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Enhancing Pakistani Jaggery Exports: An AHP Driven Analysis

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The demand for natural raw products is increasing worldwide, especially in areas that prioritize health and wellness. Jaggery, a non-refined natural sweetener, has emerged as an economic and ecological alternative to processed white sugar. Despite Pakistan's notable production capacity, the inconsistent quality, inefficient processing technologies, and government policies are hindering its export potential. This study employs the analytical hierarchy process (AHP) to identify and prioritize key factors that influence jaggery export potential. The data for AHP were extracted from a structured questionnaire, which was completed by 100 respondents, including producers, exporters, and farmers. The insights from the analysis revealed that skilled labor, mechanized crushers, and quality of raw material are the most critical factors. However, government policies, water consumption, water wastage, carbon emissions, carbon credits, fair trade, and sustainable fuel are undervalued, which pose a long-term threat to this industry. By prioritizing challenges, decision makers can amicably enhance the sector's viability. This paper contributes to agro-industrial development by offering recommendations for sustainable jaggery production and export.

Keywords: Jaggery, Natural Sweetener, Sugar Cane, Jaggery Export, Jaggery Production

Introduction:

In recent years, the demand for organic foods has grown exponentially, and the global shift towards natural sweeteners has renewed interest in jaggery [1]. Jaggery, also known as gur, is a traditional sweetener used in various parts of the world. It is an unrefined sugar made by concentrating sugarcane juice [2]. It is widely consumed in South Asia and Southeast Asia, and it is becoming increasingly known in other parts of the world as a healthier sugar substitute [3]. Jaggery is natural, nutritious, and offers a unique flavor along with added health benefits. Jaggery is produced by boiling sugarcane juice till it turns to a thick caramel color. It is then placed into molds where it is allowed to cool to gain its solid-state form or diced into small cubes [4]. It has a very unrefined taste, a little like caramel and molasses, and is very distinct from sugar. It also contains slightly higher nutritive value than refined sugar; it contains traces of iron, calcium, and magnesium [5][6]. It can be consumed in its raw form and used in teas, coffee, milk, desserts, and even as a topping to savory dishes. It is also used in the customary Ayurvedic preparations [7].

In Pakistan, the average sugarcane yield ranges from 45 to 50 tons per hectare, which is below the global average [8]. Sugarcane yields vary depending on the variety grown, soil type, climatic conditions, and irrigation practices. In Pakistan, sugarcane production for 2025–26 is projected to reach 83.5 million metric tons [9].

The global jaggery market size is valued at 4.2 billion and is forecasted to be $7.5 billion in 2032 [10]. However, higher production costs, ineffective supply chain management, and a lack of advanced technologies are hindering this market. Moreover, sugarcane also has some risks, such as disease attacks, pests, and global climate change.

Identifying opportunities to strengthen the jaggery market is essential. Growing global demand for natural sweeteners, particularly in countries such as China, Indonesia, and Malaysia, presents promising prospects for increasing export shares. However, there exists room for value addition and product diversification, as it would contribute to the expansion of the industry. By addressing the aforementioned challenges and capitalizing on available opportunities, Pakistan can enhance its competitive position in the global jaggery market.

In Pakistan, the Dera Ghazi Khan district of Punjab, the Charsadda district of Khyber Pakhtunkhwa, and Tando Allahyar of Sindh are the major hubs [11]. India has been a major exporter of jaggery [3]. However, the Pakistan government's decision to ban the jaggery export in 2020 has slowed down this industry [12].

Regulating Pakistan jaggery in the foreign markets is a challenge due to smuggling [13] and diverse export destinations' requirements [14]. It is different for different countries, which is difficult to meet.

Pakistan's jaggery industry faces significant challenges, hindering its potential to become a major player in the global market. The low export volume is due to inadequate quality control, international certifications, limited access to international markets, inefficient supply chain management, unskilled labor, political decisions, sugarcane, and outdated production methods. These challenges have severe consequences, including reduced revenue and livelihoods for sugarcane farmers and jaggery producers. A systematic study considering a multi-criteria decision-making model (MCDM) can be helpful to identify quality and address all these issues and challenges. By addressing these challenges, this research can transform Pakistan's jaggery industry into a vibrant and competitive sector, contributing to national economic growth and rural development.

Charsadda is one of the best jaggery-producing districts of Pakistan. However, limited research is available to identify and quantify the factors and challenges associated with jaggery production. Moreover, the export potential is discussed in the literature.

Literature Review:

Jaggery has long been a cornerstone of agro-based economies. It is produced by heating and condensing sugarcane juice through a process that involves extraction, clarification, boiling, cooling, molding, drying, powdering, packaging, and storage [15]. During production and storage, it faces challenges such as low crushing efficiency, space-intensive bagasse drying, labor-intensive processes, use of chemical clarifying agents, short storage life, high fuel consumption, and poor thermal efficiency [4]. Revitalizing the industry requires a focus on improving quality standards, minimizing production expenses, and diversifying offerings by introducing fortified and innovatively designed value-added products. Adding nutritional additives can enhance export potential and attract high market prices. Researchers are working on technological advancements in processing, preservation, storage, and packaging to ensure profitability [6].

India is a leading exporter of jaggery and confectionery, with a long history of production and trade [16]. However, export prices and quantities fluctuate due to changing market scenarios. A Markov chain model was used to analyze export data from 2004-2018 and predict future trends. The model found that North African countries are the largest importers of Indian jaggery and confectionery [16]. Export quantities are expected to remain high, but prices may fluctuate, requiring exporters to adapt to maintain their global market share [16]. India and Pakistan have a low trade volume despite sharing a border. Political tensions and a fear that India's cheap agricultural products will flood Pakistan's markets are the main reasons. Although Pakistan agreed in 2012 to grant India Most Favored Nation (MFN) status, it has yet to implement this decision. An analysis examines the trends and opportunities for increasing agricultural trade between India and Pakistan, including comparative advantages and trade complementarities. The research advocates deeper trade integration to benefit both economies, given the high dependence on agriculture and a significant share of agro-products in overall trade.

Jaggery can significantly contribute to the farmer community within Pakistan by providing an alternative to selling sugarcane to grain mills that is both lucrative and low-cost. In addition to the creation of labor-intensive activities to expand jobs in the rural areas, its production is also environmentally friendly since it prolongs making use of its by-products, such as bagasse. Jaggery is culturally important and commonly used in traditional foods, and because of its health benefits, it is becoming very popular, and there are more local and international demands for jaggery. It reinforces the economy of the countryside and in states such as Punjab, Sindh, and Khyber Pakhtunkhwa, and helps to create an atmosphere of decentralization and farmer-friendliness because of the issues regarding general sugar manufacturing [8].

Table 1. Comparison of different studies

Author(s) & Year	Focus / Contribution	Findings	Critical Comparison
[16]	Analysis of Indian jaggery and confectionery exports using a Markov chain model (2004–2018).	North African countries are identified as the largest importers; export quantities remain high, but prices fluctuate.	Provides quantitative forecasting but is limited to the Indian context; it does not explore small-scale producers' challenges or socio-economic impacts.
[16]	Trade dynamics of jaggery exports.	Prices are expected to fluctuate, requiring adaptation by exporters.	Strong predictive insights, but recommendations are generalized; it lacks policy-focused strategies for stability in export markets.

[8]	Role of jaggery in Pakistan's rural economy.	Jaggery production supports farmers, generates rural employment, uses by-products (bagasse), and has growing domestic & international demand.	Provides a Pakistan-centric socio-economic perspective, contrasting with India-focused trade models. Strong on sustainability, but lacks quantitative export analysis like [16]

India is also the largest exporter of jaggery, accounting for more than 60 percent of the world's production [16]. The major export destinations are the USA, Indonesia, Kenya, the UAE, and Malaysia. The large figure of exports is an indicator of higher demand in other parts of the world for natural and unrefined sweeteners because of the rising consciousness of health. The jaggery industry in India is a healthy rural employment and value addition in agriculture, and adds to the foreign exchange earnings of the country [16][6].

However, given the increasing global demand for natural sweeteners, natural sweeteners such as jaggery are facing untapped export ability in most of Pakistan, partly because of their inconsistent quality, absence of standardization, poor branding, and inability to reach international markets. Although the past literature on the jaggery community has emphasized the economic and cultural importance of jaggery, there seems to be an overwhelming deficiency of literature that addresses issues and prospects of jaggery export. Specifically, very few facts are known in terms of what the market in importing nations thinks, and what are the conditioning factors that dictate the level of acceptability of jaggery in overseas markets, and policy or infrastructural constraints that the producers and exporters must encounter. To address these gaps, the proposed research will answer the research questions as follows:

What are the main determinants of the commercial value and acceptability of jaggery to a consumer?

What are the obstacles and possibilities to enhancing the market potential of jaggery both in local and international markets?

Objectives:

The main objective of this study is to identify the various factors associated with jaggery production and export, with a particular focus on understanding their influence on quality and marketability. Moreover, the research will seek to quantify the identified factors so that a measurable foundation measures the influence on production efficiency and export potential can be found. Moreover, it attempts to find and examine the kind of challenges that the small-scale producers of jaggery experience, thus providing information on the kind of limitations that restrict their development and competitiveness at both local and international levels.

Methodology:

The first step is the preliminary literature review, which serves as a knowledge block. The literature review helped in identifying the research gap and drafting the problem statement. A comprehensive literature review was then carried out to identify the factors, challenges, and determinants associated with jaggery production and jaggery exports. The identified factors were finalized by removing duplicates and merging similar ones. Multiple field visits were conducted to validate the questionnaire and its factors, with the received suggestions incorporated into the final version. The final questionnaire was distributed to potential respondents. The acceptable sample size was 100, which was statistically calculated through Slovin's formula.

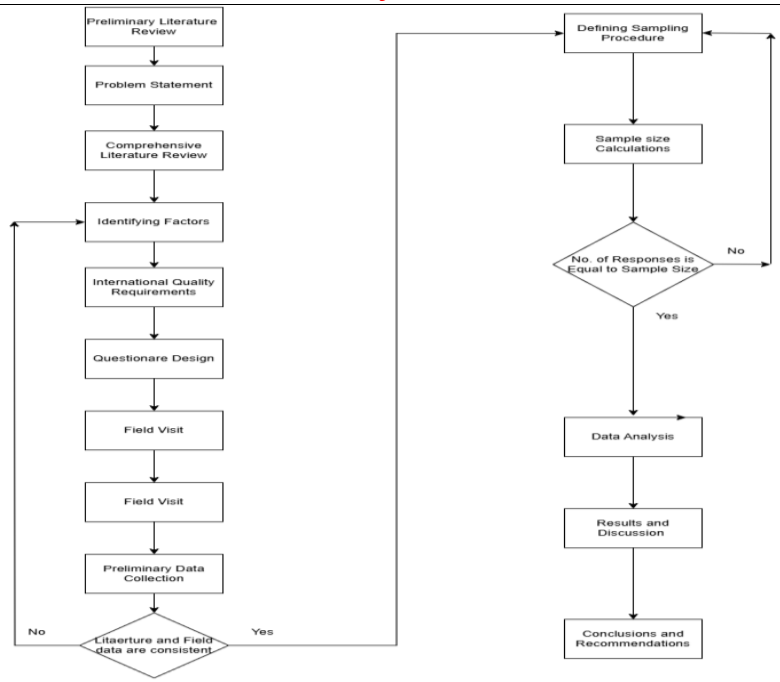

Figure 1. Proposed Methodology

A critical examination of existing research is conducted to identify the primary factors influencing the sustainable production and export of jaggery. A comprehensive search of academic journals, conference proceedings, and reputable sources was conducted to gather relevant information. Typically, sustainability is assessed through the triple bottom line. However, this research includes time and quality too. Table 2 shows the collected factors categorized into social, environment, economic, time, and quality categories.

Table 2. Factors Selection

S.No.	Variable	Category	Factor	References
1	EC1	Economic	Price	[8][17][6]
2	EC2	Economic	Processing Cost	[8][3][18]
3	EC3	Economic	Selling Price	[8][19][3]
4	EC4	Economic	Export	[8][3][19]
5	EC5	Economic	Taxation	[8][19][3]
6	EC6	Economic	Utility Bills	[3][6]
7	EV1	Environment	Biodiversity	[20][6][21]
8	EV2	Environment	Air Quality	[22][20][6]
9	EV3	Environment	Water Waste	[22][20][6]
10	EV4	Environment	Carbon Emissions	[22][20][6]
11	EV5	Environment	Solid Waste	[22][20][6]
12	EV6	Environment	Natural Disaster	[22][20][6]
13	EV7	Environment	Recyclability	[6][20][22]
14	S1	Social	Market Demand	[23][24][16]
15	S2	Social	Competitors	[23][24][16]
16	S3	Social	Trade Agreement	[23][24][25]
17	S4	Social	Indirect Costs	[23][24][25]
18	S5	Social	Skilled Labor	[23][24][25]
19	T1	Technology	Modern Furnaces	[20][26]
20	T2	Technology	Bagasse-Fired Furnace	[20][26][15]
21	T3	Technology	Solar Heating	[20][15]

22	T4	Technology	Mechanized Crusher	[20][26][15]
23	T5	Technology	Automatic Temperature Control	[20][26]
24	T6	Technology	Automatic Jaggery Shaping	[20][26][15]
25	T7	Technology	Automatic Packaging	[20][26]

A total of 50 factors were initially identified; however, after eliminating redundancies and merging similar or identical ones, 15 factors were finalized and classified into four main categories: Economic, Environmental, Social, and Technological.

These factors were chosen for their relevance, frequency of citation in the literature, and potential influence. They are critical as they play a significant role in determining the success, sustainability, and overall performance of various jaggery production processes and products. Understanding and managing these factors effectively is essential for achieving desired outcomes.

Data Collection:

A comprehensive survey was conducted in District Charsadda to collect primary data from 100 respondents. The questionnaire consisted of 20 items, including multiple-choice, rating-scale, and open-ended questions. Trained enumerators administered it to respondents, ensuring both clarity and accuracy in responses. The survey targeted jaggery producers, exporters, traders, and farmers in District Charsadda, providing a representative sample of stakeholders involved in the jaggery value chain. The data collection spanned approximately two weeks and provided valuable insights into the factors influencing the jaggery industry. The collected data were subsequently analyzed using the Analytical Hierarchy Process (AHP) method to identify the most critical factors.

Additionally, focus group discussions were conducted with farmer groups to gather collective insights. To reach remote areas, enumerators utilized motorcycles and public transportation, while also leveraging local events, such as agricultural fairs and market days, to intercept potential respondents. To enhance response rates, respondents were assured confidentiality and anonymity, with completed questionnaires collected promptly to minimize potential biases. This strategic distribution approach yielded a 90% response rate, providing valuable primary data for analyzing the factors influencing Pakistani jaggery export quality.

Many farmers lack formal education, making it challenging to design questionnaires that are easily understandable and accessible to them. Additionally, farmers' busy schedules, limited literacy, and lack of exposure to research surveys often result in hesitation or unwillingness to participate. Furthermore, the lack of reliable contact information, inadequate transportation infrastructure, and limited connectivity in rural areas hinder the effective distribution and collection of questionnaires. These challenges necessitate the use of alternative methods, such as face-to-face interviews, focus group discussions, and collaboration with local agricultural extension workers or community leaders to facilitate data collection and ensure representative responses. The Cronbach's alpha test was done to check the data reliability. As shown in Table 3, the Cronbach's alpha value is 0.73, which is acceptable.

Table 3. Reliability Analysis

	Mean	SD	Cronbach's α	McDonald's ω
Values	2.99	0.358	0.735	0.728

Data Analysis:

The Analytical Hierarchy Process (AHP) is a decision-making approach that involves structuring a complex problem into a hierarchical framework. The process begins with defining the problem and goal, followed by developing a hierarchy of criteria, sub-criteria, and alternatives. Pairwise comparisons are then conducted to rate the relative importance or preference of each element. The resulting priority weights are calculated and checked for

consistency. The mean of each factor calculated from available data is used to generate the pairwise matrix.

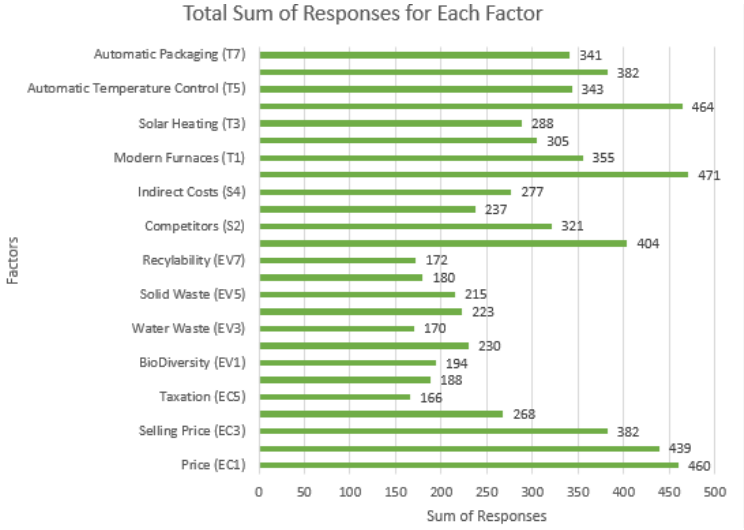

Figure 2. Representation of different factors responses

As this is a 25*25 matrix, instead of the consistency index method, the multiplying method will be used in this case. In Iteration 1, Table 4 is multiplied by itself, after which the row sums and the overall total sum were calculated. Then eigenvalues will be calculated by dividing the respective row sum by the column sum.

In the second iteration, the matrix obtained in iteration 1 was multiplied by itself, and then the row sum, total sum, and eigenvalues were calculated. If the difference in eigenvalues of iteration 1 and iteration 2 was not zero, iteration 3 followed the same steps. If the difference was zero, the iterations stopped. Table 5 presents the row sum and eigenvalues for iteration 1 and iteration 2, while the last column shows the difference in eigenvalues.

Table 4. Pairwise Comparison

	EC1	EC2	EC3	EC4	EC5	EC6	EV1	EV2	EV3	EV4	EV5	EV6	EV7	S1	S2	S3	S4	S5	T1	T2	T3	T4	T5	T6	T7
EC1	1.00	1.05	1.20	1.72	2.77	2.45	2.37	2.00	2.71	2.06	2.14	2.56	2.67	1.14	1.43	1.94	1.66	0.98	1.30	1.51	1.60	0.99	1.34	1.20	1.35
EC2	0.95	1.00	1.15	1.64	2.64	2.34	2.26	1.91	2.58	1.97	2.04	2.44	2.55	1.09	1.37	1.85	1.58	0.93	1.24	1.44	1.52	0.95	1.28	1.15	1.29
EC3	0.83	0.87	1.00	1.43	2.30	2.03	1.97	1.66	2.25	1.71	1.78	2.12	2.22	0.95	1.19	1.61	1.38	0.81	1.08	1.25	1.33	0.82	1.11	1.00	1.12
EC4	0.58	0.61	0.70	1.00	1.61	1.43	1.38	1.17	1.58	1.20	1.25	1.49	1.56	0.66	0.83	1.13	0.97	0.57	0.75	0.88	0.93	0.58	0.78	0.70	0.79
EC5	0.36	0.38	0.43	0.62	1.00	0.88	0.86	0.72	0.98	0.74	0.77	0.92	0.97	0.41	0.52	0.70	0.60	0.35	0.47	0.54	0.58	0.36	0.48	0.43	0.49
EC6	0.41	0.43	0.49	0.70	1.13	1.00	0.97	0.82	1.11	0.84	0.87	1.04	1.09	0.47	0.59	0.79	0.68	0.40	0.53	0.62	0.65	0.41	0.55	0.49	0.55
EV1	0.42	0.44	0.51	0.72	1.17	1.03	1.00	0.84	1.14	0.87	0.90	1.08	1.13	0.48	0.60	0.82	0.70	0.41	0.55	0.64	0.67	0.42	0.57	0.51	0.57
EV2	0.50	0.52	0.60	0.86	1.39	1.22	1.19	1.00	1.35	1.03	1.07	1.28	1.34	0.57	0.72	0.97	0.83	0.49	0.65	0.75	0.80	0.50	0.67	0.60	0.67
EV3	0.37	0.39	0.45	0.63	1.02	0.90	0.88	0.74	1.00	0.76	0.79	0.94	0.99	0.42	0.53	0.72	0.61	0.36	0.48	0.56	0.59	0.37	0.50	0.45	0.50
EV4	0.48	0.51	0.58	0.83	1.34	1.19	1.15	0.97	1.31	1.00	1.04	1.24	1.30	0.55	0.69	0.94	0.81	0.47	0.63	0.73	0.77	0.48	0.65	0.58	0.65
EV5	0.47	0.49	0.56	0.80	1.30	1.14	1.11	0.93	1.26	0.96	1.00	1.19	1.25	0.53	0.67	0.91	0.78	0.46	0.61	0.70	0.75	0.46	0.63	0.56	0.63
EV6	0.39	0.41	0.47	0.67	1.08	0.96	0.93	0.78	1.06	0.81	0.84	1.00	1.05	0.45	0.56	0.76	0.65	0.38	0.51	0.59	0.63	0.39	0.52	0.47	0.53
EV7	0.37	0.39	0.45	0.64	1.04	0.91	0.89	0.75	1.01	0.77	0.80	0.96	1.00	0.43	0.54	0.73	0.62	0.37	0.48	0.56	0.60	0.37	0.50	0.45	0.50
S1	0.88	0.92	1.06	1.51	2.43	2.15	2.08	1.76	2.38	1.81	1.88	2.24	2.35	1.00	1.26	1.70	1.46	0.86	1.14	1.32	1.40	0.87	1.18	1.06	1.18
S2	0.70	0.73	0.84	1.20	1.93	1.71	1.65	1.40	1.89	1.44	1.49	1.78	1.87	0.79	1.00	1.35	1.16	0.68	0.90	1.05	1.11	0.69	0.94	0.84	0.94
S3	0.52	0.54	0.62	0.88	1.43	1.26	1.22	1.03	1.39	1.06	1.10	1.32	1.38	0.59	0.74	1.00	0.86	0.50	0.67	0.78	0.82	0.51	0.69	0.62	0.70
S4	0.60	0.63	0.73	1.03	1.67	1.47	1.43	1.20	1.63	1.24	1.29	1.54	1.61	0.69	0.86	1.17	1.00	0.59	0.78	0.91	0.96	0.60	0.81	0.73	0.81
S5	1.02	1.07	1.23	1.76	2.84	2.51	2.43	2.05	2.77	2.11	2.19	2.62	2.74	1.17	1.47	1.99	1.70	1.00	1.33	1.54	1.64	1.02	1.37	1.23	1.38
T1	0.77	0.81	0.93	1.32	2.14	1.89	1.83	1.54	2.09	1.59	1.65	1.97	2.06	0.88	1.11	1.50	1.28	0.75	1.00	1.16	1.23	0.77	1.03	0.93	1.04
T2	0.66	0.69	0.80	1.14	1.84	1.62	1.57	1.33	1.79	1.37	1.42	1.69	1.77	0.75	0.95	1.29	1.10	0.65	0.86	1.00	1.06	0.66	0.89	0.80	0.89
T3	0.63	0.66	0.75	1.07	1.73	1.53	1.48	1.25	1.69	1.29	1.34	1.60	1.67	0.71	0.90	1.22	1.04	0.61	0.81	0.94	1.00	0.62	0.84	0.75	0.84
T4	1.01	1.06	1.21	1.73	2.80	2.47	2.39	2.02	2.73	2.08	2.16	2.58	2.70	1.15	1.45	1.96	1.68	0.99	1.31	1.52	1.61	1.00	1.35	1.21	1.36
T5	0.75	0.78	0.90	1.28	2.07	1.82	1.77	1.49	2.02	1.54	1.60	1.91	1.99	0.85	1.07	1.45	1.24	0.73	0.97	1.12	1.19	0.74	1.00	0.90	1.01
T6	0.83	0.87	1.00	1.43	2.30	2.03	1.97	1.66	2.25	1.71	1.78	2.12	2.22	0.95	1.19	1.61	1.38	0.81	1.08	1.25	1.33	0.82	1.11	1.00	1.12
T7	0.74	0.78	0.89	1.27	2.05	1.81	1.76	1.48	2.01	1.53	1.59	1.89	1.98	0.84	1.06	1.44	1.23	0.72	0.96	1.12	1.18	0.73	0.99	0.89	1.00

Table 4. Eigen Values Calculations

Factors	Iteration 1		Iteration 2		Eigen Values Difference
	Row Sum	Eigen Values	Row Sum	Eigen Values	
EC1	1078.31	0.0615	673942.8589	0.0615	0
EC2	1029.08	0.0587	643175.9023	0.0587	0
EC3	895.46	0.0511	559665.5916	0.0511	0
EC4	628.23	0.0359	392644.97	0.0359	0
EC5	389.13	0.0222	243205.4665	0.0222	0
EC6	440.70	0.0252	275437.5163	0.0252	0
EV1	454.76	0.0260	284228.0753	0.0260	0
EV2	539.15	0.0308	336971.4295	0.0308	0
EV3	398.51	0.0227	249065.8392	0.0227	0
EV4	522.75	0.0298	326715.7773	0.0298	0
EV5	503.99	0.0288	314995.0319	0.0288	0
EV6	421.95	0.0241	263716.7709	0.0241	0
EV7	403.19	0.0230	251996.0255	0.0230	0
S1	947.04	0.0540	591897.6413	0.0540	0
S2	752.47	0.0429	470294.9081	0.0429	0
S3	555.56	0.0317	347227.0817	0.0317	0
S4	649.33	0.0371	405830.8085	0.0371	0
S5	1104.09	0.0630	690058.8838	0.0630	0
T1	832.17	0.0475	520108.0759	0.0475	0
T2	714.97	0.0408	446853.4173	0.0408	0
T3	675.11	0.0385	421946.8334	0.0385	0
T4	1087.69	0.0621	679803.2316	0.0621	0
T5	804.04	0.0459	502526.9579	0.0459	0
T6	895.46	0.0511	559665.5916	0.0511	0
T7	799.35	0.0456	499596.7715	0.0456	0
Total Sum	17522.51	1.00	10951571.46	1.00	0.00

Results and Discussion:

Figure 3 presents the eigenvalues of different factors across the four categories. The respondents indicate that none of the environmental factors have more than 0.35 eigenvalues. Moreover, four economic factors, four social factors, and all the technology factors have scored more than 0.35.

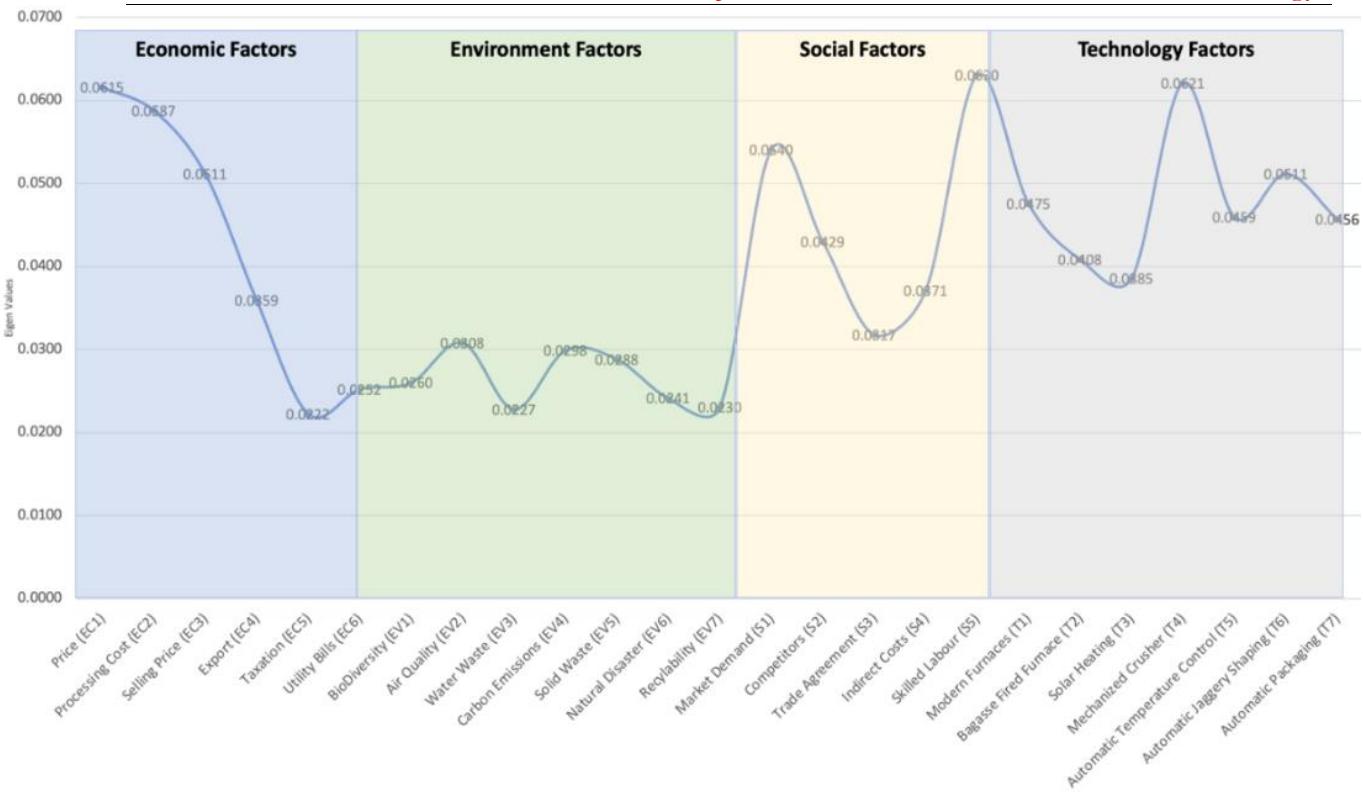

Figure 3. Significant Categories and Factors

Table 6 shows the ranking of all 25 factors in descending order. The color coding is for simplifying the discussion. The yellow shows the social factor, the orange shows technology, the blue shows the economy, and the green shows the environment.

The most important factor is skilled labour, which has scored an eigenvalue of 0.0631, representing 6.3 percent, followed by the mechanical crusher with an eigenvalue of 0.0621 and a percentage of 6.21. However, the first economic factor is in third position, with an eigenvalue of 0.0615, is the price of sugar cane, followed by another economic factor, which was processing cost.

Table 5. Ranking of Factors

Factors (Variables)	Eigen Values	Rank	Percentage
Skilled Labour (S5)	0.0630	1	6.30
Mechanized Crusher (T4)	0.0621	2	6.21
Price (EC1)	0.0615	3	6.15
Processing Cost (EC2)	0.0587	4	5.87
Market Demand (S1)	0.0540	5	5.40
Selling Price (EC3)	0.0511	6	5.11
Automatic Jaggery Shaping (T6)	0.0511	7	5.11
Modern Furnaces (T1)	0.0475	8	4.75
Automatic Temperature Control (T5)	0.0459	9	4.59
Automatic Packaging (T7)	0.0456	10	4.56
Competitors (S2)	0.0429	11	4.29
Bagasse Fired Furnace (T2)	0.0408	12	4.08
Solar Heating (T3)	0.0385	13	3.85
Indirect Costs (S4)	0.0371	14	3.71
Export (EC4)	0.0359	15	3.59
Trade Agreement (S3)	0.0317	16	3.17
Air Quality (EV2)	0.0308	17	3.08

Carbon Emissions (EV4)	0.0298	18	2.98
Solid Waste (EV5)	0.0288	19	2.88
BioDiversity (EV1)	0.0260	20	2.60
Utility Bills (EC6)	0.0252	21	2.52
Natural Disaster (EV6)	0.0241	22	2.41
Recyclability (EV7)	0.0230	23	2.30
Water Waste (EV3)	0.0227	24	2.27
Taxation (EC5)	0.0222	25	2.22

The five factors that have the greatest impact on jaggery production and exportation are Skilled Labor (S5), Mechanized Crusher (T4), Price (EC1), Processing Cost (EC2), and Market Demand (S1). This is so crucial since it directly relates to efficiency of production, cost control, and competitiveness. Skilled labour and modern plant are necessary for quality and consistent jaggery production. Moreover, mechanization in the crushers enhances the extraction of juice yield, which enhances resource utilization and profit. Finally, the need of the market leads the whole supply chain, since the market affects the target of production. Findings are corroborated in the literature; various studies point to the fact that the key areas in enhancing value addition and increasing export potentials in agri-based products, such as jaggery, include cost-effectiveness, efficient processing, and skilled human resources.

The five least significant factors are Taxation (EC5), Water Waste (EV3), Recyclability (EV7), Natural Disaster (EV6), and Utility Bills (EC6). The weightage given to these factors was, perhaps, low since they either affect jaggery production and trade indirectly or very rarely. As an example, where taxation and utilities can be part of the general profitability, they do not directly contribute to the production or readiness to go to export, as would labor, technology, and market demand. Similarly, other environmental concerns, such as water wastage, recyclability, and the impact of natural disasters, often receive little attention in many traditional or small-scale jaggery production facilities in South Asia. The five factors that are ranked moderately are Automatic Jaggery Shaping (T6), Modern Furnaces (T1), Automatic Temperature Control (T5), Automatic Packaging (T7), and Competitors (S2). These are some of the factors that act as a bridge between the old and new practices of making jaggery. Automatic shaping, temperature commands, and packaging can also enhance the quality of the product, its consistency, hygienic values, and shelf life, which are extremely important aspects of exportable products. Although they are not essential, these technologies may be used to distinguish jaggery in the competitive markets. Competitor presence, in its turn, makes producers innovate and enhance their productivity. The moderate ranking denotes that the establishment of these factors is understood, but their implementation might not be as significant because of the cost factor or lack of awareness.

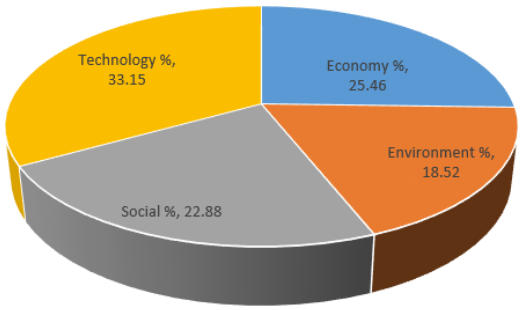

Figure 4. Categories Percentage Distribution

The most common categorization for sustainability is done through the triple bottom line (TBL), which focuses on three categories only, which are environment, economic, and social. Technology is typically merged in economic and social domains. However, innovation and technology should be treated as separate pillars. As shown in Figure 4, the overall percentage score

of the technology domain is higher than others. This means respondents believe that for sustainable jaggery production and export, technology should be of prime importance.

Discussion:

The literature on jaggery trade and manufacturing offers relevant but incomplete insight into the dynamics of the sector. Author (2021) implements a Markov chain model of predicting trade flows, whereby they indicate the North Africa region as a leading importer, and discuss price volatility; however, they fail to identify production-level problems experienced by producers and exporters. Author (2016) examines the issue of agricultural trade between India and Pakistan, emphasizing the concept of comparative advantage as well as political trade impediments, including the concept of MFN status, but the results of their research are concentrated on the policies established between the cross-border relations, rather than on the domestic weaknesses of production. Similarly, Afghan, Khan, Verma, and Nikpay (2024) highlight the socio-economic value of jaggery to the rural population in Pakistan, including but not limited to its role in the generation of revenues and the use of by-products, and do not focus on technical or policy-related factors in a systematic manner. A combination of these studies provides some insights into trade patterns, political factors, and socio-economic effects, but fails to reveal the interconnected causes of export potential. Comparatively, the current AHP-based research contributes to the body of knowledge by integrating stakeholder views within a systematic multi-criteria decision-making approach. In comparison to the earlier studies where trade, / policy, or socio-economic factors are singled out, the proposed study would be an integrated assessment of technical, operational, and policy-based factors, thus acting as an opportunity to prioritize the determinants. The evidence expresses that the trained labour force, mechanised crushers, and quality of raw materials are decisive towards production efficiency, whereas water supply, government policy, and carbon emission are long-term matters of sustainability that have not been valued despite their significance in terms of export preparedness. This study can serve as an actionable framework of a holistic approach, as the three aspects, i.e., forecasting, policy analysis, and socio-economic evaluations, have been combined to cover both the short-term issues in production as well as the structural reforms needed to make jaggery production in Pakistan a competitive industry on a global scale.

Table 6. Comparison with different Studies

Study	Focus	Methodology	Key Findings	Comparison with the AHP Study
Revathy et al. (2021)	Indian jaggery & confectionery exports (2004–2018).	Markov chain model for trade forecasting.	North Africa = largest importer; exports are stable, but prices fluctuate.	Forecasts demand but ignores producer-level issues. AHP adds depth by prioritizing production/export factors directly from stakeholders.
Gaurav & Bharti (2016)	India–Pakistan agricultural trade.	Policy & comparative advantage analysis.	Low trade volume due to political tensions and MFN issues.	Focuses on cross-border policy barriers; AHP addresses internal (domestic) production/export weaknesses in Pakistan.
Afghan, Khan, Verma, & Nikpay (2024)	Jaggery's role in Pakistan's rural economy.	Qualitative socio-economic study.	Jaggery boosts rural incomes, uses by-products (bagasse), and rising demand.	Explains socio-economic benefits, but not systematically prioritized. AHP quantifies the weights of socio-economic vs. technical vs. policy factors.
Our AHP Study (2025)	Jaggery export potential from Pakistan.	Analytical Hierarchy Process (AHP)	Skilled labour, mechanized crushers, and raw	Unlike others, it integrates stakeholder input with multi-criteria decision-making.

		with 100 stakeholder questionnaires.	material quality = most critical; undervalued issues: govt. Policy, sustainability, water use.	Bridges the gap between trade forecasting, policy analysis, and socio-economic perspectives.

Conclusion:

The natural sweetener, jaggery, is a good alternative to refined sugar, since it is cost-effective, organic, and environmentally friendly. Although Pakistan has a favorable production base, its jaggery exports are restricted by an export ban, quality control issues, and low processing and export readiness. Under the Analytical Hierarchy Process (AHP), the research was able to find out the key factors affecting jaggery potential and rank them. The findings indicate that the efficiency and consistency in production are based on the management of skilled labor, crushers that are mechanized, and good quality of raw materials. As far as export-specific determinants are concerned, price competitiveness, demand, processing cost, packaging standards, and trade facilitation were some of the variables that played a critical role in determining the international attraction of jaggery. Nevertheless, the poor emphasis on key long-run factors, including government policy, trade policies, carbon emissions, water wastage, and sustainable processes, causes a legitimate fear for the resiliency and scalability of the sector. Modern technology, adherence to international hygienic and packaging standards, and promotion of favorable trade policies are some of the factors that the stakeholders need to integrate to harness the jaggery export market potential.

Future Recommendations:

This research can be further expanded by investigating the impact of climate change on sugarcane production, developing sustainable packaging solutions, and exploring the potential of jaggery as a natural remedy for various health issues. Additionally, studies on market segmentation, consumer behavior, and digital marketing strategies could help jaggery producers expand their customer base and increase sales. By conducting comparative studies with other traditional industries, analyzing the supply chain, and exploring market trends and consumer preferences, the industry can identify new opportunities. Furthermore, exploring product diversification, such as new jaggery-based food products, can help identify new markets and revenue streams, ultimately contributing to the industry's growth, innovation, and sustainability.

References:

[1] G. S. Suresha, G. Krishnappa, M. Palanichamy, H. K. M. Swamy, H. Kuppusamy, and H. Govindakurup, "Value Addition and Product Diversification in Sugarcane," *Value Addit. Prod. Diversif. Sugarcane*, pp. 1–362, Jan. 2024, doi: 10.1007/978-981-97-7228-5/COVER.

[2] N. Bashir, K. Younis, and O. Yousuf, "An Overview Encompassing the Present Status of Jaggery Processing," *Sugar Tech*, vol. 25, no. 6, pp. 1303–1315, Dec. 2023, doi: 10.1007/S12355-023-01297-6/METRICS.

[3] A. Singh, "Agro-processing industry: Trends and challenges of jaggery," *Indian Econ.*, vol. 212, 2021.

[4] B. Madhu, "EVALUATION ON EDIBLE COATINGS AND PACKAGING METHODS ON STORAGE OF SOLID JAGGERY," *M.Tech. (Agril. Engg.) Thesis*, 2017, [Online]. Available: https://krishikosh.egranth.ac.in/server/api/core/bitstreams/7169fb18-3262-48f3-8fd0-24c26ad68921/content

[5] S. S. and D. K. Jaswant Singh, "Manufacturing Jaggery, a Product of Sugarcane, As Health Food," *Agrotechnology*, 2013, doi: 10.4172/2168-9881.1000S11-007.

[6] V. I. Er. PD Ukey, "Jaggery making reforms, value addition and preservation: A comprehensive review," *Int. J. Adv. Biochem. Res.*, vol. 8, no. 1, p. 1, 2024, doi:

10.33545/26174693.2024.v8.i1i.480.
[7] G. P. Rao and P. Singh, "Value Addition and Fortification in Non-Centrifugal Sugar (Jaggery): A Potential Source of Functional and Nutraceutical Foods," *Sugar Tech*, vol. 24, no. 2, pp. 387–396, Apr. 2022, doi: 10.1007/S12355-021-01020-3,.
[8] K. B. M. and A. N. Shahid Afghan, Muhammad Ehsan Khan, Waqas Raza Arshad, "Economic Importance and Yield Potential of Sugarcane in Pakistan," *IntechOpen eBooks*, 2023, [Online]. Available: https://www.intechopen.com/chapters/82527
[9] "Pakistan: Sugar Annual | USDA Foreign Agricultural Service." Accessed: Aug. 21, 2025. [Online]. Available: https://www.fas.usda.gov/data/pakistan-sugar-annual-8
[10] A. 4. B. More, "Jaggery Market Report | Global Forecast From 2025 To 2033," DataIntelo. Accessed: Aug. 21, 2025. [Online]. Available: https://dataintelo.com/report/jaggery-market
[11] Aysha Imtiaz, "Jaggery: South Asia's sweet, sentimental cure-all," *BBC*, 2021, [Online]. Available: https://www.bbc.com/travel/article/20210330-jaggery-south-asias-sweet-sentimental-cure-all
[12] "Jaggery exporters seek ban lifting." Accessed: Aug. 21, 2025. [Online]. Available: https://tribune.com.pk/story/2221716/jaggery-exporters-seek-ban-lifting
[13] M. Aslam, "Customs Authorities Foil Attempt to Illegally Export Jaggery to Spain," *Cust. Dly.*, 2025, [Online]. Available: https://customnews.pk/2025/01/15/customs-authorities-foil-attempt-to-illegally-export-jaggery-to-spain/
[14] S. S. Narendra Mohan, "LIQUID JAGGERY – Potential of Value Addition," *Int. J. Eng. Res. Technol.*, vol. 12, no. 3, 2023, doi: 10.17577/IJERTV12IS030087.
[15] P. Singh, "Technological Interventions for Organic Jaggery Production," *RASSA J. Sci. Soc.*, vol. 6, no. 1, pp. 19–25, 2024, doi: 10.5958/2583-3715.2024.00003.8.
[16] R. Revathy, P. Murali, V. Venkatasubramanian, D. P. Prathap, and S. Balamurali, "An Appraisal of Indian Jaggery and Confectionery Exports in the Global Market: Markov Chain Model Approach," *Sugar Tech*, vol. 23, no. 1, pp. 118–129, Feb. 2021, doi: 10.1007/S12355-020-00866-3/METRICS.
[17] R. M. A. Raza, Hafiz Ali, "ANALYSIS OF SUGARCANE PRODUCTION IN PUNJAB, PAKISTAN; CONSTRAINTS AND YIELD NEXUS," *Humanit. Soc. Sci. Rev.*, vol. 9, no. 3, pp. 350–362, 2021, [Online]. Available: https://pdfs.semanticscholar.org/7dd2/9d69e36c60f9e07e1e9fae4d03961ac4fd6b.pdf
[18] A. . Thorat, "Modification and development of stirring and filling mechanism for hot j aggery processing," *MPKV*, 2024.
[19] H. T. Asma Waheed Qureshi, "Street Vended Juices as A Risk Factor of Microbial Diseases in District Mardan, Pakistan," *MARKHOR (The J. Zool.*, 2022, [Online]. Available: https://markhorjournal.com/index.php/mjz/article/view/50
[20] V. V. T. S.K. Tyagi, S. Kamboj, Himanshu, N. Tyagi, R. Narayanan, "Technological advancements in jaggery-making processes and emission reduction potential via clean combustion for sustainable jaggery production: An overview," *J. Environ. Manage.*, vol. 301, p. 113792, 2022, doi: https://doi.org/10.1016/j.jenvman.2021.113792.
[21] "Conservation of Biodiversity in the North Eastern States of India," *Conserv. Biodivers. North East. States India*, 2023, doi: 10.1007/978-981-99-0945-2.
[22] G. S. BISHAL THAGUNNA, "DEVELOPMENT AND QUALITY EVALUATION OF BIODEGRADABLE EDIBLE CUTLERY: A REPLACEMENT FOR A CONVENTIONAL ONE," *Asian J. Pharm. Clin. Res.*, 2023, doi: 10.22159/ajpcr.2023.v16i2.46382.
[23] A. S. R. and M. Y. Dr. D. Ashalatha, "ASSESSMENT OF E-NAM (ELECTRONIC-NATIONAL AGRICULTURE MARKET) ON JAGGERY PRODUCERS IN VISAKHAPATNAM DISTRICT, ANDHRA PRADESH," *IJMER*, 2022, [Online].

Available: https://s3-ap-southeast-1.amazonaws.com/ijmer/pdf/volume11/volume11-issue7(6)/3.pdf

[24] R. V. Powar, S. A. Mehetre, T. R. Powar, S. B. Patil, J. S. Ghatge, and Y. V. Patil, "Life Cycle Assessment-Based Comparison of Sugar and Jaggery Production: A Case Study from Western Maharashtra, India," *Sugar Tech*, vol. 24, no. 2, pp. 551–562, Apr. 2022, doi: 10.1007/S12355-021-01046-7/METRICS.

[25] A. Gangwar, L., Prakash, B., Sharma, A., Singh, K., Pathak, "Quality jaggery production and its marketing forenhancing sugarcane farmers' income in Uttar Pradesh-Issues and challenges," *Indian J. Agric. Mark.*, vol. 35, pp. 242–252, 2021.

[26] C. L. Manimozhi Selvi Venkatesan, "Jaggery Making Process and Preservation: A Review," *Agric. Rev.*, vol. 5, 2022, [Online]. Available: https://arccjournals.com/journal/agricultural-reviews/R-2367