwood or softwood racket blade (Heaton 2012).

Faster racket blades tend to lose the feel needed for tapping, such as a short push, making overall control more difficult. Most top pro players tend to choose an allround or offensive racket blade combined with faster rubbers to give the racket extra speed while maintaining the necessary feel and control (Heaton 2012). It is stated that the main factors affecting the function of the racket blade are density, modulus of elasticity, modulus ratio, and strength. According to the theory of kinetic energy and Newton's second law, the higher the weight, the greater the kinetic energy. Therefore, the ball's rebound velocity will be higher after hitting the ball with a heavy paddle blade. Blades with a high modulus of elasticity also have a high ability to prevent deformation. The modulus ratio is the ratio between modulus and density that can be used to measure the contribution of the material's specific gravity to the elastic modulus to the racket blade. It is stated that the high specific modulus is one of the important foundations in developing new materials for rackets (Yu 2014). The paddle blade and the layers that make up the racket rubber and the paddle blade dimensions are shown in Figure 1. The paddle blade in the example is composed of Limba, Ash, a carbon layer, and Ayous layers, from the top layer to the core layer, respectively. Racket rubber consists of a sponge layer and rubber layer.

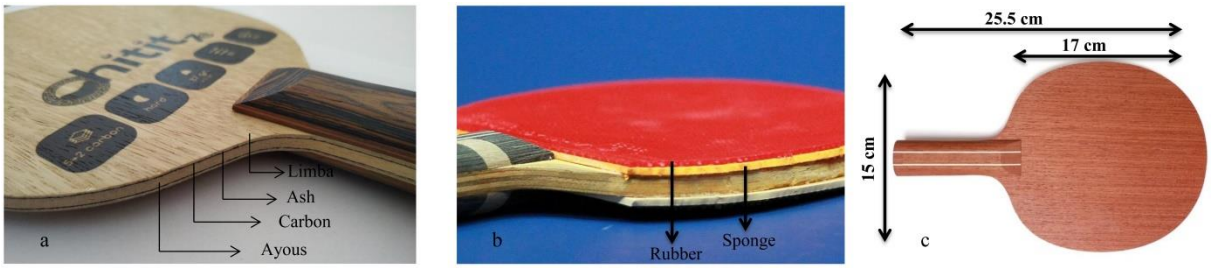

Figure 1. Racket blade (a), racket rubber (b) layers, and (c) racket blade dimensions

3. The Historical Development of The Racket Blade

Considering the historical development of the racket blade, while long-handled rackets covered with parchment were used in the early days, it changed significantly with the development of hard rubber-coated rackets after 1930. In the 1950s, racket rubbers with elastic sponges were developed, providing more spin and speed to the ball during the stroke. In this context, the tree species that make up the racket blade, their properties, shapes, and sizes have undergone changes and developments and started to be produced with standard features (McAfee 2009). Almost half a century ago, African Okoume wood was widely used to manufacture slow-featured, perfectly controlled rackets. Later, single-layer racket blades with fast characteristics were produced from Japanese Hinoki wood. Although it was difficult to control the paddle blade made of Hinoki wood, the game gained an excellent pace. Although the blades made of heavy Chinese wood were used by European players for a certain period, they were not used for a long time because the rubber attached to the surface of the racket blade increased the weight of the racket (URL6).

Today, with the development of engineering, materials, and sports sciences, racket blades are produced more modern and according to the needs. Although the racket blade is produced from solid timber, composite materials such as plywood and laminated wood are used, which are produced from veneer and papels obtained by sawing, cutting, or peeling the logs (Buragohain 2017). The wooden layers that make up the racket blade are reinforced with reinforcement materials such as cellulose, carbon, glass wool allowed in the ITTF regulation (Wang et al. 2012). Experiments have been done on the suitability of all shapes in the production of racket blades, which do not have any limitations in size and shape. Each racket that is proven suitability has advantages and disadvantages. The M-shaped handleless racket blade form was patented in 1989. Penhold curved handle racket blade started to be produced in 1979, and penhold round-square shaped racket blade started to be produced in 1980. Racket blade production in the form seen in figure 1(a) is common today (URL3; McAfee 2009; URL6; Liu 1996).

4. Types of Wood Used in Racket Blade Production

It is often confusing what wood species table tennis racket blades are made of, their properties, and how they affect a player's performance. In a controlled attack game close to the table, it is appropriate that the racket blade is not very fast but has five layers focusing on providing more control and spin to the ball. In the production of racket blades for this type of game, Kiri in the core (middle) layer, Ayous in the inner layers, and Hinoki in the outer layers are used. Kiri has excellent anti-vibration properties, Ayous has excellent flexibility for counter-attack close to the table, and Hinoki is suitable for touch and feel, especially when speed and spin variations (URL7).

Different types of wood are used in table tennis blade production, Ash, Spruce, Linden, Walnut, Willow, Poplar, Hinoki, Limba, Balsa, Kiri, etc. Rarely, solid wood consisting of a single layer is used, but generally, wood composite (plywood) materials consisting of 3, 5, 7, or 9 layers are used. For the wood species used in the production of racket blades to give a good performance, it is recommended to prefer natural drying methods and to carry out long-term drying processes. Racket blades can consist of veneer or laminate obtained from the

same tree species, as well as from different tree species. The composite racket blade generally consists of four parts: middle part (core), intermediate layer, surface layer, and racket handle. It is reinforced with materials such as carbon fibers, glass fibers, and cellulose fibers to strengthen the racket blade. Commonly used tree species and their characteristics are given below.

Abachi (*Triplochiton scleroxylon* K. Schum)

Abachi wood is in the same family as Ayaous and Samba and is used as the outermost or core layer of racket blade. It blends well with many types of wood and is a light and flexible wood perfect for counter-attacking close to the table. This wood is found in 90% or more of all racket blades on the market (URL8; URL9).

Anegre (*Pouteria altissima* (A. Chev.) Baehni)

This wood that is suitable for controlled playing style is used in the middle and upper layers in the production of racket blades. Depending on the other wood layers it is used with, it has features suitable for defense and attack play. It provides a soft feel to players when in contact with the ball. It is generally preferred by many players with all-round playing styles (URL8; URL9).

Ash (*Fraxinus excelsior* L.)

This tree species, which also spreads in Turkey, is preferred in the production of racket blades with high-speed features. Due to its heavy and rigid structure blends best with lighter and softer core and outer layers. It is rarely used, but when used, it usually forms the core layer of the paddle blade (URL8; URL9).

Balsa (*Ochroma pyramidale* (Cav. ex Lam.) Urb.)

Balsa, one of the lowest density woods, creates surfaces that have a non-linear effect on ball contact. Its soft structure allows the ball to sink into the racket rubber, which spins a lot resulting in a high waiting period required for attacking players and players with a cutting playing style. It is also suitable for spin variations due to its softness and non-linear effect. It is generally used as the core layer (URL8; URL9).

Linden (*Tilia* spp.)

Linden wood has been used in racket construction for over fifty years due to its high control and economical price. It is preferred by counter attackers close to the table and by players who want to buy their first professional rackets. This hardwood is used in racket blades suitable for all-round playing styles (URL8; URL9).

Lawson liar cypress (*Chamaecyparis lawsoniana* (A.Murray bis) Parl.)

Attack players have preferred it for decades because of the speed and softness it brings to the racket blade. It pairs well with Ayous, Ash, and Pine (URL8; URL9).

Red cedar (*Thuja plicata* Donn ex D.Don)

It is suitable for producing a single-layer racket blade (URL8; URL9).

Hinoki "Japanese cypress, Kiso Hinoki" (*Chamaecyparis obtusa* Siebold & Zucc.)

It is one of the most used wood species in racket blades. Hinoki is only used in racket blade manufacture when 300 years old or more. The most significant disadvantages are that it is heavy and costly in producing racket blades. It is suitable for each layer in constructing the paddle blade (URL8; URL9).

Princess tree “Paulownia” (Paulownia tomentosa (Thunb.) Steud.)

This type of wood, known as Kiri in Japanese in the table tennis market, is generally used as the core layer of the racket blade. It blends well with the blade's heavier middle and outer layers with high-speed properties. It reduces the vibration that occurs when hitting the ball. In addition, the racket blade made of this wood has less ball-feel on hits (URL8; URL9).

Jatoba (*Hymenaea courbaril* L.)

This wood is tough and very heavy. Its only practical use is as a very thin top layer. It combines well with balsa wood to create a paddle blade that adapts to long pimple rubber (URL8; URL9).

Koto (*Pterygota macrocarpa* K. Schum.)

It is an ideal wood for soft topspin games. It is typically used in extremely thin outer layers to produce a faster and harder racket blade. It is suitable wood for players who rely on both loop and counter-attack techniques. Koto wood surface coats encourage crisp, fast blocks and hard hits for sharper ball contact and faster response. It is a suitable tree for offensive-style games (URL8; URL9).

Limba (*Terminalia superba* Eng. & Diels)

It is mostly used as a surface coating with a 0.7–0.8 mm thickness. Limba is a wood suitable for the outer and middle layers of the racket blade. It has a medium-soft feel. Limba wood provides the smooth feel and excellent control today's modern topspin players need. Limba is a classic European topspin wood (compared to Hinoki, a classic Asian topspin wood) heavy and fast, but not springy. It is lighter and softer than Hinoki or Koto. Although Limba wood is soft, it alone cannot give a soft feel to the racket blade, and when used in combination with other veneers, the Limba racket blade can provide a hard feeling. Limba provides a good acoustic sound as it has excellent acoustic properties. Topspin players like it because of its vibrations or flexibility. The higher the thickness of the limba layer, the higher the batting power of the racket blade (URL8; URL9).

Planchonella (*Planchonella* spp.)

They are preferred in the production of racket blades where high speed is required. This tree is most commonly used on a racket blade designed for strong attacking players (URL9).

Poplar (*Populus* spp.)

It is more suitable for the core and outer layer in the racket blade. It shows similar characteristics to Ayous and linden trees (URL8; URL9).

Sitka spruce (*Picea sitchensis* (Bong.) Trautv. & C.A.Mey.)

It is used to achieve higher speed on the racket blade. Spruce layers provide a loud sound and a good feel when the ball is hit. However, when this wood layer gets too close to the surface where the racket rubber is attached, the ball's spin rate will be low because the sound and feel will be too strong. For this reason, it is stated that it is more appropriate to use the middle layers under the surface layer instead of the top layer of the racket blade. It is similar in feel to Cypress and Cedarwood (URL8; URL9).

Tung (*Vernicia fordii* (Hemsl.) Airy Shaw)

It is used as the core layer. The blade of this low-density tree is light and strong. It is used instead of balsa, paulownia, or linden wood in blade production (URL8; URL9).

Walnut (*Juglans spp., Lovoa trichilioides* Harms)

Walnut, a fast, hard, and expensive surface ply material, is dark wood. It blends well with a soft core layer. This type of wood is usually used as the top layer but is sometimes used as the middle layer. It has a hard but sharp feel (URL8; URL9).

Willow (*Salix* spp.)

It is a heavy wood that makes hard and fast balls easy to control. It is often used as an outer layer due to its damping effect. It reduces the power of an incoming ball has a hollow feel. It is suitable for the production of racket blades suitable for cutting and defensive playing style (URL8).

5. Racket Blade Production

Racket blade production requires experience and knowledge in table tennis as well as material knowledge and production experience. The wood and composite materials used in each layer of the racket blade, which is designed according to the needs, differ. The racket blade, which usually consists of 1-7 layers, is produced from solid wood or plywood composites. It is an important issue how to use wood and composite materials appropriately in the production of racket blades. The blade production process includes raw material selection, coating production, bonding, shaping, and surface treatments. The wood types and coating thicknesses used in the production of racket blades differ according to the racket's characteristics. The coatings are selected in the desired combination and number according to the table tennis playing styles and traditionally adhered on top of each other in the longitudinal and transverse directions. However, after the 2000s, new techniques have been developed in the production of racket blade by positioning the fiber direction of the outer and core layers parallel to each other and the racket handle, while the other layers are positioned to form an angle of 45° (Wang 2012; URL10). In order to add speed and stiffness to the racket blade, reinforcement materials such as carbon fiber, glass fiber, or compressed paper fiber can be used between the layers in accordance with the relevant regulation of the ITTF, with less than 0.35 mm or 7.5% of the total blade thickness (URL 5). In this context, mostly carbon fibers, aryl, aryl-carbon mixed, and glass fibers are used. Since carbon fibers have lower amplitude, they are used between layers of wood to improve the player's sense of proprioception during hitting the ball and add rigidity to the wood. It is emphasized that since carbon fiber has a higher vibration frequency than other fibers used, it reduces the time the ball stays on the blade during the stroke and therefore increases the attack power by reducing the striking arc of the player. Since the aryl fiber has a higher amplitude, it shortens the vibration damping time of the blade. Therefore, it provides a soft-hitting feeling to the player. This feature of the aryl fiber increases the characteristic of the racket blade to spin the ball, as it increases the contact time of the racket with the ball. Aryl-carbon fiber is produced by weaving two fibers with different properties together. Because the vibration frequency is between carbon fiber and aryl fiber, the ball stays in the racket longer than carbon fiber and gives the ball more spin than carbon fiber. However, since the damping time is shorter than that of carbon fiber, blades made of aryl-carbon fiber do not produce uncontrollable sensations such as scattering and uneven bouncing when hitting the ball. Aryl-carbon fiber can be used if it is desired to provide both hardness and softness to the racket blade. Glass fiber provides players with a soft hitting feel, similar to aryl fiber. Among the reinforcing fibers, glass fiber has the closest properties to natural timber. The physical properties of the wood material to be used in the production of the racket blade, the thickness of the coating, the weight of the plywood, and the reinforcement materials affect the character of the racket blade. For example, a heavy racket blade is faster than a light racket blade. Knowing the quality of the wood to be used in production, choosing the appropriate coating type, and knowing the thickness of the different coatings are important factors affecting the quality of the racket blade. Factors such as adhesive types, properties, amount of pressure required, temperature and time that affect the bonding process, and finishing processes are other factors that affect the quality of the racket blade. In addition, reinforcement materials such as carbon, glass, wood fiber used in blade production also affect the performance of the racket blades (Wang 2012; Sun et al. 2012; URL10).

The characteristics of the wood to be used in table tennis rackets, such as impact absorption energy, hardness, lightness, and elasticity, are considered. For the wood species used in the production of racket blades to give a good performance, it is recommended to prefer natural drying methods and carry out long-term drying processes. Racket blades are produced from logs using one of the sawing methods, cutting and peeling. There should be no veneer and plywood production defects, such as cracking and surface fluctuation. The bark of the logs is peeled and cooked with steam in steam ovens or boilers at temperatures and times appropriate for the tree type. Veneers are produced by sawing, cutting, or peeling. The dried veneers are adhered to each other under temperature and pressure with suitable adhesives, longitudinally and transversely. After the racket blades are cut on CNC machining benches, finishing processes are applied. The racket blades varnished according to

the relevant regulation of ITTF are made ready for use by determining the resonance feature and frequency from the quality control tests (URL11).

6. Results and Discussion

Table tennis emerged at the end of the 19th century and has changed over time depending on equipment development. The development of composites has contributed to the change and development of the structure of the table tennis racket. One piece of table tennis rackets began to be replaced by hybrid rackets consisting of two pieces (racket blade and racket rubber). Although a racket blade comprises a single layer, generally, wood composite racket blades comprised of 3 to 7 layers are more widely used and preferred by table tennis players. With the developments in table tennis, wooden composite racket blades are being changed and developed by the manufacturers to meet the players' needs. According to ITTF regulations, at least 85% of the racket blade thickness is made up of natural wood, but the wood surface can be flat, smooth, hard, and have a thin layer of varnish 0,1 mm thick. Reinforcing materials such as carbon fiber, glass fiber, or compressed paper fiber can be used in its production to add rigidity and speed to the racket blade. However, according to the relevant regulation, the layer of reinforcing material used should be less than 0.35 mm or 7,5% of the total blade thickness. The paddle blade can be triangle, square, circle, etc. can be of any shape, size, or weight. Commonly used racket blade sizes average 17 cm long and 15 cm wide. One of the important aspects that should be known in the properties of the material to be used in the production of table tennis racket blades is the impact absorption energy. It is understood that the production factors such as the number of layers, thickness, type of adhesive, type of reinforcement material of the plywood blades used in the production of racket blades affect the quality and performance. According to the literature review's information, the racket blade's ability and performance are affected by factors such as shape, weight, thickness, hardness, and impact absorption energy. It has been stated that the required features for the table tennis racket blade; spin (15%), control (25%), speed (25%), shape (10%), and racket handle (25%) (Arifin et al. 2017; URL5; Wang et al. 2012).

As a result, it has been seen that racket blade production has constantly been developing and changing from the beginning to the present. It is recommended to use long-term natural drying methods for tree species to give good performance. In recent years, reinforcement materials such as carbon fiber, glass fiber, and wood fiber have been used together with wood veneers to produce racket blades. It is emphasized that the number of scientific studies on the subject in the world is very limited. Therefore, it is important to conduct interdisciplinary studies on the development of the properties of wooden materials to be used in the production of racket blades. Turkey, which ranks 5th in the production of wood composite panels in the world, is one of the important producer countries (İstek et al. 2017). However, it has been determined that this production ability in racket blade manufacturing is very limited. It is important for Turkey to accelerate R&D and design studies in the production of racket blades. In addition, it is recommended to carry out studies on the suitability of endemic tree species growing in Turkey for racket blade production.

Conflict of Interest

The authors declared no conflict of interest.

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