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Input-output evaluation of kenaf biomass utilization for upstream supply chain optimization in agroindustry

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ABSTRACT

Hibiscus cannabinus L. emerged as a promising natural fiber crop in Indonesia, offering significant value-added potential across its biomass components—bast, stem core, leaves, and seeds. This study presented a comprehensive value-added analysis along the upstream and midstream supply chain networks of the kenaf agroindustry. The research specifically focused on optimizing the upstream supply chain by evaluating the economic contribution of each biomass component and identifying opportunities for full biomass utilization. The Input-Output method from Indonesia's Central Statistics Agency (BPS) was applied, along with a sensitivity analysis on market pricing scenarios. The results revealed that, for each hectare of cultivation, optimized utilization of kenaf components yielded an added value of IDR31,357,322 in the upstream network and IDR130,309,594 in the midstream traditional textile production. Notably, the incorporation of stem core (KCC and KCP), seed oil, and fermented leaf-based animal feed contributed to a 21.67% increase in upstream added value, alongside a 17.65% rise in farmers' income. These findings demonstrated the potential for upstream supply chain optimization through low-tech, full biomass processing, supported Indonesia's competitiveness as a global kenaf supplier, and highlighted the need for institutional frameworks to enable scale-up and sustainability.

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INTRODUCTION

Kenaf fiber has high economic value (Santoso et al. 2016, 2021) Today, kenaf production in Indonesia is still limited to kenaf bast utilization (Ibrahim et al. 2019, Austin et al. 2024, Ya et al. 2024). In fact, the stem core, seeds, and leaves, when processed, potentially produce value-added products for the kenaf plant. Kenaf consists of stems, leaves, flowers, fruits, and seeds. Kenaf stem is a fiber producer whose use is very wide in the industrial world. Kenaf seeds can be processed into cooking oil, because the fat content is 20% and has unsaturated fatty acid properties (Pramushinta 2016, Nurnasari and Khuluq 2017). This research analyzed the value added from all parts of the kenaf plant, except for roots and flowers.

Derived from *Hibiscus cannabinus L*., kenaf seed oil is rich in triacylglycerols and contains high levels of health-promoting fatty acids, notably oleic and linoleic acid. Its antioxidant, anti-inflammatory, and cholesterol-reducing properties underscore its potential as a functional bioactive compound in nutraceutical and food formulations (Chew and Nyam 2019).

The analysis carried out showed that this approach is feasibly implemented by the upstream and midstream supply chain networks, as the process does not require high-tech machinery. The increasing value of kenaf plants is directly proportional to the increase in performance of the supply chain network in the kenaf fiber agro-industry. Thus, conducting research to analyze the value added of kenaf is essential. Results of this research are expected to contribute to the development of the kenaf fiber agro-industry in Indonesia. In addition, Indonesian kenaf fiber is forecasted to have global competitiveness.

This research aimed to obtain the value added of the kenaf plant (*Hibiscus cannabinus L.*) derived from the bast, stem core, leaves, and seeds. The calculation of value added was carried out using an input-output analysis method used by the Central Statistics Agency ([BPS] Badan Pusat Statistik 2022). This research can be used as an input in the calculation of supply chain performance in the kenaf fiber agroindustry. This research is necessary because the value-added analysis results have indicated that kenaf fiber has the potential to develop (Suparno 2020).

The novelty of this research lies in the fact that no one has conducted research on the added value of all parts of the kenaf plant, except for what has already been studied by the researcher in previous research. Feasibility studies on kenaf have been conducted (Abdelrhman 2022). However, a comprehensive assessment of the value added across all parts of the plant remains unexplored.

This research provides valuable insights into the potential economic, industrial, and policy impacts of utilizing all parts of the kenaf plant. Traditionally, only the bast fibers of kenaf were widely used. Still, this research highlights the untapped opportunities in processing stem core, seeds, and leaves, significantly increasing the overall value-added potential.

Implications of the research on Kenaf Fiber Agro-industry in Indonesia are: (1) Economic Expansion and Resource Optimization: By demonstrating the value added from various kenaf plant components, this research encourages farmers and industries to optimize resource utilization. This can lead to increased revenue streams for stakeholders and a more efficient agro-industrial supply chain. (2) Enhancing Supply Chain Performance: The research identifies how different parts of the kenaf plant contribute to supply chain performance, particularly in upstream and mid-stream industries. These findings provide a foundation for better coordination among stakeholders, ensuring a more sustainable and profitable supply chain. (3) Strengthening Indonesia's Global Competitiveness: Indonesia has the potential to become a major global supplier of kenaf fiber. By expanding the utilization of the plant, industries can increase production efficiency and diversify product offerings, making Indonesian kenaf fiber more competitive in international markets. (4) Sustainability and Industrial Growth: The research considers both conventional and innovative processing methods, highlighting opportunities for sustainable production. This can encourage investment in environmentally friendly processing technologies and reduce waste in the agro-industry sector, and (5) Policy Development and Institutional Support:

The findings emphasize the need for institutional support and policy frameworks to foster the natural fiber industry in Indonesia. The absence of structured institutions for kenaf fiber management presents an opportunity for

government intervention to regulate and facilitate the industry's growth.

METHOD

This research was initiated by identifying business processes and supply chain mechanisms of the kenaf fiber agroindustry. Subsequently, a literature study was carried out in order to determine the most suitable value-added method for the kenaf fiber commodity in its supply chain network. The literature study was conducted by comparing 5 methods, namely BPS input-output analysis, Rucker plan, and Tololiu (Nurhasanah et al. 2020), Hayami (Sundari et al. 2021, Nurhaliza et al. 2024, Saputra et al. 2025), and modified Hayami (Hidayat 2019).

A previous study explored the comparison of input-output variables and their implications within the kenaf fiber supply chain, forming a critical part of the literature review. This comparative analysis provided a foundational understanding of the strengths and limitations of various value-added assessment methods. Among these, the BPS input-output analysis (Nurhasanah et al. 2020, Abdelrhman 2022) was identified as the most suitable approach for evaluating value added in the development of the kenaf fiber agroindustry, particularly in the upstream segment of the supply chain.

Value-added calculation was carried out from raw materials derived from the bast, stem core, leaves, and seeds of the kenaf plant. The framework of this research is presented in Figure 1.

The formulation of value-added in the BPS input-output is presented as follows:

Value Added = Output Value – Input Cost – Indirect Taxes …….…… (1)

Output Value = Produced Products + Industrial Services Received from Other Parties……..……..…….. (2)

Input Cost = Raw and Auxiliary Materials + Fuel, Electricity, and Gas + Land, Machinery, and Equipment Rental + Services Provided by Other Parties + Other Expendit……..…...…. (3)

Primary data were collected from the kenaf fiber agroindustry, including seed suppliers and kenaf crop experts from Balittas. A comprehensive cost analysis was conducted to identify, quantify, and evaluate expenditures related to seeds, fertilizers, labor, machinery operation, and land rental. Furthermore, a sensitivity analysis was performed by introducing variations in the selling price of kenaf fiber. This analysis considered three pricing scenarios—optimistic, moderate, and pessimistic—to assess the potential impact on overall economic feasibility.

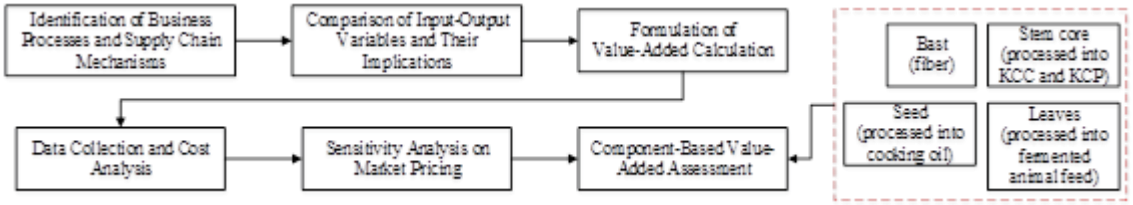


Figure 1 Research Framework

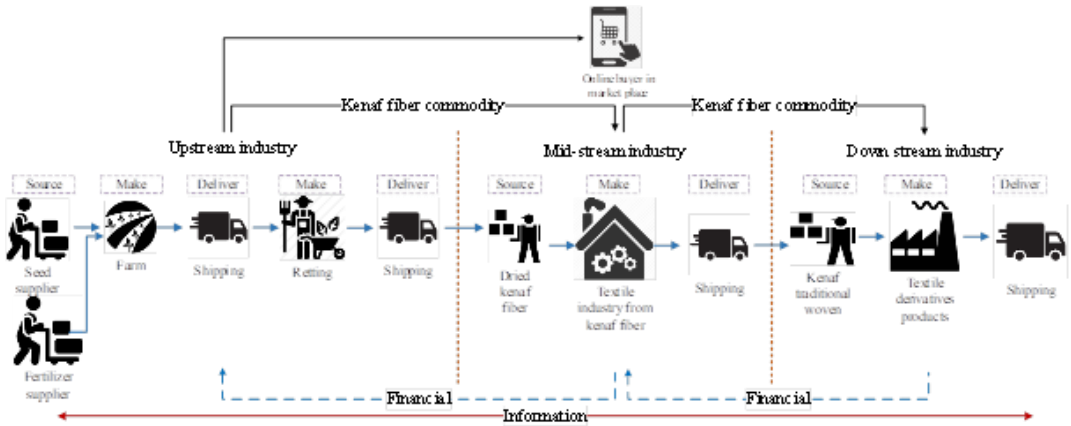


Figure 2 The Supply Chain Network Mechanism

Table 1 Comparison of Input-Output Variables and Their Implications

Comparison of criteria results	Variables	Implications
Input	Raw materials, Fuel and electricity, Land and truck rental, Industrial services provided to other parties, Miscellaneous expenses	These variables can represent the actual costs incurred in the upstream network. These variables detail the expenses for land rental and transport trucks. Similarly, industrial service costs are highly feasible and are therefore considered separate variables. Although labor cost variables appear here, they can be combined with other expense variables.
Output	Produced products, Industrial services, received from other parties, Electricity sold, Stock value difference of semi-finished goods, Other income from non-industrial services	This method includes the five most comprehensive output variables. The electricity sold variable has no value, as this agro-industry does not have surplus electricity for sale. Inventory plays a crucial role in industrial activities, making this method representative for value-added analysis. Additionally, other income from non-industrial services allows by-products, such as kenaf stem core, to serve as an additional revenue source.
BPS Value Added Analysis	Output value, Input cost, Indirect taxes	This analysis considers taxes as a crucial variable in determining value-added, even though the amount included does not become direct income, as it must be remitted to tax authorities. Taxes are a tangible expense that industries must bear; therefore, this method is highly representative for assessing the value-added of kenaf fiber in the upstream, midstream, and downstream supply chain networks of the agro-industry.

RESULT AND DISCUSSION

Business Process and Supply Chain Network Mechanism

The business process of the kenaf fiber agroindustry begins with the cultivation of Hibiscus cannabinus L. within the upstream supply chain network, followed by the harvesting of its biomass components, such as bast, stem core, seeds, and leaves, for further processing. These components are processed using low-tech machinery, enabling local farmers and small-scale industries to participate without requiring advanced equipment or certified operators.

The mechanism that occurs in the supply chain network of the kenaf fiber agroindustry flows from upstream to mid-stream and downstream. The mid-stream and downstream industries have a horizontal collaboration path, while online shoppers in the marketplace are on a vertical collaboration path.

The flow of demand information is carried out regularly on the horizontal collaboration line, while in the vertical collaboration line, orders do not occur regularly and repeatedly, and therefore, the agroindustry has to show adaptive properties in meeting demands from consumers coming from the vertical collaboration line. The supply chain network mechanism is presented in Figure 2.

Comparison of Input-Output Variables and Their Implications

The comparison of value-added analysis results across five methods establishes the BPS input-output value-added analysis as the appropriate identifier for the value added in the upstream supply chain.

The comparison is conducted based on input and output variables and their implications for the value added in the upstream supply chain network, as presented in Table 1.

Variable Cost

Variable cost data processing was carried out on seeds, fertilizer, labor, machine operating, and rental costs. The recapitulation of costs is presented in Table 2.

Table 2 Recapitulation of Costs

No	Description	Cost (IDR)
1	Seed and fertilizer	4.635.000
2	Labor	7.600.000
3	Machine	3.088.865
4	Land and truck lease	7.200.000
	Total	22.523.865

The Value Added of Kenaf Fiber from the Bast

The operational cost used in the value-added analysis of kenaf fiber from the bast was only coming from a ribboner machine (Shambhu et al. 2023). Therefore, the machinery operating cost incurred was IDR980,000.00. This resulted in a total labor cost of IDR7,200,000.00. The total production cost that must be incurred to produce 2500 kg of kenaf fiber from the bast on 1 Ha of land was IDR20,045,636.00, or equivalent to IDR8018.00 per kg of kenaf fiber.

Variations strongly influenced the value-added analysis of kenaf fiber in the selling price of kenaf in marketplaces. Therefore, in this research, sensitivity analysis was carried out on price variations that occurred in the marketplaces. Variations were classified into three price criteria, namely pessimistic, moderate, and optimistic prices. The pessimistic price is the price charged to a large-scale industrial segment of kenaf fiber users, such as PT ABC. In this pessimistic price condition, the sales volume is high despite a low price, as the plant was planted on a land partnership with farmers, covering an area of 3000 Ha. The pessimistic price resulted in IDR 7,000.00 per kg. The sensitivity analysis for the value-added calculation with pessimistic prices is presented in Table 2.

The input calculation in Table 2 did not include the amount of industrial services received (tolling). This was because the upstream industry carried out all of its own production activities without being subcontracted to third parties. Thus, this variable did not affect the input values in the upstream supply chain network.

Similarly, the variable of industrial services did not contribute to the output values in the supply chain network. This condition occurred as the upstream industry currently does not serve other jobs from third parties.

The most critical work stage for producing kenaf fiber was the retting process, since the quality of the kenaf fiber was determined based on the fiber produced. Retting is scientifically defined as the process of degrading the components (non-cellulose) that attach to the fiber, namely pectin, hemicellulose, lignin, and other impurities, without damaging the cellulose fiber.

The retting process (Arini 2020, Chakrabarti et al. 2022, Sheichenko et al. 2024, Mukherjee et al. 2025, Shadhin et al. 2025) currently being carried out is by immersing the kenaf stems into a pond that has been added with urea to facilitate the degradation process. This process is known as conventional retting. The disadvantages of this process include (1) requiring a lot of water and is only possibly carried out in ponds or watersheds; (2) uncontrolled degradation process of plant parts, causing a decrease in fiber quality in several parts; (3) polluting the environment with foul smell, methane (CH_4) emission, and wastewater due to anaerobic processes of microorganisms in the water; and (4) an uncomfortable environment for workers. However, this conventional retting process has several advantages, including (1) high effectiveness, good fiber quality, and (2) an efficient process in ponds or watersheds.

On a laboratory scale, Balittas had developed a kenaf dew retting technology (Santoso et al. 2021). This technology incorporates selective microorganisms to degrade components that bind the fiber, enabling the fiber to be produced at the end of this fermentation process. Microorganisms used include bacteria and fungi.

This process does not require a lot of water for soaking the kenaf stems, but it requires a suitable environment for microorganisms to work properly. Advantages of this process are: (1) utilization of selective microorganisms to degrade pectin, lignin, and hemicellulose; (2) application to potential kenaf development areas without depending on water availability for the retting process, and (3) no environmental pollution. However, this process still has a huge challenge, which requires a long series of research processes in terms of time, facilities, and competence to carry out exploration, isolation, effectiveness testing, formulation, formula testing, and applications in the field.

According to information obtained from interviews with expert researchers at Balittas, the dry retting process technology (Chakrabarti et al. 2022) had been developed on a laboratory scale. The treatment given is spraying the kenaf stems

with microorganisms. This method has the advantage of efficiency in water usage. However, there is also a challenge of obtaining effectiveness in the quality of produced fiber, as it requires an even spraying process to allow the degradation process of non-cellulose components. In addition, this process has not been tested in mass production.

This negative value added indicates that kenaf fiber was not worth selling at a market price of IDR7000 per kg for only a land area of 1 Ha. Therefore, the pessimistic price was only worth selling for the kenaf fiber that was planted at least on an area of 1000 Ha.

A sensitivity analysis for the value-added calculation at moderate prices was set at a market price of IDR10,400.00 per kg. Moderate prices were obtained by averaging pessimistic and optimistic prices and calculating the cost of goods sold. The sensitivity analysis for the value-added calculation at moderate prices is presented in Table 2.

Similar to the conditions of the optimistic price sensitivity analysis, details of the input values did not change. Changes were noticed in the amount of sales with this pricing towards 2500 kg of kenaf fiber yield. The sales obtained by the upstream industry were IDR26,017,494 with a value added of IDR3,370,108. This demonstrated that kenaf fiber still provides good value added when being sold at moderate prices, both for land of 1 to 2 Ha and more than 1000 Ha.

The sensitivity analysis for value-added calculation with an optimistic price was set at a market price of IDR15,000 per kg. Optimistic price is the price charged to the small and medium industry segment, such as the textile industry, in the mid-stream supply chain network studied in the study. In addition, optimistic prices are usually given for research needs on a laboratory scale, as has been done by the Indonesian National Research and Innovation Agency (Afkari et al. 2021, Feborando et al. 2021). In optimistic price conditions, the price was high despite low volume, as kenaf was planted on land in partnership with farmers, covering an area of 1 to 2 Ha. The sensitivity analysis for the value-added calculation with optimistic prices is presented in Table 2.

In Table 2, it can be seen that the detailed input values were the same as the pessimistic price calculation in Table 2. This showed that there was no change that occurred when the price was changed to the optimistic price, because the basis of calculation was still carried out on the basis of 1 Ha of kenaf land.

In the calculation of optimistic price analysis, the same condition occurred for industrial services that were received and provided at pessimistic prices; there was no financial income or expenditure. This was because the upstream industry did not provide services, and had not received services from third parties in the kenaf processing activities in the upstream supply chain network.

In Table 4, it can be seen that the amount of sales achieved at an optimistic price was IDR13,704,364. Sensitivity analysis on the value added with optimistic prices showed a very significant increase in the value added of kenaf fiber in the upstream industry compared to pessimistic prices. Therefore, the optimistic price of IDR15,000 per kg is very feasible for the purchase of kenaf fiber based on an area of 1 to 2 Ha.

Results of the sensitivity analysis on pessimistic, moderate, and optimistic pricing treatments are presented in Table 2. This analysis was conducted to show the changes that occurred and the variables that showed changes.

Table 3 shows that prices strongly influence sales and value added, while inputs were not affected. This shows that the pessimistic price is only suitable for kenaf cultivation on the land above 1000 Ha. Moderate prices can be applied to kenaf cultivation on the land of 1 Ha to infinity, through cultivation on the land of 1000 Ha, while the optimistic price can be applied to kenaf cultivation on the land of 1 to 2 Ha to more than 1000 Ha. If the upstream industry is able to offer optimistic prices to all its buyers, the amount of sales will be very high. The optimistic price is very profitable for the upstream industry if the Grade-A quality fiber can be offered to online buyers.

Value Added of Kenaf Fiber From Stem Core

On every 1 Ha of land producing 10,000 kg of wet kenaf plants, there are plant parts that have value added, other than the bast, for kenaf fiber production. Those are the stems, cores, seeds, and leaves of kenaf. Overall, utilization of the bast counts for 3% of the kenaf biomass, while the remaining 97% is derived from the other three parts mentioned. In the stem, 40% of the bast can be processed into kenaf fiber, while the remaining

60% is the stem core, which can be processed into Kenaf core chip (KCC) and Kenaf core powder (KCP).

Currently, only 40% of the kenaf stem is used to make kenaf fiber. While the stem core, which counts for 60% of fiber after the retting process and in dry conditions, cannot be utilized. Kenaf stem core is best harvested for KCC and KCP at an age of 125 to 130 days. However, the harvest time for kenaf fiber production, KCC, and KCP can be done simultaneously, at a plant age of a maximum of 140 days. This is because the strength of the kenaf fiber decreases if harvested at an age of more than 140 days.

In Jabung Village, Laren, Lamongan, the dried stem core is sold as firewood at a price of IDR500 per bunch. One bunch is equivalent to 50 sticks of dry kenaf. If it is estimated that 250,000 kenaf plants are harvested, then 5000 bunches are obtained, and the amount of sales is 2.5 million rupiah for every 1 Ha of kenaf land.

Therefore, this research analyzed the value added of the kenaf stem core if it was processed into KCC and KCP. KCC in the form of pellets can be used by industrial users in the mid-stream supply chain network as an absorbent. A granular absorbent is used in the oil and mining industries because of its ability to absorb oil and other organics from oil spill areas on land and water. This product is sold in the online market for USD 36 or equivalent to IDR 521,460.00 per bag with a weight of 20 lbs. equal to 9.07 kg. In addition, KCC can be used by the mid-stream industry as pet litter for its ability to absorb odors naturally.

KCP in powder form can be used by industrial users in mid-stream supply chain networks as pet bedding or a horse riding mat. In addition, it can be used as a filler for the head protection of two-wheeled motorists or bicycles (Ardani 2013).

The weight of the stem core, as mentioned, was 60% of the total dry stem of kenaf, and therefore, it was estimated to be 3750 kg. The value-added analysis calculation of dry stem core processing was divided into KCC and KCP, resulting in a production yield of 1875 kg each. The selling price of KCC and KCP was IDR14,000 per kg.

Processing of dry stem core into these two products required a chopper machine to chop, and a crusher machine to grind the dry stem core into powder form. Points 1 to 4 did not change, as in Table 2. However, the amount for total expenditure increased at point 5. This was due to the additional employment of the two machines mentioned above and the cost of machine operators.

Table 3 The Sensitivity Analysis Value Added by Pessimistic, Moderate, and Optimistic Values

No	Description	Pessimistic Value (IDR)	Moderate Value (IDR)	Optimistic Value (IDR)
	Input:	20.045.636	20.045.636	20.045.636
1	Seed	1.085.000	1.085.000	1.085.000
2	Gasoline and electric	430.636	430.636	430.636
3	Land and truck lease	7.200.000	7.200.000	7.200.000
4	*Makloon*	-	-	-
5	Other expenses:	14.990.742	14.990.742	14.990.742
	- Kenaf farmer labor	3.200.000	3.200.000	3.200.000
	- Operational cost	3.550.000	3.550.000	3.550.000
	- Retting farmer labor and *ribboner* machine operator cost	3.600.000	3.600.000	3.600.000
	- Machine operational cost	979.999	979.999	979.999
	Output:	17.500.000	37.500.000	37.500.000
6	Products	17.500.000	37.500.000	37.500.000
7	Industrial services	-	-	-
	Value added:	-4.295.636	3.370.108	13.704.364
8	Output value	20.045.636	26.017.494	37.500.000
9	Input cost	20.045.636	20.045.636	20.045.636
10	Indirect tax	1.750.000	2.601.749	3.750.000

The stem core processing into these two products must go through a retting stage. This aims to separate the bast from the stem in order to obtain the stem core. After being separated from the skin, the stem core was dried in the sun for about 2 days. The dried stem core was then cut to produce KCC and ground to produce KCP.

Value-added calculation of the kenaf stem core resulted in IDR24,561,316, obtained from the difference between output costs of IDR52,795,351, input costs of IDR22,954,500, and indirect taxes of IDR5,279,535. The value added obtained was greater when compared to the production of kenaf fiber from the bast, following the greater amount of biomass produced, 60% from dry stems. Therefore, this has demonstrated that the amount of production significantly affects the value added.

Value Added of Kenaf Seeds

Kenaf seeds contain essential fatty acids, the highest of which is oleic acid, accounting for 44.73% of the KR 9 seed variety and 43.01% of the KR 14 seed variety. Subsequently, linoleic acid content counts for 42.19% of the KR seed variety 12 (Nurnasari and Nurindah 2020).

The value-added analysis of kenaf seeds was carried out based on their processing into cooking oil. This was in line with information obtained from the Balittas official website (www.balitas.litbang.pertanian.go.id). On this page, it is stated that kenaf seeds contain 20% fat, which is good for processing into cooking oil due to their saturated fatty acid contents, namely oleic and linoleic acids.

Analysis of the value added of kenaf seeds to cooking oil was assumed to be similar to that of sunflower seeds. This was because sunflower seeds have total fats and unsaturated fat composition that almost resembles kenaf seeds. Research on sunflower oil processing reported that sunflower seeds have an oil content of 23%–45%, with a composition of 44%–72% linoleic acid and 11.7% oleic acid (Pramushinta 2016).

The price of seeds is lower than the price of seeds for processing kenaf fiber. This occurs as they are different seed varieties. Seed varieties used to produce kenaf fiber must be better, with a minimum price of IDR45,000 per kg, while those used to produce kenaf seeds are sufficient to use a variety at IDR30,000 per kg.

In the processing of kenaf seeds, transportation costs can be eliminated because there is no fiber processing that requires the agro-industry to transfer the harvest. Producing kenaf seeds can be done in kenaf fields. The selling price of kenaf seed oil was assumed to be the same as that of sunflower seed oil, which was around IDR56,770 per liter. Therefore, the amount of sales was IDR18,254,734 with input costs of IDR13,941,543, resulting in a value added of IDR2,487,718.

Value Added of Kenaf Leaves

Kenaf leaves contain 24% crude protein, which is suitable for animal and ruminant feed (Santoso et al. 2021). Ruminants are mammals that eat vegetation, for example, cows, sheep, goats, buffalo, and the like. Leaves for animal feed are best harvested at the age of 90 days, because of their high protein content.

Animal feed production using leaves at the age of 90 days cannot be grown from kenaf plants intended for kenaf fiber production or KCC and KCP. Therefore, if the production of animal feed from kenaf leaves is harvested on one land in order to obtain fiber from the stems, the raw material used for animal feed is dried leaves. Processing of dried leaves into animal feed is conducted through fermentation, which aims to preserve animal feed, enabling it to be used during the dry season, when leaves for animal feed are difficult to find. In addition to fermentation, dried kenaf leaves can also be ground with rice bran to be processed into animal feed. In this research, the step of kenaf leaves processing into animal feed was performed through a fermentation process.

From interviews with researchers at Balittas, it is known that kenaf leaves produced from planting 1 Ha of land are around 8 to 10 tons. The agro-industry reported that the dried leaves were sold at IDR500 per kg. If ASK succeeds in selling these dried leaves to the animal feed industry, the proceeds of the sale will be 5 million rupiah.

The value added of kenaf leaves was calculated into the cultivation costs of kenaf plants based on the sales ratio for a basis of 1 Ha of kenaf land, as the leaves were obtained from the cultivation of the kenaf plant. It is known that the sales ratio of kenaf fiber from the bast was 82.18%, while the sales ratio of the leaves was 17.82%. Based on the determination of the sales ratio, the value added of kenaf leaves was obtained at IDR936,288.

Value Added of Kenaf In The Mid-Stream Industry

The value added in this network was calculated at IDR130,309,594. This amount was obtained based on a 2500 kg purchase of kenaf fiber at IDR37,500,000. In this network, the production was not carried out in-house, but it was outsourced to a housewife community in Pekalongan with a total cost of IDR18,840,580.

The cost of *makloon* was calculated based on the number of woven fabrics that have been successfully woven, as many as 1449 pieces of cloth. Each cloth is 1.73 square meters in area, which is 1.5 meters in length and 1.15 meters in width. Each sheet of cloth was equivalent to 1 kg of kenaf fiber, which was valued at IDR150,000 per piece of cloth. Therefore, 1449 sheets of cloth can be produced from 4000 kg of kenaf fiber.

This *makloon* work was conducted on a wholesale basis by a housewife community in Pekalongan. The wholesale work is done per 10 meters of fabric, which can produce 3 to 5 woven fabrics. In the value-added analysis, it was assumed that 5 sheets of woven fabrics can be optimally produced. Therefore, a wholesale amount of IDR65,000 for every 10 meters of fabric was obtained, resulting in the total wholesale of 290 fabrics at a cost of IDR18,840,580.

A fuel cost was incurred for cooking the woven cloth. The materials used include 5 sacks of wood and shells for 3 times of cooking, purchased at IDR25,000 per sack, resulting in a total fuel cost of IDR875,000.

The recapitulation of the value-added analysis of kenaf fiber in the upstream and mid-stream supply chain networks is presented in Table 4. In this value-added recapitulation, the results of the sensitivity analysis on the selling price of moderate kenaf fiber were used, IDR10,407 per kg. This was because it benefits the upstream agroindustry, even though it is only sold from 1 Ha of harvest yield. This condition is certainly more profitable if there are sales through kenaf cultivation on more than 3000 Ha of land.

The total value added produced by the upstream agroindustry through the value added analysis that has been carried out was IDR31,357,322, based on the calculation basis of 1 Ha of kenaf land with a total harvest of 2500 kg of kenaf. In addition, the value added obtained from the industry using kenaf fiber for the processing of traditional woven fabrics was IDR130,309,594.

Based on the value-added analysis, discussions with expert researchers at Balittas, and field observations, it is possible to produce the above four kenaf plant components in the upstream supply chain network. This is in consideration of the use of simple machine technology, and therefore, there is no need for certified operators. However, it is possible to use operators from the local community workers who are trained to use machines for producing fiber trunks, KCC, KCP, cooking oil, and animal feed.

Kenaf is an annual plant that is planted during the rainy season, between January and February, according to land conditions in Cibiuk, Garut. In addition to cultivating kenaf, farmers plant corn or tomatoes before or after cultivating and harvesting the kenaf crop.

When the land is planted with corn, farmers are able to produce 10 to 14 tons per Ha at a selling price of IDR3900 per kg. If collectors sell all crops, the farmers are able to earn a gross profit of 39 million rupiahs. If the crops are not sold out, they are brought to market.

Table 4 Recapitulation of Value Added Analysis of Kenaf

No	Upstream network		Mid-stream network	
	Description	Value added (IDR)	Description	Value added (IDR)
1	Dried kenaf fiber from the bast	3.370.000	Textile from kenaf fiber	130.309.594
2	KCC and KCP from the steam core	24.561.316		
3	Oil from the seed	2.487.718		
4	Animal feed from leaves	936.288		
	Total	31.357.322	Total	130.309.594

Table 5 The Comparison of The Current Conditions with The Utilization of Value Added

Current Condition			Utilizing Value Added		
No	Item	Value Added (IDR)	No	Item	Value Added (IDR)
1	Core into KCC and KCP	24,561,316	1	Bast into kenaf fiber	3,370,000
			2	Core into KCC and KCP	24,561,316
			3	Seed into cooking oil	2,487,718
			4	Leaves into animal feed	936,288
	Total	24,561,316		Total	31,357,322

When the land is planted with tomatoes, farmers are able to produce 14.36 tons per Ha with a selling price of IDR5000 per kg. If collectors sell all the crops, the farmers are able to get a gross profit of up to IDR71,800,000. Similar to corn harvests, the crops are brought to market when they are not sold out by the collectors.

In terms of the sales per Ha, corn and tomatoes are reported to be higher than that of kenaf. However, kenaf is a plantation crop that is not sold per kg to buyers, but on a contract in the form of a purchase guarantee letter. In this letter, it is stated that all kenaf harvested products are guaranteed to be purchased by the buyer, with the attachment of quality and its selling price. This letter guarantees that all kenaf harvests produced by upstream farmers or industry must be purchased. However, only 40% of kenaf fiber meets Grade-A, while the remaining 60% meets Grade-B and Grade-C.

In addition, due to the seasonal nature of the kenaf plant, the kenaf land in Laren Lamongan employs an intercropping technology, in which kenaf seeds are planted first. When they are 15 weeks old, the corn seeds begin to be planted. In addition to intercropping with corn, farmers plant rice at the end of the kenaf harvest.

The kenaf plant in Laren Lamongan is considered profitable because it is harvested when water inundates the land. When other crops cannot be harvested during flooding, kenaf actually brings benefits if planted on watershed land. Thus, farmers or the upstream industry still earn income by utilizing their land throughout the year.

The comparison of the current conditions in the upstream supply chain network, where only the core stem is utilized as kenaf fiber, results in a profit of IDR24,561,316. Meanwhile, if the bast, core stem, seeds, and leaves are also utilized, the value added that can be leveraged is IDR31,357,322, as shown in Table 5. This indicates an increase in value added within one production cycle in the upstream supply chain network by 21.67%.

Furthermore, planting kenaf remains more profitable for farmers, as all harvests are guaranteed to be marketed. The existence of a digital platform prototype design is expected to help farmers and the upstream industry improve their welfare. In addition, the existence of a digital platform in the future can increase the competitiveness of Indonesia's kenaf fiber at the global level.

However, in order to increase the value added of kenaf plants in the upstream supply chain network, institutions are required to assist the kenaf fiber agroindustry. Currently, there are no institutions for natural fibers [9], in particular, kenaf fiber, managed for the development of the kenaf agroindustry.

This research contributes significantly to the development of the kenaf fiber agro-industry in Indonesia. Traditionally, only the bast fiber of the kenaf plant has been widely utilized. This research highlights the potential value-added opportunities in processing the stem core, seeds, and leaves, paving the way for product diversification and increased revenue for farmers and industries.

By examining the value added across different segments of the supply chain, this research provides insights into optimizing production and improving overall efficiency. A deeper understanding of these processes can lead to better coordination among stakeholders, ultimately strengthening Indonesia’s position as a global supplier of kenaf fiber.

Sustainability and technological innovation are also key aspects of this research. It explores both traditional and modern processing methods, encouraging industries to adopt more environmentally friendly technologies that

enhance production efficiency while reducing waste.

Additionally, the research underscores the need for institutional and policy support to foster the growth of the kenaf fiber industry. The absence of structured institutions for kenaf fiber management presents an opportunity for regulatory improvements that can drive industrial expansion and competitiveness. By addressing these dimensions, the research provides a foundation for innovation, improved farmer welfare, and enhanced competitiveness in the global market.

CONCLUSION

This research highlighted the significant potential for developing the kenaf fiber agroindustry in Indonesia, driven by increased value-added utilization across the supply chain network. By focusing on the upstream supply chain, the study demonstrated how optimizing the use of all kenaf plant components (bast, stem core, seeds, and leaves) can enhance economic performance and supply chain efficiency. The upstream optimization approach, which emphasized full biomass utilization using low-tech processing methods, resulted in a 21.67% increase in value added and a 17.65% rise in farmers' income per hectare. These outcomes underscore the importance of upstream supply chain optimization as a strategic pathway to improve profitability, empower rural communities, and strengthen Indonesia's position as a globally competitive kenaf supplier.

However, the study was limited by the number of upstream industries involved in the performance assessment. Future research should expand the scope by including more upstream actors to further validate and refine the optimization framework.

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