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The fabrication of wood alternative material from cassava rhizome and cassava peel pulp

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ABSTRACT

The increasing demand for wood alternative material in construction and furniture. Corresponds to global efforts to reduce pressure on forests, necessitating the exploration of alternative materials to wood. The agricultural industry can not only supply raw materials from non-wood plants but also waste material and byproducts. The aim of this research was to explore and manufacture wood alternatives using cassava rhizomes and cassava peels, thereby valorizing agricultural waste. The research methodology involved blending milled rhizomes and cassava peels with urea-formaldehyde resin followed by a hot-pressing process to form the final product. The samples size for this study was 450x450x10 mm were made using 6-10 percent urea-formaldehyde resin by weight of the composite materials aiming to achieve a sheet density about 600 kg/cu-m. Three distinct ratios of Cassava rhizome to cassava peel pulp were examined as potential wood substitutes. All test results of sample were compared with the industrial standards outlined in Thai Industrial Standard. The study found that wood substitutes created from Cassava rhizome and Cassava peel pulp combined with urea-formaldehyde resin could meet the set standards. Cassava rhizome improves important properties like density, moisture content, thickness swelling, formaldehyde content, modulus of rupture, and modulus of elasticity according to TIS 876-2547 standards. However, adding peel pulp tends to reduce these qualities. There is no significant change in the density of the wood-alternative materials. However, a 10% urea formaldehyde content improves the mechanical properties. The study found that wood substitutes created from Cassava rhizome and Cassava peel pulp combined with urea-formaldehyde resin could meet the set standards. Moreover, the production cost of these wood substitute materials was lower than the prevailing market prices. This study disseminates knowledge from research that utilizes cassava rhizomes and peels to create sheet like wood substitute materials. Using modern methods and appropriate technologies, cassava rhizomes and peels can be transformed into a diverse range of wood substitute products, and capable of effectively competing with wood and other materials in the future.

Keywords: Cassava rhizome, Cassava peel pulp, Wood-alternative material

INTRODUCTION

The demand for wood panels in buildings and furniture increases and with global concerns over forest conservation, so worldwide need to find different materials that can replace wood [1-3, 5-7]. This aligns with a growing need for living space, driving the demand for building and furniture materials [2]. With increasing global demand for environmentally friendly products, forests are under significant pressure as they are a primary source of renewable materials [3]. Agricultural waste materials have the potential to be recycled into practical natural wood substitutes which can help generate income and employment opportunities within the local community through the production of these materials [4]. However, they generally possess a lower density compared to wood [5]. This offers the advantage of producing low-density composites. Therefore, the use of alternative materials in panel manufacturing is only feasible to a certain extent in conjunction with wood. Alternatively, greater quantities of adhesives are necessary to achieve the desired mechanical strength level of the panels [1]. Urea-formaldehyde (UF) resin is widely used as an adhesive in the manufacture of wood-alternative materials due to its excellent bonding performance and cost-effectiveness. Products like particleboard, medium-density fiberboard (MDF), and hardwood plywood are commonly fabricated with

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UF resin as a binder, providing them with significant mechanical strength and durability [6]. The ratio of urea to formaldehyde in UF resins significantly impacts the performance and properties of wood alternative products. A balanced ratio optimizes the adhesive's durability, water resistance, and mechanical strength while simultaneously minimizing formaldehyde emissions [7].

Cassava, or *Manihot esculenta*, thrives in tropical and subtropical regions and is cultivated for its starchy root known as the cassava rhizome. Rich in starch and carbohydrates, it serves as a crucial food source for millions globally [8]. The "Cassava peel pulp" is the waste left after peeling and processing the cassava root for human or industrial use. It consists of cassava peels and leftover root parts and is known for its high fiber and carbohydrate content. Traditionally, people have used it as animal feed because it is nutritious [9]. Researchers have recently uncovered new potential uses for cassava, including biofuel production and as a raw material for eco-friendly, wood-alternative products. These discoveries show how important it is to use all parts of the cassava plant, turning waste into valuable materials that can help with sustainable development and protect the environment. Cassava, scientifically known as *Manihot esculenta*, holds a crucial role in Thailand's agriculture. Thailand is the world's largest exporter of cassava products, making a significant impact on the global cassava market [10]. The main processing of cassava revolves around its rhizome, or root, which is rich in starch. This starch finds wide applications in various industries, including food, feed, and biofuel production. Due to extensive cassava processing, Thailand generates a large amount of cassava peel pulp as a byproduct. In the past, these peels were considered waste or used as inexpensive animal feed. However, recently, there is growing recognition of their potential to be transformed into valuable products [11]. By utilizing cassava peel pulp, which is abundant in carbohydrates and fiber, as a raw material for eco-friendly wood substitutes, Thailand aligns with the concept of a circular economy. This approach turns waste into wealth and promotes environmental sustainability [12]. The diverse uses of cassava emphasize the importance of this resource, showcasing the benefits of both economic value addition and waste management in Thailand's cassava industry.

This study is focused on the exploration and fabrication of wood substitute materials from cassava rhizomes and cassava peel pulp, which includes conducting physical and chemical properties tests, studying fiber morphology of samples, physical test and evaluating their mechanical properties. All observed properties are associated with the industry standard TIS 876-2547 [13]. chemical properties. This research is marking the first venture into this specific field of study.

MATERIALS AND METHODS

The use of wood and alternative materials, either alone or blended with wood fibers or chips, in panel production has been widely researched over recent decades. These materials have been utilized as raw inputs in fiberboard or particleboard manufacturing, often combined with different adhesives in varying quantities. Panels produced from these combinations were assessed based on their mechanical and physical properties, including internal bond strength, modulus of elasticity, modulus of rupture, thickness swelling, and water absorption.

Figure 1 Characteristics of wood substitute materials from rhizomes and cassava peel.

Table 1 The symbols representing the samples tested.

Sample symbol	Cassava rhizome (%)	Cassava peel (%)	Urea formaldehyde (%)
R1P0-6	100	0	6
R1P0-8	100	0	8
R1P0-10	100	0	10
R0P1-6	0	100	6
R0P1-8	0	100	8
R0P1-10	0	100	10
R6P4-6	60	40	6
R6P4-8	60	40	8
R6P4-10	60	40	10

Note: R= Cassava rhizome, P = Cassava peel

In research on the development of substitutes for natural wood from waste materials in casava fields, there is a study of the types and quantities of adhesives as well as the conditions required to produce wood substitute materials. Test methods are available for evaluating chemical properties, fiber morphology, and enlarged images of cassava rhizomes and peels. Additionally, the produced wood-based panels are tested for density, moisture content, thickness swelling, modulus of rupture, and modulus of elasticity. It was tested according to the industrial standard TIS 876-2547 as well as studying the economic cost of forming sheets using urea formaldehyde in the amounts of 6, 8, and 10% as the adhesive. The fibers from cassava rhizome and cassava pulp were evaluated for their

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morphological characteristics following established standards. Fiber length was measured using the ISO 16065-1 standard, while the coarseness of the fibers was determined using the ISO 23713 standard. The produced sheet has a size of 450x450x10 mm, and the specified sheet density is 600 kg/cu-m. It was tested for chemical, physical, and mechanical properties according to the industrial standard TIS 876-2547. The preliminary molding experiments results showed that using cassava stock at concentrations below 60% hinders the proper formation of the workpiece. This is likely due to the lack of sufficient bonding, which affects the material's stability and cohesion. The wood substitute used in the study had 3 mixing ratios: cassava stock: cassava peel 100: 0, 0: 100, and 60: 40. Properties of substitute materials derived from rhizomes and cassava peels used as wood alternatives as to shown in Figure 1. Table 1 displays the symbols representing the samples that were utilized for testing and discussion.

RESULTS AND DISCUSSION

This research is a study of the development of substitutes for natural wood from waste materials in casava fields. The wood substitute materials were used to study the physical and mechanical properties, as well as the economic costs. The research results can be summarized as follows:

Chemical properties test results

The results of the study on chemical properties and fiber size of cassava rhizomes and cassava peels. The study delved into the compositional characteristics of cassava by examining samples of waste material sourced from cassava fields, including both rhizomes and peels.

These samples were dried at 105°C for 24 hours to assess their chemical properties, specifically the cellulose and lignin content. Following the drying process, they were finely ground and the cellulose and lignin were extracted using the detergent method. Several studies have investigated using cassava waste like rhizomes and peels to extract cellulose and nanocellulose.

Widiarto et al. extracted these from cassava peels, resulting in nanofibers with unique properties [14]. Pasquini et al. extracted cellulose whiskers from cassava bagasse a byproduct of cassava starch production using them to reinforce natural rubber [15]. These studies show the potential of cassava waste for making cellulose and nanocellulose useful in various industries. Table 2 presents the results of the chemical property tests conducted on rhizomes and cassava peels.

Table 2 Test results of chemical properties of rhizomes and cassava peels.

Chemical Properties		Testing method	Cassava rhizome	Cassava peels
- Chemical Properties	% as received	[16]	5.63	3.69
- Ash content	% as pulp	[17]	24.28	16.35
- Acid-insoluble Lignin	% as pulp	[18]	56.80	35.01
- Holocellulose	% as pulp	[19]	24.56	11.23

The results of the chemical composition of cassava rhizome and cassava pulp showed that the cassava rhizome contained 5.63% of ash while the cassava pulp contained 3.69% of ash. Cassava rhizomes contained 24.28% of acid-insoluble lignin, while cassava pulp contained 16.35% of acid-insoluble lignin. Cassava rhizomes contained 56.80% holocellulose, while cassava pulp contained 35.01% holocellulose. Cassava rhizomes contained 24.56% of cellulose, while cassava pulp contained 11.23% of cellulose.

In conclusion, cassava is a plant that has high holocellulose, cellulose, and lignin contents suitable for hot pressing processing due to the amount of the above 3 substances mixed with the filler (binder). It will make the wood panels have the strength to hold together in sheets suitable for forming synthetic wood sheets used in the general market.

Table 3 Fiber morphology test results of cassava rhizome and cassava peel samples.

Pulp properties	Unit	Testing method	Cassava rhizome	Cassava peels
Pulp yield (Soda pulp AA20% H-factor 1300)	% as received	-	27.79	13.68
Pulp Reject	% as receive	-	1.816	0.003
Length-weighted Fiber Length	mm	[20]	0.659	0.496
Fines	% as pulp	[20]	44.90	73.60
Fiber width	µm	[20]	35.25	35.15
Fiber coarseness	Mg/m	[21]	0.133	0.701

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Fiber morphology test results of cassava rhizome and cassava peel samples

The fibers from cassava rhizome and cassava pulp were analyzed for fiber morphology, utilizing specific standards. The ISO 16065-1 standard was employed to measure fiber length [20], while the ISO 23713 standard was used to gauge the coarseness of the fiber length [21]. Table 3 exposed test results reveal the fibrous morphology of samples derived from cassava rhizomes and cassava peels.

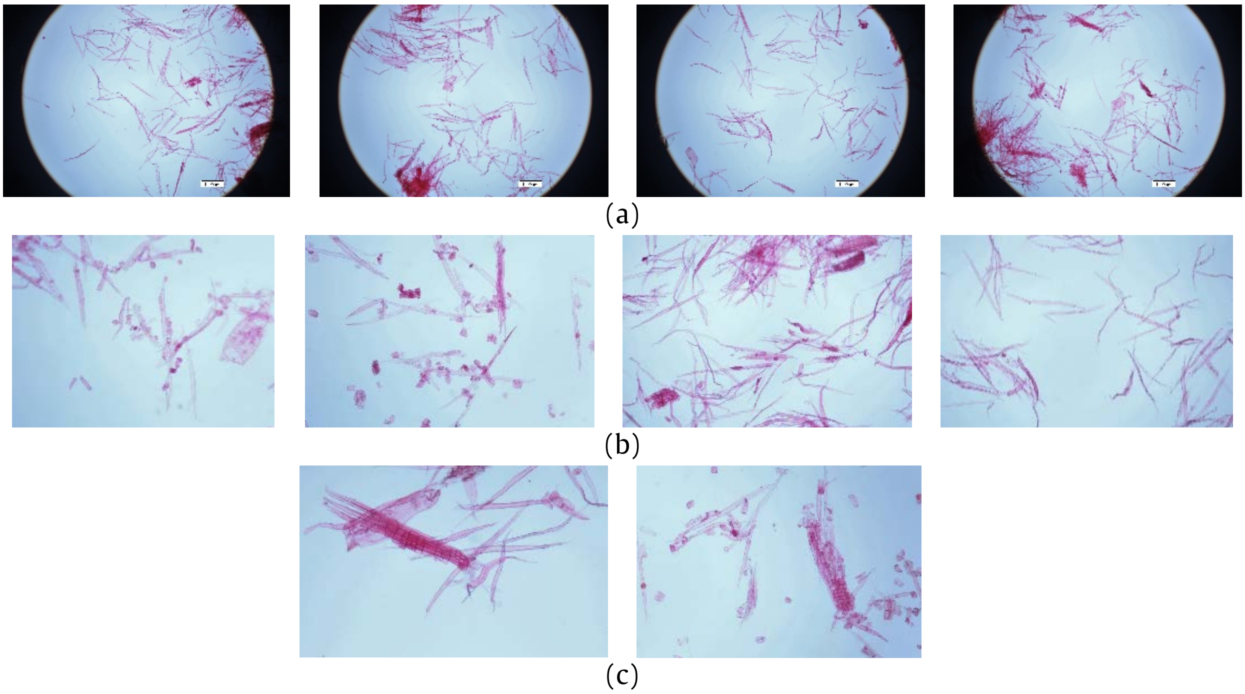

Figure 2 Enlarged images of cassava rhizome pulp: (a) at 4x magnification, (b) at 10x magnification, (c) at 20x magnification.

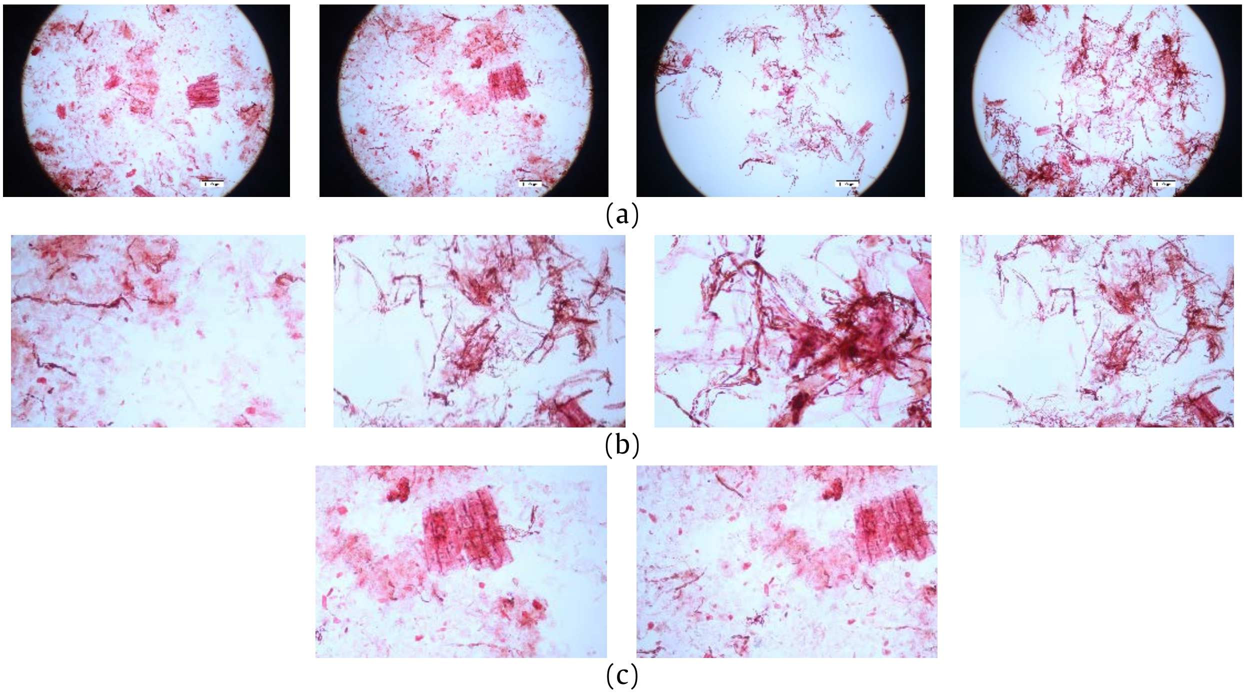

Figure 3 Enlarged images of cassava peel pulp: (a) at 4x magnification, (b) at 10x magnification, (c) at 20x magnification.

Based on analysis with ISO 16065-1, which is a standard for measuring fiber length found that cassava rhizome contained fiber length at 0.659 mm, while cassava peel contained fiber length at 0.496 mm. The analysis of ISO16065-1, which is a standard for measuring fiber length found that the fines of cassava rhizome have 44.90%, while the fines of cassava peel have 73.60%.

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The analysis of ISO 16065-1, which is a standard for measuring fiber length found that fiber width of cassava rhizome is at 35.25 µm, while fiber width of cassava peel is at 35.15 µm. The analysis of ISO 23713 which is the length measurement of fiber coarseness found that fiber coarseness of cassava rhizome weighs 0.133 mg/m, while fiber coarseness of cassava peel weighs 0.701 mg/m. Figure 2 illustrates cassava rhizome pulp, and Figure 3 demonstrates the pulp of cassava peel in magnifications of 4, 10, and 20 times.

Physical test results

The produced wood-based panels were tested for physical properties in terms of density, moisture content and thickness swelling in accordance with the standard of flat pressed particleboard industry TIS 876-2547.

Density test results

The density of a fabricated wood-alternative material refers to its mass per unit volume. These materials are often designed to mimic the appearance and function of wood but may be composed of various substances like plastics, resins, recycled wood fibers, and other additives. The density of these materials can vary widely depending on their composition and the manufacturing process used. The key points related to the density of wood-alternative materials are composition, manufacturing process and application-specific.

In this study, the density test at moisture content between 6-9% for a sample size 450x450x10 mm, which is the proportion of mass with moisture to the volume of specimen at moisture content. The samples are first weighed, and their thickness is measured at the diagonal intersection point. Measurements of b1 and b2 are taken at two points parallel to the sample's edge, along lines passing through the center of opposing edges. Density is then calculated using Equation (1):

$$\rho = \frac{m}{b1 \cdot b2 \cdot t} \tag{1}$$

where

ρ = density (kg/m^2)
m = mass (kg)
t = thickness (m)
$b1$ and $b2$ = dimension of edges (m)

The adhesive content can pass the specified standard value, which is the density value of 400-900 kg/cu-m because the property of cassava rhizome and cassava peel can absorb water well according to the standard criteria as shown in Figure 4.

Moisture content test results

Moisture content (MC) of wood refers to the amount of water present in the wood, expressed as a percentage of the weight of the oven-dry wood.

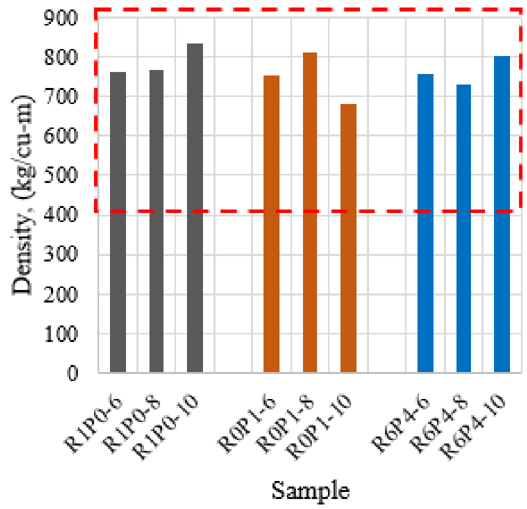

Figure 4 Test results pertaining to the densities of the three distinct sample groups.

It is a critical parameter in many aspects of wood science, processing, and utilization because the physical and mechanical properties of wood can change significantly with variations in moisture content. The moisture content test measures the weight of moisture in the sample dimensions 450x450x10 mm relative to its dry weight. This contains baking the sample in an oven at 103 ± 2°C for 24 hours. The moisture ratio is calculated using Equation 2.

$$w = ((m_v - m_s) / m_s) \times 100 \tag{2}$$

where

w = moisture content (%)
m_s = dry mass (g)
m_v = humid mass (g)

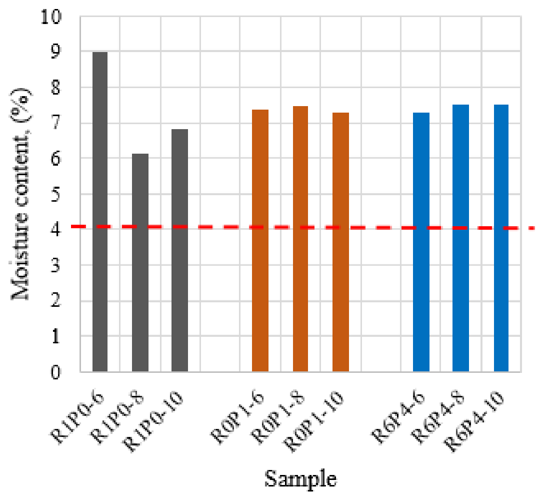

Figure 5 Moisture content between the quantity of adhesive in each ratio.

Figure 5 shown the wood substitute materials from cassava rhizome and cassava peel, all ratios pass the standard criteria, which has a moisture content value between 4 -1 3%. It was found that the ratio of cassava rhizome: cassava peel, R1P0-6 (100:0, UF 6%),

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has a highest moisture content, and the ratio of cassava rhizome: cassava peel, R1P0-8 (100:00, UF 8%) has a lowest moisture content. It can be determined that every component of wood-based panels from cassava rhizome and cassava peel, when physically tested, it was found that it was in the standard criteria.

Thickness Swelling test results

Thickness Swelling (TS) refers to the increase in thickness of a material when it absorbs moisture. This term is often associated with wood-based materials, such as particleboard, fiberboard, and plywood, but can also apply to other porous materials.

When these materials come into contact with water or high humidity, they can absorb the moisture, causing the individual fibers or particles to expand. This results in an increase in the thickness of the material, known as thickness swelling. Thickness swelling can be a concern in construction and manufacturing, as it may lead to changes in the dimensions and properties of the material. It may cause warping, deformation, and loss of mechanical strength, potentially affecting the functionality and appearance of the product. In this study, the Thickness Swelling test was conducted on an average of 5 samples, which were submerged in clean water with pH 7 ±1, at a temperature of 20 ±1 °C and must remain submerged in 25 ±5 mm of water for 24 hours. The percentage of thickness swelling was determined using Equation 3:

$$G_t = \frac{(t2 - t1)}{t1}\ 100 \tag{3}$$

where

G_t = thickness swelling 24h (%)
$t1$ = initial thickness (mm)
$t2$ = final thickness after 24h (mm)

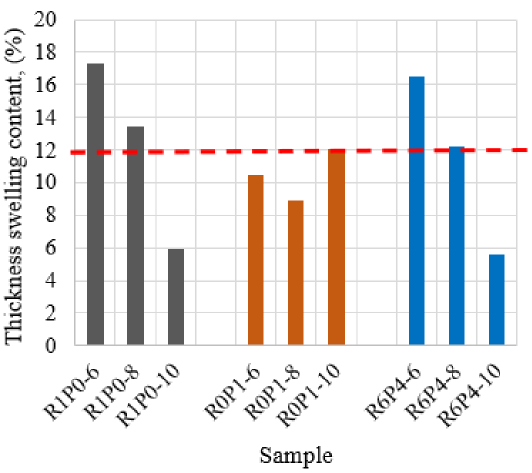

Figure 6 Thickness swelling result between the amount of adhesive in each ratio.

The physically of wood-based panels from cassava rhizome and cassava peel in every component found that it passed the standard criteria for 4 components and did not pass the standard criteria for 5 components. Sheets that contain a minimum of 6% urea-formaldehyde E2 have higher properties than sheets that use a large amount of it. High-density test strips had low swelling and moisture content but had high mechanical properties, with 10% urea-formaldehyde E2 adhesive having the highest density as shown in Figure 6. It was found that four formulations met the specified standards: R1P0-10, R1P1-6, R1P1-8, and R6P4-10. Generally, increasing the amount of urea-formaldehyde in the mixture results in reduced swelling.

Mechanical properties test results

The produced wood- based panels were tested for mechanical properties, Modulus of rupture (MOR), Modulus of elasticity (MOE), Tensile strength perpendicular to the surface value, and Formaldehyde content in accordance with the standard of flat pressed particleboard industry TIS 876 -2547.

Modulus of rupture and modulus of elasticity

The Modulus of Rupture is a measure of a material's tensile strength. It represents the maximum stress that a material can withstand before failure in bending. The Modulus of Elasticity, also known as Young's Modulus, describes how a material deforms under stress. It's a measure of the material's stiffness in the elastic region (i.e., the range where deformation is reversible). MOR is related to the material's strength, specifically its resistance to bending until failure. MOE, on the other hand, is related to the material's stiffness and its ability to resist deformation within the elastic range.

In static bending tests for determining modulus of elasticity (MOE) and modulus of rupture (MOR), rectangular samples with a width (b) of 50 ± 1 mm are utilized. The length (l_1) equals 20 times the nominal thickness plus 50 mm. Specimens are conditioned until reaching a constant weight at a relative moisture of (65 ± 5) % and a temperature of 20 ± 2 °C. Constant weight is attained when two consecutive weighing, separated by at least 24 hours, show a difference of no more than 0.1% from the initial sample weight.

Modulus of elasticity in bending strength (MOE) is then computed using Equation 4, with the mean value derived from samples taken from the same panel.

$$\text{MOE} = ((l_1^3 \cdot (F2 - F1))/(4 \cdot b \cdot t^3 \cdot (a2 - a1)) \tag{4}$$

l_1 = distance between the support centers (mm);
b = sample width (mm)
t = sample thickness (mm)
$F2 - F1$ = force increase, Newton, in the rectilinear section of the force-arrow curve,

where F1 should be about 10% and F2 about 40% of the rupture force;
$a2 - a1$ = increase of corresponding arrow $F2 - F1$.

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The MOR value of each sample, given in N/mm², is calculated by Equation 5. Each set of samples taken from the same panel gives the mean value to MOR:

$$MOR = (3 \cdot F_{max} \cdot l_1)/(2 \cdot b \cdot t^2) \quad (5)$$

F_{max} = Rupture force (N)
l_1 = distance between support centers (mm)
b = sample width (mm)
t = sample thickness (mm)

Figure 7 illustrates the variation in Modulus of Rupture and Modulus of Elasticity of a sample with different urea formaldehyde content levels. The black curve represents the sample containing pure cassava rhizome, the red curve illustrates the sample containing pure cassava peel, and the blue curve depicts a mixture of 6 parts cassava rhizome to 4 parts cassava peel. The sample with pure cassava rhizome exhibited the highest MOR and MOE values, in contrast to the sample containing pure Cassava peel, which had the lowest values. Cassava rhizome used as a pure material with 10% urea formaldehyde is the only ingredient that meets the criteria specified in TIS 876-2547.

The modulus of rupture and modulus of elasticity are higher when cassava rhizome is the primary ingredient. In contrast, using cassava peel as a composite material yields lower test results.

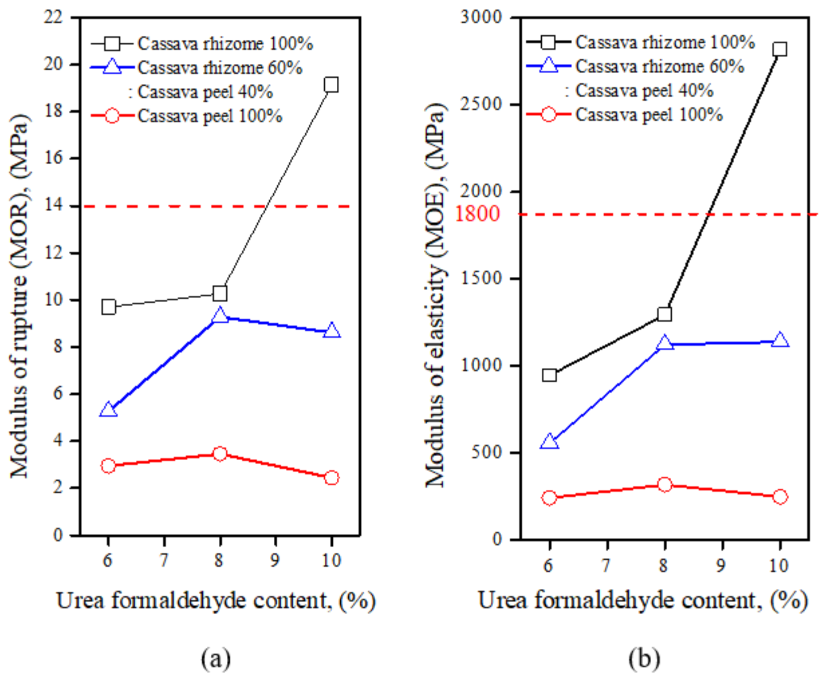

Figure 7 The sample with different urea formaldehyde content levels: (a) Variation in Modulus of Rupture (MOR), (b) Modulus of Elasticity (MOE).

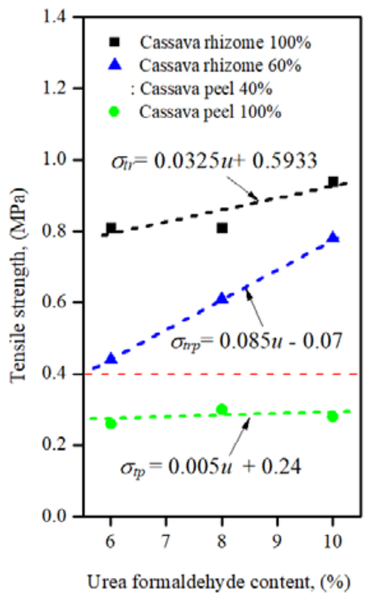

Figure 8 Tensile strength of samples varied in relation to urea formaldehyde content.

Tensile strength test results

The dumbbell-shaped specimens were prepared following ASTM D3500 [22] standards, with dimensions set at a length of 400 mm, a width of 48 mm, and a narrowed middle section width of 25 mm to ensure typical tensile failure mode occurrence.

Tensile strength and urea-formaldehyde (UF) content are vital factors in the fabrication of wood-alternative materials. Tensile strength refers to the ability of the material to withstand pulling or stretching forces without breaking. UF resin is a common adhesive used in the production of wood-alternative products like particleboard and medium-density fiberboard (MDF). Urea-formaldehyde resin offers strong bonding properties, making it suitable for binding wood fibers and other lignocellulosic materials together.

Figure 8 exposed the tensile strength of the samples varied in correlation with the urea-formaldehyde content. The fabrication of wood-alternative materials

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utilizing pure cassava rhizome resulted in the highest tensile strength. This was followed by a mixture comprising 6 parts cassava rhizomes to 4 parts cassava peel, with pure cassava peel exhibiting the lowest tensile strength among the tested compositions. The research findings align with studies on agricultural materials combined with formaldehyde [23 -25].

The tensile strength of wood-alternative materials fabricated from cassava rhizome and cassava peel is determined by Equations 6 to 8:

$$\sigma_{tr} = 0.0325u + 0.5933 \quad (6)$$
$$\sigma_{trp} = 0.085u - 0.07 \quad (7)$$
$$\sigma_{tp} = 0.005u + 0.24 \quad (8)$$

where

σ_{tr} is tensile strength of materials from pure cassava rhizome.

σ_{trp} is tensile strength of materials from a mixture comprising 6 parts cassava rhizomes to 4 parts cassava peel.

σ_{tp} is tensile strength from pure cassava peel.

u is urea formaldehyde content ($6\% \leq u \geq 10\%$)

Table 4 Formaldehyde content test results.

Property	Unit	Testing Result
Formaldehyde Emission (After corrective 6.5%MC.)	Mg/100g ODB	15.76

Table 5 Criteria and methods formaldehyde quantity.

Quality level	Criteria	Methods
1	Not over 8 mg/100g	[26]
	Not over 0.5 mg/1 (E0)	[27]
	Over 0.5 mg/1 - 1.5g/1 (E1)	[27]
2	Over 8 mg/100 g - 30 mg/100 g	[26]
	Over 1.5 mg/1 - 5.0 mg/1 (E2)	[27]

Note: E0 E1 E2 means Formaldehyde Emission quantity
Source: The industrial standard TIS. 876-2547

Formaldehyde content test results

In this research, the sheet material was tested for formaldehyde content by using 10% of urea-formaldehyde E2 at a sheet thickness of 10 mm and a specified density of 600 kg/cu-m in accordance with the standard of flat pressed. The formaldehyde content test generated a result of 15.76 mg/100g, as presented in Table 4. The testing method for formaldehyde content used in this research is outlined in Table 5. When compared with criteria and formaldehyde content test method by using the Perforator by BS EN 120 found that wood-based panels at the ratio of cassava rhizome: cassava peel R1P0-10 had met the standard of flat pressed particleboard industry TIS 876 -2547. The test result showed that the formaldehyde content of wood-based panels at the ratio of cassava rhizomes: cassava peel R1P0-10 is in the 2nd quality level with a criteria of formaldehyde content which is over 8 mg/100 g to 30 mg/100 g using Perforator by BS EN 120.

Results of studies on economic costs

Based on the cost estimate from an economic analysis of the production of wood- based panels from cassava rhizome and cassava peel the ratio of cassava rhizome: cassava peel as 100:0, UF 10% which is a mixture ratio that meets physical and mechanical properties according to industrial standard. The economic cost analysis consists of the cost of tools and equipment, chemicals and raw materials, electricity, labor and other materials used in the production of wood-based panels from cassava rhizome and cassava peel with a width of 450 mm, a length of 450 mm and a thickness of 10 mm. The total cost of producing wood-based panels of this study concluded that wood-based panels from cassava rhizome and cassava peel using urea formaldehyde is 42.68 baht/sheet, which was lower than the market price when compared to the price of construction materials.

Table 6 Cost of manufacturing tools and equipment for Cassava Rhizome and Peel Pulp Wood-Alternative Material.

Manufacturing tools and equipment	Price (Thai baht)
1. Hydraulic hot press equipment	85,000
2. Hot press assembly machinery set	30,000
3. Biomass shredding device	45,000
4. Grinder for cassava rhizomes and peels	4,500
5. Equipment for mixing and spraying glue	20,000
6. Circular saw table	15,000
7. Air pump	8,000
8. Balance	4,500
9. Urea-formaldehyde adhesive e2	2,000
10. Other	2,000
Total cost price	216,000

Note: All of the price is the purchasing price in 2022.

Table 6 illustrates that the production cost of wood substitute panels made from cassava rhizomes and bark is significant, involving an initial investment of around 216,000 baht. With a lifespan of 10 years, there are also enduring maintenance expenses amounting to 25,000 baht annually.

CONCLUSION

Agricultural waste materials offer a sustainable alternative for wood-based panel production, as they

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originate from renewable sources and can replace wood chips and fibers partially or entirely. These materials share physical and mechanical properties similar to wood, which facilitates their integration into industrial manufacturing processes for wood panels. Their compatibility with traditional methods provides a practical solution for reducing reliance on wood resources while promoting environmentally friendly practices.

This paper details the fabrication of wood-alternative material using pure cassava rhizome, pure cassava peel pulp, and a blend of cassava rhizome with cassava peel pulp, all bound together with urea formaldehyde. The test results demonstrated that the mixture R1P0-10, consisting solely of cassava rhizome with 10% urea formaldehyde as a binder, successfully met the standards of the TIS 876-2547 test. The characteristics of the sample boards can be summarized as follows.

1. Cassava rhizome contributes to enhancing the desirable properties in accordance with TIS 876-2547, while cassava peel pulp tends to reduce those properties.

2. In the range of 6-10% urea formaldehyde content, there is no noticeable increase or decrease in the sample density of the wood-alternative materials. However, when the urea formaldehyde content reaches 10%, it leads to an enhancement in the mechanical properties of the product. This observation underscores the importance of optimizing the urea formaldehyde concentration to achieve desired structural characteristics in the fabrication of wood-alternative materials.

3. In this study, it was discovered that pure cassava peel is a material that does not enhance tensile strength to meet the standard. Therefore, this material should be discarded prior to the fabrication of artificial wood panels.

Therefore, composites made from cassava rhizome should present a highly competitive alternative to traditional wood-based composites, potentially becoming a significant agricultural product in the future. Cassava rhizome is a wood substitute and an agricultural waste. It has properties similar to natural wood but has not yet been used in industrial applications. Its utilization could help reduce waste and decrease pollution from incineration.

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