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Performance Evaluation of Coco Wood Chairs Constructed with Traditional Joints

Evaluacija svojstava stolica od drva kokosove palme izrađenih tradicionalnim spojevima

ORIGINAL SCIENTIFIC PAPER
Izvorni znanstveni rad
Received – prispjelo: 5. 9. 2025.
Accepted – prihvaćeno: 26. 1. 2026.
UDK: 684.4.058; 684.432
https://doi.org/10.5552/drvind.2026.0294

ABSTRACT • *Furniture is an engineered structure that is subjected to various loads throughout its service life. As a result, to guarantee that furniture satisfies the standards of the target market for strength and durability, it must be designed and constructed with the appropriate strength features. This study, therefore, assesses the structural and aesthetic performance of three chairs made from West African Tall Coco Wood (Cocos nucifera) using three traditional joints: mortise and tenon, halving, and dowel joints. With rising demand for sustainable alternatives to tropical hardwoods, coco wood represents an underutilised yet promising material in Ghana's furniture sector. The coco wood was obtained from the Abura Asebu Kwamankese District in the Central Region of Ghana. The chairs were produced at the Asuansi Technical Institute and were tested at the laboratory of the Wood Mechanic and Furniture Testing Centre (FORIG), Kumasi, according to European Standards (EN 1022 and EN 1728). The results indicate that mortise and tenon joints performed best, followed by halving joints and dowel joints. On the aesthetic side, coco wood was found to be visually attractive and comparable to many commonly used hardwoods, thus making it suitable for furniture that does not undergo heavy use. Overall, the study suggests that coco wood can be a sustainable and eco-friendly material choice for light to medium furniture. Mortise and tenon joints are recommended for furniture that requires load-bearing. Dowel and halving joints are suitable for secondary and decorative purposes. The study demonstrates the potential for wider adoption of coco wood in Ghana's furniture sector and provides guidance for improved joint selection and furniture design.*

KEYWORDS: *coco wood; mortise and tenon joint; halving joint; dowel joint; eco-friendly furniture*

SAŽETAK • *Namještaj je proizvod koji je tijekom svog vijeka trajanja izložen različitim opterećenjima. Zbog toga mora biti dizajniran i izrađen tako da posjeduje odgovarajuću čvrstoću kako bi zadovoljio standarde ciljanog tržišta u smislu čvrstoće i trajnosti. U ovom se istraživanju procjenjuju strukturna i estetska svojstva triju stolica od drva zapadnoafričke visoke kokosove palme (Cocos nucifera) izrađenih primjenom triju tradicionalnih spojeva: čepa i rupe, spoja na preklop i spoja s moždanicima. U uvjetima sve veće potražnje održivih alternativa tropskim listačama, drvo kokosove palme nedovoljno je iskorišten, ali obećavajući materijal u industriji namještaja u Gani.*

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Za potrebe ovog istraživanja drvo kokosove palme nabavljeno je iz okruga Abura Asebu Kwamankese u središnjoj regiji Gane. Stolice su proizvedene u Tehničkom institutu Asuansi i ispitane u laboratoriju Centra za mehaniku drva i ispitivanje namještaja (FORIG) u Kumasiju, i to prema europskim normama (EN 1022 i EN 1728). Istraživanjem je utvrđeno da spoj s čepom i rupom daje najbolje rezultate, a slijedi spoj na preklop i spoj s moždanicima. S obzirom na estetska obilježja, drvo kokosove palme pokazalo se vizualno privlačnim i usporedivim s mnogim uobičajeno upotrebljavanim vrstama drva listača, što ga čini pogodnim za namještaj koji nije u intenzivnoj uporabi. Zaključno, rezultati studije sugeriraju da drvo kokosove palme može biti održiv i ekološki prihvatljiv materijal za lagani do srednje teški namještaj. Spoj s čepom i rupom preporučuje se za namještaj od kojega se očekuje veća nosivost. Spojevi s moždanicima i na preklop prikladni su za namještaj koji ima sekundarnu i dekorativnu namjenu. Studija je potvrdila potencijal drva kokosove palme za širu primjenu u proizvodnji namještaja u Gani i ponudila je smjernice za odgovarajući odabir spojeva i bolji dizajn namještaja.

KLJUČNE RIJEČI: *drvo kokosove palme; spoj s čepom i rupom; spoj na preklop; spoj s moždanicima; ekološki namještaj*

1 INTRODUCTION
1. UVOD

Traditional woodworking joints play a critical role in determining the structural integrity and overall quality of furniture manufactured from coco wood, a material valued for its natural appearance, strength, and durability (Vlaović, 2024). For Ghana's furniture industry to remain competitive in the global market, particularly within the emerging coco wood sector, there is a growing need to adopt designs that balance mechanical performance with aesthetic appeal. In recent years, the furniture design industry has transitioned from predominantly traditional practices toward more innovative and performance-oriented approaches (Han *et al*., 2021; Rame *et al*., 2023).

Furniture design integrates functionality, stability, continuity, and aesthetics. Coco wood furniture exemplifies this balance due to the material's strength, sustainability, and visual appeal (Fathi *et al*., 2023; Hummel, 2023).

Previous studies indicate that the selection of appropriate joints is fundamental to woodworking and directly influences the mechanical performance and durability of furniture (Carpenter, 2021; Zhu *et al*., 2022). In addition, joints contribute significantly to the visual quality and perceived craftsmanship of furniture products (Furniture Crafters, 2022; Hughes, 2023).

Aesthetic quality, defined by balance, order, and visual harmony, is another important factor affecting consumer preference (Goldman, 2001; Handy *et al*., 2008). Aesthetic judgment can be formed independently of material properties, highlighting the role of design perception in market competitiveness (Schepman *et al*., 2018; Sibley, 2001).

The decline in traditional hardwood resources has increased interest in alternative materials such as coco wood. Ghana's deforestation rate is estimated at approximately 2 % annually (IUCN, 2022), thereby encouraging the exploration of sustainable materials derived from senile and non-productive coconut palms (Fathi *et al*., 2023; Hummel, 2023; Okai *et al*., 2004).

However, the anatomical variability of coco wood affects its physical and mechanical properties (Fathi, 2014). Studies indicate that density ranges from 0.41–1.11 g/cm³ and moisture content from 50 % to 400 %. Despite such variability, coco wood exhibits relatively low shrinkage and swelling, making it less prone to warping (Fathi *et al*., 2023). Density strongly influences its performance, while moisture content has little effect (Gonzalez *et al*., 2014).

Despite the availability of coco wood and its growing use in construction and furniture, limited information exists on the influence of joint type on the structural performance and aesthetic quality of the coco wood chair. This lack of data constrains evidence-based design decisions among Ghanaian furniture manufacturers.

Therefore, this study evaluates the structural performance of mortise and tenon, halving, and dowel joints in a coco wood chair construction to support durable, aesthetically pleasing, and sustainable furniture design.

1.1 Objectives of the study
1.1. Ciljevi istraživanja

The objectives of this study are:

1. To evaluate the structural performance of coco wood chairs constructed with mortise and tenon, halving, and dowel joints in accordance with the EN 1022 and EN 1728 standards;
2. To assess the durability and load-bearing capacity of the joints under stability and fatigue loading conditions;
3. To examine the aesthetic qualities of coco wood chairs in comparison with those of traditional hardwood furniture;
4. To identify the most suitable joinery methods for both functional and decorative applications in sustainable furniture design.

2 MATERIALS AND METHODS
2. MATERIJALI I METODE

2.1 Study area and sample selection
2.1. Područje istraživanja i odabir uzoraka

Coco wood samples were collected from Abakrampa in the Abura Asebu Kwamankese (AAK) District of Ghana's Central Region (5°05′N–5°25′N; 1°05′W–1°20′W). The district covers approximately 380 km² and spans ecological zones ranging from coastal savanna to tropical rainforest (GDS, 2024).

Two senile *Cocos nucifera* palms of the West African Tall variety, infected with Cape St. Paul wilt disease, were purposively selected to ensure uniformity in age, disease condition, and stem diameter.

The selected palms were approximately 20 years old, with an average height of about 30 m and a stem diameter of 45 cm. Mean ambient temperatures at the collection site ranged between 26 and 28 °C.

2.2 Sample collection and preparation
2.2. Prikupljanje i priprema uzoraka

Felling and Cutting: The selected palms were felled in accordance with environmental and safety guidelines. Logs were converted into planks measuring 50 mm × 150 mm × 2400 mm using a chainsaw. The planks were sawn radially from the outer stem zone toward the inner stem zones.

Air-Drying: The planks were air-dried for three days before machining to reduce surface moisture and minimise machining defects.

Chair Production: Three coco wood chairs were constructed, each representing a different traditional joint type: mortise and tenon, halving, and dowel joints. Each chair incorporated twelve joints. For each joint type, four replicate joints were tested, resulting in a total of 12 joints per joint category. The sample size was determined based on material availability and is consistent with similar exploratory studies on timber joints.

Chair fabrication was carried out in the Furniture Design Technology Department Workshop of Asuansi Technical Institute.

2.3 Material properties of coco wood
2.3. Svojstva drva kokosove palme

The physical and mechanical properties of the coco wood used in this study were determined in accordance with BS 373:1957 and ASTM D143 standards. Measured properties included density, moisture content, modulus of elasticity (*MOE*), modulus of rupture (*MOR*), hardness, and shrinkage. The results are summarised in Table 1.

2.4 Equipment
2.4. Oprema

Workshop Equipment: Personal protective equipment (PPE), thickness planer, circular saw, cross-cut saw, surface planer, dimension saw, band saw, hollow-chisel mortiser, sanding machine, drilling machine, air compressor, spray gun, and chainsaw.

Consumables: Polyvinyl acetate (PVA) wood adhesive and clear lacquer finish.

2.5 Chair design and construction
2.5. Dizajn i konstrukcija stolice

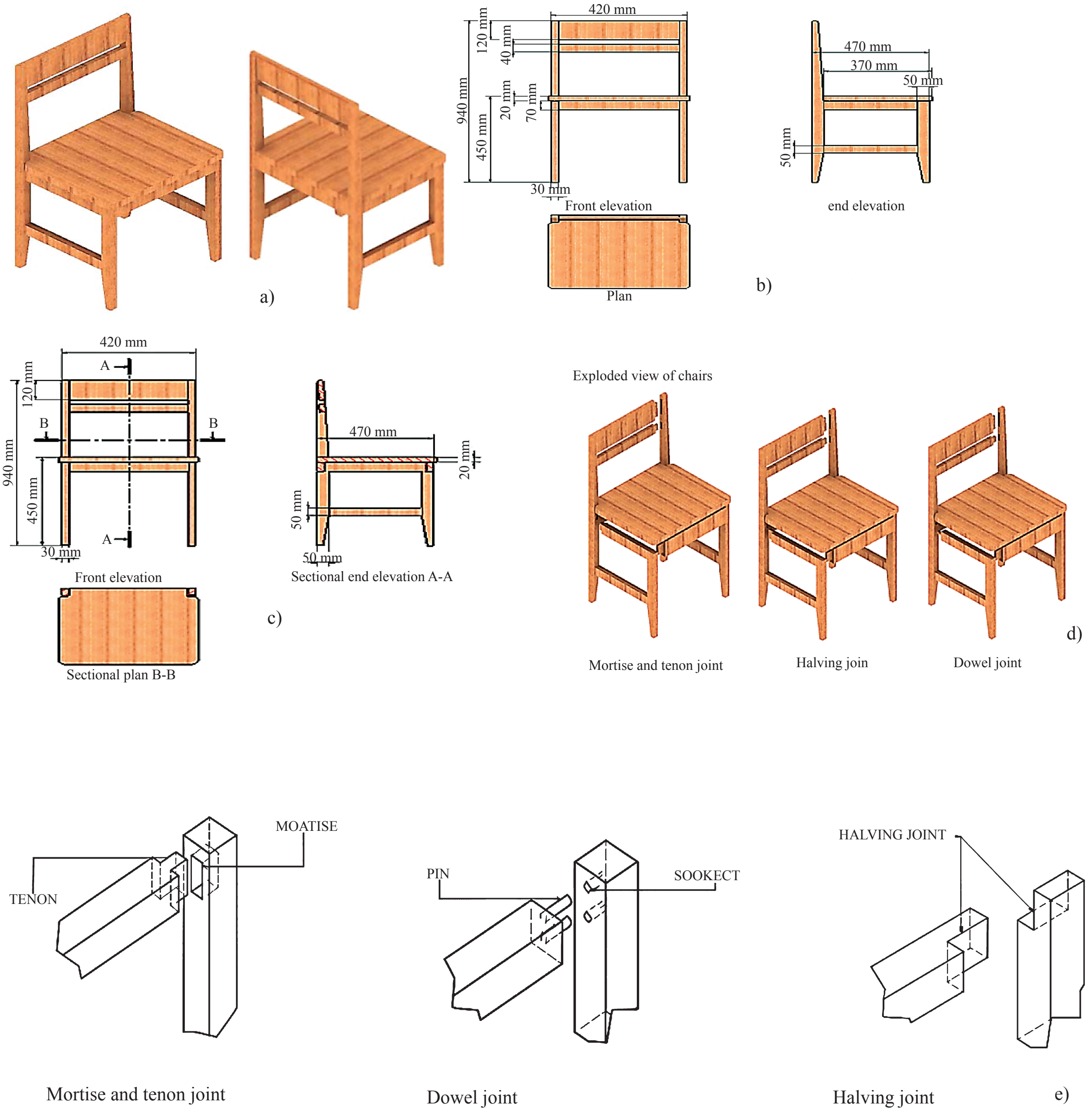
Working drawings, including isometric, orthographic, sectional, and exploded views, were developed using Autodesk Inventor software (version 2008). These drawings were used to prepare a cutting list (Table 2), which guided accurate preparation of materials and ensured dimensional consistency.

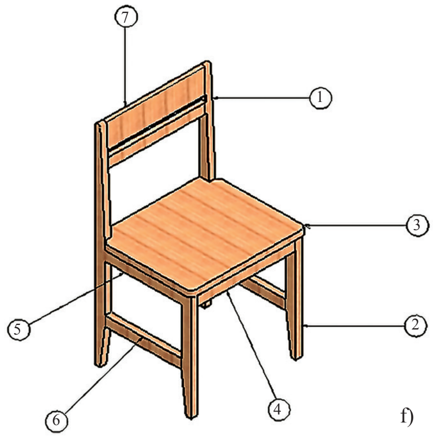
To ensure comparability among specimens, the geometric dimensions of all joint types were kept constant. Mortise and tenon joints were fabricated with a tenon length of 30 mm, a width of 40 mm, and a thickness of 10 mm, fitted into corresponding mortises of identical dimensions. Halving joints were produced with a half-depth overlap of 15 mm over a joint width of 40 mm. Dowel joints consisted of two cylindrical dowels, each 10 mm in diameter and 40 mm in length, inserted into pre-drilled holes with a centre-to-centre spacing of 50 mm.

All joints were bonded using polyvinyl acetate (PVA) wood adhesive and assembled under uniform clamping pressure to ensure adequate glue-line contact.

Table 1 Physical and mechanical properties of west African tall coco wood
Tablica 1. Fizička i mehanička svojstva drva zapadnoafričke visoke kokosove palme

Property / *Svojstvo*	**Value** / *Vrijednost*	**Unit** / *Jedinica*
Density (oven-dry) / *gustoća u apsolutno suhom stanju*	0.62 ± 0.05	g/cm³
Moisture content (air-dried) / *sadržaj vode (u zrakosuhom drvu)*	12 ± 1.5	%
Modulus of elasticity (*MOE*) / *modul elastičnosti (MOE)*	10,500 ± 300	MPa
Modulus of rupture (*MOR*) / *modul loma (MOR)*	75 ± 5	MPa
Janka hardness / *tvrdoća prema Janki*	3,200 ± 100	N
Radial shrinkage / *radijalno utezanje*	3.5 ± 0.2	%
Tangential shrinkage / *tangentno utezanje*	5.8 ± 0.3	%





Parts list / *Popis dijelova*	
Part No. *Broj dijela*	Description *Opis*
1	Back leg / *stražnja noga*
2	Front leg / *prednja noga*
3	Seat / *sjedalo*
4	Front rail / *prednja okvirnica*
5	Side rail / *bočna okvirnica*
6	Bottom rail / *poveznik nogu*
7	Back rest / *naslon*

Figure 1 Working drawings of the coco wood chair components: a) isometric view, b) orthographic view, c) sectional view, d) exploded view, e) details of joint construction, f) parts list
Slika 1. Radni crteži dijelova stolice od drva kokosove palme: a) izometrijska projekcija, b) ortogonalna projekcija, c) presjek, d) rastavljeni prikaz, e) detalji konstrukcije spoja, f) popis dijelova

Table 2 Cutting list for coco wood chair components
Tablica 2. Krojna lista dijelova stolice od drva kokosove palme

Item *Stavka*	Description *Opis*	Qty *Količina*	Dimension, mm *Dimenzija*, mm	Material *Materijal*	Finish *Premaz*
1	Front leg / *prednja noga*	2	430 × 50 × 30	Coco wood / *drvo kokosove palme*	Lacquer / *lak*
2	Back leg / *stražnja noga*	2	940 × 50 × 30	Coco wood / *drvo kokosove palme*	Lacquer / *lak*
3	Seat / *sjedalo*	1	470 × 460 × 20	Coco wood / *drvo kokosove palme*	Lacquer / *lak*
4	Side rail / *bočna okvirnica*	2	410 × 70 × 30	Coco wood / *drvo kokosove palme*	Lacquer / *lak*
5	Front rail / *prednja okvirnica*	1	400 × 70 × 30	Coco wood / *drvo kokosove palme*	Lacquer / *lak*
6	Back rest / *naslon*	1	400 × 70 × 30	Coco wood / *drvo kokosove palme*	Lacquer / *lak*
7	Bottom rail / *poveznik nogu*	2	410 × 50 × 30	Coco wood / *drvo kokosove palme*	Lacquer / *lak*

2.6 Construction process
2.6. Proces izrade

The chair construction process included planing, ripping, shooting, cross-cutting, marking out, joint fabrication, trial assembly, final assembly, seat lamination, sanding, and application of the final surface finish.

2.7 Experimental setup
2.7. Postavke eksperimenta

All tests were conducted at the Wood and Furniture Testing Centre of the Forest Research Institute of Ghana (FORIG), Kumasi, in accordance with European standards (EN 1022 and EN 1728; CEN, 2018). Elaeis

Figure 2 Construction stages of the three coco wood chairs: a) planing, b) ripping, c) shooting, d) cross-cutting, e) marking out and joint construction, f) trial and final assembly of joints, g) sanding of the chair structure, h) lamination of the chair seat, i) application of the final coating material, j) final products
Slika 2. Faze izrade triju stolica od drva kokosove palme: a) ravnanje, b) uzdužno raspiljivanje, c) blanjanje, d) poprečno piljenje, e) označivanje i izrada spojeva, f) probno i konačno sastavljanje spojeva, g) brušenje stolice, h) laminiranje sjedala stolice, i) nanošenje završnog premaza, j) gotovi proizvodi

guineensis, is by far the most important global oil crop, supplying about 40 % of all traded vegetable oil. Palm oils are key dietary components consumed daily by over three billion people, mostly in Asia, and also have a wide range of important non-food uses including in cleansing and sanitizing products. Main body: Oil palm is a perennial crop with a > 25-year life cycle and an exceptionally low land footprint compared to annual oilseed crops. Oil palm crops globally produce an annual 81 million tonnes (Mt Prior to testing, all chairs were conditioned in a climate-controlled environment at 20–25 °C and 60–65 % relative humidity for 24 hours.

During the testing procedure, the chairs were placed on a rigid, level surface, and loads were applied vertically or horizontally at specified locations on the seat, backrest, and legs using a calibrated loading system. The loading direction, support conditions, and points of load application were kept constant across all specimens to ensure repeatability. The ultimate load sustained prior to failure was recorded. In cases where no failure occurred, testing was terminated once the performance requirements specified in the relevant standards had been satisfied.

Figure 3 Experimental testing of coco wood chairs in accordance with EN standards: a) chairs in a climate-controlled room, b) chair at the marking-out centre, c) forward stability test, d) sideways stability test, e) rearward stability test, f) seat and back static load test, g) leg forward and sideways static load test, h) combined seat and back durability test, i) seat impact test
Slika 3. Ispitivanje stolica od drva kokosove palme u skladu s EN normama: a) klimatiziranje, b) označivanje, c) ispitivanje stabilnosti prema naprijed, d) ispitivanje bočne stabilnosti, e) ispitivanje stabilnosti prema natrag, f) ispitivanje statičkog opterećenja sjedala i naslona za leđa, g) ispitivanje statičkog opterećenja nogu prema naprijed i bočno, h) kombinirano ispitivanje trajnosti sjedala i naslona za leđa, i) ispitivanje sjedala udarom

Table 3 Summary of the performance of coco wood chairs constructed with mortise and tenon, halving, and dowel joints according to European test standards
Tablica 3. Sažetak performansi stolica od drva kokosove palme izrađenih spojem s rupom i *čepom*, spojem na preklop i spojem s moždanicima, ispitanih prema europskim standardima

Joint type *Vrsta spoja*	**Test (EN standard)** *Ispitivanje* (EN standard)	**Specified force** *Odabrana sila*	**Ultimate load, N** *Krajnje opterećenje,* N	**Result** *Rezultat*
Mortise and tenon *rupa i čep*	Forward stability / *stabilnost prema naprijed* (EN 1022, 6.2)	600 N	625 ± 15	Passed / *zadovoljavajući*
Mortise and tenon *rupa i čep*	Rearward stability / *stabilnost prema natrag* (EN 1022, 6.6)	600 N	640 ± 20	Passed / *zadovoljavajući*
Mortise and tenon *rupa i čep*	Sideways stability / *bočna stabilnost* (EN 1022, 6.4)	600 N	580 ± 10	Failed / *nije zadovoljavajući*
Mortise and tenon *rupa i čep*	Seat & back static load / *statičko opterećenje sjedala i naslona za leđa* (EN 1728, 6.4)	1600 N, 410 N	1620 ± 25	Passed / *zadovoljavajući*
Mortise and tenon *rupa i čep*	Seat front edge static load / *statičko opterećenje prednjeg ruba sjedala* (EN 1728, 6.5)	1300 N	1325 ± 20	Passed / *zadovoljavajući*
Mortise and tenon *rupa i čep*	Combined seat & back durability / *kombinirana trajnost sjedala i naslona za leđa* (EN 1728, 6.17)	1000 N, 330 N, 25,000 cycles	1010 ± 30	Passed / *zadovoljavajući*
Mortise and tenon *rupa i čep*	Leg forward static load / *statičko opterećenje nogu prema naprijed* (EN 1728, 6.15)	1000 N	1020 ± 18	Passed / *zadovoljavajući*
Mortise and tenon *rupa i čep*	Leg sideways static load / *statičko opterećenje nogu bočno* (EN 1728, 6.16)	1000 N	1015 ± 20	Passed / *zadovoljavajući*
Mortise and tenon *rupa i čep*	Seat impact / *udar na sjedalo* (EN 1728, 6.24)	600 N	610 ± 12	Passed / *zadovoljavajući*
Halving *preklop*	Forward stability / *stabilnost prema naprijed* (EN 1022, 6.2)	600 N	610 ± 12	Passed / *zadovoljavajući*
Halving *preklop*	Rearward stability / *stabilnost prema natrag* (EN 1022, 6.6)	600 N	625 ± 15	Passed / *prošao*
Halving *preklop*	Sideways stability / *bočna stabilnost* (EN 1022, 6.4)	600 N	555 ± 10	Failed / *nije zadovoljavajući*
Halving *preklop*	Seat & back static load / *statičko opterećenje sjedala i naslona za leđa* (EN 1728, 6.4)	1600 N, 410 N	1605 ± 28	Passed / *zadovoljavajući*
Halving *preklop*	Seat front edge static load / *statičko opterećenje prednjeg ruba sjedala* (EN 1728, 6.5)	1300 N	1310 ± 18	Passed / *zadovoljavajući*
Halving *preklop*	Combined seat & back durability / *kombinirana trajnost sjedala i naslona za leđa* (EN 1728, 6.17)	1000 N, 330 N, 25,000 cycles	1005 ± 25	Passed / *zadovoljavajući*
Halving *preklop*	Leg forward static load / *statičko opterećenje nogu prema naprijed* (EN 1728, 6.15)	1000 N	1008 ± 20	Passed / *zadovoljavajući*
Halving *preklop*	Leg sideways static load / *statičko opterećenje nogu bočno* (EN 1728, 6.16)	1000 N	1002 ± 22	Passed / *zadovoljavajući*
Halving *preklop*	Seat impact / *udar na sjedalo* (EN 1728, 6.24)	600 N	605 ± 15	Passed / *zadovoljavajući*
Dowel *moždanici*	Forward stability / *stabilnost prema naprijed* (EN 1022, 6.2)	600 N	600 ± 10	Passed / *zadovoljavajući*
Dowel *moždanici*	Rearward stability / *stabilnost prema natrag* (EN 1022, 6.6)	600 N	615 ± 15	Passed / *zadovoljavajući*
Dowel *moždanici*	Sideways stability / *bočna stabilnost* (EN 1022, 6.4)	600 N	540 ± 12	Failed / *nije zadovoljavajući*
Dowel *moždanici*	Seat & back static load / *statičko opterećenje sjedala i naslona za leđa* (EN 1728, 6.4)	1600 N, 410 N	1595 ± 30	Passed / *zadovoljavajući*
Dowel *moždanici*	Seat front edge static load / *statičko opterećenje prednjeg ruba sjedala* (EN 1728, 6.5)	1300 N	1305 ± 18	Passed / *zadovoljavajući*
Dowel *moždanici*	Combined seat & back durability / *kombinirana trajnost sjedala i naslona za leđa* (EN 1728, 6.17)	1000 N, 330 N, 25,000 cycles	1000 ± 20	Passed / *zadovoljavajući*
Dowel *moždanici*	Leg forward static load / *statičko opterećenje nogu prema naprijed* (EN 1728, 6.15)	1000 N	1005 ± 18	Passed / *zadovoljavajući*
Dowel *moždanici*	Leg sideways static load / *statičko opterećenje nogu bočno* (EN 1728, 6.16)	1000 N	998 ± 20	Passed / *zadovoljavajući*
Dowel *moždanici*	Seat impact / *udar na sjedalo* (EN 1728, 6.24)	600 N	600 ± 12	Passed / *zadovoljavajući*

3 RESULTS AND DISCUSSION
3. REZULTATI I RASPRAVA

3.1 Furniture test results: mortise and tenon joint, halving join, and dowel joint
3.1. Rezultati ispitivanja namještaja: spoj rupe i čepa, spoj na preklop i spoj s moždanikom

Ultimate loads were recorded for all chair joint configurations. Mortise and tenon joints consistently exhibited the highest mean ultimate loads across all tests, followed by halving and dowel joints. In cases where failure did not occur, tests were terminated once the performance criteria specified in EN 1022 and EN 1728 criteria were satisfied. One-way analysis of variance (ANOVA) indicated significant differences between the joint types ($p < 0.05$), confirming that mortise and tenon joints exhibit significantly greater load-bearing capacity compared to halving and dowel joints. These findings highlight the mechanical superiority of mortise and tenon joints for structural applications in coco wood chair construction.

3.2 Stability tests and failure mechanisms
3.2. Ispitivanje stabilnosti i mehanizmi loma

3.2.1 Forward stability (EN 1022, 6.2)
3.2.1. Stabilnost prema naprijed (EN 1022, 6.2)

All three chair types demonstrated adequate resistance to forward tipping and maintained structural integrity under repeated loading conditions. No glue-line separation or wood failure was observed, confirming the effectiveness of the coco wood joints in ensuring functional stability (Ceylan *et al.,* 2021).

3.2.2 Rearward stability (EN 1022, 6.6)
3.2.2. Stabilnost prema natrag (EN 1022, 6.6)

The chairs successfully resisted rearward forces of 600 N without any indication of structural weakness. Neither glue-line separation nor wood failure was observed. These results support Dunbar's (2023) findings that rearward stability is a critical determinant of user safety and further validate the structural capacity of coco wood chairs under such loading conditions.

3.2.3 Sideways stability (EN 1022, 6.4)
3.2.3. Bočna stabilnost (EN 1022, 6.4)

All chair configurations failed under lateral loading, indicating a limitation in sideways stability. Mortise and tenon and halving joints mainly failed due to wood splitting near the joint, while dowel joints showed occasional glue-line failure. This suggests that dowel joints are more susceptible to adhesive-related stresses under lateral loading conditions. The findings are consistent with Vlaović (2024), who recommends that future designs incorporate cross-bracing elements or increased joint dimensions to enhance lateral performance.

Figure 4 Typical failure modes observed during testing
Slika 4. Tipični načini loma uočeni tijekom ispitivanja

3.2.4 Seat and back static load (EN 1728, 6.4)
3.2.4. Statičko opterećenje sjedala i naslona za leđa (EN 1728, 6.4)

All chairs withstood static loads of 1600 N on the seat and 410 N applied to the back without any visible damage. No glue-line separation or wood failure was observed, indicating high resistance to static loading. These results are consistent with Kasal *et al.* (2016), who emphasised the importance of joint selection in the effective distribution of static loads.

3.2.5 Seat front edge static load (EN 1728, 6.5)
3.2.5. Statičko opterećenje prednjeg ruba sjedala (EN 1728, 6.5)

Under a 1300 N static load applied at the front edge of the seat, all chairs successfully passed the test. Minor wood compression was observed near the joints in halving and dowel joint chairs, whereas mortise and tenon joints remained fully intact, confirming their superior load-bearing performance. These findings further support Kasal *et al*., (2016) assertion that front-edge structural integrity is essential for long-term furniture functionality.

3.2.6 Combined seat and back durability (EN 1728, 6.17)
3.2.6. Ispitivanje trajnosti sjedala i naslona za leđa (EN 1728, 6.17)

All chair configurations remained structurally sound after 25,000 loading cycles of 1000 N on the seat and 330 N on the backrest. No glue-line failure was recorded, demonstrating high durability under cyclic loading conditions. These results align with Smardzewski (2015), who identified endurance under repeated use as a key criterion of furniture quality.

3.2.7 Leg static load (EN 1728, 6.15 & 6.16)
3.2.7. Statičko opterećenje nogu prema naprijed i bočno (EN 1728, 6.15 i 6.16)

Both forward and sideways leg loading tests confirmed that the coco wood joints effectively distributed applied forces. These results corroborate the findings of Uysal *et al*. (2015), who reported that joints such as mortise and tenon and dowel joints provide excellent resistance to cyclic stresses.

3.2.8 Seat impact (EN 1728, 6.24)
3.2.8. Udarno ispitivanje sjedala (EN 1728, 6.24)

All chairs withstood repeated impact loading without structural failure. Minor surface cracking was observed only in dowel joints, indicating slightly reduced resistance to sudden loading compared with mortise and tenon and halving joints. These findings support Antal *et al*. (2015) the functions has always significant priority. The ever changing design philosophies require accommodations to the new viewpoints. These adaptations, along with technical and technological advances, eventually will lead to the decrease of products or production expenses. The objective may be realised by the application of cost – analysis of design and development methodology, prior to production. Thus, the unnecessary expenses could be eliminated. The essence of usage of functional analysis method in design is an abstract approach where the functions of the products are used to model the realisation of demands. The relationships between functions and function-expenses are defined and designed at every step of the development (design, who emphasised that furniture design must balance aesthetic quality and functional strength.

3.2.9 Novelty of the study
3.2.9. Izvornost istraživanja

The novelty of this study lies in its integrated evaluation of coco wood (*Cocos nucifera*) as a sustainable alternative to conventional hardwoods for furniture production in Ghana. Unlike previous studies that primarily focused on material properties, this research combines structural performance testing of traditional joints with an assessment of aesthetic suitability, using European testing standards.

The findings provide new insights into joint behaviour, durability, and design limitations – particularly lateral stability – thereby supporting evidence-based furniture design using locally available materials.

4 CONCLUSIONS
4. ZAKLJUČAK

The results indicate that coco wood chairs constructed with mortise and tenon, halving, and dowel joints exhibit satisfactory structural performance and acceptable aesthetic quality for light to medium-duty furniture applications. With the exception of sideways stability, all joint types met the relevant European performance standards. Mortise and tenon joints consistently demonstrated the highest strength and reliability, making them most suitable for load-bearing furniture applications.

Although halving and dowel joints performed adequately under most loading conditions, their reduced resistance to lateral forces highlights the need for design modifications, such as the incorporation of cross-bracing or increased joint dimensions.

Overall, coco wood has been shown to be a practical and sustainable material for furniture production with high potential for diversifying Ghana's timber resources. Future research should focus on enhancing lateral stability, increasing the sample size, and evaluating the economic feasibility of large-scale coco wood furniture manufacturing.

Acknowledgements – Zahvala

We are thankful to Mr. Anthony Awuah, Mr. George Abaidoo, and all the students of the Furniture Department of Asuansi Technical Institute for their unwavering support during the chair construction phase.

Also, to Felix Boakye of the Wood Mechanic and Furniture Testing Centre of the Forest Research Institute of Ghana (FORIG), Kumasi, for his invaluable assistance in the preparation and testing of the Coco wood chairs.

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