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Design of an ergonomic lounge chair using water hyacinth material after going through a tensile test

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ABSTRACT

In Indonesia, Water Hyacinth (Eichornia crassipes) is a wild plant species that grows in rivers or lakes. This species multiplies, which can cause a significant problem for water transportation. Due to increasing concerns around climate change and environmental sustainability, the construction industry is looking for alternative materials and methods to reduce environmental impact. The "Adjustable Chair" u ses an ergonomic approach to achieve an attractive and comfortable product. This research seeks to positively impact fishermen's job security and the biodiversity in the water bodies' ecosystem and to develop an ergonomic product that uses both traditional and modern minimalist styles in designing the product. Therefore, a product that is both comfortable and attractive can be created. This research aims to utilise wild WH waste on water bodies' surface that threatens water transportation and its ecosystem for designing the adjustable chair through the market research study and ergonomically design with product development selection concept and tensile test. Based on the tensile test that has been carried out, it can be seen from the graph that the tensile test of 3 twisted WH stems has a tensile strength that is much stronger than the tensile test using one WH stem, two WH stems, and three WH stems. The tensile test of 3 twisted WH stems had more muscular strength with a tensile test time of 9 min 38 s with an increase in length of 2.5 mm. So, making an adjustable chair will use twisted WH stems. It can form an adjustable chair, which, if woven with large amounts of WH, the resulting product will be more durable, and the material will be more robust.

1. Introduction

In Indonesia, the Water Hyacinth(WH) (Eichhornia crassipes) is a wild plant species that grows in rivers and lakes. This species multiplies, which can cause a significant problem for water transportation. Fishermen are among the most affected communities, as the plant will block their roads [1]. Dead WHs will accumulate on the surface of the water bodies, causing them to become shallower and disrupting the ecosystem there [2,3].

Wh(Eichhornia crassipes) is often recognised as one of the most harmful aquatic weeds in the world. WH is known for its rapid growth rate, and it was announced that two plants could augment to 1200 Herbs

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in 120 days, allowing the herbs to enclose huge water surfaces rapidly [4]. WH is notorious for causing severe environmental degradation and posing an economic challenge to control. Invasive in nature, WH has been a severe issue that requires attention due to its destructive impact and associated financial difficulties [5]. WH primarily reproduce through runners or stolon, eventually forming daughter plants. Each plant can produce thousands of seeds each year, and these seeds can remain viable for >28 years [6]

WH is considered an invasive weed variety and has caused significant negative economic and ecological impacts. It deleteriously impacts biodiversity, freshwater ecosystems, and native species [7]. The WH forms dense mats that obstruct sunlight from entering the water, reducing its warmth and blocking plant photosynthesis [8]. The rapid distribution of WH causes sedimentation and shallowing phenomena in water bodies [9]. If its growth is not adequately controlled, WH can cause severe environmental problems.

Water pollution is a massive problem for developing countries. As society grows, household and industrial waste increases exponentially [10]. The amount of waste is increasing, but centralised processing systems and the habit of disposing of non-concentrated waste are insufficient to deal with it, resulting in severe water pollution [11]. In particular, heavy metal pollution involving cadmium (Cd), arsenic (As), lead (Pb), zinc (Zn), and copper (Cu) is a severe problem because the dangerous toxicity of these elements affects human health, organisms, and the environment [12].

Globally, WH is recognised as an invasive species that poses a significant threat to the pillars of sustainability. The cost of controlling this invasive plant is considered high, and many countries in South Africa cannot afford this responsibility due to the lengthy process required. Despite these challenges, the recovery of valuable resources from WH can generate both financial and environmental benefits [13].

Because it is uncontrolled, this WH plant covers lakes and ponds. If these plants grow larger, they will quickly impact water flow. These plants alter the water's pH level and salinity simultaneously, creating an imbalance and affecting the physical and chemical properties of the entire water body system [14].

Due to growing concerns about climate change and environmental sustainability, the construction industry is seeking alternative materials and methods to minimise its environmental impact [15]. For this reason, wild WH waste can be used in the handicraft industry as it has unique, attractive, and environmentally friendly fibre. WH fibre is a material gaining market traction and an alternative for the furniture industry [16–18].

Using waste from the waste industry as a material for the furniture industry is expected to create an aesthetic value that will provide comfort in the room [19]. Wild WH waste is also expected to become a business opportunity for the handicraft industry, allowing for the creation of woven furniture with high commercial value [20].

Wild WH waste handicrafts have improved the environment. They have also created new jobs for people in CV Tashinda, Kasihan District, Bantul Regency, Yogyakarta, Indonesia, a company that processes wild WH waste as one of the materials used in its handicraft products.

The "Adjustable Chair" aims to reduce water pollution while creating a product that combines traditional and modern minimalist styles. The woven WH resembles the classic Indonesian furniture style, evident in the seats, backrest, armrest, and legrest. The carbon steel resembles the modern minimalist design of the backrest and legs. It is designed to have a backrest frame and legs that tilt 60 degrees to ensure comfort. By utilising wild WH waste, this product has helped protect environmental sustainability and the water ecosystem in some parts of Indonesia [21, 22]). The "Adjustable Chair" employs an ergonomic design approach to create an attractive and comfortable product. The ergonomic approach employed is anthropometry, which is the study of human body measurements [23]. This research aims to enhance the job security of fishermen and promote biodiversity in the water body ecosystem while developing an ergonomic product that incorporates both traditional and modern minimalist design styles. Therefore, a product that is both comfortable and attractive can be created. This research aims to utilise wild WH waste on water bodies' surfaces that threaten water transportation and its ecosystem to design an adjustable chair through a market research study and ergonomic design, incorporating product development selection concepts and tensile tests. The objective of this research is to design and develop the best model for the Lounge Chair that satisfies the market research's criteria with the ergonomics measurement standard, and through the tensile strength testing requirement of the WH material.

2. Material and data analyis technique

2.1. Water hyacinth (WH)

Dried WH stem is the primary material used in making the "Adjustable Chair," as it has a high tensile strength, indicating that it can support the mass of the human body [24,25]. A large quantity of WH is gathered from a nearby lake to obtain dried WH stem. Then, the WH stem will be dried in an oven at 100 °C Dried. The WH stem used as material is shown in Fig. 1.

2.2. WH process

Physical methods consist of two control types: manual and mechanical removal. Humans manually remove WH plants from water bodies [4], whereas machines perform mechanical removal methods. Therefore, WH was manually separated from leaves and roots, dried in the open air, spread on a large surface, and at room temperature for one week. Next, WH is placed in an electric oven at 100 °C until it is scorched. Dried WH was chopped by hand and crushed with a glass blender. Finally, sieving allows for the separation of different particle size ranges [15].

2.3. WH environment

WH is a floating aquatic plant that multiplies in the Amazon Bay of South America [26]. This plant is known for its tendency to reproduce, doubling its population in 11–18 days [27]. Its tendency to thrive in highly contaminated waters is also well known. WH has been intensively explored as an aquatic plant capable of improving the quality of oxidation pond effluent and is a critical factor for single, integrated, and advanced treatment systems for urban, agricultural, and industrial waste streams [11].

High temperatures, eutrophic conditions, and other environmental factors encourage plant proliferation in their introduced areas [28]. Warm, nutrient-rich water is ideal for WH growth. The growth consistency of this plant depends on the temperature range of 18–35 degrees Celsius. At the highest degree, this WH plant does not grow [14].

Fig. 1. Dried WH Stem used as the Main Material of the "Adjustable Chair".

2.4. WH characteristics

El-Wakil et al. found that increasing the WHS content in WHS and styrene-butadiene rubber (SBR) composite materials improved sound absorption at low frequencies [29]. Another study reported combining 50 % WH fibre with abaca and bamboo plants in a composite improved its acoustic performance [15].

Rohman et al. [30] analysed carpets made from woven WH fibres and found that they effectively reduced sound at specific frequencies, thus indicating that WH is a suitable sound-absorbing material. Although Sharma et al. [31,32] have studied mechanical, hygroscopic, and thermal properties, there is still a lack of research that systematically explores the modification of various properties such as particle size, biomass ratio, applied load, and the type of binder used for the same material.

WH is a free-floating aquatic plant primarily found in tropical and subtropical regions, such as the Amazon River, Africa, and Indonesia. This plant grows to a height of 5 or 8 cm in water bodies. The seeds of this plant can survive for up to 28 years on the surface of the water and exhibit high growth rates compared to other plants and natural fibres [14]. These plants deplete the amount of oxygen and nutrients in water bodies. This condition is why various plants and animals die because of this WH. This plant achieves hydrophilic properties. So, they absorb water content up to 70 per cent. This plant is considered very problematic. The stalk is long. Separate parts of WH, such as stems, petioles, and roots, are used to produce various applications and ornamental items [14].

Fresh plants of WH contain 95.5 % moisture, 0.04 % nitrogen, 1.0 % ash, 0.06 % P2O5, 0.20 % K2O and 3.5 % organic matter. It has 75.8 % organic matter, 1.5 % nitrogen, and 24.2 % ash on a zero-moisture basis. The ash contains 28.7 % K2O, 1.8 % Na2O, 12.8 % CaO, 21.0 % Cl, and 7.0 % P2O5. The crude protein (crude protein¼amount of nitrogen 6.25) using the Kjeldahl method contains, per 100 g, 0.72 g methionine,4.72 g phenylalanine, 4.32 g threonine, 5.34 g lysine, 4.32 g isoleucine, 0.27 g valine, and 7.2 g leucine [33].

2.5. WH benefit

These materials are renewable, sustainable, and possess good insulating properties; their disposal poses a threat that can hinder social development in rural areas. Research and development in this area are ongoing, with a focus on enhancing the performance and durability of these materials, as well as developing new materials from biowaste products [15]

Apart from wastewater treatment, WH can be utilised in the production of valuable products, including biogas, bioethanol, biohydrogen, and biofertilizers. Ecological technology's ability to recover and reuse resources is an environmentally friendly feature. In aquatic ecosystems, for example, nutrients from wastewater components containing phosphorus and nitrogen are recycled into usable biomass through ecological food chains [11].

Ilo et al. [13] stated that 29 articles out of 48 retrieved were on the use of WH. The majority (28 %) of the recovery methods are on bioenergy (biogas, bioethanol, and briquette), 21 % of these articles used it for phytoremediation, 10 % for biofertilizer, 7 % for high-value chemicals (Furfurals), 7 % for animal feed, 4 % for insulation board in building, 10 % for enzyme production, 10 % for biopolymers, and 3 % used a combined method (used it for phytoremediation and subsequently bioethanol.

2.6. Advanced WH treat system

Developing invasive WH plants causes ecological, economic, public health and agricultural problems. Various efforts have been made to control its spread, but no actual results have been obtained. Considered one of the world's worst invasive weeds, WH is almost impossible to control and eradicate without an integrated approach and community participation. The effectiveness of control methods varies, but continued community involvement determines the long-term success of these methods. Proliferating rapidly, WHs have the resource capacity to support a unique microeconomic ecosystem, providing incentives to control WHs by generating sustainable revenues [34].

Traditional methods, including physical and chemical processes, are being applied to treat heavy metals. However, most of these methods have complex processes, are economically expensive, and require high technical expertise [35]. A study on removing arsenic contamination in soil through phytoremediation has been published [36]. In addition, wastewater treatment using aquatic plants has been implemented in many parts of the world, offering the advantages of low cost, ease of operation, and high pollutant treatment rates [37]. This wastewater treatment technology is utilised in natural and environmentally friendly conditions, thereby increasing biodiversity and enhancing the landscape, environment, and local ecosystem [38].

2.7. Wood

Solid wood is one of the primary materials used in furniture making in Indonesia. Furniture is a term commonly used to describe household items that serve as a place to store goods, such as beds and chairs. The types of solid wood that can be used for furniture include teak, mahogany, jackfruit, rosewood, pine, and ebony, among others. These trees are found in various regions of Indonesia and are not difficult to obtain; therefore, many furniture companies and artisans are seeking them. Solid wood, apart from being used for furniture, can also be used in building construction. However, many people now use solid wood to create furniture and wood crafts. In addition to knowing the types of wood used in making furniture, people must also understand the construction of the furniture being made. Construction is a connection between two components that are structurally arranged. From the various furniture designs, the construction used is also distinct from that of other furniture designs [39]

The advantages of wood as a furniture material include strength, durability, natural beauty, design flexibility, and environmental friendliness. Wood offers good strength and durability, so wooden furniture can be durable and long-lasting, even with minimal maintenance. In addition, wood provides a natural and elegant feel to the interior of the room. Wood is also easy to shape and carve, allowing for the creation of various furniture designs and styles. Finally, wood is a renewable and environmentally friendly natural resource [40]

2.8. Metal

Iron material is used to strengthen the structure and provide a touch of modern aesthetics. The results of the study show that the resulting chair has good strength and stability because it utilises legs made of iron material. Stainless steel (SS) is increasingly used in structural applications within the construction industry, as its beneficial properties outweigh the initial material costs when sustainability aspects and the entire life cycle of structures are appropriately accounted for in the structural design. Despite the well-recognised significance of connections in bare metallic construction, experimental research on SS beam-to-column connections, especially full-scale test results, is scarce. The importance of incorporating strain hardening, as offered by austenitic grades, lies in capturing the semi-rigid response of such connections [41].

Stainless steel has several advantages over regular iron, particularly in terms of corrosion resistance, cleanliness, and aesthetic appeal. Stainless steel contains chromium, which forms a protective oxide layer on its surface, preventing rust [42]. The advantages of Stainless steel include:

1. Corrosion resistance: Stainless steel contains chromium, which forms a protective oxide layer on its surface, making it more resistant to rust and corrosion, especially in wet or acidic environments.
2. Cleanliness: Stainless steel's smooth, non-porous surface makes it easy to clean, making it suitable for kitchen and medical equipment;
3. Aesthetics: Stainless steel has a modern and elegant appearance, making it a popular choice for decoration and architecture;
4. High durability: Stainless steel is extreemly strong and durable, making it suitable for applications that require high mechanical resistance;
5. Environmentally friendly: Stainless steel is recyclable, helping to reduce waste and minimize environmental damage;
6. Hygienic: Stainless steel does not absorb bacteria or dirt, making it a hygienic choice for a variety of applications;
7. Resistant to extreme temperatures: Stainless steel can withstand high and low temperatures, making it suitable for a wide range of applications;
8. Easy to clean: Stainless steel is easy to clean with soap and water, so it requires no special maintenance or treatment;
9. Strength and stability: Stainless steel is extremely strong and stable, making it ideal for applications that require high strength and stability;
10. Cost and long-term investment: Although more expensive, stainless steel has a longer service life and can be recycled, making it a better long-term investment.

2.9. Foam

Providing a seat or foam cushion on top of it will reduce the level of comfort for the user if used for an extended period of relaxation. The comfort of the chair can be closely related to the seat cushion or seat support used on the chair. A good and proper seat cushion can significantly enhance the comfort of the congregation when they sit. Some things to consider regarding the seat cushion include the thickness of the other cushions. A thick enough seat cushion can provide better support for the body parts that support body weight when sitting. This material helps reduce soreness or discomfort that can occur when people sit for extended periods of time. Cushion material. The choice of materials for seat cushions varies, including foam, sponge, or specialised materials designed to provide maximum comfort. The materials used must be durable and resistant to flattening or damage in long-term use [43].

2.10. Product development

Product development is the process of creating a new product or improving an existing product. The objective of product development is to fulfil the needs of customers. This objective can be achieved by developing a product that is functional and of high quality. On the other hand, this process must also consider the aesthetic of the final product ([44,45]; X [46]). Developing a product involves five phases [47]). These steps are shown in Fig. 2.

Phase 0 in product development is Planning. Planning is the process of generating ideas for a new product or identifying improvements that can be made to an existing product. This process involves identifying existing opportunities to help generate ideas. These opportunities are then evaluated to prioritise the most feasible. The next step is to allocate resources to start the product development process. This process is initiated by creating a project plan for product development [48–52].

Phase 1. is concept development. This phase involves identifying customers' needs, specifying products, creating concepts, selecting concepts, and testing concepts [53].

Phase 2. is system-level design. This phase involves determining the components, subsystems, and their functions. These include the shape, arrangement, and connections of components and subsystems [54].

Phase 3. is the detailed design. Based on the concept developed and chosen in phase 2, all the details of the selected concept are being considered. This detail includes the material specification, shape, and dimensional tolerance of each component [55,56]).

Phase 4. is testing and refinement. Testing and refinement are conducted to ensure that the product meets the specifications that have been developed. This phase will also ensure that the product meets the standard applicable in a particular region [57–59].

Phase 5. is the product launch. This phase is also referred to as the start of the production phase. A production system is implemented in this phase to produce the developed product commercially. During this phase, workers are also trained to get used to the workflow of the production system [60–62].

2.11. Market research

Market research is conducted to understand customers' needs [63,64]. The market research employs a questionnaire method, focusing on customers' needs, including sturdiness of materials, durability, ease of use, safety, comfort, and aesthetics. The questionnaire was created using Google Forms and shared on social media to reach a broad audience, which is the product's target market.

Market research is a technique used to gather information about customers' needs and the market. Market research aims to understand customers' needs, identify market potential, and identify opportunities [65,66]. Market research is also a method for evaluating the feasibility of a new or improved product or service. Therefore, market research can help a company make more informed business decisions [67]. A few market research methods include questionnaires, focus group discussions, interviews, observations, and field research.

There are four steps to market research: identifying and evaluating opportunities, analysing market segments and selecting target markets, planning and implementing a marketing mix that will satisfy customers' needs and meet the organisation's objectives, and exploring the marketing performance [68].

The first step is to identify and evaluate opportunities. This step can be done by observing socio-economic activity, such as purchasing behaviour. This step aims to understand the product to be developed, ensuring it will fulfil the customers' needs [69,70].

The second step is to analyse market segments and select target markets. In this step, the target markets are studied using questionnaires, interviews, or other methods to get valuable information for product development [71–73].

The third step is to plan and implement a marketing mix that satisfies customers' needs and meets the organisation's objectives. The purpose of this step is to ensure that the product that is being developed is the right product and will be available at the right time with the suitable

Fig. 2. Six Phases of Product Development.

promotion method and right price so that it can satisfy the customers' needs [74–76].

The last step is to analyse the marketing performance. This step monitors marketing performance to provide feedback on marketing activities. This step aims to determine whether marketing activities are executed as planned and whether the set goals are accomplished ([77]; J [78,79]).

2.12. Data collection

Data collected from market research is then analysed using several methods to ensure the accuracy of the data and to interpret the data that has been collected [80–82]. Firstly, the validity of the test is determined by the method used. Validity testing is conducted using Minitab software and the Bivariate Pearson Correlation test. The interpretation of the R-calculated score in Minitab software depends on the R table score. R table score depends on the number of respondents and the level of significance used [83–85]. The R table score is shown in Table 1. If the data is valid, it will be tested for reliability. The reliability of the data is tested using Minitab software and Cronbach's alpha. The data is reliable if Cronbach's Alpha value exceeds 0.60 [86–89].

After the data is proven to be valid and reliable, it can be interpreted. The data is weighted using the Likert Scale to understand the importance of each variable aspect [90]. Then, the data is assessed using the Pairwise Comparison method to compare each data point with the others. The purpose is to calculate which variable is more important. Lastly, the consistency ratio is calculated to know whether the data obtained is consistent. The data is considered consistent if the consistency ratio is less than or equal to the random consistency index. The value of the random consistency index is determined based on the matrix size (i.e., the number of variable aspects) [91,92]. The value of the random consistency index is shown in Table 2.

2.13. Validity test

A validity test is conducted to ensure the validity of the measuring instrument used to collect data. An instrument is considered to have a high validity if it has a small error rate; therefore, the data collected is adequate. The validity test shows the extent to which the measuring instruments are required to calculate [94,83,95]. This research employs the Pearson Bivariate Correlation method to conduct a validity test using Minitab software. Bivariate Pearson Correlation is an analysis used to determine the linear relationship between two variables [96,97]). The data used is on an interval or ratio scale. The correlation value (R) is 0 to 1. The closer to 1, the more robust the relationship is [98,99]. Invalidity testing compares calculated R values, table R values, and significant values with a probability of 0.05. If the computed R-value> *R* table value, the question item or arrangement in the questionnaire significantly correlated with the total score (item declared valid). If the calculated R-value is less than the R table value, then the question item or statement in the questionnaire is not significantly correlated with the total score (the item is declared invalid). The following are the R table values, as seen in Table 1.

Table 1
R Table Value (Indra Nara [72]).

N	Level of Significance	
	5%	1%
100	0.195	0.256
125	0.176	0.230
150	0.159	0.210
175	0.148	0.194
200	0.138	0.181
300	0.113	0.148
400	0.098	0.128
500	0.088	0.115
600	0.080	0.105
700	0.074	0.097
800	0.070	0.091
900	0.065	0.086
1000	0.062	0.081

Table 2
Random Consistency Index [93].

Matrix Size	Random Consistency Index
1	**0**
2	0
3	0.58
4	0.90
5	**1.12**
6	1.24
7	1.32
8	1.41
9	1.45
10	1.49
11	1.51
12	1.48
13	1.56
14	1.57
15	1.59

2.14. Reliability test

A reliability test is a test to calculate the consistency of a measuring instrument. A measuring instrument is considered reliable if it can accurately measure an object multiple times, even at different times. If the data is trustworthy, it can represent real-life conditions [100–102]. In this research, the measuring instrument used is a questionnaire. In this research, a reliability test was conducted using Minitab software and Cronbach's Alpha. Cronbach Alpha is a benchmark that describes the correlation or relationship between the scale created and all existing variable scales. Data are considered reliable if the Cronbach's Alpha result exceeds.60 [103].

2.15. Likert scale

The Likert scale is a tool used to measure the extent to which respondents agree with a given statement. The Likert scale is often used to measure one's attitude, perception, and opinion about a social event. With this scale, variables are translated into variable aspects. Then, these indicators are used as a starting point for compiling instrument items in the form of questions or statements. A well-designed Likert scale generally exhibits high reliability, producing accurate data [104–107].

In the questionnaire, respondents must score each statement or question. Generally, five numbers are used in this scale, which are 1 (strongly disagree), 2 (disagree), 3 (neutral), 4 (agree), and 5 (strongly agree) [108,109]. The Likert scale is calculated using Eq. (1).

$$T \times P_n \tag{1}$$

The total number of respondents who choose a particular number in the scale is represented as T in the equation. The number that those respondents have chosen is described as Tn.

2.16. Pairwise comparison method

The pairwise comparison method compares each variable aspect to all the variable elements, one by one, to evaluate the more critical value. The pairwise comparison method is employed in various contexts, including research on preferences, attitudes, voting systems, social choice, and public choice. The consistency ratio of the data is calculated from the pairwise comparison of each variable aspect. The purpose of calculating the consistency ratio is to determine whether the data's inconsistency is acceptable for use ([110,111,112]; Aprillita et al.,

2021).

Equations for calculating the consistency ratio are presented in Eqs. (2) and 3.

$$CI = \frac{\lambda - n}{n - 1} \tag{2}$$

$$CR = \frac{CI}{IR} \tag{3}$$

The consistency index, represented by CI, is calculated by subtracting the eigenvalue from the matrix size and then dividing it by the matrix size minus 1. The consistency ratio, defined by CR, is obtained by dividing the consistency index with the random consistency index. The random consistency index is obtained based on the matrix size shown in Table 2.

2.17. Ergonomics

Ergonomics studies human interaction with system elements, which can be a product or a work environment. This study involves psychological and physiological principles when designing a product or work environment. When creating a product, an ergonomic approach is used to ensure that it is comfortable and safe to use. This approach can help reduce or even eliminate the risks of accidents associated with product usage [93,113,114]. The functional dimensions of a chair for 95 % of the adult population (in centimeters) can be seen in Fig. 3.

2.18. Anthropometry

In the product design process, this research utilises anthropometric approaches to ensure the product's dimension is well-suited to its users [116,117]. The anthropometric data of Indonesians at the 95th percentile is used as a reference for the product's dimensions.

Anthropometry is a component of the ergonomics approach, which involves measuring human body size [118,119]. Anthropometry utilises data collected through measurements using various tools, such as anthropometry kits and chairs [120,121]. Anthropometric measurements include height, weight, head circumference, body mass index (BMI), body circumferences (e.g., waist, hipsand limbs), and skinfold thickness [122]. This measurement is presented in percentiles, organised by race and gender. This activity aims to have accurate data representing races and genders [123–125].

In designing a product, anthropometry is used to find the correct dimension that will fit the user of that object. For example, when designing clothes, small sizes may use a 25 % percentile of the anthropometry measurement, and large sizes may use a 75 % percentile. If the clothes are designed for Indonesians, it will use Indonesian anthropometric data as the average Indonesian has a different body build than Europeans [126–128]. The Anthropometric data statistic can be seen in Table 3.

3. Method

3.1. Oven drying

Oven drying is a method used to dry waste. This tool is both practical and efficient as it requires less time than traditional drying methods. The conventional drying method takes approximately 7 to 10 days to dry WH waste on a sunny day. However, this method is also very dependent on the weather conditions. Drying WH waste on cloudy or rainy days can take approximately three weeks. Oven drying the WH waste speeds up the drying process. This method is also more reliable than the traditional method as it is independent of the weather and requires less time to dry the WH waste [129,15].

3.2. Tensile test

The tensile strength of the dried WH stem is tested to understand how well it performs under a certain amount of stress [130–132]. This test uses the Shimadzu UMH-30 Universal Testing Machine. The test connects the dried WH stem end to the machine. Then, the machine exerts stress by pulling the dried WH stem. The test is conducted on a dried WH stem, two dried WH stems, three dried WH stems, and three dried WH stems woven together. The increase in length of the WH stem is measured. Then, the tensile testing graph is created to illustrate the performance of dried WH under stress.

The tensile test is a method to measure the tensile strength of a material. The tensile test is conducted using a Universal Testing Machine. The test works by connecting the material to two axes, and the material will be pulled by one of the axes. The result of this test is used to determine the temporal resilience towards a static pulling force [133, 134].

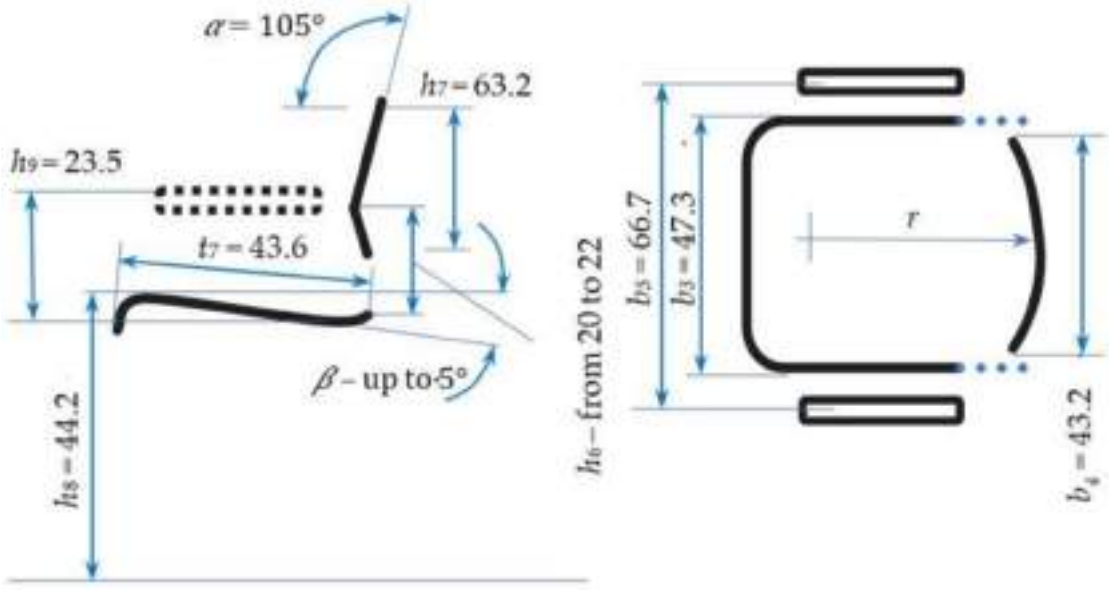

Fig. 3. The functional dimensions of a standard chair for 95 % of the adult population (in centimeters). (Sydor & Hitka, [115].

Table 3
Anthropometric data statistics of respondents aged 18–25 in year 1993–2022 [63].

Dimensions	Z	Arithmetic Mean	Median	Standard Deviation	1st Percentile	5th Percentile	50th Percentile	95th Percentile	99th Percentile
Body weight	14,664	73,2	72	15,67	46	51	72	100	115
Stature height	14,664	171,9	171	18,35	152	157	171	188	195
Buttock–knee length	3,869	57,2	58	6,98	39	46	58	66	70
Knee height—sitting with shoes	1,736	44,7	45	9,26	30	36	45	54	59
Hip width	1,303	39,9	39	8,21	23	31	39	50	63
Hip circumference	1,055	98,1	97	12,03	67	81	97	118	130
BMI	14,664	24,9	24	20,63	17	18	24	33	38

Note: Dimensions are in cm.

3.3. 3D modelling

The 3D model is created to visualise product concepts more effectively ([135,136]; Z [137]). The purpose of a 3D model is to understand how the product will function in real-life applications [138,139]. The 3D model is created using Autodesk Fusion 360 software in this research. This software was chosen because it is easy to use and offers numerous features, such as converting 3D models to 2D drawings and simulating the product to understand its performance in real-life scenarios [140, 141].

3.4. Prototype

Creating a prototype is undertaken to deepen the understanding of the product's functionality [142,143]. This prototype serves as a tool for collecting user feedback, facilitating ongoing product improvement, and addressing any imperfections identified in the prototype (B [144]). The prototype for this research was crafted by a local handicraft manufacturer, CV Tashinda, in Yogyakarta. It uses dried WH stem and carbon steel on a 1:1 scale.

4. Research methodology

Research begins with initial observation to identify problems that will be addressed during the research [145]. Following the formulation of the problem and its background, the study proceeds with a literature review and field observations. The research continues with data collection, and if the data are sufficient, they will be processed and analysed. The results of data processing serve as the basis for creating prototypes and the final design [50] . The final design will then be reviewed and revised. The research will be completed after the conclusion is drawn. The research methodology is illustrated in Fig. 4.

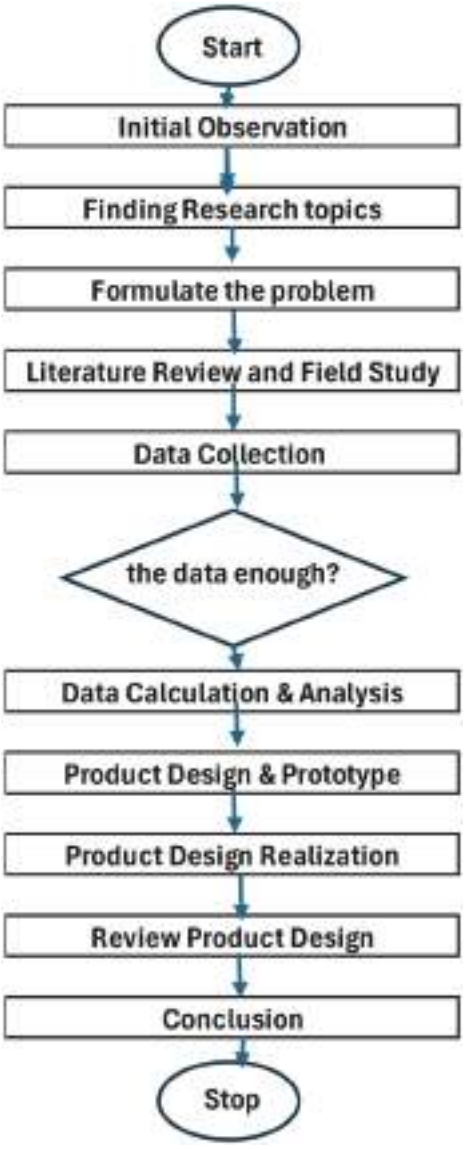

Fig. 4. Research Methodology.

5. Result

5.1. Data collection

Data is an essential component in research. Data serves as a source and research material, and can be either primary or secondary [146]. This research collected primary data using an online questionnaire created with Google Forms. Primary data is data sources that directly provide data to data collectors. The researcher now collects data directly from the first source or place where the research object is carried out [147]. A questionnaire can be defined as a data collection technique that provides respondents with a set of questions or written statements to answer. The questionnaire is divided into two types of questions: open-ended questions and closed-ended questions. The primary data collected are presented in Table 4.

A collection of respondents' data was obtained based on the results of primary data collected by distributing questionnaires to 108 respondents. The results of the questionnaire regarding respondent demographic data are presented in Table 4.

Table 4
Primary data.

Type of Data	Number of Primary Data
Tools used to collect data	108 Questionnaires, which include respondent data and customer needs for the adjustable chair
Number of Respondents	108 Random Samples (64 Men and 44 Women)

Based on the graph for the gender aspect, it can be concluded that 40.7 % of respondents were women and 59.3 % were men. Based on the graph for the age aspect, it can be supposed that most respondents were aged 17–27 years with a total of 75 %, followed by respondents aged 39–49 years with 13 %, followed by respondents aged 28–38 years with 11.1 % and finally among respondents aged >49 years it was 0.9 %. Based on the graph for the residential aspect, it can be concluded that 27.4 % of respondents originated from outside Jakarta, while 72.6 % of respondents were from Jakarta.

After collecting the demographic information from the respondents, the questionnaire proceeds to gather their needs. The customer's needs are divided into critical questions created to identify aspects of product requirements using a Likert scale rating system. The complete data from 108 respondents is presented in Table 5.

Based on the graph for the needs of the respondents, it can be concluded from the data that the material sturdiness aspect is essential, which can be seen from the highest respondent was at very important 5 with a percentage of 36.1 %, and the lowest respondent was at 1 with a percentage of 0 %. It can be concluded from the data that the durability aspect is essential, as evidenced by the highest respondent, who rated it as very important, with a percentage of 34.3 %. The lowest respondent was at 1, with a percentage of 0 %. From the data, the ease-of-use aspect is essential, as evident from the highest respondent, who rated it 5 with a percentage of 38.9 %, and the lowest respondent, who rated it 1 with a percentage of 0 %. The safety and comfort aspect is essential, as indicated by the highest respondent, who scored 5 with a percentage of 47.2 %, and the lowest respondent, who scored 1 with a percentage of 0 %. Lastly, aesthetics is essential, as seen by the highest respondents, who ranked it as very important, with a percentage of 33.6 %, and the lowest respondents, who ranked it as unimportant, with a percentage of 0 %.

After obtaining respondents' data regarding their views and responses to the problems and research that will be undertaken, the following are the results of the respondents' questionnaire regarding the importance of the aspects that will be implemented in the product being designed. A total of 108 respondents were asked to rate this aspect on a scale of one to five, where one represents that, according to consumers, this aspect is very unimportant, and five means that, according to consumers, this aspect is essential to consider for this product. The identification of respondents' needs is presented in Table 6.

Data is an essential component in research. Data serves as a source and research material; it can be either primary or secondary data [146]. This research collected primary data using an online questionnaire created with Google Forms. Primary data is data sources that directly provide data to data collectors. The researcher collects data from the first source or place where the research object is carried out [147]. A questionnaire can be defined as a data collection technique that gives respondents a set of questions or written statements to answer. The questionnaire is divided into two types of questions: open-ended questions and closed-ended questions. The primary data collected are presented in Table 5–7.

5.2. *Validity test*

From the questionnaire, Table 5 describes the respondent needs for

Table 5
Respondent demographic information.

Variable aspect	Results of Questionnaire
Respondent's gender	Gender Woman 41% Man 59% • Man • Woman
Respondent's age	Age 13% 1% 75% • 17-27 Year • 28-38 Year • 39-49 Year • >49 Year
Respondent's domicile	Domicile 27% 73% • Jakarta • Outside of Jakarta

Table 6
Respondent interest scale of needs.

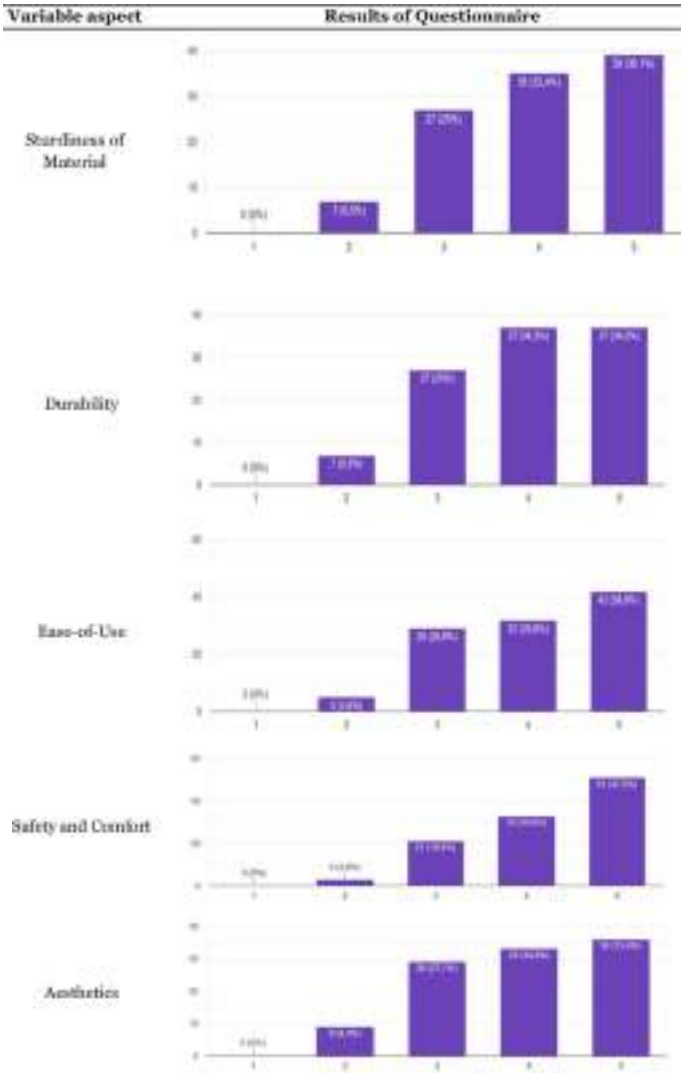

Table 7
Customers' Needs Identification.

Matrix of Needs	1	2	3	4	5
Sturdiness of Material	0	7	27	35	39
Durability	0	7	27	37	37
Ease-of-Use	0	5	29	32	42
Safety and Comfort	0	3	21	33	51
Aesthetics	0	9	29	33	36

the product that will be developed. Developing products based on respondent needs is essential and will require some validity and reliability tests. The validity test measures whether a questionnaire is valid [95]. The test uses Minitab software with a Bivariate Pearson correlation testing technique for validity tests.

Based on Table 1, the distribution of r table values obtained using the significance level of 95 % and 100 Respondents is 0.195. Validity test calculations were performed using Minitab software with Pearson Correlation testing technique on five levels of importance criteria on a product. After that, the calculated R-value will be seen and compared. The Results for R-Value using Minitab Software can be seen in Fig. 5.

The comparison results between the R Table and the R-value collected using Minitab software are presented in Table 8.

Based on the comparison, it can be concluded that the Sturdy

Correlation : X1, X2, X3, X4, X5; TOTAL

	X1	X2	X3	X4	X5
X2	0.065				
X3	0.010	0.009			
X4	0.072	-0.040	0.158		
X5	0.114	0.272	0.516	0.095	
Total	0.461	0.482	0.617	0.444	0.741

Cell Contents : Pearson correlation

Fig. 5. Validity test result.

Table 8
Comparison between R table value and calculated R-value using Minitab Software.

Attribute	Calculated R	R table	Conclusion	Attribute
Sturdy Material	0.461	0.195	Data Valid	Sturdy Material
Durability	0.482	0.195	Data Valid	Durability
Ease-of-use	0.617	0.195	Data Valid	Ease-of-use
Safety and Comfortable	0.444	0.195	Data Valid	Safety and Comfortable
Aesthetics	0.741	0.195	Data Valid	Aesthetics

Material aspect, Durability aspect, Ease-of-use aspect, Safety and Comfortable aspect, and Aesthetics aspect have the R calculated the Minitab software having the R-value which is greater than the R Table, therefore it can be stated that the data that have been gathered through questionnaire is a valid data and the research can be continued with further data testing.

5.3. Reliability test

Reliability testing measures the consistency of the questionnaire, which serves as an indicator of the variable or construct being assessed. A questionnaire is considered reliable if a person's answers to questions remain consistent or stable over time [148]. The test utilises Minitab software, incorporating Cronbach's Alpha testing for reliability assessment. The instrument used in this variable is considered reliable if it has a Cronbach's Alpha of >0.60 [103]. The Cronbach's Alpha result, as calculated using Minitab software, is shown in Fig. 6.

Through analysis of the data results, the reliability of the questionnaire data is calculated using Minitab. It can be seen that the Cronbach's Alpha value is 0.6288. The Cronbach's Alpha Value is greater than 0.60, indicating that each aspect collected for research on the level of importance in the questionnaire can be considered reliable.

5.4. Likert scale

The Likert Scale is a research scale used to measure attitudes and opinions. In a Likert scale, respondents are asked to complete a questionnaire that requires them to indicate their level of agreement with a series of questions [149]. The measuring level of importance of this variable uses a Likert scale research instrument of 1 – 5, which can be defined as follows:

1: Very Unimportant, 1 point
2: Not Important, 2 points
3: Moderately Important, 3 points
4: Important, 4 points
5: Very important, 5 points

Based on the questionnaire results, the percentage level of importance for each variable is then calculated, as shown in Table 9.

After obtaining the weighted percentage value at the variable importance level, it is used for comparative analysis using the AHP (Analytical Hierarchy Process) method to determine the relationship between two critical variables. Analytical Hierarchy Process (AHP) evaluates and makes multi-criteria decisions. It considers various alternatives based on different criteria and assigns a relative score to each option [150,151]. The example of calculating sturdy material variables in products is below.

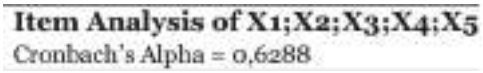

Fig. 6. Reliability test result.

Table 9
Importance of variable percentage.

Variable	1	2	3	4	5	Total	Percentage
Sturdy Material	0	14	81	140	195	0	92.8%
Durability	0	14	81	148	185	0	92.4%
Ease-of-use	0	10	87	128	210	0	93.9%
Safety and Comfortable	0	6	63	132	255	0	98.4%
Aesthetics	0	18	87	132	180	0	90.7%

$$\textbf{Percentage importance scale} = 430 / (5 \times 108) \textbf{ x } 100\% = 92.8\%$$

It can be seen here that the Sturdy Material aspect has an importance value of 92,8 %, the durability aspect has an importance value of 92.4 %, the ease-of-use aspect has an importance value of 93.9 %, the safety and comfortable aspect has an importance value of 98.4 %, and last for the aesthetics aspect has importance value of 90.7 %.

After gathering the importance percentage value for each aspect, the next step in processing the data is to sort the existing needs variables from those with the largest scale of importance to those with the smallest. With the criteria, it can be calculated as follows:

$$100\% / 5 = 20\%.$$

A percentage value of 20 % indicates that the range of each interest value is 20 %, starting from 0 %. The following are the importance value criteria, as shown in Table 10.

Based on Table 9, the value at a percentage of 20 % for each interest value range is 20 %. Therefore, it can be concluded that the importance value for each variable is presented in Table 11.

Based on the percentage Table of Importance in Table 10. the percentage difference range will be calculated as follows:

Highest percentage value = 98.4 %
Lowest percentage value = 90.7 %
Range = Highest score value – Lowest score value
Range = 98.4 % - 90.7 % = 7.7 %
Range per scale = (7.7 %)/4 = 1.925 = 2 %

Based on the data presented in Table 8, comparisons were made using an importance scale. The paired comparison matrix is available in Table 12.

Next, it is necessary to set (Pairwise) the variables in the rows and columns of the matrix. Comparisons are made by looking at the importance scale, after which normalisation is carried out to obtain eigenvalue calculations and priority weights for each variable. The paired comparison matrix is shown in Table 13.

Normalisation calculations were performed after completing the pairwise comparison matrix, as shown in Table 14.

After showing the normalisation calculation data that has been carried out, eigenvalues, priority weights, and total scores can be calculated. The calculation of eigenvalues, priority weights, and total scores can be seen in Table 15.

From the Eigen Value and Priority Vector calculation, the weight for every variable in developing the product can be found. The most essential variable to notice in developing the product is the material's sturdiness, which is continued by durability in the second place. Third place, It is crucial to see the ease-of-use variable, continued by the safety

Table 10
Range of importance value.

Percentage	Criteria	Importance Value
0 – 20%	Very unimportant	1
21 – 40%	Not important	2
41 – 60%	Fairly important	3
61 – 80%	Important	4
81 – 100%	Very important	5

Table 11
Scale of importance level [12].

Level Importance	Definition	Explanation
1	Equally Important	Both elements have the same influence
3	A Little More Matters	Experience and judgment strongly favour one element over its counterpart
5	More important	Experience and judgment indicate a preference for one activity over another.
7	Much More Important	Experience or judgment indicates a strong preference for one activity over another.
9	Very Important	One element is preferred over its counterpart at the highest level of confidence.
2, 4, 6, 8	The middle value between two adjacent values	When compromise is needed

Table 12
Range of importance scale.

Importance Scale	Definition	Range (%)
1	Equally Important	0
3	A Little More Matters	0.1 – 2.1
5	More important	2.2 – 4.2
7	Very important	4.3 – 6.3
9	More Important	6.4 – 8.4

Table 13
Paired comparison matrix.

	SM	D	EU	SC	AE
SM	1	3	5	5	7
D	0.333	1	3	3	5
EU	0.200	0.333	1	3	5
SC	0.200	0.333	0.333	1	5
AE	0.143	0.200	0.200	0.200	1
Total	1.876	4.866	9.533	12.200	23

Explanation:
SM: Sturdy Material
D: Durability
EU: Ease-of-use
SC: Safety and Comfortable
AE: Aesthetics

Table 14
Normalisation calculation.

	SM	D	EU	SC	AE	*Eigen*	*Priority*
SM	0.533	0.617	0.524	0.410	0.304	0.478	2.388
D	0.178	0.206	0.315	0.246	0.217	0.232	1.161
EU	0.107	0.068	0.105	0.246	0.217	0.149	0.743
SC	0.107	0.068	0.035	0.082	0.217	0.102	0.509
AE	0.076	0.041	0.021	0.016	0.043	0.040	0.198
Total	1.000	1.000	1.000	1.000	1.000	1.000	5.000

Explanation:
SM: Sturdy Material
D: Durability
EU: Ease-of-use
SC: Safety and Comfortable
AE: Aesthetics

and comfort variable, and last but not least is the aesthetics variable. The consistency vector is calculated after calculating the eigenvalues, priority weights, and total score, which can be seen in Table 16.

After calculating the eigenvalues of each pairwise comparison matrix, the next step is to calculate the consistent ratio test (CR). The

Table 15
Calculation of eigenvalue, priority vector, and weight.

Variable	Eigen *Value*	*Priority Vector*	Weight (%)
Sturdy Material	0.478	2.388	48%
Durability	0.232	1.161	23%
Ease-of-use	0.149	0.743	15%
Safety and Comfortable	0.102	0.509	10%
Aesthetics	0.040	0.198	4%
Total	1.000	5.000	100

Table 16
Consistency vector calculation.

Variable	Eigen Value * Total	Consistency Vector
SM	0.478 * 1.876	0,91
D	0.232 * 4.866	1,13
EU	0.149 * 9.533	1,42
SC	0.102 * 12.200	1,24
AE	0.040 * 23	0,90
λ_{max} (Total)		5.60

Consistency Ratio (CR) is a comparison of results between the Consistency Index (CI) and the Random Consistency Index (IR) [152]. If the consistency ratio value is smaller than 0.1, the respondent's questionnaire results can be accepted and declared consistent. Meanwhile, if the hierarchical consistency value is greater than or equal to 0.1, the respondent's questionnaire results are declared unacceptable and inconsistent. Hierarchical consistency testing calculations are performed using random consistency index variables. The random consistency index is presented in Table 2.

The 5th matrix size with an IR value of 1.12 is used in testing this hierarchical consistency. The matrix size used is the 5th because the number of matrices refers to the number of requirement variables used, namely five. The results of the λ max, CI (Consistency Index), IR (Random Index), and CR (Consistency Ratio) calculations are presented in Table 17.

The calculation to find the consistency index value using five matrices is as follows:

$$\lambda_{max} = \sum (\text{Total Pairwise} \times \text{Eigen Score})$$

$$\lambda_{max} = (0.478 \times 1.876) + (0.232 \times 4.866) + \ldots + (0.040 \times 23)$$

$$\lambda_{max} = 5.597 - 5.60$$

Finding CI (Consistency Index):

$$\text{CI} = \frac{\lambda - n}{n - 1}$$

$$\text{CI} = \frac{5.60 - 5}{5 - 1}$$

$$\text{CI} = 0.1$$

Finding Consistency Ratio (CR):

$$\text{CR} = \frac{CI}{IR}$$

Table 17
Consistency value calculation.

	Value
λ_{max}	5.60
n	5
CI (Consistency Index)	0.15
IR (Index Random)	1.12
CR (Consistency Ratio)	0.089

$$CR = \frac{0.1}{1.12}$$

$$CR = 0.089$$

Based on the calculation above, a consistency value of 0.089 is obtained, which is smaller than the hierarchical consistency value of 0.1. Therefore, the questionnaire data collected for the five variables used is consistent so it can proceed to the product's development process.

5.5. Tensile testing

The initial stage of the tensile test begins with machine calibration, which ensures that the observation results are correct and accurate. After the specimen material is ready, the WH stem is currently prepared for testing. The machine will be tested first. The tensile test process begins with clamping the ends of the WH stem before the pulling procedure is carried out until it breaks. The data obtained is appropriately recorded, and the pulling process with a new specimen is repeated for each type of desired treatment data.

A tensile test is a mechanical material testing method used to determine material characteristics. Depending on the material, testing is used as a standard method according to the respective standards for the determination of yield strength, tensile strength, breaking strain, and Other material properties (Y [153]). The data and calculations for the tensile test of dried WH, along with documentation, are presented in Appendices A to M. These include results from tests using one stem, two stems, three stems, and three twisted stems, conducted on a Shimadzu-branded universal tensile tester, Type UMH-30. Table 18 shows the result data of all the tensile tests with specific break pressures and elongations.

The tensile test was carried out five times for each different number of WHs. The following are the results of tests carried out on one stem of WH, which can be seen in Appendix A to Appendix M. Based on the tensile test carried out, the graph shows that the tensile strength of the 3 twisted WH stems is significantly stronger than that of the tensile tests using one WH stem, two WH stems, and three WH stems. The tensile test of three twisted WH stems demonstrated greater muscular strength, with a tensile test time of 9 min 38 s and an increase in length of 2.5 mm. So, making an adjustable chair will use twisted WH stems. It can form an adjustable chair, which, if woven with large amounts of WH, will result in a more durable product and a more robust material. Because the combination of WH fiber and twisted WH fiber can provide up to 30 % more strength than the original, adding up to nearly 70 % of the reinforcement. WH material can also be reinforced with four or five fibers or twisted with four or five fibers to support even greater loads.

5.6. Product concept

Product design and development are processes related to the existence of a product, encompassing all activities from identifying consumer desires to the fabrication, sales, and delivery of the product [154].

Table 18
Data Recapitulation of WH Break Pressure and Elongation.

Type	Break Pressure (MPA)		Δ Elongation (mm)	Break Pressure Average (BPA)	Increasing BPA
WH 1 stem	3.0401	3.2362	6-7	3.13815	
WH 2 stem	3.5304	3.8246	4-5	3.6775	17%
WH 3 stem	4.2169	4.7072	3.5-5	4.46205	21%
WH 3 stems twisted	5.5898	6.0801	2-2.5	5.83495	31%

In product design and development, numerous product concepts are typically designed. The product concept is all designed with the assumption that consumers will like quality, valuable products with helpful features. This concept must focus on product quality and meeting consumer demand [155]. Based on the data obtained from the market research, 3 product concepts were designed, which are described as follows:

- First Product Concept

The first product concept design was made from dried WH waste. The conceptual part of this product features an iron frame that is bent and connected by welding, and it only has a headrest. The product image is shown in Fig. 7.

- Second Product Concept

The second product concept design is made from dried WH waste. The conceptual part of this product features an iron frame that is bent and connected by welding, a modern design with a curved chair. The product image is shown in Fig. 8.

- Third Product Concept

The third product concept design is made from dried WH waste. This product concept part utilises a Carbon Steel frame that is cut, bent, and then assembled using rivets, bolts, and nuts. This concept model has several advantages: it can be easily adjusted, features armrests, and is easy to move. A picture of the product is shown in Fig. 9.

After getting the product concept design, it is necessary to determine the degree of importance. The degree of importance of a need is a degree in Likert scale units, where the value of the degree is obtained from respondents to the level questionnaire importance of product criteria whose scale results are processed using a geometric average to get the results of the degree of importance of needs [156]. Determining the degree of importance is used to distinguish between the most important and the least essential needs. This determination becomes the basis for designing and developing products that prioritise needs according to their degree of importance. The degree of importance can be determined in Table 19.

In designing a product, a percentage of needs must be addressed. The percentage of needs is shown in Table 20.

When designing an adjustable chair, it is necessary to consider the percentage of needs. This research reveals that the highest percentage of needs can be found in the Safety and Comfort aspect, with a score of 31 %, which will be the primary focus in developing an "Adjustable Chair". The lowest percentage of needs can be found in the aesthetic aspect, with a score of 8 %, which will be the minor focus in developing an "Adjustable Chair". Based on the percentage of needs, the next step is to determine the scale of the percentage of interests based on the importance scale percentage, as shown in Table 21.

Each variable's importance scale is created based on its corresponding importance scale percentage. The scale of significance of needs is evident in Table 22.

Fig. 7. First product concept.

Fig. 8. Second product concept.

Fig. 9. Third product concept.

Table 19
Degree of need importance.

Variable	Degree of Importance									
Sturdy Material	1	0	0	1						
Durability	0				0	0	1			
Ease-of-use		1			1			0	1	
Safety and Comfortable			1			1		1		1
Aesthetics				0			0		1	0

Explanation:
• 0 – 1 = The degree of importance of a need with a value of 1 is higher than that of 0.
• 1 – 1 = the two needs being compared have a balanced (same) degree of importance.

Table 20
Percentage of needs.

Variable	Number of Needs	Percentage of Needs
Sturdy Material	3	23%
Durability	2	15%
Ease-of-use	3	23%
Safety and Comfortable	4	31%
Aesthetics	1	8%
Total	13	100%

According to the results of the needs importance scale, it can be concluded that safety and comfort have a value of 4, indicating that this need is relatively critical compared to other needs. Next, sturdy material and ease of use have a value of 3, indicating that this need is balanced between important and less important. Next, the need for durability in products is valued at 2, which can be considered less important than other needs. Furthermore, the need for aesthetics is considered less important than other needs, as the product has a value of 1.

Choosing or selecting a concept is evaluating several existing concepts that meet the criteria determined to fulfil consumer needs. In this selection, the strengths and weaknesses of each concept are Compared, and one is considered worthy of further development. Concept selection is carried out not only during concept development but also through the subsequent design and development process. Concept selection is a collaborative process that facilitates easier decision-making.

Table 21
Importance scale percentage.

Percentage	Importance Scale
≤ 5%	1
5%< Percentage of needs ≤10%	2
10%< Percentage of needs ≤15%	3
15%< Percentage of needs ≤20%	4
20%< Percentage of needs ≤25%	5

Explanation:
• A value with an importance scale of 1 indicates that this need is less critical than others. This need must not be met. So, this will not affect the product's market share. This need will not affect the product's market share if completed.
• A value with an importance scale of 2 explains that this need is less critical than others. This need must not be met. So, this will not affect the product's market share. If these needs are met, it will add value to the product.
• A value with an importance scale of 3 explains that this need is balanced between important and less important. If this need is not met, it will not affect market share. If this need is fulfilled, it will positively impact the market, increasing the product's value. At this value, this need will prompt consumers to consider purchasing the product.
• A value with an importance scale of 4 explains that this need is more critical than others. If this need is not met, it will affect market share. If these needs are met, the product will get a positive response from consumers.
• A value with an importance scale of 5 explains that this need is critical compared to other needs. If this need is not met, it will significantly impact market share, and consumers will consider this when purchasing the product. The product will meet the specified market share target if these needs are met.

Table 22
Scale of importance for each variable.

Variable	Importance Scale
Sturdy Material	3
Durability	2
Ease-of-use	3
Safety and Comfortable	4
Aesthetics	1

5.7. Concept selection

Choosing or selecting a concept is evaluating several existing concepts that meet the criteria determined to fulfil consumer needs. In this selection, the strengths and weaknesses of each idea are compared, and one is considered worthy of further development [157]. Concept selection is carried out not only during concept development but also through the subsequent design and development process. Concept selection is a collaborative process that facilitates easier decision-making. Concept

Table 23
Concept screening.

Variable	Product Concept		
	Concept 1	Concept 1	Concept 1
Sturdy Material	+	+	+
Durability	+	+	+
Ease-of-use	-	-	+
Safety and Comfortable	-	+	+
Aesthetics	0	+	+
Amount of (+)	2	4	5
Amount of (0)	2	0	0
Amount of (-)	2	1	0
Final Results	0	3	5
Ranking	3	2	1
Continue to Concept Assessment?	No	Yes	Yes

screening for the product concept, as created, is presented in Table 23.

From the concept selection process, it is evident that the highest score is found in Concept 3, followed by Concept 2, and the lowest score is found in Concept 1. Therefore, it can be concluded that the concepts that will be continued in the concept assessment are Concepts 2 and 3. After obtaining two product designs, Concept 2 and Concept 3, from the results of the concept screening process, the next step is to conduct a concept assessment to determine which option will be developed. Concept assessment emphasises the differences between the concepts to be compared. At this stage, weighting is conducted based on the relative importance of the selected criteria, with a focus on a more detailed comparison of each criterion [158]. Concept assessment is conducted using the rating scale method, as shown in Table 24.

The selected concept is design concept 3 because it has a final score of 4.75, more significant than the score of concept 2, which has a final score of 3.45. Based on the selected concept, it will be used and will continue to fulfil the needs of refinement before the production stage, aiming to achieve the best outcome. The development process is carried out to create the resulting product. In the final development phase, the chosen concept is re-evaluated by applying ergonomic principles and anthropometric data.

5.8. Concept Evaluation and Development

Based on the chosen product, then the process of product development continues by making the technical drawing for

Adjustable chair. Technical drawing serves as a communication tool between planners and implementers, conveying information in a pictorial language that is practical, clear and easily understood by both parties [159]. The technical drawing of the chosen product concept is shown in Fig. 10.

5.9. Final product design and dimensions

After designing the product using Fusion 360 software, the stages of transforming the design into a physical product with a 1:1 prototype are carried out. The dimensions in the open chair position are 176 cm x 60 cm x 30 cm, and the folded chair position is 110 cm x 15 cm x 55 cm. The following is a modification of the innovation: an "adjustable chair" that utilises waste from WH, featuring a carbon steel frame with the final design of the chair's dimensions and measurements, as shown in Table 25.

5.10. Evaluation of final product results

After the modified ergonomic adjustable chair innovation product using waste had been developed, a questionnaire was distributed again to determine what design products had been created. The evaluation process utilised 15 respondents based on the mentioned variable aspect, using pairwise comparison. The results of this evaluation are presented in Table 26–27.

Based on Table 33, the Sturdiness of Material and Durability aspect shows the respondents' experience with the product. Based on the graphic image, it can be concluded that 53.3 % of respondents felt very good, 33.3 % felt good, and 13.2 % felt the plan was quite good. For the ease-of-use aspect, show the respondent's experience using the product. Based on the graphic image, it can be concluded that as many as 40 % of respondents felt very good, 33.3 % felt good, and 26.7 % felt the plan was quite good. The safety and comfort aspects show the respondent's experience using the product. Based on the graphic image, it can be concluded that 66.7 % of respondents felt very good, 26.7 % felt good, and 6.7 % felt the plan was quite good. Last, the aesthetic aspect shows the respondents' experience with the product. Based on the graphic image, it can be concluded that 46.7 % of respondents felt that the plan was good or very good, and 6.7 % felt that it was quite good.

Table 24
Concept assessment.

Variable	Weight	Rating	Score	Rating	Score
Material Sturdiness	30%	4	1,2	5	1,5
Durability	25%	2	0,5	5	1,25
Ease-of-use	20%	4	0,8	5	1
Safety and Comfortable	15%	3	0,45	4	0,6
Aesthetics	10%	5	0,5	4	0,4
Results	Final Score	3,45		4,75	
	Ranking	2		1	
	Conclusion	Not Continue to Develop		Continue to be Developed	

6. Discussion

In several papers that discuss furniture made from WH stems, most examine it from both artistic and mechanical perspectives. Armante et al [160] in the Philippines stated that they focused on the design of automatic biofiber extractor machines, which aim to develop machines for processing hemp in the field. This machine mechanically harvests raw hemp and then separates the bast and hemp core fibres by splitting and cutting them, using dried WH fibre as the main feed [1] reported that the products manufactured include that household accessories (Baskets, tissue holders, coasters, placemats, tray boxes), Interior (Carpet, table and chair sets, lamps, walls clocks, rope), decorative (Vases, photo frame, mirror, toys/miniature), fashion (Shoes, sandals, wallets, bags, necklaces). It also describes the context of WH's study area, including its biology and environment at Rawapening Lake. The positive impact of WH at Rawapening Lake includes Bioremediation, Handicrafts, Biogas, and Organic fertilizer. The lack of interest and support from the younger generation, community, and government, as well as the complicated process for biogas energy, makes these positive activities unable to achieve higher expectations and results in Indonesia. Gamata et al [161] designed the chair and table based on ergonomic and anthropometric measurements using WH materials without conducting any market research study or material testing and without employing a product development selection method. Harun et al [28] discuss WH ecology and the impact of invasion on rural communities, suggesting a green push: a microeconomic model based on various potential WH valorisation schemes for affected rural communities, aiming to achieve sustainable WH management and control WH expansion. Negative impact on humans and the environment. Rezania et al [33] review some papers highlighting the WH function, with a particular focus on its utilisation in energy and engineering fields over the last three decades. Rezania et al [33] reported that the use of WH for making furniture remains challenging due to the demands for higher-quality materials and the difficulty of the manufacturing process. However, Jafari [162] stated that biomass can be converted into durable, aesthetically pleasing furniture and handicrafts in professional management. Mulyono & Cristy [163] reported that furniture and handicraft products manufactured after the COVID-19 era were produced in some form and design with WH material without conducting market research studies, testing materials, performing ergonomic and anthropometric measurements, or applying a product development selection concept. Rakotoarisoa et al [164] reported a case study from Madagascar on the handicraft product as a potential application of WH handicrafts to improve rural art, using the SWOT analysis method. The SWOT analysis identified simple production processes and new market opportunities as the main factors driving the production and commercialization of WH crafts. In contrast, a lack of marketing competence and weak craft organizations are potential obstacles.

By conducting in-depth research using market research studies, carrying out ergonomic product designs using anthropometric measurements, carrying out product development selection concepts and testing WH materials that are strong enough to withstand the weight of the human body in designing adjustable chairs, this is a novelty from this

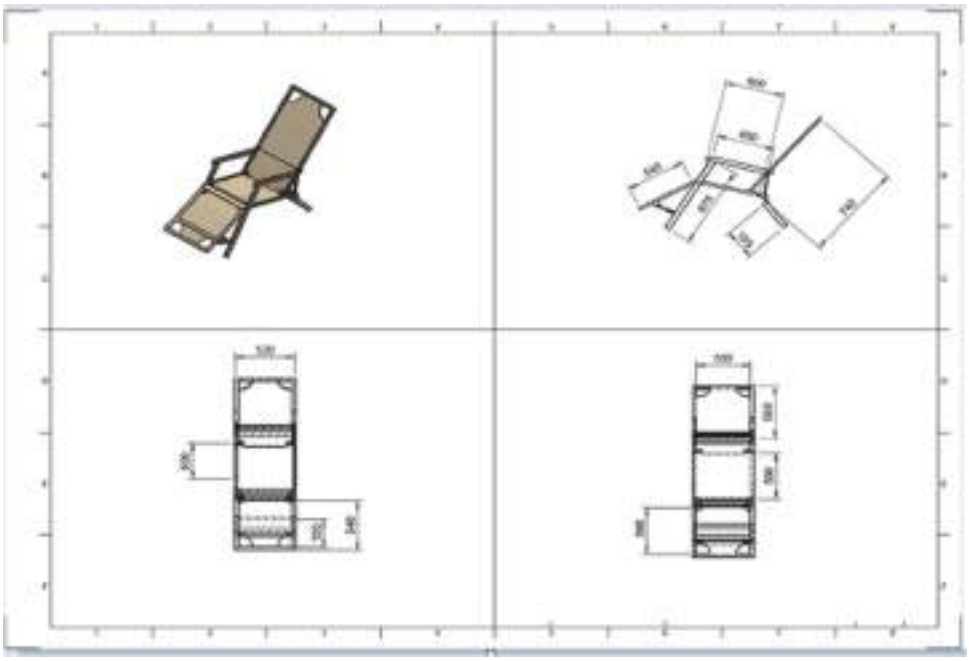

Fig. 10. Technical drawing of the final product concept.

Table 25
Final design of chair dimensions and measurements.

No	Part of the Chair	Part of the body	Persentil	Measurement (cm)	Allowance	Result (cm)
1	Chair height from the floor	Shoulder height in sitting position	95%	72.03	+3.97	76
		Popliteal height	95%	49.10	+0.49	54
2	Height of chair seat from floor	Popliteal height	95%	49.10	+3.9	53
3	Upper shoulder width on chair	Upper shoulder width	95%	47.19	+4.81	52
4	Width of seat cushion on chair	Hip width	95%	43.00	+9	52
5	Length of seat cushion on chair	Popliteal length	95%	49.65	+0.35	50

research that cannot be found in previous studies. Concerning about body weight [165,166], the chair design in nowadays should be considered for heavy weight person.

The novelty of this research is that there is no comprehensive paper on the product development of ergonomic chairs using WH material and the tensile testing method used on WH material. This could provide further insight into the methods required for the development process on other materials and whether other materials can also maintain the strength of the ergonomic chair being developed. After conducting a search on the Scopus website for information on ergonomic chair design using tensile testing, it was discovered that this had never been done before in the research world. This is the first state-of-the-art product design research that combines the science of product design from Industrial Engineering, ergonomics from Industrial Engineering, and tensile testing from Mechanical Engineering.

7. Research limitation

The limitations of this study are that it focused solely on designing general chairs and did not include calculations for chairs designed for obese or overweight individuals. Furthermore, the study only designed ergonomic chairs using WH material and did not design ergonomic chairs using other basic materials. The combination of knowledge from the fields of industrial engineering and mechanical engineering has not yet involved aesthetic concepts from the fields of architecture or interior design or other fields of art.

A key limitation of the current study on the WH chair is the potential lack of data regarding its long-term durability and cost-effectiveness. While the chair may be effective in initial trials, its ability to maintain ergonomic support over several years, especially with varying usage patterns, remains a significant question. The cost of producing a highly ergonomic product with advanced materials might also limit its market accessibility, making it unaffordable for many potential users. Furthermore, the existing user testing may not have been broad enough, potentially overlooking the needs of individuals with diverse body types, specific physical conditions, or other unique requirements, thus limiting its universal applicability.

8. Conclusion

This research concludes from the tensile test results of WH waste that three twisted WH stems have more muscular strength than one, two, or three stems. Then, utilising this waste in product design through a twisted technique woven onto a carbon steel shell in large quantities will significantly enhance the design of a chair. The chair's dimensions are 176 cm x 60 cm x 55 cm, incorporating anthropometric data for Indonesian men and women, as well as ergonomic principles. From the Adjustable Chair that has been designed, it can be concluded from the perspective of 15 respondents who used it that this adjustable chair felt good comfort. From the implementation of the product, it can be observed that WH waste can be utilised as a material in the craft and creative industries for designing products that serve as an environmentally friendly alternative and also help reduce WH waste.

This research helps give confidence to small and medium-sized entrepreneurs who can continue to develop WH products in the furniture sector. For academics, this product design method using WH material

Table 26
Final product result.

View of Product	Picture
Isometric view	
Side view	
Front view	
Back view	

can be helpful for research on materials for other products. The design and development of this WH product have gone through an in-depth market research study process, as well as ergonomics and through the product selection concept process, which is needed for product development and not only seen from an artistic perspective, and it will be beneficial for the satisfaction of product users and other academics. WH can be effectively used as a sustainable material for furniture. The tensile strength of WH can be enhanced through specific processing techniques. The ergonomic design of the WH lounge chair is well-received by users.

Future research

Future research on the WH chair should therefore focus on three key areas. Firstly, longitudinal studies are crucial to evaluate the chair's durability and the long-term impact on user health, potentially leading to the development of new, robust materials. Secondly, research into cost-effective production methods, such as modular designs and alternative materials, would make the chair more accessible to a wider market. Finally, future studies should include broader user testing with a more diverse population and explore the integration of "smart" technologies to provide real-time posture feedback, allowing for greater customization and a more personalized ergonomic experience for all users.

Ethical approval

This study was reviewed and approved by [INTI Ethical Research Panel] with the approval number: [INTI/FHLS/sept2023/001], dated [1 September 2023].

This study was reviewed and deemed exempt from ethics approval by [INTI Ethical Research Panel] with the reference number [INTI/FHLS/sept2023/001], dated [1 September 2023].

Consent to participate

All participants gave informed consent for inclusion before participating in the study."

Consent to publish

Individuals consent to participate in this research and have the data published in this journal article. All authors seek consent from individuals to publish their data before submitting their paper to a journal.

Authors are responsible for the correctness of the statements provided in the manuscript.

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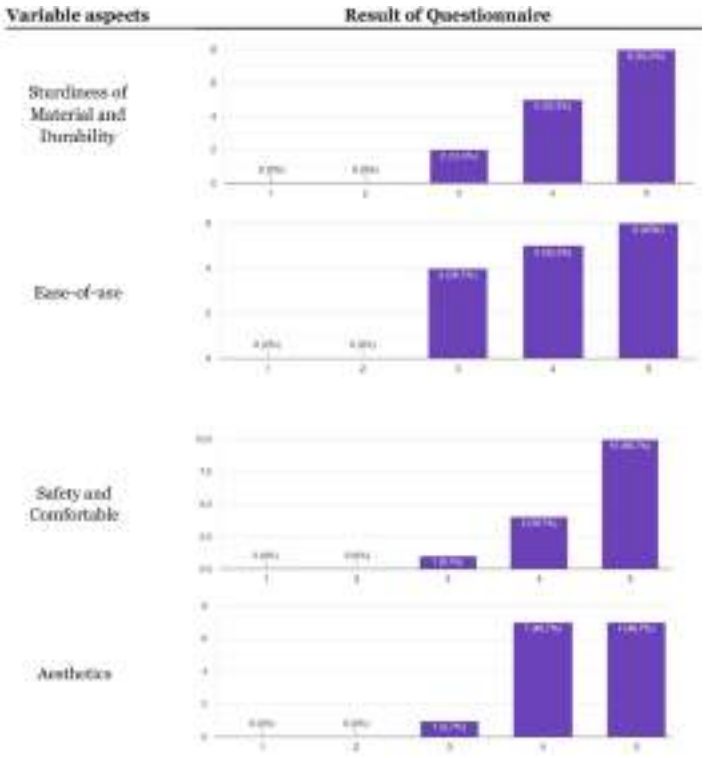
Table 27
Evaluation results.



authorship, and/or publication of this article.

Data availability

Data available within the article or its supplementary materials. The authors confirm that the data supporting the findings of this study are available within the article [and/or] its supplementary materials. Data available on request from the authors The data that support the findings of this study are available from the corresponding author upon reasonable request.

CRediT authorship contribution statement

Lina Gozali: Writing – original draft. **Ronaldo Setiawan:** Project administration. **Frans Jusuf Daywin:** Conceptualization. **Geraldo Rafael:** Supervision. **Ariawan Gunadi:** Funding acquisition. **Syuhaida Ismail:** Methodology. **Togar Mangihut Simatupang:** Data curation. **Jose Arturo Garza-Reyes:** Formal analysis. **Vikas Kumar:** Formal analysis. **Wan Hee Cheng:** Resources. **Yuri T Zagloel:** Writing – review & editing. **Maslin Masrom:** Investigation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.sftr.2026.101788.

Appendix A. Tensile test WH 1 stem

No	do (mm)	Lo (mm)	di (mm)	Li (mm)	Break (MPa)
1	17	526	6	532	3.2362
2	15	586	6	592	3.1381
3	16	545	6	551	2.942
4	17	516	7	523	3.2362
5	16	533	6	539	3.0401

Explanation:.
do: Initial Diameter.
lo: Initial Length.
di: Elongation.
EU: Final Length.

After getting five samples of the tensile test of 1 stem of WH, one of the samples from the tensile test of 1 stem is used, as seen in Table 18.

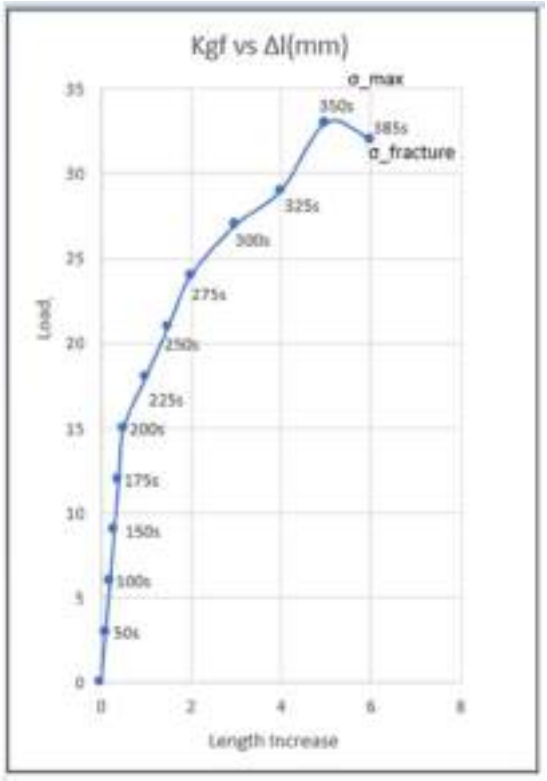
Appendix B. . Processing of tensile test samples of 1 WH stem

F (Newton)	Δl (mm)	Time per Second
0	0	0
1000	0,1	50
2000	0,2	100
3000	0,3	150
4000	0,4	175
5000	0,5	200
6000	1	225
6200	1,5	250
6400	2	275
6600	3	300
6800	4	325
7000	5	350
6800	6	385

Explanation:.
F(N): Load.
Δl (mm): Elongation.

Then, after processing the tensile test sample of 1 WH stem, the resulting graph can be seen in Appendix C

Appendix C. Tensile test graph for one WH stem



After the tensile test for one stem of WH, the test is repeated five times for two additional stems of WH, as shown in Table 19.

Appendix D. Tensile test WH 2 stem

No	do (mm)	Lo (mm)	di (mm)	Li (mm)	Break (MPa)
1	16	521	5	526	3.5304
2	18	580	5	585	3.5304
3	17	564	5	569	3.5304
4	15	580	4	584	3.8246
5	17	519	5	524	3.7265

Explanation:.
do: Initial Diameter.

lo: Initial Length.
di: Elongation.
EU: Final Length.

After obtaining five samples from the tensile test of 2 stems of WH, one of the samples is used from the tensile test of 2 stems, as shown in Table 20.

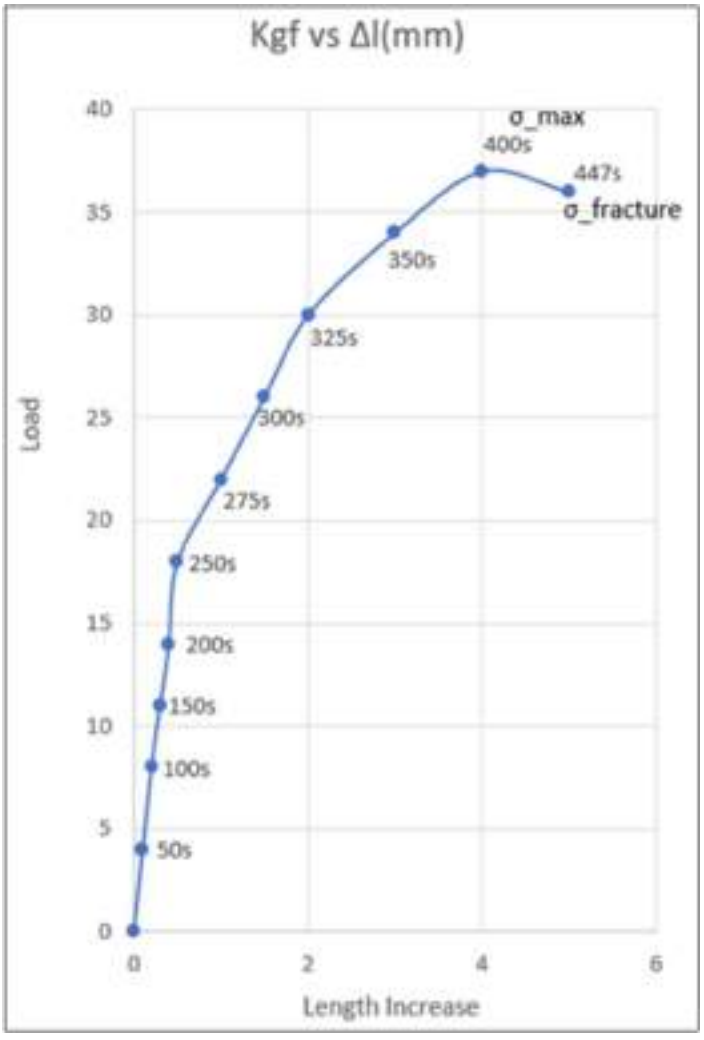
Appendix E. Processing of tensile test samples of 2 WH stem

F (Newton)	Δl (mm)	Time per Second
0	0	0
1000	0,1	25
2000	0,2	50
3000	0,3	75
4000	0,4	100
5000	0,5	150
6000	1	200
6300	1,5	250
6600	2	300
6900	3	350
7000	4	400
6800	5	447

Explanation:
F(N): Load
Δl (mm): Elongation

Then, after processing the tensile test sample of 2 WH stems, the resulting graph can be seen in Appendix F.

Appendix F. Tensile test graph for two WH stems



After the tensile test for two stems of WH, the test is repeated five times for three additional stems of WH, as shown in Table 21.

Appendix G. Processing of tensile test samples of WH stem

After the tensile test for one stem of WH, the test is repeated five times for three additional stems of WH, as shown in Appendix H.

Appendix H. Processing of tensile test samples of 3 WH stem

No	do (mm)	Lo (mm)	di (mm)	Li (mm)	Break (MPa)
1	17	538	4	542	4.511
2	18	531	3,5	534,5	4.217
3	19	580	4	584	4.511
4	17	575	3,5	578,5	4.707
5	16	521	4	525	4.511

Explanation:.
do: Initial Diameter.

lo: Initial Length.
di: Elongation.
EU: Final Length.

After getting five samples of the tensile test of 2 stems of WH, one of the samples from the tensile test of 2 stems is used, which can be seen in Appendix I .

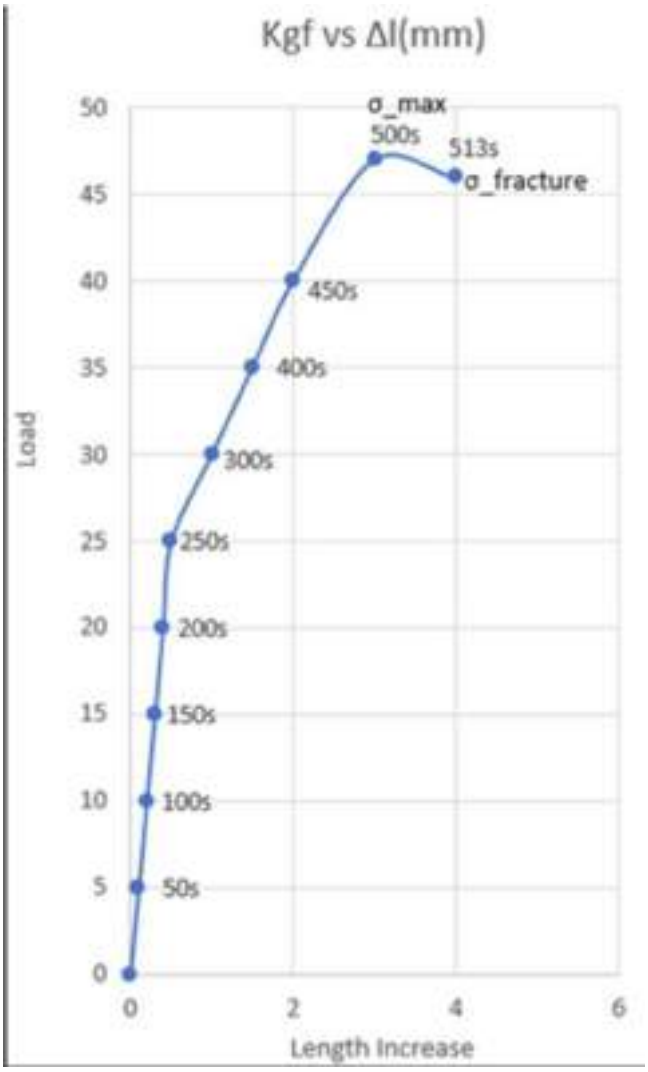
Appendix I. Processing of tensile test samples of 3 WH stem

MPa	Δl (mm)	Time/Second
0	0	0
0.490333	0,1	50
0.980665	0,2	100
1.471	0,3	150
1.9613	0,4	200
2.4517	0,5	250
2.942	1	300
3.4323	1,5	400
3.9227	2	450
4.6091	3	500
4.8053	4	513

Explanation:.
F(N): Load.
Δl (mm): Elongation.

Then, after processing the tensile test sample of 3 WH stems, the resulting graph can be seen in Appendix J. .

Appendix J. Tensile test graph for three WH stems



After the tensile test for three stems of WH, the last tensile test continues by running the test 5 times for three stems of WH, but the WH is twisted this time. The test can be seen in Appendix K. .

Appendix K. Tensile test WH 3 stems twisted

No	do (mm)	Lo (mm)	di (mm)	Li (mm)	Break (MPa)
1	19	443	2,5	445,5	6.0801
2	18	440	2,5	442,5	5.5898
3	17	442	2	445	6.2763
4	18	442	2,5	444	5.884
5	19	440	2	442	5.884

Explanation:.
do: Initial Diameter.
lo: Initial Length.
di: Elongation.
EU: Final Length.

After obtaining five samples from the tensile test of 3 stems of WH twisted, one of the samples from the tensile test of the 3 stems twisted is used, as shown in Appendix L .

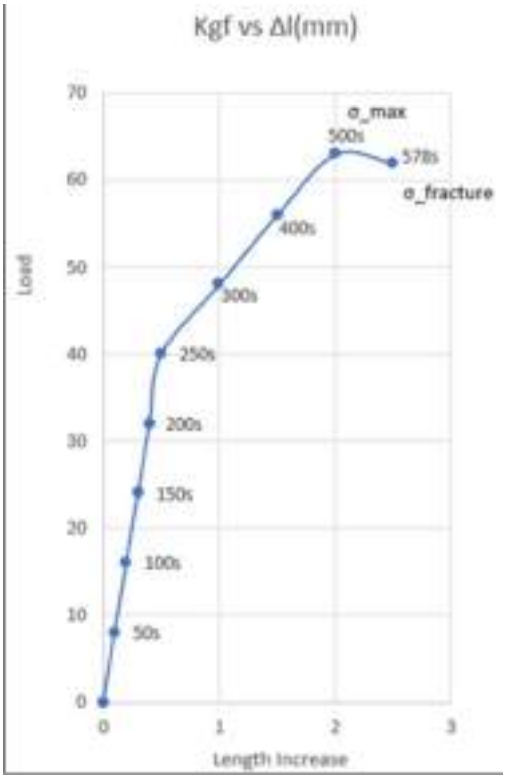
Appendix L. Processing of tensile test samples of 3 WH stems twisted

F (Newton)	Δl (mm)	Time per Second
0	0	0
1000	0,1	50
2000	0,2	100
3000	0,3	150
4000	0,4	200
5000	0,5	250
6000	1	300
6500	2	400
7000	3	500
6900	3,5	578

Explanation:.
F(N): Load.
Δl (mm): Elongation.

Then, after processing the tensile test sample of 3 WH stems twisted, the resulting graph is shown in Appendix M. .

Appendix M. Tensile test graph for three WH stems



Data availability

No data was used for the research described in the article.

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