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Assessing the Multidimensional Sustainability of Crystal Coconut Sugar Production in Banyumas Regency, Central Java, Indonesia

Titin Handayani[1*], Arif Dwi Santoso[1], Moh. Husein Sastranegara[2], Sri Lestari[2], Ira Nurhayati Djarot[1], Netty Widyastuti[1], Nuha Nuha[1], Amita Indah Sitomurni[1], Adim Hadi[1], Anggara Lomak Prihatin[1], Feddy Suryanto[3]

[1] Research Center for Sustainable Production System and Life Cycle Assessment, Research Organization for Energy and Manufacture, National Research and Innovation Agency, South Tangerang 15314, Indonesia
[2] Faculty of Biology, University of Jenderal Soedirman, Banyumas 53122, Indonesia
[3] Research Center for Environmental and Clean Technology, National Research and Innovation Agency, South Tangerang 15314, Indonesia

Corresponding Author Email: titi001@brin.go.id

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ABSTRACT

Crystal coconut sugar is a product of indigenous knowledge which is very beneficial for health, as the population increases, the production of crystal coconut sugar needs to be increased and its sustainability maintained. Banyumas Regency is one of Central Java Province's main crystal coconut sugar-producing districts. The purpose of this study was to look at the sustainability of crystal coconut sugar by 1) assessing the multidimensional sustainability index as well as the state of crystal coconut sugar manufacturing; 2) evaluating the sustainability index in each of its dimensions (environmental, social, economic, and technological); 3) identifying the parameters that influence crystal coconut sugar systems; and 4) determining the most influential factors affecting crystal coconut sugar systems to enhance performance and production sustainably. This research used multidimensional scaling with four dimensions and 30 attributes. According to the findings of the analysis, the average performance shows a fairly sustainable status with a value of 65.42%. The economic dimension shows very good performance for sustainability, namely with a value of 90.86%, however, the environmental dimension features a value of 52.73%, and the technological dimension with a value of 49.83% shows less sustainability, while the social dimension with a value of 68.24% is fairly sustainable. For crystal coconut sugar production to have a good sustainable status, it is necessary to pay attention to leverage factors seen from low-value attributes to make improvements.

1. INTRODUCTION

Indonesia is a country rich in coconut plants. According to data from the Department of Agriculture, in 2021 the coconut plantation area was 3.80 million hectares of productive land of 3.20 million tons of copra equivalent, and more than 98% was cultivated by smallholder plantations. Coconut plantation areas are spread across various islands in Indonesia, namely Sumatra Island accounts for 33.63%, Java Island for 22.75%, Sulawesi for 19.40%, Bali, NTB, and NTT for 7.70%, Maluku and Papua for 8.89%, and Kalimantan for 7.62% of the total coconut area in Indonesia. Banyumas Regency Agriculture and Food Security Agency (2020) reported that Banyumas is the second-largest producer of coconut plants in Central Java. The area of land planted with coconut in Banyumas Regency totals 5,111.49 hectares, with 638,936 coconut trees [1].

The crystal coconut sugar production center in Banyumas Regency has great potential for development. In almost every village in several sub-districts, there are coconut sugar production centers. Quite large production centers are in Cilongok, Karanglewas, and other sub-districts. Based on data from the Banyumas Regency Industry, Trade, and Cooperatives Service, in 2019 there were more than 18,000 coconut sugar business units. This number is 52.70% of the total industrial businesses in Banyumas Regency, which total reaches 34,000 units. The absorption of labor in the informal sector is quite large, reaching 37,254 people. Meanwhile, for each unit, the production ranges from 3-8 kg/day. If an average of 4 kg is taken, then coconut sugar production in Banyumas is 72,224 kg/day or more than 2 million kg/month (Banyumas Central Bureau of Statistics, 2022). The coconut plant is a plant with high economic value because almost all parts of the coconut plant can be used [2]. This plant takes 12 months from planting to fruiting. The flowers of this plant are called “mayang” and are located between the leaf axils [3]. One of the products from the coconut plant is sap. “Nira” is a liquid with a high sugar content extracted from coconut flowers. One product that can be developed from sap is crystal sugar with

the regional name Crystal Coconut Sugar. The quality of crystal coconut sugar produced in Banyumas Regency is the best coconut sugar [4].

Crystal coconut sugar is produced using traditional methods and drying (spray drying and vacuum drying) with the addition of drying aids in the form of maltodextrin. Traditional crystal coconut sugar has a predominantly crystalline structure while dried coconut sugar has an amorphous structure [5]. Crystal coconut sugar is made from palm juice and is processed into powder or granules. Even though its appearance is brown, Crystal coconut sugar has advantages compared to white granulated sugar. The low sugar content and useful compounds contained in it make Crystal coconut sugar a healthier choice than white granulated sugar. Crystal coconut sugar has advantages over molded sugar, including a distinctive aroma, a water content of 2-3% that allows for longer storage, easy solubility in water, practical packaging, and compatibility with other ingredients in the food and beverage industry. Crystal coconut sugar has good prospects because ant sugar has reached the international market [6].

The advantages of crystal coconut sugar compared to palm sugar (lumps of sugar) include that it dissolves more easily, has a longer shelf life, has a more attractive shape, has easier packaging and transportation, a more distinctive taste and aroma, and a higher price than regular molded palm sugar. This advantage can also be created by the availability of raw materials for crystal coconut sugar around the production location [7]. According to the Public Housing and Settlement Area Service (2022), Banyumas Regency is one of the largest crystal coconut sugar production locations in Central Java Province, with a total of 27,112 families. The Banyumas Regency area is suited for coconut production since it is a lowland area with an average altitude of +108 meters above sea level between longitude 7°15'05"-7°37'10" South Latitude and 108°39'17"-109°27'15" East Longitude. Banyumas Regency has a land area of 1,327.59 km^2. This district is made up of 27 sub-districts. Cilongok District, with an area of 105.34 km^2, is the largest sub-district [8].

Several issues exist in the crystal coconut sugar sector, including product quality, human resources, equipment, and technology, capital, marketing, clusters, and restricted government development funding [9]. The issue in the crystal coconut sugar growth of the industry is collecting raw materials, specifically sap, which is the key raw material for coconut sugar and is of poor quality [10]. The many challenges that exist in the coconut sugar company, as well as a lack of sufficient business income to offer a decent life and welfare, will result in the emergence of a business in this sector that producers must abandon. To raise revenue, entrepreneurs must be able to detect difficulties in their business sector and apply numerous remedies to boost production and sales, such as enhancing product quality and diversification and expanding their network of product marketing, as well as creating sustainable production [11].

The problem formulation used is to answer the question, what is the value of the multidimensional sustainability index of crystal coconut sugar production and what is the appropriate strategy to implement in managing crystal coconut sugar production in a sustainable manner in Banyumas Regency, Central Java. The state of the art of this research is sustainability of crystal coconut sugar production has been carried out in a qualitative descriptive method to examine the sustainability of production in terms of the strengths and weaknesses of the craftspeople. Research has been carried out on the sustainability of sugar production, but not sugar made from coconut sap, but crystal sugar from sugar cane [10]. Research using Multidimensional Scaling (MDS) is the latest research to determine the sustainability index of ant sugar production. The values obtained can be used to indentify the weaknesses and strengths of the dimensions in determining sustainable production methods.

MDS is a multivariate statistical analysis method that uses similarity/resemblance to describe patterns of closeness. MDS can assist researchers in obtaining quantitative estimates of item similarity. MDS can convert similarity or preference ratings from customers (for example, story or brand liking) into multidimensional space distance. MDS is a series of statistical processes used to minimize data set complexity, allowing for a visual understanding of the underlying relationship patterns [12]. MDS has had many successes in analyzing sustainability index, for example in maggot cultivation [13], and biorefinery from microalgae cultivated at the Palm Oil Mill Effluent [14].

The MDS approach was used to generate the sustainability index on crystal coconut sugar production is extremely beneficial in measuring the level of sustainability. The proposed sustainable idea in this study appears to have high feasibility to be implemented in crystal coconut sugar production in Indonesia in general, and in Banyumas Regency, Central Java in particular. Much research on the possibility of sugar sustainability has been published, but none has used MDS to analyze the data. As a result, the sustainability index of organic crystal coconut sugar developed in this study could reduce pollution while also improving quality. MDS's practical approach provides information to help organic crystal coconut sugar enterprises make waste management decisions; and improve technology.

The purpose of this study was to examine the sustainability of crystal coconut sugar through 1) assessing the multidimensional sustainability index as well as the state of crystal coconut sugar manufacturing; 2) evaluating the sustainability index in each of its dimensions (environmental, social, economic, and technological); 3) determining the parameters that influence crystal coconut sugar systems; and 4) identifying the most influential factors affecting crystal coconut sugar systems in order to increase performance and production in a sustainable manner.

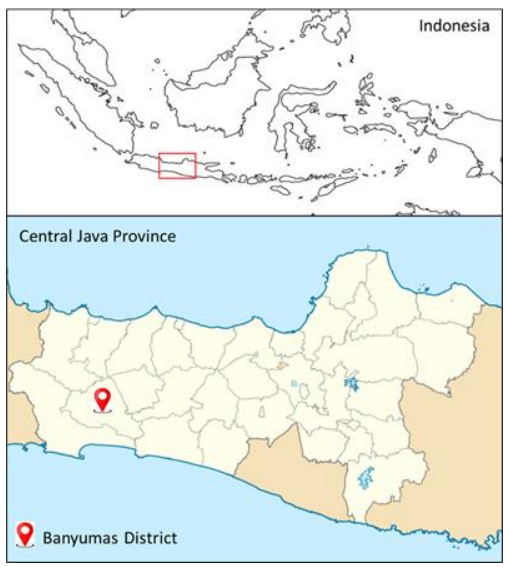

Figure 1. Site location

2. MATERIAL AND METHODS

2.1 Site location and data collection

The study was conducted from February to August 2023 in Purwokerto Banyumas Regency, Centre Java Province (Figure 1). Data was carried out along with a focus group discussion (FGD) and filling out questionnaires to crystal coconut sugar factory managers, researchers, extension workers, and commercial actors. The focus group discussion (FGD) was carried out to determine the current circumstances of commercial players and support for the resources of the crystal coconut sugar sector at the study site as raw materials for preparing dimensions and sustainability qualities (Table 1). It is known that there are five dimensions, including environmental, economic, social, and technology. The number of attributes used in this study was 30. Then, a questionnaire with response options using a Likert scale describes these dimensions and attributes. The expert responders gave the questionnaire's questions scores of 0, 1, and 2 for poor, average, and good responses.

Table 1. Dimension and attributes for crystal coconut sugar production

No.	Environmental	Social	Economic	Technological
1	Material efficiency (biodegradable) for the manufacturing of crystal coconut sugar	Education level of crystal coconut sugar entrepreneurs	Productivity level of crystal coconut sugar	The simplicity with which the crystal coconut sugar-producing technology can be adopted by the surrounding community
2	Chemical efficiency during coconut tree cultivation and post-harvest sap	Family members are involved in the manufacture of crystal coconut sugar	Production management level	Employers must have a certain level of specialization/expertise/skills
3	Efficiency in the utilization of electrical energy and fuel during coconut tree cultivation and after sap harvest	Level of corporate motivation	Potential improvement in business scale/business success rate	Production facility and infrastructure availability
4	Water efficiency during coconut tree cultivation and post-harvest	Potential for public disturbance as a result of the manufacturing process	Contribution to the well-being of managers/workers	Potential for enhancing technology/production techniques
5	Potential air pollution generated by the boiling of sap into crystal coconut sugar	Other employment losses are possible as a result of the crystal coconut sugar business	Raw material efficiency in production	The degree of technical/method sensitivity to crystal coconut sugar output quality and quantity
6	Water pollution from the process of cooking sap into crystal coconut sugar	Managers' and workers' awareness of environmental conservation and restoration	The ease with which raw materials for manufacture can be obtained	
7	Waste created during the crystal coconut sugar production process is processed and used.	Possibility of workplace accidents	The market absorption rate of crystal coconut sugar manufacturing	
8	Natural resource exploitation (soil, plants) in order to produce crystal coconut sugar		Possibility of job creation for local residents	
9	The presence of crystal coconut sugar company could harm biodiversity.			
10	Disease spread due to the development of the crystal coconut sugar business			

2.2 Data analysis

The rap-crystal coconut sugar approach rapid appraisal for crystal coconut sugar production (Rap-sugar) was used to analyze the data. This method was adapted and developed from the Rapfish (Rapid Appraisal for Fish) method for determining the sustainability of crystal coconut sugar manufacturing through the processes outlined below [15, 16].

Analysis of sustainability indices is a quick technique for evaluating the sustainability status of the product in a particular locus in a multidimensional manner. Analysis of all dimensions was carried out simultaneously to generate a scale vector. Rapfish is based on the ordination technique of placing a value (score) on a measured attribute using Multidimensional Scaling (MDS) involving several dimensions. Each dimension has indicators related to sustainability [16]. Since the object studied is a crystal coconut sugar, the word Rapfish is replaced with RapSugar.

The sustainability status and leverage attributes of the introduction of intensive crystal coconut sugar production technology in Banyumas district through RapSugar analysis have several steps according to studies [16, 17], namely a) selection of attributes for measuring sustainability status and leveraged attributes, referring to good benchmarks for intensive sugar production; b) reviewing attributes on an ordinal scale referring to the sustainability criteria of each

dimension, c) compiling an index of sustainability status and leverage attributes of crystal coconut sugar technology introduction. Furthermore, the analysis results will draw a) the index of each dimension in introducing intensive crystal coconut sugar production and b) the leverage/sensitive attribute, which is an attribute that affects the sustainability status of the intensive process of crystal coconut sugar production.

The index of sustainability level status points will be drawn in two dimensions, namely vertical and horizontal ordinates, and illustrated by a flat line. The lousy extreme has a value in the index of 0%, and the excellent extreme has a value in the index of 100%. The scale of the sustainability status index of crystal coconut sugar technology ranges between 0-100%. It is sustainable if it has a more excellent value of 50%. Still, it is not sustainable if it is less than 50% (Table 2).

Table 2. Index category and sustainability status for every dimension

No.	Index Value	Category	Status
1.	0-25	bad	Not sustainable
2.	>25-50	less	Less sustainable
3.	>50-75	fairly	Fairly sustainable
4.	>75	good	Good sustainable

Source: Reference [17].

The sustainability status ordination is an overview of the sustainability status of each dimension, represented to the score of each attribute. The point on the axis (x) reflects the sustainability status of crystal coconut sugar technology, and the ordinate (y) shows the variation in each attribute studied. It will add the ordination analysis by running the normalization of the model's value emphasize (S) and determinant coefficient (R^2). If S<0.25% value and R^2 are close to 1, then the model is rated good. The value of S-stress and the determinant coefficient (R^2) also reflect the accuracy of the dimensions reviewed with the actual state [18].

Ordination or distance determination techniques in MDS were based on Euclidian distance in n-space, and written as follows [16]:

$$d = \sqrt{(|x_1 - x_2|^2 + |y_1 - y_2|^2 + |z_1 - x_2|^2 + \cdots)} \quad (1)$$

Configurations of objects or points in MDS were then approximated by regressing Euclidian distance (d_{ij}) from point i to point j with point of origin (oij), as the following equation shows:

$$d_{ij} = \alpha + \beta\delta\beta_{ij} + \varepsilon \quad (2)$$

The regression technique used for the equation above was the ALSCAL algorithm. The ALSCAL method optimizes squared distance (squared distance = d_{ijk}) against squared data (point of origin = o_{ijk}), which in three dimensions (i, j, k) is written in a formula called S-Stress as follows:

$$s = \sqrt{\frac{1}{m}\sum_{k=1}^{m}\left[\frac{\sum_i\sum_j \left(d_{ijk}^2 - o_{ijk}^2\right)^2}{\sum_i\sum_j o_{ijk}^4}\right]} \quad (3)$$

where, the squared distance is Euclidian distance assigned a value:

$$d_{ijk} = \sum_{a=1}^{r} w_{ka}\left(x_{ia} - x_{ja}\right)^2 \quad (4)$$

Furthermore, leverage analysis is used to assess attributes sensitive to sustainability. This analysis aims to select the attributes that have the highest role in each dimension as leverage factors that affect the value of sustainability. The most vulnerable indicators are indicated by the biggest Root Mean Square (RMS) values [16]. Meanwhile, Monte Carlo Analysis helps examine: a) the influence of attribute scoring errors, b) the impact of changes in scoring due to differences in researcher opinions or evaluations, c) the MDS analysis process's stability that is repeated, d) mistakes in data entry or the existence of missing data, and e) the high-stress value of the findings of the MDS analysis. If the distinction between the MDS and the Monte Carlo calculation results is less than one, then the system under study is excellent or corresponds to actual conditions [16, 17]. The MDS ordination will be represented by a circle with variable values (index quantity), references, and anchors (limit value). The x-axis for Good has a maximum value of 100, and Bad has the lowest value of 0, while the y-axis for up is half the top attribute score (50), and down is half the minimum attribute score (-50) [19].

3. RESULTS AND DISCUSSION

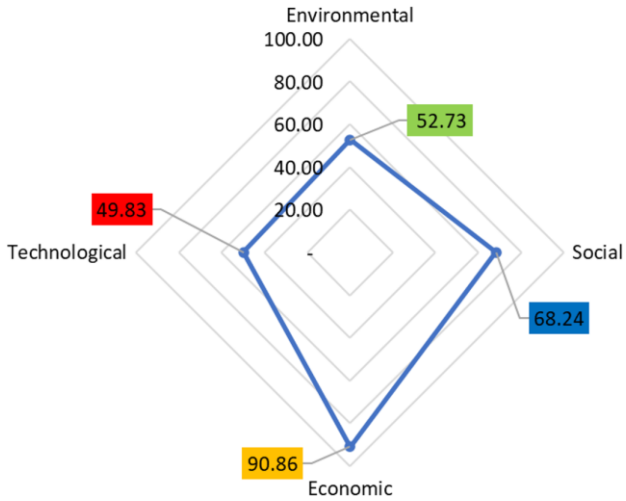

Figure 2. The sustainability level attained in integrated production (Maximum coordinates 100 (very good), Minimum coordinates 0 (very bad))

Table 3. The index of sustainability results for all aspects dimensions, along with data quality indexes

Dimension	Index (%)	Stress	R^2 (SQR)	Status
Environmental	52.73	0.148	0.946	Less sustainable
Social	68.24	0.148	0.944	Fairly sustainable
Economic	90.86	0.137	0.947	Very good sustainable
Technological	49.83	0.159	0.936	Less sustainable
Average	65.42			Fairly sustainable

The results of the MDS analysis for the performance of the crystal coconut sugar industry are 65.83% on a sustainability scale of 0-100 with R^2 (SQR)>0.80 indicating that it is quite sustainable. This value is the result of an evaluation of 30 attributes are covered over four dimensions. (environmental,

social, economic, and technological). Each dimension has an index value for the environmental dimension of 52.73%, social dimension of 68.24%, economics of 90.86%, and technology of 49.83% (Figure 2). The four dimensions show an average index value of 65.83% with R^2 (SQR)>0.80. This shows that performance still requires improvement in the environmental and technological dimensions. The results of the Monte Carlo analysis can be seen in Table 3.

3.1 Environmental dimension

The environmental factor of the sustainability index value is significant in the activities of crystal coconut sugar production in Banyumas Regency. The leverage analysis results demonstrate that the environmental dimension contributes less to sustainability by 52.73% (Table 3), so to improve the sustainability status of the environmental dimension, it is necessary to improve the leverage attributes, especially the use of biodegradable materials by 0.63 (Figure 3). Other leverage attribute factors that need to be considered are the processing and utilization of waste produced, air pollution due to smoke from cooking, the natural resources level of exploitation (land, crops), and the potential for disease transmission due to the existence of the crystal coconut sugar business.

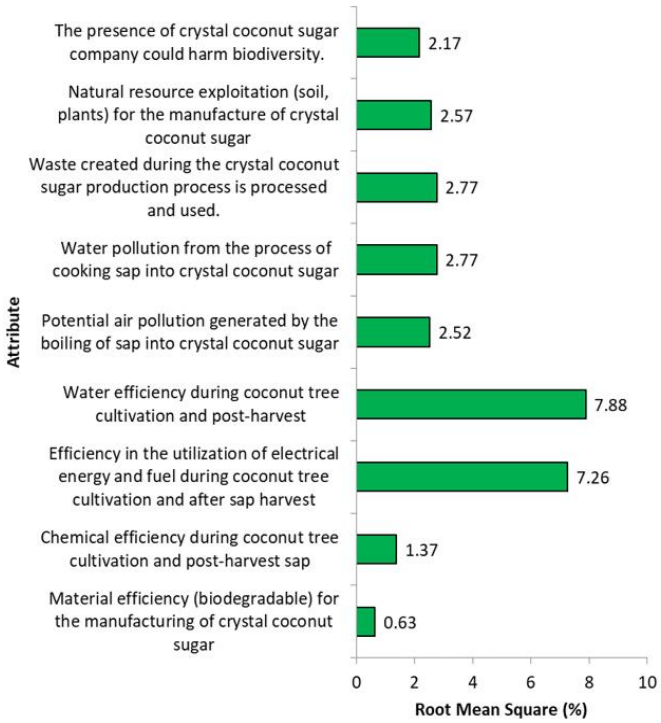

Figure 3. Leverage of environmental attributes

The sugar tapper begins this process by preparing the necessary equipment for tapping, such as pongkor (sap container), laru (a concoction to suppress sap fermentation), and safety belts. Unlike pongkor cans containing leftover paint, which do not fulfil food safety regulations, the pongkor used by tappers today is constructed of food-grade ingredients. Bamboo pongkor is used when discussing organic standards. The community, however, changes it to match their needs [20]. The effect of this process is that the use of biodegradable materials is reduced. So, the use of biodegradable materials needs to be increased so that the results of the crystal coconut manufacturing process are effective.

The effect of this process is that the use of biodegradable materials is reduced. So, the use of biodegradable materials needs to be increased so that the results of the crystal coconut manufacturing process are effective. The use of biodegradable materials that need to be increased is (1) “pongkor” made from bamboo; (2) organic fertilizer applied when farmers plant coconut trees; (3) sap preservative solution (“laru”) that has been used by farmers in the form of jackfruit scroll, mangosteen skin shells, and whiting; (4) “nipah” used when cooking crystal coconut sugar using coconut oil; and (5) the condition of the processing kitchen which is clean from dangerous chemicals in Cilongok District. This sub-district is the center for making coconut sugar in Banyumas and is followed by Karanglewas, Gumelar and Sumpiuh sub-districts [21]. Coconut sugar has been improved in crystal form with a high market share known as organic sugar (respondent). Coconut sugar, palm sugar, lontar sugar and nipah sugar are products that are known to come from sap as raw materials for brown sugar, liquid sugar and crystal coconut sugar [22].

The quality requirements for crystal coconut sugar according to SNI (SII 0268-85) have components (1) sugar (min. 80%), (2) saccharose (min. 75%), (3) reducing sugar (max. 6%), (4) water (max. 3%), (5) ash (max. 2%), and (6) water-insoluble parts (max. 1%). Meanwhile, granulated palm sugar (granule) complies with the Indonesian National Standard (SNI 3743:2021) for coconut sugar products (crystal coconut sugar) in terms of several parameters such as (1) condition (normal color, normal smell, normal taste), (2) size particles (max. 1.41 mm), (3) water-insoluble parts (max. 1%), ash content (max. 2.5%), water content (max. 3%), reducing sugar (max. 3 %), saccharose sugar (80-93%), as well as metal contamination (Pb max. 0.25 mg/kg, Cd max. 0.20 mg/kg, Sn max. 40 mg/kg, Hg max. 0.03 mg/kg, As max. 1 mg/kg).

The use of econometrical methods should be considered while calculating green domestic product (GDP). However, if the industry's energy consumption, air-control and wastewater-treatment system efficiency were enhanced and linked with productivity of sugar promotion. The enhanced value of the sugar industry's new green GDP in comparison to the basic case as a result of the new green GDP grew due to higher productivity of sugar and decreased impact of environmental air and water prolusion. Finally, have a look at the circular economy practices were backed by government planning to create a green economy related to growth of sustainable industrial in the future [23].

To reduce the sugar industry's technological impact on water and air, new technologies for core production and waste water treatment, as well as industrial environmental control and the construction of a modern environmental management system, must be introduced [24]. Strategic paths for further enhancing the environmental profile, such as sugarcane production and processing, could include (a) continuing pursuit of high yields, which is a key predictor of agricultural product environmental impacts, (b) precision fertilizer application to limit the possibility of environmental losses, and (c) maximization of coproduct usage to increase environmental credits [25].

3.2 Social dimension

The social dimension in the sustainability index value means that the ant sugar production in Banyumas Regency, when viewed from the social dimension, proves a sufficient value for sustainability, namely 68.24% (Table 3). Increasing

the sustainability index needs to be done by increasing the education of crystal coconut sugar entrepreneurs which has a score of 2.55 and reducing the potential for work accidents in the process of making ant sugar which has a score of 2.7 (Figure 4). Improving the education of crystal coconut sugar entrepreneurs can be done by providing assistance and training relevant to the production and marketing of environmentally friendly crystal coconut sugar. The assistance for crystal coconut sugar related to the introduction and use of marketplaces can increase the productivity of crystal coconut sugar.

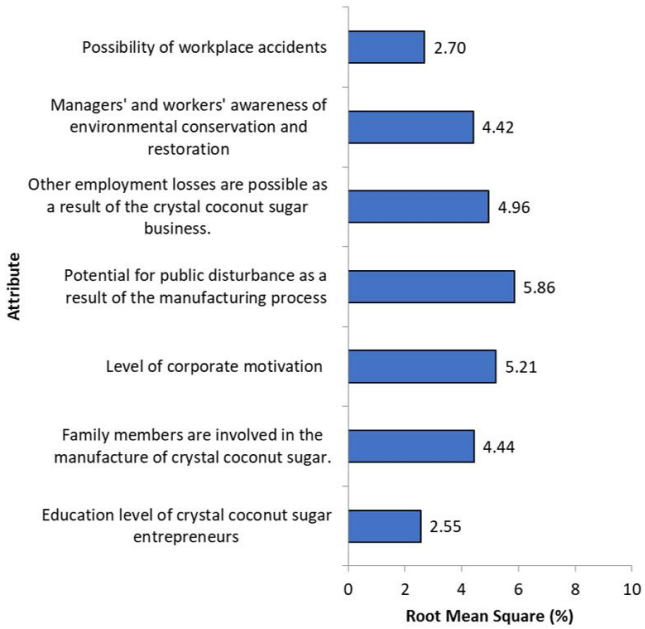

Figure 4. Leverage of social attributes

Efforts to reduce work accidents can be made by socializing and implementing Occupational Safety and Health Management System (OSHMS) in all aspects. An OSHMS is needed to ensure that there is an integrated system in the business environment that can create the best atmosphere for all parties involved in it; so that the productivity of crystal coconut sugar will continue to be sustainable [26].

To increase the export quality of coconut sugar, coconut sugar industry operators must be guided, as just regular sugar products of sugar are allowed in international marketplace. The Micro, Cooperative and Business Office and the Department of Industry and Trade in Pacitan Regency provide counselling and facilitation. Training, work equipment, product legality, promotional facilities, and capital facilities are all part of the supervision and assistance [27].

For social resources or social capital, the Bina Sejahtera Women's Farmers Group has many networks or connections, including with companies and the central government. And in terms of physical capital or infrastructure, the Bina Sejahtera Farming Women's Group has buildings and land from the village government to be used for empowerment activities for the community. Meanwhile, fertilizer and seeds come from the allocation of village funds and assistance from the central government and companies [28].

The United Nations Environmental Programme efforts created standards for assessing the social life cycle of South African sugar industry goods. Although it is beneficial that the sugar business reduces employment in some places, the decline in sugar production during the 2010-2011 season might provide significant financial and social issues for these communities, as well as the rest of South Africa [29]. The Indian sugar industry strives to deliver sustainability value to farmers by increasing resource efficiency regenerating ecosystems, and strengthening rural neighbourhoods. Because small-scale farmers get low returns in this sector, industry is dedicated to teaching them ways for new and alternative revenue generation methods such as boosting cane yield, entrepreneurship, and intercropping [30]. The development of a social impact assessment approach with a weighting scheme can assist the government and business sectors in prioritizing their efforts to minimize negative social impacts throughout the life cycle of biofuel systems. However, evidence on the relevance of social factors and satisfaction is subjective; consequently, uncertainty analysis or sensitivity analysis must be used to further observe the fluctuation of different possibilities to ease decision-making [31]. The coconut sugar producers were highly motivated to cultivate organic coconut sugar. Farmer group, Internal Control System, production method, farming experience, number of dependents, and age all have a beneficial effect on motivation; however, education has no effect [32].

Based on the results of social impact, empowerment, and analysis, the author concluded that empowerment by optimizing crystal coconut sugar processing in Banyumas Regency was carried out by the intended program by using Banyumas' environmental potential. The manufacturing and marketing processes incorporate strategic tools and human resources, which has an impact on the projected marketing results. Despite obstacles, the implementation of empowerment activities had a positive impact on residents. Economic problems did not have a significant impact. This can serve as a stimulus to improve residents' economic conditions by leveraging the potential in the Banyumas Regency environment. Banyumas crystal coconut sugar is exported to several countries and used by several prominent soft drink businesses. However, the status of social capital among craftsmen who have not yet developed productively, as well as institutional cooperation, remains unfavorable to the craftsmen. As a result, the living conditions of coconut sugar craftspeople remain poor. This study suggests the necessity for coconut sugar craftspeople to be regenerated through modernization of production and more profitable product diversification, as well as the development of social capital toward a more productive and connecting social capital.

3.3 Economic dimension

In such conditions, it is clear that judging from the results of the index analysis, it shows that it is very good for determining the status of sustainability crystal coconut sugar production process in Banyumas Regency with a value of 90.86% (Table 3). The economic dimension in the sustainability index value means that the status is very good for sustainability in crystal coconut sugar production activities, so that it can provide good economic income for craftsmen in Banyumas Regency [20]. Then in the future it must be maintained so that the sustainability status in the future is well maintained by the craftsmen's children and grandchildren. The lever attributes that need attention and improvement is the potential for creating jobs for local residents and the level of market absorption of crystal coconut sugar production with low values, namely 0.39 and 0.91, respectively (Figure 5).

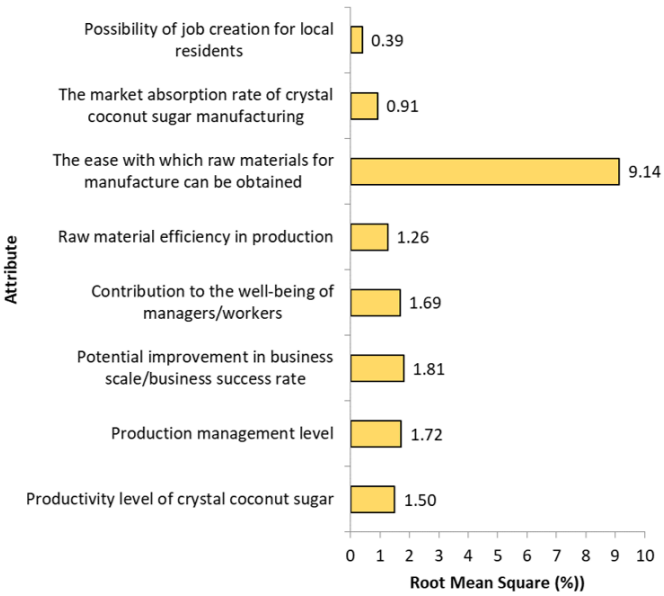

Figure 5. Leverage of economic attributes

The economic dimension of crystal coconut sugar production is the economic point of view of this food industry taking into account several aspects such as raw materials, production efficiency, business ecosystem, market absorption, and beneficiary from this industry. There are 8 attributes analyzed using MDS scaling to find the most significant attribute of the economic aspect of this industry. Those are the possibility of job creation for local residents, the market absorption rate of crystal coconut sugar manufacturing, ease with which raw materials for manufacture can be obtained, Raw material efficiency in production, contribution to the well-being of managers/workers, possible improvement in scale/success rate of business, the production level of management and productivity level of crystal coconut sugar.

Among those attributes, ease with which raw materials for manufacture can be obtained got the highest score which is 9.15 followed by potential improvement in business scale/business success rate which scores 1.81, and production management level which scores 1.72. This indicates that raw materials are presents in abundant and accessible. This explains the high score for potential improvement in business scale. The industry has the potential to expand due to raw materials and low cost for material transport. Therefore, production management has to be improved so that the usage of raw materials can be more efficient and profitable.

The coconut sugar industry in Banyumas Residence has existed for decades marked by the presence of a cooperative which is a forum for farmers. However, it is not known exactly when the Cilongok people of Banyumas Residence began to engage in the coconut sugar business [33]. The industry progressed especially after the farmers shifted from producing printed coconut sugar to crystal coconut sugar which has a higher economic value [34]. In this case, improvement in production management coupled with innovation will be the key to expanding the scale of the crystal coconut sugar industry in Banyumas Residence into an international supplier for this product. To boost input productivity and production efficiency, more effective production processes and technologies must be used to produce high-quality products with better selling prices [4].

The community empowerment program is about increasing public understanding and awareness regarding crystal coconut sugar which has a higher monetary value compared to shell sugar. Community skills regarding making ant sugar are increasing. the skills of the people of Pusuk Lestari Village in packaging crystal coconut sugar have increased. Business management and marketing strategies are provided so that the business remains sustainable and expands marketing reach [6]. SWOT analysis revealed, the Nira Perwira Cooperative's more activities of promotional, more loyalty of farmer, increased agreements with third parties, extended advertising networks, enhanced internal reorganization and more qualified marketing personnel should all be part of powdered organic coconut sugar development strategy [35].

The waterfall technique was utilized to create this system, which has five stages: analysis of user requirements, design of system, implementation, testing, and upkeep. The results of the black-box tests show that all functionality is valid, indicating that the website works as expected. Based on the findings of black-box testing, it is possible to infer that his website is suitable for use as a means of putting e-marketing plans into action at Central Agro Lestari, Purbalingga [36]. The waterfall technique was utilized to create this system, which has five stages: user needs analysis, system design, implementation, testing, and maintenance. The black-box test results reveal valid results for all functionalities, indicating that this website works as expected. Based on the findings of black-box testing, it is possible to infer that his website is suitable for use as a tool to implement e-marketing strategies at Central Agro Lestari, Purbalingga [37]. The Central Agro Lestari website is a resource for learning about firms in the organic coconut sugar industry. A dependable system is required to offer information to the public as customers [38].

The business of processing crystal coconut sugar during a month production period produces an average of 384 kg. This result is economically feasible with an R/C Ratio value of 3.60. The income earned by artisan farmers during a monthly production period is IDR 7,771,412 [9]. Many farmers have coconut trees at a height that can be reached for sap tapping, making it easier and reducing the risk for those who climb them. Apart from that, the coconut juice is sent to the processing place more quickly, thereby avoiding damage during the journey. Dwarf coconut types would be appealing to young tapers and might be offered to farmers in different provinces for tapping in order to produce coconut sugar [39].

3.4 Technological dimension

The technological dimension in the sustainability index value means that the crystal coconut sugar production activities in Banyumas Regency. The leverage analysis results demonstrate that the environmental dimension contributes less to sustainability status, namely 49.83% (Table 3). The attribute factors in the results of the leverage analysis that are most leveraged for sustainability status are with values of 1.37, 0.20, and 0.74, respectively, for the number of specialization / expertise / skills required for entrepreneurs, the availability of manufacturing facilities and infrastructure, and the potential for upgrading technology/production processes (Figure 6). Another key aspect is the ease with which the ant sugar producing method can be adopted by the local community with a value of 5.18, needs to maintain its status.

The priority alternative implementation of green manufacturing as the main alternative that repair, screening, and modification of drying and packaging apparatus must be implemented which takes into account technical and

technological skills in terms of criteria, human resources, funding, and the environment. This will show "Green Manufacturing" of crystal coconut sugar producers is projected to grow the "Green Economic" competitiveness on a global scale [40]. Technological improvements need to be made to increase production, for example using a mixture of lime as sap preservatives, mangosteen peel, coconut milk as a defoaming agent, a long-time tapping time of 8 hours (heating) +16 hours, and a cooking temperature of 135°C with a yield of 15.58%, part of water-insoluble in 0.07%, color 62.30, moisture content 6.87%, hardness 99.92 N, ash content 1.96%, sucrose content 77.77%, sugar content has been lowered by 8.09%, with organoleptic test values close to 4 (like) and SNI equal [41].

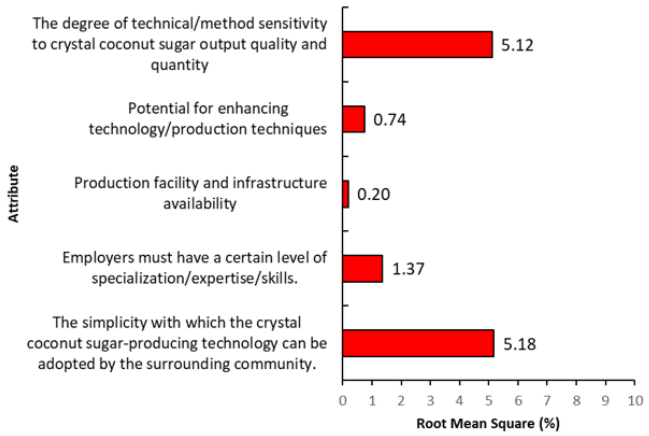

Figure 6. Leverage of technology attributes

Advanced processes such as vacuum drying, freeze drying, and spray drying, among others, can also be employed for the hygienic but small-scale and more expensive manufacture of crystal coconut sugar. Dry granulation may be a low-cost method for producing granular crystal coconut sugar in large quantities. It is best stored with a moisture content of less than 2-4% [42]. The methods of sap collection: (1) the traditional way of collecting sap in a clay pot with a lime coating; (2) a story "coconut-sap chiller method". It was created to obtain fresh, unfermented sap devoid of extraneous substances. The traditional method of collecting coconut sap provided oyster white sap, whereas the new method yielded golden brown sap [43]. Gluten, starch, C4 plant sugars, and coconut or palm oil may be present in coconut blossom sugar. These additives may be employed for anti-foaming agents and releasing agents, for example, or they may merely assist in yield enhancement. Despite the fact that it's a natural product with variances, caramel's fragrance and flavor are distinct [43].

The availability of raw materials is a critical component in managing the supply chain to enhance the sustainability of the palm sugar company. Several variables, including environment, economy, and coconut trees themselves, influence the number of raw materials utilized in the palm sugar industry. These elements are interconnected and interact to increase raw material availability in the palm sugar industry [44]. Alternatives to green production that are technically, ecologically, socially responsible, and economically viable include converting ash into organic fertilizers, cooking furnace replacement, changing equipment for drying, process materials replacement, screening, drying, packing machinery maintenance, and modification. Priority alternatives for green manufacturing implementation indicate repairs and screening, drying, and packaging equipment modifications [45]. Sugar industry waste management incorporates technical, environmental, and Good Housekeeping considerations, as well as social, institutional, and economic considerations, depending on management and employee perspective [46].

Sugarcane yield progress without increasing planted area or reducing environmental consequences due to a lack of cooperation among stakeholders, governmental policies, and markets will be critical to long-term sustainability, with social, economic, and environmental benefits and wellness [47]. The sugar business is an excellent example of a rising system of sustainability with multiple self-sufficiency prospects. Sugarcane and sugar-producing methods that use innovative technologies, as well as the potential for diversification, have propelled the local and global sugar industries to the forefront of the idea of sustainability and self-reliance [30].

The world's largest coconut sugar producer is Indonesia. However, the condition of Indonesian coconut sugar growers remains deplorable. One of the reasons for Indonesian coconut sugar producers' low welfare is their inability to address the international market's need for organic products. The small number of farmers who use techniques for organic coconut sugar contributes to the inability to meet organic criteria for coconut sugar. As farmers continue to adopt organic coconut sugar technology, farmers' contentment must be increased by stakeholders by disseminating the advantages of technology of coconut sugar and supplying farmers with support regarding the company to make it easier for farmers to implement organic coconut sugar technology and lower the risk of failure [48].

Hugo company innovation by holding SOP outreach, increasing ICS supervision by employing freshly harvested coconut juice, ensuring clean juice filtration results, and utilizing sophisticated cooking equipment such as crystal coconut sugar machines to control and improve the quality of organic coconut sugar [1]. The addition of sugar palm or coconut sap to pollen from sugar palms increases the bee *Apis cerana* production. However, coconut sap with added sugar palm pollen is advised as an alternate sustainable nutrition for bees [49].

3.5 Comparative study with other regions

Banyumas Regency and its surroundings are the center of crystal coconut sugar production in Indonesia. There are already crystal coconut sugar producers in other areas besides Banyumas Regency, for example, Kebumen, Cilacap, Pacitan, Lumajang, Banyuwangi, Bali, and Gorontalo districts.

A comparative study analyzing crystal coconut sugar production in several regions in Indonesia shows that in general, coconut sugar craftsmen are the main source of income, with an average working period of 22 years [1]. This condition reflects that they have long experience in their field of work. The longer the experience, the better the abilities and skills. Years of work, age, and level of education have a positive effect on the productivity of coconut sugar craftsmen. On the other hand, age and years of service do not affect workers' income [4]. Coconut sugar craftsmen with an income level below the minimum cost indicate that their income is low, even though a look at their work experience shows that they have quite a long work experience [5].

For jobs that rely on human capabilities, increasing age causes productivity to decrease which will have an impact on income. Especially in the work of collecting coconut sap,

where the productivity of coconut trees is influenced by nature. However, through increasing knowledge and/or education, this can still be mitigated by caring for coconut trees. Apart from mitigating coconut trees, efforts to increase the production and income of craftsmen can also be made with good processing and product diversification. The income and cost ratio of crystal sugar production is higher than molded sugar [6]. Even though in the research sample this condition is in a good category, it still needs to be improved.

In terms of weaknesses, it was identified in the condition of coconut sugar craftsmen and coconut sugar production. These weaknesses are divided into four groups, namely: 1) regarding business sustainability; 2) internal conditions of craftsmen; 3) marketing conditions, and 4) conditions of social capital. Regarding business continuity, 99.96 percent of craftsmen do not want their children to continue working as coconut sugar craftsmen because based on their experience, the income they receive is not sufficient to meet their welfare. Apart from that, the children are also not interested in continuing their parents' business. The phenomenon of children not being interested in the agricultural sector is also found in Bali. Things that influence children's interest in not continuing their business in the agricultural sector are the child's income and interests. The market opportunity for coconut sugar is still very wide, in both domestic and foreign markets (exports). Weaknesses related to the internal conditions of coconut sugar craftsmen are limitations in education and knowledge, capital ownership, and capital in the form of land ownership.

3.6 Comparative study of analysis sustainability index with other products

The study of sustainability index using MDS has been widely studied with subjects studied on various products. Table 4 compares the results of studies of agricultural and industrial products MDS with their dimensional diversity.

Table 4. Comparative study of other products using MDS analysis

No.	Topic	Dimension	Sources
1	Animal feed production	Environmental, social, economic, and technical aspects	[50]
2	Microalgal biomass production	Ecological, social, economic, technological	[51]
3	Compost production	Environmental, social, economic, institutional dimensions, and technological	[52]
4	Environmentally low-input integrated farming	Environmental, economic, social, technological, and institutional aspects	[53]
5	Chili production	Technical, social, economic, and ecological aspects	[54]
6	Rice production	Institutional, environmental, social, economic, and technical aspects	[55]
7	Garlic production	Environmental, technological, economic, social, and institutional dimensions	[56]
8	Chocolate production	Ecological, social, economic, institutional dimensions, and technological	[57]
9	Coffee production	Environmental, social, economic, and technical aspects	[58]
10	Corn production	Environmental, technological, social, economic, and institutional dimensions	[59]
11	Dairy cattle production	Dimensions of environmental, social, economic, technological, and institutional	[60]
12	Sugarcane production	Materials, machines, methods, humans, management, economy, market, environment	[61]

4. CONCLUSIONS

Based on the findings of sustainability index research for crystal coconut sugar manufacturing in Banyumas Regency using the MDS method, it can be concluded that the average sustainability index value shows good performance, namely 65.42%. The index of sustainability analysis shows that the environmental dimension is 52.73%, so it has less sustainable status; the social dimension is 68.24%, so it has quite sustainable status; the economic dimension is 90.86%, so it has very good status for sustainability; and the technological dimension is 49.83%, then it has less than sustainable status.

Strategies for increasing sustainability status need to be carried out, especially for the environmental, social, and technological dimensions based on the priority scale for each dimension. The factors that have the most leverage are the following attributes:

a) Attributes in the environmental dimension are the use of biodegradable materials, processing, and utilization of waste produced, air pollution due to smoke from cooking, the extent to which natural resources (land, plants) are exploited, as well as the possibility for disease transmission as a result of the business's presence.

b) Attributes in the social dimension are an increase in educational attributes and a reduction in the potential for accidents.

c) Attributes in the economic dimension are the potential for creating jobs for residents and the level of market absorption of production results.

d) The level of specialization/expertise/skills required for entrepreneurs, the availability of production facilities and infrastructure, and the potential for upgrading technology/ production processes are all technological dimension features.

The technological dimension has the lowest performance rate, at 49.83%. In this scenario, an improvement strategy is implemented to increase the crystal coconut sugar industry's performance by improving its technological dimension. The technological dimension of this research only covers the performance of the crystal coconut sugar industry in the off-farm section, even though the main problems in the sugar industry are primarily caused by the on-farm section, which varies by region; thus, suggestions for future research in performance assessment in terms of attributes are required. On-farm technological aspects include the use of high-yielding types of early maturing coconuts and trees that are not too tall to facilitate harvesting, organic coconut cultivation technology, farmer education on cultivation technology, and government support in increasing the distribution of government subsidies to farmers for capital for technological improvements.

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NOMENCLATURE

As	Arsenic
Cd	Cadmium
FGD	Focus Group Discussion
GDP	Green Domestic Product
Hg	Hydrargyrum (Mercury)
ICS	Internal Control System
kg	Kilogram
Max	Maximum
mg	Milligram
Min	Minimum
Mm	Millimeter
MDS	Multidimensional Scaling
N	Nitrogen
NTB	Nusa Tenggara Barat
NTT	Nusa Tenggara Timur
O	Oxygen
OSHMS	Occupational Safety and Health Management System
Pb	Plumbum (Lead)
POME	Palm Oil Mill Effluent
R^2	determinant coefficient
RMS	Root Mean Square
S	Value emphasize
Sn	Stannum
SNI	Indonesian National Standard
SOP	Standard Operating Procedure
SQR	R^2
X	Axis
Y	Ordinate