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Assimilating the Responsible Factors for the Technical Efficiency of Organic Brown Sugar Production: Stochastic Frontier Approach

Mahmuda Khatun [a], Mashrat Jahan [a*], Kazi Tamim Rahman [a], M. Abdul Karim [b] and Md. Rezaul Karim [c]

[a] Department of Agricultural Economics, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur-1706, Bangladesh.
[b] Department of Agronomy, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur-1706, Bangladesh.
[c] General Manager, Motijheel Commercial Area, Sonali Bank PLC, Dhaka-1000, Bangladesh.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The demand for organic brown sugar has shown significant growth in recent years, presenting an opportunity to enhance production by strategically leveraging existing expertise among stakeholders. The objective of this study was to assess the viability of producing brown sugar, with a particular focus on the technical efficiency of marginal cane farmers. This study investigates the technical efficiency of sugarcane farmers who are concurrently engaged in the production of organic brown sugar within a specific region in Bangladesh. The data collection process involved

**Corresponding author: E-mail: mjahan.aec@bsmrau.edu.bd;*

the use of purposive sampling, which resulted in the collection of 163 farm data sets from September to December 2021. Subsequently, a stochastic frontier production function was carefully employed to estimate the technical efficiency of the selected brown sugar producers. The findings of the current study demonstrate that less than half of the respondents (47.24%) were involved in activities linked to maintain a high efficiency level that was greater than 91 percent. It was discovered that a range of technical efficiency scores, which varied from 49.94 to 98.38 percent, with a mean value of 84.5%. There exists a significant potential for enhancing crop productivity by up to 15.5% with the implementation of improved agricultural management techniques like substantial experience, education, and training which tends to exhibit enhanced the efficiency of the production.

Keywords: Technical efficiency; sugarcane; indigenous; SFA.

1. INTRODUCTION

Being an ancient annual crop, sugarcane has become one of the most important cash and industrial crops in the country. The best utilization of a farmer's sugarcane is to make sugar from it rather than sell it directly. Brown sugar is a product of processed sugarcane. In order to diversify the sugar market, the production of organic brown sugar has a growing demand in both domestic and international markets. Farmers, who are interested in maximizing their revenue from the sale of their sugar cane, have another option in the form of brown sugar [1]. In the study area, sugarcane is produced by lots of farmers, and they make brown sugar in a traditional way from their produced sugarcane. Brown sugar is one kind of sucrose that has a different color due to the molasses, and it (non-centrifugal cane sugar) is quite popular due to the pleasurable fragrance that is reminiscent of caramel and also for its sugariness [2]. This kind of soft sugar can be totally unprocessed or to some extent processed; it can be made of sugar crystal, or it can sometimes be made by amalgamating molasses with rectified white sugar. This item is considered rich in nutrition, and the indigenous dehydration process was thoroughly followed [3].

The use of brown sugar is distinct from that of white crystal sugar due to the fact that brown sugar imparts a taste similar to that of sweet caramel, which is absent in white sugar. As a result, brown sugar plays a distinct role in the preparation of sweet food [4]. Brown sugar is regarded first over white sugar as it improves blood flow and also amplifies blood cell production, which renders more minerals and nutrition, although it depends on its different processing systems. When comparing the quality of natural brown sugar to that of commercial brown sugar, which is derived through various manufacturing techniques and usage of raw materials, one may find that human health is experiencing distinct convenience and threat [5]. So, being indigenous, brown sugar is more affordable and safer for daily intake. The calorie intake per 100g of brown sugar consumption contains 377 calories (Table 1) [6]. 100g of brown sugar contains 7% of both potassium and calcium, respectively, and 11% of the Daily Value for iron, with no other vitamins or minerals of significant content. However, due to its smaller crystal size, brown sugar packs are thicker than white sugar and could have more calories when assessed in terms of volume.

We have historically used sugar in common daily consumption, such as sweetening dishes. But the production of brown sugar is geared towards the population of individuals whose dietary practices prioritise the elimination or reduction of the use of chemical products throughout the sugar processing stage [7]. So, if supplied with guaranteed eminence and essence, the demand for red sugar (the local name for brown sugar) will be highly appreciated because people are now more health conscious. Two different categories of brown sugar are widely seen: one is made locally, straight from the cane's extracted juice, and another is made at the time of the processing of raw sugar. The refined brown sugars are produced in factories that are capital-intensive. The local production is popular for its cost-saving nature and is apt for tiny farm units. But to be successful in this small-scale business, experience, aptitude, and expertise are also prerequisites for the survival of the traditional farmer. Also, in the manufacture of brown sugar, technology that is efficient with energy use may enhance the approach of using fuel proficiently, the number of job possibilities, and the income of rural communities while supporting the preservation of agrarian land and woodland [8].

Table 1. Nutritional value of brown sugar (sucrose with molasses) per 100 g

Energy (377 Calories)	Quantity	% Daily Values*
Total Fat	0 g	0 %
Saturated Fat	0 g	0 %
Trans Fat		
Polyunsaturated Fat	0 g	
Monounsaturated Fat	0 g	
Cholesterol	0 mg	0 %
Sodium	39 mg	2 %
Total Carbohydrate	97.33 g	35 %
Dietary Fiber	0 g	0 %
Sugars	96.21 g	
Protein	0 g	
Vitamin D		
Calcium	85 mg	7 %
Iron	1.91 mg	11%
Potassium	346 mg	7 %
Vitamin A	0 mcg	0 %
Vitamin C	0 mg	0 %

** % Daily Value (DV) tells how much a nutrient in a serving of food contributes to a daily diet. 2000 calories a day is used for general nutrition advice.*
Source: Fat Secret Platform API

Table 2. Yield of brown sugar in study area (Fulbaria, Mymensingh)

Year	Area of Sugarcane Production (ha)	Brown sugar Production (tons)
2016	1250	6839
2017	1255	6393
2018	1280	7082
2019	1280	6746
2020	1285	6746
2021	1285	6682

Source: field survey, 2021

Only in the study area do farmers produce handmade brown sugar, as they still have a tradition to preserve their ancient profession in Bangladesh. Although they make brown sugar on a small scale and sell their product in the local market, their share of production has increased over time.

Measuring the efficiency of firms is a tactful way of estimating their performance. A firm becomes technically efficient only when it can bring out the optimum results from operating with the least amount of effort.

Nowadays, production and resource use efficiency in the farming sector have started to seize an important place in agricultural policy frameworks that seek to raise domestic production by inspiring optimal resource utilization, where it is an important issue to see technical efficiency in the production process. Flourishing technical efficiency is a significant issue in yield raising and is more suitable in Bangladesh because of limited resources and where production is not increased through improved efficiency by either boosting existing sources or evolving different expertise. Arru [9] predicted in her study that the margins for enhancing the efficiency of recreational services are bigger than those of other services, and various technological aspects subsidies the technical efficiency to varying degrees. In the study area, over the years, cane cultivation has been considered a means of living for the unprivileged rural people, although inputs used for sugarcane production, such as fertilizer and labor, are not optimally available because of high prices and scarcity. Also, the farmer lacks technical knowledge and extension services. So, the production sometimes disappointed farmers. In that case, achieving sugar self-sufficiency, which has been sometimes unsuccessful thus far, demonstrates that the sugarcane sector has to find alternatives in order to satisfy the demand for sugar nationwide [10].

The refining of cane into brown sugar was carried out in huts located near the field of sugarcane. Sugar cane in the study area was processed traditionally using traditional methods. They sell their brown sugar only to Paiker or wholesalers, and sometimes to their native ones. They do not get the appropriate price for their product. The wholesalers sell the brown sugar only to the local market. So, this nutritious brown sugar is used only by some people. So, if the production can be increased with the efficient use of resources and the processing of sugar can be done in a modern way, then the farmers can produce the ultimate brown sugar easily. Thus, the production of brown sugar can contribute to local demand in other parts of the country, which also contributes to the economy of the country. This in-depth investigation was conducted in order to detect the efficiency measures of the brown sugar respondent.

2. MATERIALS AND METHODS

This study focuses on the assessment of technical efficiency in the manufacture of brown sugar within a specific upazila located in the Mymensingh district of Bangladesh. The analysis focused on five villages, namely Asim, Kaladaha, Biddanonda, Valukjan, and Polashtoli, located in the Fulbaria upazila of Mymensingh. These villages were selected due to the favourable climatic conditions that enable the year-round cultivation of sugarcane in the targeted area.

Fulbaria Upazila, located in the Mymensingh district, stands out as a unique case due to the local farmers' utilization of a traditional method to produce red sugar. Instead of using molasses, they extract and purify the cane juice, following an indigenous procedure. The technique employed in the production of brown sugar described in this study has been used since ancient times, predating the establishment of sugar mills. The agricultural practices employed by the farmers in Fulbaria continue to be utilized exclusively within the region, with no evidence of their adoption elsewhere in the country at the moment.

The efficiency of brown sugar manufacturing is significantly reduced due to the improper allocation of inputs, which is among the contributing causes. Within this particular environment, there exists the potential for increasing production through the utilization of advanced technology, improving the operational efficiency of farmers, or even a combination of both approaches.

The primary data from 163 farm units was assessed to obtain detailed information on various aspects of brown sugar production during the period of September to December 2021. Only 163 units were selected purposefully because, in the study year, the whole world faced a pandemic situation for COVID-19. So, it was difficult to interview people as all the concerned people were traumatized by the pandemic.

The assembled and pre-determined data from the social perspective of the study was critically scrutinized via the software programs named Stata 16 and Frontier 4.1. Among them, widespread descriptive statistics of brown sugar production were used in the course of checking out and narrating the input variables, predominantly brown sugar production, hired labor, fertilizer, seeds, and pesticide application by the respective units.

2.1 Econometric Analysis

The technical efficacy of brown sugar production in the research area was calculated following the process of stochastic frontier production model. The model is suited in this situation because the stochastic frontier method may be used to describe the divergences in real production from the frontier originates by the ineptitude and random distress, where the ineptitude arises by the incompetent practice of scarce resources [11].

The best suitable frontier model in the current study is specified as follows:

$Y_a = f\ (X_a;\ \beta)\ \exp\ (V_a - U_a)$ wherea = 1, 2,., n...(1)

Where Y_a represents the output of a^{th} farm unit; X_a is an input parameter appointed to produce Y; β refers a technology parameter that needs estimation; V_a denotes the disturbance and presumed to be dispersed as N (0, $\sigma_u{}^2$). The U_i termed as the model's technical inefficiency accompanying with its non-negative values and both of its uniform and autonomous spread curtails at zero of the normal distribution [12].

The proposed inefficiency model is,

$$u_a = \delta_0 + \sum\nolimits^{n}_{a=1} \delta_a Z_a$$

where, Z_a embodies the aspect of socio-orient variables and δ_0 denotes ingredient of strange coefficients of the farm-oriented inefficiency variables [13]

The TE of a distinct farm unit is precisely articulated as:

$TE = Y_a / Y_a^*$

TE= f (X_a; β) exp (V_a – U_a) / f(X_a; β) exp (V_a)...(2)

This term (V_a – U_a) plays a crucial role in allowing the observed production level to potentially go below the output function associated with the frontier [15]. The results from the Cobb-Douglas elasticities could be comparable to all those produced from the trans-log specification at the sample mean [14]. Followed by the trend, a Cobb-Douglas production function was ascertained for brown sugar production.

$Y_i = \beta \Pi^n_{b=1} X_{ab}^{\beta j} e^{\varepsilon a}$……………………………(3)

where, $\varepsilon_a = \upsilon_a – u_a$. and a is used to index farms and b is used to index inputs.

$\ln Y_a = \beta_0 + \beta_b \sum^n_{b=1} X_{ab} + \upsilon_a – u_a$… …………(4)

The following definition of the technical efficiency index is used since the frontier production function is stated in logarithmic form: [12].

$TE_a = \exp(-u_a)$… …………………………(5)

moreover, to use (5), it is necessary to isolate technical inefficiency from statistical noise in the compound disturbance term. (υ_a - u_a). The probability distribution that comes from the subgroup of u is used to calculate the assesment of u for each unique observation in the sample., given ε (ε = υ - u):

$E(u|\varepsilon) = \int^0_{-\infty} u f(u|\varepsilon) du$… …………………(6)

where f (u |ε) termed as standard normal density function. [15] showed that

$E(u|\varepsilon) = \sigma_u \sigma_v / \sigma \{f(\varepsilon\lambda/\sigma)/1 - F(\varepsilon\lambda/\sigma) – (\varepsilon\lambda/\sigma)\}$…...(7)

where, F(ελ/σ) is the standard normal distribution function, $\sigma^2 = \sigma_u^2 + \sigma_v^2$, and $\lambda = \sigma_u / \sigma_v$ .The following formulation is used to obtain the allotment for each specific competence index: f (ελ/σ) and F(ελ/σ) evaluated at (ελ/σ). After the estimation of ε, λ and σ all these values again appeared to rate the density and distribution functions.

$TE_a = \exp\{E(u_a | \varepsilon_a)\}$ ……………………... (8)

2.1.1 Empirical model

The specific appearance of stochastic frontier model written as follows:

$Y = \beta_0 X_1\beta_1 X_2\beta_2$ ……….$X_7\beta_7 e^{Va-Ua}$

The aforementioned function is in double-log linear form.:

$\ln Y = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + \beta_6 \ln X_6 + \beta_7 \ln X_7 + V_a - U_a$

Similarly, as it is a significant source of inefficiency, utilizing the variates of the inefficiency function to evaluate the possessions based on the model [12] was specified as:

$Ui = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4 + \delta_5 Z_5 + W_a$

δ_1, ... δ_5 unidentified variables requiring estimation. To determine the parametric numerical values of the stochastic frontier function and also technical inefficiency, the program Frontier 4.1 was utilized [16]. Broadly the equation can be written as for the study area is below

$U_a = \delta_0 + \delta_1$ Age+ δ_2 Education + δ_3 Sugarcane farming experience + δ_4 Extension service + δ_5 Training + W_a

Where, W_a is two-sided uniform variable that is positively distributed. The simultaneous estimation of this recent developed model is using statistical package STATA version 16.
The variance parameters must be calculated along with the coefficients of the unknown parameters and which are expressed in terms of,

$\sigma^2 = \sigma_u^2 + \sigma_v^2$ and $\gamma = \sigma_u^2 / \sigma^2$

The 0 ≤ γ ≤ 1 interpreted as the critical measure of γ which has a recumbent limit between 0 and 1.

3. RESULTS OF THE STUDY

3.1 Socio-demographic Status of Brown Sugar Farmers

Table 3 demonstrates the social demographic cultures of selected brown sugar respondents to describe their fundamental information that illustrates and stimulates the progressive behavior of those respondents.

Table 3. Sociodemographic snapshot of sugarcane growing farmers

Variables	Category	Score range	Frequency	Percentage
Age	Young	25-35	41	25.25
	Middle	36-50	65	39.88
	Old	51-above	57	34.97
Education	Illiterate	0	67	41.10
	Primary	1-5	46	47.92
	Secondary	6-10	38	39.58
	Higher Secondary	11-12	4	4.17
	Above HSC		8	8.33
Family Size	Small	1-5	95	58.28
	Medium	6-10	66	40.49
	Large	Above 10	2	1.23
Experience	Low	1-15	96	58.90
	Medium	16-30	50	30.67
	High	Above 30	17	10.43
Training Facilities	Training Received	1	117	71.78
	No Training	0	46	28.22
Extension Services	Services Received	1	111	68.09
	No Service	0	52	31.91

As shown, 41% of the sampled farmers were found to be illiterate, while only 8.33% of them embraced a higher education. Alongside, more than half of the participants had farming experience beyond 16 years, as most of their ages ranged from 36 to 50 years old. While being interrogated about receiving training and extension services, most of the respondents (more than 50% of the total sample) avowed to receive them.

Table 4 exhibits all the input and output measurement variables of cane farmers that were estimated by simple statistical tools. The output of brown sugar in the particular research area was 4839.75 kg, which is grown from an average of 10205.21 saplings. The average quantity of fertilizer that was required to produce is 916.32 kg. On average, 11563.19 Tk/ha is required to prepare the land. In the study area, the production requires a huge water supply through irrigation at a regular interval during the entire season, equivalent to an average of 27751.656 Tk of the total cost. Average human labor was 507-man days, indicating sugarcane production as a labor-intensive crop. This outcome corroborated [1], as they found 72.2% of workers share in each kilograms of brown sugar. Normally, the average insecticide used per hectare is 63.061 kg.

The average working personnel age was 46 years, with a range of 25 to 50 years. The minimum institutional educational attainment of the respondent farmers was 4.503 years at the primary level. The farmers are well acquainted with their traditional methods, as the area has an average of 15 years of research experience. The mean frequency of catch-up with extension workers and training facilities was 68% and 71%, respectively.

3.2 Technical Efficiency of the Brown Sugar Farmers

The examination of TE is necessary in the field of sustainability studies due to the fact that TE places an emphasis on the decisions made by farmers, who are, in the end, the most significant factor in ensuring the economic viability of a region [17,18]. In the context of TE, the "production frontier" functions as one example of such a standard. TE may be termed the capacity and inclination of a farm unit to acquire the greatest potential output with a particular bequest of inputs. This is the maximum output that can be obtained with the inputs that are available.

3.2.1 SFP model diagnosis through maximum likelihood estimates

Individual efficiency levels in sugarcane-producing farm units were measured using the stochastic frontier production function. One of the commonly employed formulas to perceive the presence of multicollinearity among explanatory variables was VIF testing. The VIF values of all variables entered into the model were below ten, which is an indicator for the absence of severe multi-collinearity among the proposed explanatory variables. The variance parameters for sigma square and gamma were found significant by 0.33947 and 0.73, respectively. The gamma postulates the coherent pressure of the residuals by the production function, which is the ultimate mainspring of disturbance [19]. The estimate of = 0.73, or 73 percent, of the inefficiency effects has a considerable influence on the incompetence of sugarcane producers. That means 73% of the differences found in the production of sugarcane are because of discrepancies in technical efficiency. So, there is potential to raise efficiency levels by changing the existing level of production technology. Table 5 reveals that if farmers produce on large land areas, they can reduce their cost of production by 0.01%, which makes them efficient producers. Labor coefficient insignificancy stimulates the sugarcane outcome because the extreme use of labor raises the production cost, which in turn lowers the profit.

The standardized figure from the land formulation cost was -0.2331, and spending more on this factor decreased the possible output loss to sugarcane by 23.31 percent. In the study area, farmers produce with a small farm area. If they spend more on land preparation, it increases their cost, which reduces other spending on other inputs. So, it affects the production. At the initial stage of sugarcane production, irrigation acts as an important input to help the sugarcane survive the setts in the new field. The spending on irrigation, while increasing the per-unit production of sugarcane, would be raised by 4.67 percent. In the study area, because farmers are poor and have a deficiency in capital investment for production, they have not planted enough seeds. So, if there was a possibility to raise the rate, sugarcane production would increase by 7.55 percent. Fertilizer is an important factor as it increases soil nutrients and makes the sugarcane plant healthy and vigorous. It is a very common practice to increase production. Here, fertilizer also had a statistically significant effect on sugarcane cultivation, which increased the yield by 6.95%. The insecticide costing is found irrelevant, having seldom an effect on production, which makes it an advantage for the farmers to reduce insecticide cost from their cost item.

3.2.2 Interpretation of technical inefficiency model

Results from the technical inefficiency effect model (Table 6) show that farm expertise, education, and training postulate the anticipated (negative) values. Farmers with more experience are strictly considered more competent than others, although the calculated values of experience dictate their significance at 5%.

The average functional value of education was negative with a value of 0.2050, though the coefficient was not statistically significant. This postulates that producers with higher education turn out to be more capable than uneducated producers. The negatively significant (1 percent) coefficient of training implies that trained producers were basically more effective compared to those who had no training. The coefficient of age is positive, which means younger farmers are more effective than older farmers. It can be seen because younger farmers are literate, so they have knowledge about modern agriculture and can easily overcome any problems they find in the production process. The coefficient of extension services is also positive, which implies that if extension services increase, inefficiency also increases. This can happen in the study area, as many farmers are seen who only write or read; they do not care about extension services and do not understand their advice about modern agriculture. Here, the coefficients of age and extension services were not statistically important. Hence, all the above-stated factors remain impartial in the case of the inefficiency of making brown sugar.

3.2.3 Technical efficiency and its distribution

Table 7 expresses the frequency dispersal of farm-oriented technical efficiency for sugarcane farmers, and 84.49 percent TE was assessed for brown sugar. Approximately 47.24 percent of the respondents were found to be engaged in activities related to the cultivation of crops that were located near the frontier outputs, hence maintaining a high efficiency level of above 91 percent. On the contrary, the next peak share constituted about 18.40% and attained an 81–90 percent technical efficiency level. Even the lowest percentage of 1.23 touched 41–50 percent efficacy. The paramount range of this current technical efficiency constitutes the maximal level of 98.38%, where the marginal was 49.93% correspondingly.

Table 4. Abridged statistics of the variables

Variables	Description of Variables	Mean
Output and Input Variables		
Y	Total Brown Sugar Production (kg/ha)	4839.75
X_1	Land in hectares	0.16
X_2	Human Labor (man/days)	507.75
X_3	Land Preparation Cost(tk./ha)	11563.19
X_4	Irrigation Cost (tk./ha)	27751.66
X_5	Number of sapling/ha	10205.22
X_6	Fertilizer in kg/ha	916.32
X_7	Insecticides in kg/ha	63.06
Farm Specific Variables		
Z_1	Age in Years	46.10
Z_2	Education in Score	4.50
Z_3	Experience in Years	15.91
Z_4	Extension Services (=1 if received, 0 otherwise)	0.68
Z_5	Training Facilities (=1 if received, 0 otherwise)	0.72

Table 5. Parameter estimation of cobb douglas stochastic frontier analyses

Parameters	Variables	Coefficient	Standard-error	t- ratio
β_0	Constant	10.23	1.06	9.67*
β_1	Lnland	0.01	0.01	2.49**
β_2	Lnlabor	-0.03	0.03	-0.94
β_3	Lntractor	-0.23	0.08	-3.01*
β_4	Lnirrigation	0.05	0.02	1.97**
β_5	Lnseed	0.08	0.04	1.74***
β_6	Lnfertilzer	0.07	0.03	2.17**
B_7	Lninsecticide	-0.01	0.02	-0.51
Sigma squared		0.34	0.04	7.94***
γ		0.73	0.03	23.49
Log likelihood		194.82		
LR test of the one-sided error		4.23		

****significant at 1%; **significant at 5%; *significant at 10%*

Table 6. MLE estimates for the parameters of SFA for technical inefficiency model

Parameters	Inefficiency variables	Coefficient	standard-error	t- ratio
δ_0	Constant	-69.8579	3491.395	-0.02
δ_1	Age	0.1998	0.1611	1.24
δ_2	Education	-0.2050	0.3361	-0.61
δ_3	Experience	-0.2648	0.1156	-2.29**
δ_4	Extension Service	0.01956	1.0349	0.0189
δ_5	Training	-0.01353	0.0073	-1.85*

****= significant at 1%; **= significant at 5%; *= significant at 10%*

Table 7. Frequency distribution of technical efficiency

No	Efficiency Range	Frequency	%
1	91-100	77	47.24
2	81-90	30	18.40
3	71-80	27	16.56
4	61-70	20	12.27
5	51-60	7	4.29
6	41-50	2	1.23
Maximum Level of TE	98.38%		
Mean Average	84.49%		
Minimum Level of TE	49.93%		

4. DISCUSSION

Sugarcane, being classified as a long-lived crop, exhibits elevated irrigation and nutritional demands. The current study also observed a substantial level of relevance in the use of fertilizer and irrigation. The utilization of the two variables outlined in Table 5 is expected to enhance sugarcane productivity. The findings also indicate that increasing the quantity of seeds and the size of farms is necessary in order to maintain the potential yield. The cost of land preparation had a significantly negative impact, as it accounted for a substantial proportion of the entire cost. Furthermore, any increase in this cost would have an adverse effect on production. The regression analysis revealed that the coefficient associated with insecticides exhibited a negative and statistically insignificant relationship.

As preparing brown sugar and selling it in the nearest market has a long tradition in the study area, farmers are well acquainted with this strategy, although it has some efficiency gaps. The age and level of skill are significant external factors that impact the amount of productivity attained in the process of preparing brown sugar [20]. However, in our study, it was seen that all farmers in the sample were male, and the majority of them fell within the most productive age group. Despite this, inefficiency was still evident. Furthermore, this study found the same thing as Murali et al. (2017): both education and experience play significant roles in determining technical efficiency within the context of sugarcane farming [21]. Experienced farmers have a higher level of competence compared to their counterparts, owing to the acquisition of expertise through prolonged engagement in the same agricultural activities. Also, individuals who have received training exhibit a higher level of proficiency in farming due to the technical knowledge disparity between them and others who lack such training. Contrary to expectations, our research findings suggest that the extension service does not significantly improve efficacy levels as the service is only available for growing sugarcane and not brown sugar processing. This finding contradicts previous studies in the sector, which have generally shown a positive correlation between higher levels of extension service and improved TE scores [22]. The findings of this study suggest that there is potential for future increases in output without incurring additional costs, as indicated by the average estimated technical efficiency results.

Many challenges plagued farmers as they attempted to cultivate sugarcane. The key issues encountered by sugarcane growers were the fluctuations between input and output prices, a lack of scientific understanding, training, extension service, quality standards, a lack of finance, and the wasteful waste of sugarcane. Unskilled workers, a shortage of available workers, and excessive input costs are also factors. For the purpose of increased sugarcane harvests, the government and other NGOs should work to mitigate or eradicate these issues.

5. CONCLUSION

Sugarcane holds the position of being the fourth-most significant cash and industrial crop in Bangladesh. The data suggests that the social well-being of the participants could be enhanced through the production of brown sugar derived from sugarcane. By effectively employing the existing knowledge and techniques, it is possible to enhance the overall production. The inefficiency of the respondents can be attributed to various factors, including their limited experience, illiteracy, inadequate training, and insufficient extension services. In order to address the anticipated challenges in brown sugar production, it is imperative to establish research collaborations that encompass a comprehensive understanding of the potential demand.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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