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Sustainability of Palm Sugar Home Industry Management in Rambah District, Rokan Hulu Regency

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Abstract

The palm sugar industry in Rokan Hulu Regency, Indonesia, is a prominent agro-industry operating at a household level and mainly relies on raw palm sap. This study assesses the sustainability of the industry by analyzing its ecological, economic, social, legal/institutional, and technological dimensions. Using Multi-Dimensional Scaling (MDS) and participatory prospective analysis, findings indicate moderate sustainability in all dimensions except for legal/institutional aspects, which require improvement. Practical recommendations focus on institutional support, adoption of agroforestry, digital literacy, and women empowerment to enhance the industry's resilience and adaptability. These recommendations aim to facilitate long-term sustainability by strengthening community involvement and integrating modern technology. The outcomes contribute to broader insights on managing small-scale agro-industries sustainably within rural communities.

Keywords: *Sustainability, Palm Sugar, Home Industry, Agroindustry Management, Rokan Hulu.*

Introduction

Palm sugar production in Rokan Hulu Regency is an integral part of the local economy, serving as a household industry. This industry not only sustains local livelihoods but also represents a deeply rooted cultural tradition. However, global environmental challenges, such as climate change and resource scarcity, have underscored the need for sustainable practices in natural resource-based industries. Sustainability in these contexts is often challenged by ecological degradation, limited technology access, and insufficient institutional support (Novita et al., 2012; Kuncoro, 2004). The present study evaluates the sustainability of palm sugar production by examining its key dimensions—ecological, economic, social, legal, and technological—to identify priority areas for improvement. Strengthening these dimensions can enhance the resilience of small-scale agro-industries and support sustainable economic development within rural communities.

Palm sugar production in Rokan Hulu Regency is a critical element of the local economy, primarily functioning as a household industry. The palm sugar agroindustry has long been an economic lifeline for rural communities, especially in regions rich in natural palm resources. However, the sustainability of this industry is under pressure due to ecological degradation, limited access to modern technology, and insufficient institutional support (Putra et al., 2018).

Table 1. Characteristics of Palm Sugar Crafters in Rambah District

Characteristics	Category	Percent
Craftsman experience	< 13 years	6.25
	13 - 20 years	31.25
	21 - 28 years	37.50
	> 28 years	25.00
Level of education	Never Went to School or Did Not Finish Elementary School	6.25

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	Graduated from elementary school	15.63
	Graduated from junior high school	56.25
	Graduated from high school	21.88
	College	0.00
Age of craftsman	> 64 Years	6.25
	52- 64 Years	53.13
	28 - 51 Years	40.63

Sustainability in the context of natural resource-based industries is defined as the ability to maintain production and economic viability without depleting the resources upon which the industry depends (Novita et al., 2012). For palm sugar production, the ecological aspects are particularly important as deforestation, land degradation, and unsustainable harvesting practices threaten the long-term viability of the industry (Kuncoro, 2004). According to Minarti et al. (2015), the integration of conservation strategies is essential for industries reliant on natural resources, such as the palm sugar agroindustry, to continue providing economic benefits while preserving the environment.

At the same time, social sustainability is equally crucial. The industry relies heavily on traditional knowledge and community-based practices, with most palm sugar craftsmen having inherited their skills from previous generations (Ichsan et al., 2020). Despite the cultural significance, the low level of education and lack of formal training among craftsmen have limited their ability to adopt modern techniques that could enhance productivity and sustainability (Kavanagh & Pitcher, 2004). Education is a key determinant of success in rural industries, as it improves not only individual productivity but also the ability to innovate and adapt to changing market conditions (Sofia & Sanjaya, 2021).

Moreover, the legal and institutional framework governing the industry remains weak. In many cases, small-scale industries such as palm sugar production operate without clear regulatory support, leaving craftsmen vulnerable to market fluctuations and environmental degradation (Coleman, 2009; Caballero, 2015). Strengthening institutional support, particularly through local government initiatives, is essential to create a more conducive environment for sustainable business practices (Osei-Tutu et al., 2015).

Given these challenges, the aim of this study is to assess the sustainability of palm sugar production in Rambah District through an analysis of its ecological, economic, social, legal, and technological dimensions. By identifying the key drivers of sustainability and the areas in need of improvement, this research contributes to the broader effort to enhance the resilience of small-scale agro-industries in rural Indonesia.

The palm sugar industry, as a resource-dependent agro-industry, faces significant risks from climate change. Changes in temperature, rainfall patterns, and extreme weather events can adversely affect palm tree productivity, further exacerbating raw material shortages (Osei-Tutu et al., 2015).

Deforestation, driven by agricultural expansion, also poses a threat to the sustainability of this industry by reducing the availability of suitable land for palm cultivation.

Literature Review

The sustainability of small-scale agro-industries, such as the palm sugar home industry, relies on a multi-dimensional approach encompassing ecological, economic, social, legal/institutional, and technological factors. Each of these dimensions plays a critical role in determining the long-term viability of the industry, particularly in resource-dependent communities (Putra et al., 2018; Novita et al., 2012).

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Ecological Sustainability

Ecological sustainability in agro-industries is essential for preserving natural resources and ensuring continuous raw material supply. Kuncoro (2004) emphasizes that industries relying on natural resources must prioritize environmental conservation to avoid resource depletion. For the palm sugar industry, the primary ecological concerns include deforestation, land degradation, and the unsustainable harvesting of palm sap. Implementing agroforestry, which integrates palm trees with other perennial crops, can mitigate these issues by enhancing biodiversity, conserving soil quality, and promoting water retention (Minarti et al., 2015). This approach not only maintains ecological balance but also increases the resilience of the palm sugar supply chain against environmental changes, such as climate variability.

Economic Sustainability

Economic sustainability in the palm sugar industry is influenced by market access, financial resources, and the ability to adapt to fluctuating prices. As noted by Kuncoro (2004) and Putra et al. (2018), small-scale industries often face challenges in accessing capital, which limits their capacity for growth and innovation. Diversifying income streams through value-added products, such as organic certifications and premium branding, can help palm sugar producers capitalize on the increasing demand for sustainable and ethically produced goods. Furthermore, the integration of culinary tourism into the palm sugar production process could boost economic sustainability by attracting local and international consumers (Soleh et al., 2016).

Social Sustainability

Social sustainability focuses on the well-being of local communities and the preservation of traditional knowledge. Ichsan et al. (2020) highlight the importance of traditional craftsmanship and intergenerational knowledge transfer in sustaining small-scale industries. In the context of the palm sugar industry, social sustainability is reinforced by the involvement of family members, particularly women, in production and marketing activities. However, a low level of formal education among craftsmen presents challenges in adopting new technologies that could improve productivity. Providing educational programs and vocational training in sustainable practices and business management could empower local communities to innovate while maintaining their cultural heritage (Sofia & Sanjaya, 2021).

Legal and Institutional Sustainability

A robust legal and institutional framework is necessary to provide small-scale producers with protection and support. Coleman (2009) and Caballero (2015) argue that effective legal regulations can prevent market exploitation and encourage fair competition. However, small industries such as palm sugar production often operate in informal sectors, lacking regulatory oversight and institutional support. Establishing cooperative models and formal recognition from local governments can improve the resilience of these industries. Furthermore, institutional support in the form of business development services and access to financial resources can create a more favorable environment for sustainable growth (Osei-Tutu et al., 2015).

Technological Sustainability

Technology is a key factor in enhancing productivity and expanding market reach for small-scale industries. In traditional sectors like palm sugar production, technological adoption has been slow, largely due to limited access and knowledge (Kavanagh & Pitcher, 2004). Introducing modern extraction tools and promoting digital marketing strategies can significantly improve efficiency and product quality. As digital platforms and e-commerce grow, they provide valuable channels for reaching broader markets and creating additional revenue streams. Putra et al. (2018) emphasize the importance of training programs focused on digital literacy and modern business practices to equip craftsmen with the skills necessary to adapt to technological advancements.

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Integration of Sustainability Dimensions

Integrating these sustainability dimensions can create a holistic model that strengthens the palm sugar industry's resilience. Studies show that ecological and economic improvements often enhance social outcomes, while robust legal and institutional support facilitates technological adoption (Bourgeois & Jesus, 2004). A multi-dimensional approach, therefore, provides a comprehensive framework for addressing the various challenges faced by small-scale agro-industries. By embracing this integrated model, the palm sugar industry in Rokan Hulu can not only improve its sustainability but also serve as a model for other resource-dependent industries in Indonesia.

Materials and Methods

The study was conducted in Rambah District, focusing on 32 palm sugar craftsmen, community leaders, and local government officials. Primary data collection involved field surveys, direct observations, and structured interviews. Multi-Dimensional Scaling (MDS) was employed to analyze sustainability across five dimensions: ecological, economic, social, legal/institutional, and technological. This approach facilitated an integrated understanding of the industry's sustainability index. Leverage Analysis within the MDS framework identified attributes with high impact on sustainability, while Monte Carlo simulations were used to validate the robustness of the model. Participatory prospective analysis involved local stakeholders in determining high-priority attributes, enhancing the relevance of findings for local development.

Study Area and Data Collection

This research was conducted in Rambah District, Rokan Hulu Regency, where palm sugar production is a primary livelihood for many households. Data were collected through field surveys, observations, and structured interviews with 32 palm sugar craftsmen, local business leaders, and government officials. The survey utilized random sampling to ensure representativeness and focus on key sustainability factors within the industry.

Analytical Framework

The research utilized Multi-Dimensional Scaling (MDS) to evaluate the sustainability of the palm sugar home industry across five dimensions: ecological, economic, social, legal/institutional, and technological. The MDS method allowed for an integrated analysis of these dimensions to produce a comprehensive sustainability index.

Additionally, participatory prospective analysis was used to engage local stakeholders, including government officials and community leaders, in identifying leverage attributes that could enhance sustainability. The analysis incorporated three primary methods:

Leverage Analysis: Identified sensitive attributes that have a high impact on sustainability.

Monte Carlo Simulations: Used to validate the robustness of the analysis by accounting for potential errors.

Stress and R^2 Analysis: Evaluated the reliability of the model, with a stress value below 0.25 indicating high reliability and an R^2 value approaching 1 representing strong model fit.

Results and Discussion

Table 2. Sustainability Value, Stress Value and Correlation Coefficient Value (R2)

Dimensions	Sustainability Index (%)	Stress Value (%)	Coefficient of Determination (R2) (%)
Ecology	54.20	14.65	94.13

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Economy	59.89	14.40	95.01
Social	50.79	11.53	96.97
Legal/Institutional	47.64	15.24	94.59
Technology	51.55	14.47	95.00
Average	52.81	14.06	95.14

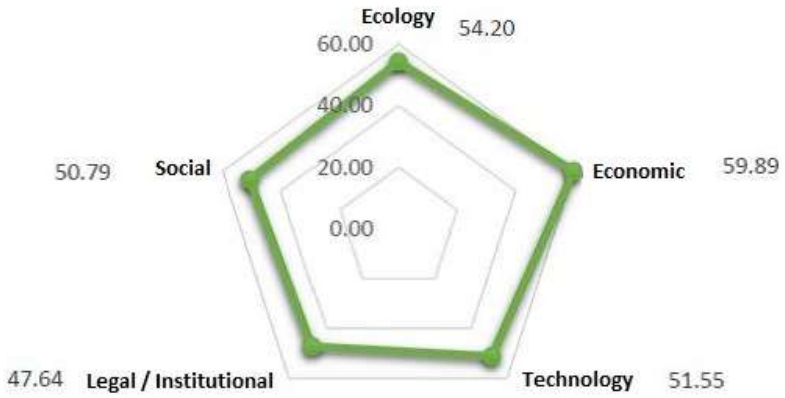

Figure 1. Flyover Diagram of Sustainability Index and Status Analysis

Ecological Sustainability

To counteract the adverse effects of deforestation, the study suggests adopting agroforestry practices. By integrating palm cultivation with other perennial crops, craftsmen can improve soil quality, conserve water, and maintain biodiversity, ultimately supporting a more resilient and sustainable resource base. Agroforestry not only conserves ecological resources but also enhances the sustainability of palm sugar production.

Palm Sugar Production (kg/day)

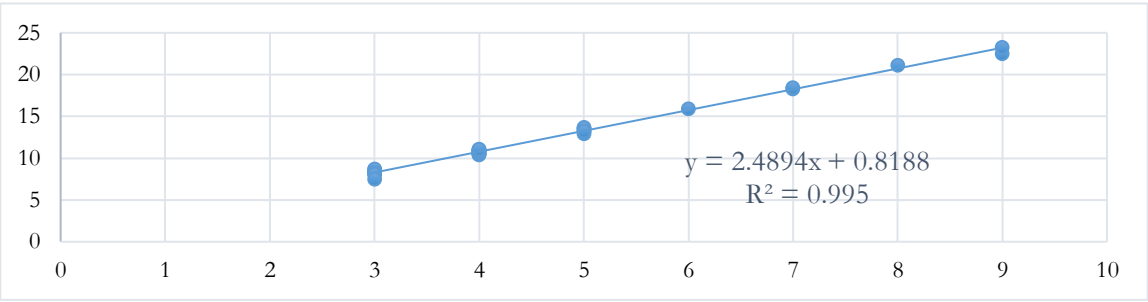

Figure 2. Relationship between Number of Trees Tapped and Palm Sugar Production

The ecological dimension is critical for the long-term sustainability of the palm sugar industry. The analysis revealed a moderate ecological sustainability index of 54.2%, largely driven by factors such as land conservation efforts, the number of tapped trees, and the availability of raw materials. As demonstrated in Figure 1, each additional tapped tree contributes approximately 2.49 kg of palm sugar per day, highlighting the close relationship between natural resource management and production output.

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However, the findings also point to challenges such as deforestation and land degradation, which pose significant risks to the sustainability of the industry (Novita et al., 2012). Conservation efforts, particularly in preserving palm tree populations and maintaining soil health, are essential to ensure the continued availability of raw materials.

To mitigate the ecological risks, adopting agroforestry practices could provide a sustainable approach to land management. Agroforestry systems that integrate palm trees with other perennial crops not only preserve biodiversity but also enhance soil fertility and water retention (Minarti et al., 2015). This dual approach can help ensure the long-term sustainability of raw material sources for the palm sugar industry.

Economic Sustainability

Economic resilience can be further strengthened through diversification of product offerings. Palm sugar craftsmen are encouraged to explore value-added products and utilize branding strategies. Certification for organic products could also open doors to premium markets, tapping into the rising demand for sustainable, organic goods.

Palm Sugar Production (kg/day)

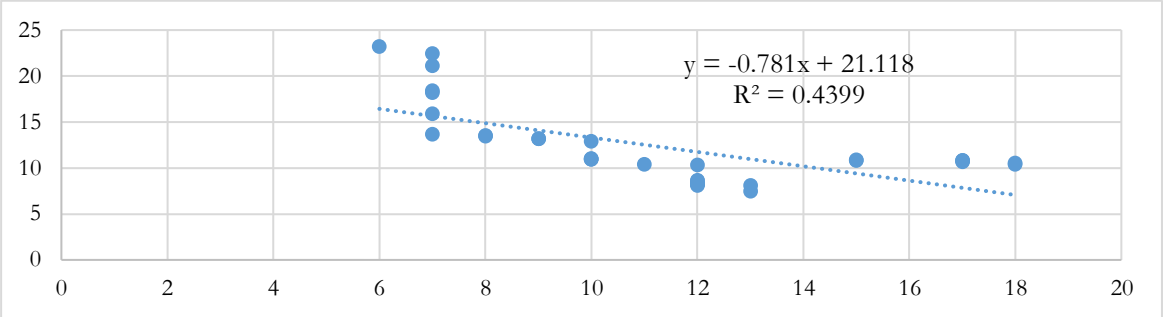

Figure 3. Relationship between Age of Tapped Trees and Sugar Production

Economic sustainability in the palm sugar industry was found to be relatively strong, with an index of 59.89%. Key factors contributing to economic resilience include the ability of craftsmen to maintain profitability despite fluctuating raw material prices and the growing market for palm sugar in local and regional markets (Putra et al., 2018). The potential for expanding the industry through value-added products and culinary tourism is significant, as indicated by the strong demand for locally sourced, artisanal products.

Nonetheless, economic challenges persist, particularly in securing access to capital and expanding market reach. Many craftsmen lack the financial resources needed to invest in modern equipment or diversify their product offerings (Soleh et al., 2016).

The global market for organic and natural products offers significant growth opportunities for the palm sugar industry. By obtaining organic certification and developing a strong brand identity, palm sugar producers in Rokan Hulu could capitalize on the growing demand for ethically sourced, sustainable products (Kuncoro, 2004). Entering global markets could boost the economic sustainability of the industry by diversifying revenue streams and increasing profitability.

Social Sustainability

Social sustainability can be greatly improved by offering targeted training in areas such as modern farming techniques, digital marketing, and small business management. Empowering women in production and marketing roles is crucial, as it enhances economic resilience and fosters gender equality. Training in digital literacy will equip craftsmen with the skills needed to engage with broader markets.

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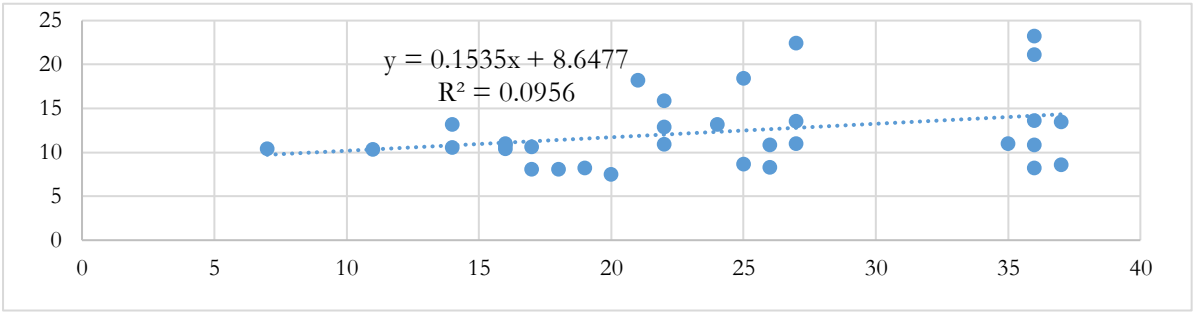
Palm Sugar Production (kg/day)



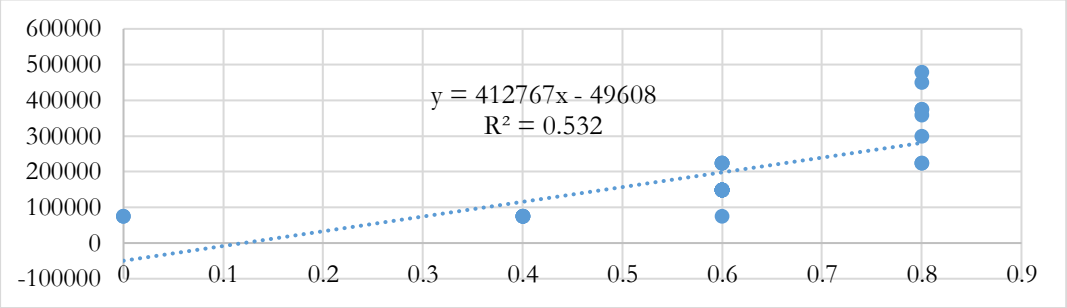
Craftsman Experience (years)

Figure 4. Relationship between Craftsmen's Experience and Palm Sugar Production

Social sustainability, with an index of 50.79%, is largely influenced by the role of traditional knowledge and the participation of family members in production. Most palm sugar craftsmen have extensive experience in the industry, with over 60% of respondents having more than 20 years of experience (Ichsan et al., 2020). The involvement of women, particularly in the marketing and sales of palm sugar, plays a critical role in sustaining household incomes and promoting economic resilience.

Despite these positive aspects, the low level of formal education among craftsmen poses a barrier to adopting new technologies and improving production efficiency. Targeted educational programs and vocational training could significantly enhance social sustainability by empowering craftsmen with the skills needed to innovate and adapt to changing market conditions (Sofia & Sanjaya, 2021).

Income Level (Rp/day)



Craftsmen Education Index

Figure 5. Relationship between Education Index and Sugar Production

Women play a pivotal role in the palm sugar industry, particularly in production and marketing activities. Empowering women through targeted training programs and access to microfinance could enhance their capacity to contribute to the industry's growth (Ichsan et al., 2020). Additionally, local capacity-building initiatives that focus on leadership and entrepreneurship development could further improve the social sustainability of the palm sugar sector.

Legal and Institutional Sustainability

Addressing regulatory gaps through local government support and cooperative development is necessary for legal sustainability. Strengthening institutions would protect craftsmen from market volatility and

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environmental risks. Government programs that provide formal recognition and business support for small-scale producers would reinforce the industry's foundation.

The legal and institutional dimension was the weakest, with an index of 47.64%. The lack of a clear regulatory framework for the palm sugar industry, coupled with weak institutional support, has left many craftsmen vulnerable to market fluctuations and environmental degradation. Government initiatives aimed at formalizing the industry and providing legal protections for small-scale producers are urgently needed (Caballero, 2015).

Additionally, the absence of cooperative business models and limited access to business development services further hampers the industry's ability to scale and compete in larger markets. Strengthening institutional frameworks and encouraging collaboration among producers could improve the industry's resilience (Osei-Tutu et al., 2015).

Strengthening public policy frameworks is essential for ensuring the legal and institutional sustainability of the palm sugar industry. Government incentives aimed at promoting sustainable practices and providing financial support for small-scale producers could significantly enhance the industry's resilience (Coleman, 2009). Establishing cooperative models and fostering stronger collaboration between stakeholders could also improve institutional coordination, helping to create a more sustainable and competitive market environment.

Technological Sustainability

Technology adoption, such as modern sap extraction techniques and online marketing, plays a key role in improving efficiency and expanding market reach. Training craftsmen on using digital platforms can foster a more connected industry, allowing for better communication with buyers and expanded distribution channels.

Technological sustainability scored an index of 51.55%, reflecting moderate adoption of technology in the palm sugar industry. While some craftsmen have begun to utilize social media for marketing and modern tools for processing, the majority still rely on traditional methods passed down through generations. Expanding access to training and modern technologies, such as improved sap extraction techniques, could greatly enhance productivity and product quality (Putra et al., 2018).

Conclusion

The palm sugar home industry in Rambah District exhibits moderate sustainability, with promising ecological, economic, and social strengths. However, significant enhancements are required within the legal and technological dimensions to secure long-term viability. Practical recommendations include the adoption of agroforestry, targeted digital and technical training, stronger institutional frameworks, and women's empowerment programs. Through collaborative efforts among government, local communities, and private sector stakeholders, the industry can thrive as a sustainable economic driver. The incorporation of digital technology and global market positioning for sustainable palm sugar products offers substantial growth potential, fostering a resilient and economically viable industry.

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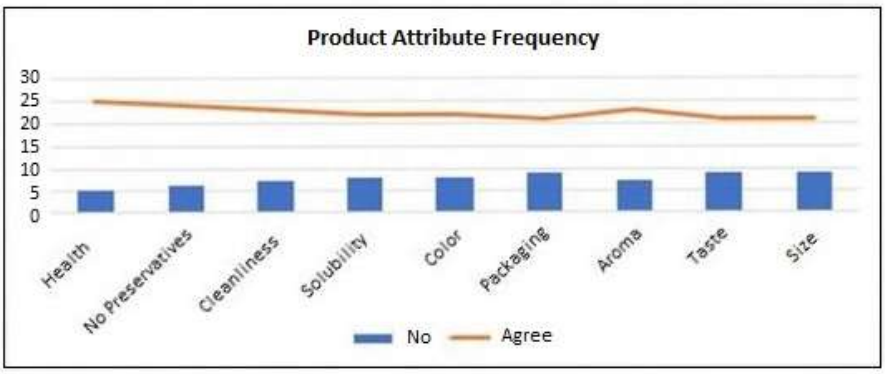

Figure 6. Main Factors in Consumer Decisions to Buy Sugar Products

Sugar Palm in Rambah District

The sustainability of the palm sugar home industry in Rambah District is moderately stable across most dimensions, with ecological, economic, and social aspects showing relative strength. However, significant improvements are needed in the legal/institutional and technological sectors to ensure the long-term viability of the industry. Strengthening local institutions, fostering business partnerships, and promoting the use of modern technologies will be critical to enhancing sustainability.

Collaborative efforts between government agencies, local communities, and private sector investors are essential in addressing the industry's current challenges. By addressing these key areas, the palm sugar industry can continue to thrive as a cornerstone of the local economy while preserving the natural resources upon which it depends.

The adoption of digital technologies, including e-commerce platforms and social media marketing, presents a significant opportunity for palm sugar producers to expand their market reach. By leveraging these platforms, producers can access a broader customer base beyond local markets, potentially increasing sales and improving economic outcomes (Putra et al., 2018). Training programs focused on digital literacy and online marketing strategies could further support this transition.

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