Assessment of cleaner production in agro processing industries: a data envelopment analysis approach

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Abstract

Cleaner production (CP) initiatives have proved to be effective in conservation of resources leading to benefits for the industry, environment and society. Internationally, cleaner production programs are disseminated by the initiatives taken by United Nations Environment Programme (UNEP), United Nations Industrial Development Organization (UNIDO) and Organization for Economic Cooperation and Development (OECD) in both developed and developing countries. Despite all these efforts the strategy has not been recognized much and implemented in industries including Micro Small and Medium Enterprises (MSMEs). Specifically, MSMEs face considerable difficulty in implementing CP initiatives due to lack of proper evaluation of CP success. To implement the CP initiative in an organisation, it requires wide spread dissemination of benefits of CP and a baseline for the CP. This requires acquiring knowledge about the prevailing practices of industries and benchmarking them against the best performer in the sector. An attempt has been made in the current paper to bring out the gaps in CP practices among cashew processing MSMEs. Constant return to scale Data Envelopment Analysis (DEA) is adopted with input and output orientations so as to elicit how much inputs are to be decreased or outputs to be increased to make the inefficient units perform on par with efficient units. DEA considers all factors that affect the unit’s performance by converting multiple inputs and outputs into a single measure of productive efficiency that allows comparing peers to identify the opportunities for further improvement. The results revealed that more than 30% of the enterprises have potential to improve their performance by 10 to 12% to match with the efficient counterparts.

Keywords: Cleaner Production, Data envelopment analysis, Agro based industries

1. Introduction

Increasing competition and absence of quality consciousness in industrial operations, products and services has deprived the business of developing countries. Managements of the companies consider the idea of environmental compliance and ISO certification undue and uneconomical [1]. In this situation managements are looking towards such a strategy which entails them to achieve the environmental compliance and economical production to grab the market. Cleaner production (CP) has proven to be such a tool which protects the environment, the consumer and the worker while improving industrial efficiency, profitability, and competitiveness. It acts as technology promoter, managerial catalyst and reformer that converted environmental protection investments into productivity benefits [2]. Despite the advantages of CP and a growing interest in it amongst the developed and developing countries, there are some barriers that prevent its worldwide implementation difficult. The major barriers identified are lack of knowledge of the appropriate technology, lack of technical expertise in the methodology of process assessment and diagnosis, lack of financial resources, lack of awareness and resistance to new ideas, government policies and regulations that only focus on end-of-pipe technologies [3]. The immediate requirement in developing world is to augment the implementation of CP from an environmental, economical and social perspective. It is also imperative to address the barriers to the adoption of this technique in Micro, Small and Medium sized Enterprises (MSMEs) as they are in quandary about how to deal with productivity and environmental issues.

Many demonstration projects were initiated to illustrate the CP benefits in MSMEs through the implementation of best practices to conserve resources, reduce the waste streams and to increase productivity. But its penetration is not rigorous and hence it calls for a different approach for the introduction of CP concepts in MSMEs as compared to large industries. MSMEs are faced with lack of information about the latest developments and thus require awareness raising and dissemination of information about CP to ensure the appreciation of this strategy. Benchmarking is an effective tool to
eliciting the information about understanding the performance of an enterprise against the best performer in the class and it enables to identify gaps in the performance to initiate appropriate action for improvement. Benchmarking of CP requires the identification of key parameters that contributes to the CP performance. The benchmark date for MSMEs is generally not available in developing countries. Thus, there is a need to develop either industrial technology specific or region specific benchmarking, which could be an important promotional tool for CP implementation [4]. Data Envelopment Analysis (DEA) is a non-parametric approach in operations research for assessing the relative efficiencies of a set of peer units with multiple inputs and multiple outputs. DEA provides a fair benchmarking tool that includes a technical efficiency score for each unit.

The current empirical study is on aspects of CP in MSMEs engaged in cashew nut production. Cashew processing is an important agro processing industry in India and the country is a key player in global cashew production. This work intends to benchmark the CP performance of cashew processing units. The data for the study were collected from the cashew processing industries in the coastal region of Karnataka, a state in India, where these industries are clustered. Every year, India imports over 7.0 lakh tonne of raw cashew nuts mainly from African countries and exports cashew kernels to USA and UK after processing. Vietnam and Brazil are major competitors to India in cashew production and export. Since the cashew processing is carried out on a micro, small and medium scales, the industrial units are faced with several difficulties and there is a need to formulate a strategic approach in a holistic manner for increasing production and productivity of cashew processing. Adopting CP techniques would a boost to this sector’s performance.

2. Literature Review

With an increased focus on environment and competitiveness in the industry it has become critical for the industrialists to adopt the best production practices which can be possible by learning from the peers. Benchmarking of CP of an industrial unit enables to understand the present status and provides an action plan to perform better. MSMEs in particular face the non availability of benchmarking data and several researchers have attempted to address this problem. Benchmarking is used as a trigger for CP in the dry cleaning industry [5] that identifies CP gaps, promotes the drivers and ensures managers to possess the correct skills to close these gaps. The important drivers identified are; economic benefits and maintaining their licence to operate. The use of environmental indicators for benchmarking and tracking their performance [6] along with the laws and regulations, force organisations to reduce their negative environmental impacts without any structured environment management systems. Data envelopment Analysis (DEA) initiated by Charnes, Cooper and Rhodes (CCR) converts fractional linear measure of efficiency into a linear programming (LP) format. This enables assessment of decision making units (DMUs) on the basis of multiple inputs and outputs, even if the production function was unknown. A benchmarking method using two-stage super-efficiency data envelopment analysis for coal-fired power plants is proposed by Zeng et.al., to improve the cleaner production performance of DEA inefficient or weakly efficient plants and then to select benchmark from performance improved power plants through super efficiency DEA model [7]. An evaluation of energy efficiency in medium sized companies has been conducted using the DEA methodology by Soner et.al., and brought out that there are significant potentials exist to save energy [8].

3. Data Envelopment Analysis: A Benchmarking Tool

DEA is an increasingly popular management tool proposed by Charnes et al [9], commonly used to evaluate the efficiency of a number of producers. DEA compares each producer with the best performer. It differs from the statistical analysis which adopts a central tendency approach in which it evaluates producers relative to an average producer. DEA is not superior to many other techniques but its data requirements are not extensive and do not expect much user intervention. In DEA a producer is usually referred to as a decision making unit (DMU). Each DMU produces an output by consuming a certain amount of input, and then it is assumed that each of the other DMUs should also be capable of doing it. DEA allows every DMU to select their most favourable weights to keep the ratios of the aggregated outputs to the aggregated inputs of all DMUs to be less than or equal to 1. This idea is formulated as a linear fractional program and solved by transforming to a linear program. In DEA several DMUs are combined to form a composite virtual DMU with composite inputs and outputs. The measurement of efficiency in production units and the identification of sources of their inefficiency is a precondition to improve the performance of any productive unit in a competitive environment. Multi criteria decision methods can also be used to estimate efficiency rate but these approaches differ in how they obtain input and output weights. Multi criteria decision methods usually expect the user to define the weights depending on the significance of individual inputs and outputs in the analysis and based on these analysis units can be ranked from the worst to the best performer. In DEA models input and output weights are derived by means of optimising calculations in which units can be classified as efficient and inefficient. In inefficient units, they tell us target values of inputs and outputs which would lead to efficiency [10].

There are various types of DEA models which may be used depending on the conditions of the problem on hand. Types of DEA models concerning a situation can be identified based on scale and orientation of the model. If one can
assume that scale of economies do not change as size of the service facility increases, then constant returns to scale (CRS) type DEA models is an appropriate choice. The other basic frontier model is the variable returns-to-scale (VRS) model. In the current benchmarking process CRS type DEA model is used. The essence of the CRS model is the ratio of maximization of the ratio of weighted multiple outputs to weighted multiple inputs. Any DMU compared to others should have an efficiency score of 1 or less, with either 0 or positive weights assigned to the inputs and outputs. The efficiency scores \( \theta_0 \) for a group of peer DMUs \( (j = 1, 2, 3, \ldots, n) \) are computed for the selected outputs \( (y_{ri}, r = 1, 2, 3, \ldots, s) \) and inputs \( (x_{ij}, i = 1, 2, 3, \ldots, m) \) using the following formula:

Maximize \( \theta_0 = \frac{\sum_{r=1}^{s} u_r y_{ro}}{\sum_{i=1}^{m} v_i x_{io}} \)  

Subject to \( \frac{\sum_{r=1}^{s} u_r y_{ro}}{\sum_{i=1}^{m} v_i x_{io}} \leq 1 \)  

\( u_r, v_i \geq 0 \) for all \( r \) and \( i \)

\( u_r \) and \( v_i \) are weights for outputs and inputs respectively for a focal DMU. The input and output values, as well as all weights are assumed by the formulation to be greater than zero. The weights \( u_r \) and \( v_i \) for each DMU are determined entirely from the output and input data of all DMUs in the peer group of data. Therefore, the weights used for each DMU are those that maximize the focal DMU’s efficiency score. In order to solve the fractional program described above, it needs to be converted to a linear programming formulation for easier solution.

This model can be algebraically rewritten as:

Maximize \( \theta_0 = \sum_{r=1}^{s} u_r y_{ro} \)  

Subject to \( \sum_{r=1}^{s} u_r y_{rj} \leq \sum_{i=1}^{m} v_i x_{ij} \)  

Further it can take the following linear programming formulation;

Maximize \( \theta_0 = \sum_{r=1}^{s} u_r y_{ro} \)  

Subject to \( \sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \leq 0 \)  

\( j = 1, 2, \ldots, n \)  

\( \sum_{i=1}^{m} v_i x_{io} = 1 \)  

\( u_r, v_i \geq 0 \)

DEA identifies a group of optimally performing units that are defined as efficient and assigns them a score of one. These efficient units are then used to create an “efficiency frontier” or “data envelope” against which all other units are compared. The DMUs that require relatively more weighted inputs to produce weighted outputs or, alternatively, produce less weighted output per weighted inputs than DMUs on the efficiency frontier, are considered technically inefficient. They are given efficiency scores of strictly less than one, but greater than zero.
4. Agro based Cashew Processing Industries in India: An outline

Indian economy is predominantly based on agriculture and agriculture related activities and agro based industries are scattered throughout the rural India. The post harvest activities of processing and preserving agricultural products for intermediate or final consumption is the main characteristic of agro based industries. They are regarded as source of potential growth and have employment and income generation capability. However, these industries are facing several problems such as - infrastructural problem, lack of proper skills, upgrading technology etc. Most of the agro-industries require agricultural output as raw material and energy, water and labour as inputs. Similarly, main product, by product, solid waste, waste water and emissions as outputs.

Cashew (anacardium occidentale) has a delicious kernel covered by a hard shell and testa. The manufacture of cashew kernels involves extracting the cashew kernels to be presented in edible form. The nuts before processing in the factory should be dried for 1-2 days to reduce the moisture to 7-8%. The processing of raw nuts involves roasting, shelling, drying, peeling, grading and packing. Roasting is done to separate the adhering shell from the kernel. Among three methods of roasting, steam roasting is adopted in this study area. After roasting and cooling the shelling takes place to separate shell. As the cashew nut shell contains the highly corrosive cashew nut shell liquid (CNSL), the process is dirty. Manual operated shelling machines or electric operated shelling machines are commonly used. After the shelling, the kernels are collected and dried in hot chambers to prevent fungus growth followed by keeping them in moist chambers to facilitate the peeling of non-edible testa covering the kernel. The testa is removed either manually or by using peeling machines with the aid of compressed air. Kernels are now graded manually to meet the market requirements and then packed either in tin boxes or flexi packs. During packing it is generally flushed with an appropriate gas to retain quality and shelf life.

Continuous innovation in all stages of production has been the hallmark of the industry. Cashew process currently employs a large number of employees in different stages of process. The inherent advantages of mechanisation have not outweighed the advantages prevailing in processing with skilled labour.

5. Assessment of Cleaner Production using DEA Methodology

In the present study it is intended to assess the cleaner production performance of the enterprises against the best performing units which would enable to understand the areas of improvement. In this research 35 cashew processing units are considered for the analysis. All the cashew processing units adopt the same processing technology irrespective of the scale of production. There is variation in the degree of mechanisation of the processes resulting in only alterations of the quantity of electrical, labour, energy, and water consumption.

The approach adopted to measure degree of CP is carried out by considering the important factors contributing to it. Cleaner production stresses on reduction in resource use, less environmental degradation, reuse and recycle of the waste generated. The data pertaining to these factors are collected through a structured researcher administered questionnaire. Contributing factors considered for CP on the input side are raw material input (X1), total water consumption (X2) and total energy consumption (X3). Energy is required in the form of heat, electrical and labour. The thermal energy is derived from biomass and fossil fuel. On the output side the factors considered are quantity of edible kernel output (Y1), onsite recyclability (Y2), share of renewable energy usage (Y3), and employment generation capability (Y4). Intentionally some of the undesirable outputs like emission, waste water generation and solid waste disposed are avoided to keep the model simple. Theoretically, if the process to be clean, it is expected that the input parameters are to decrease and output parameters are to increase. The descriptive statistics of the input values and output values pertaining to the 35 cashew processing MSMEs are listed in Table 1. and input data are listed in table 2.

| Table 1: Descriptive statistics of Inputs and output values |
|-------------|-------------|-----------|-----------|-------------|-----------|
| Raw cashew processed kgs | Water consumption Liters/kg | Total Energy Consumed MJ/kg | Cashew Kernel yield kgs | Onsite Recycling kg/kg | Renewable Energy Use % | Employment Generation Labour/kg |
| X1 | X2 | X3 | Y1 | Y2 | Y3 | Y4 |
| Minimum | 300.00 | 0.17 | 1.36 | 66.00 | 0 | 0.32 | 0.03 |
| Maximum | 18750.00 | 3.34 | 10.56 | 4687.00 | 0.39 | 0.93 | 0.09 |
| Mean | 3787.58 | 0.88 | 4.05 | 984.69 | 0.18 | 0.66 | 0.05 |
| Std. Deviation | 3384.31 | 0.83 | 2.18 | 881.09 | 0.12 | 0.15 | 0.02 |

| Table 2: Inputs and output values for DMUs |
|-------------|-------------|-----------|-----------|-------------|-----------|
| Actual Values for Inputs | Actual Values for Outputs |

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The data is subjected data envelopment analysis on radial measure of efficiency, constant return to scale analysis with double slack computation for both input orientation and output orientation.

6. RESULTS AND DISCUSSIONS

The results of the analysis reveals that 24 cashew processing MSMEs are performing as frontiers while 11 units exhibit that they can augment their practices to meet the performance of efficient units. The results are given in table 3. Technical efficiency reference set with peer DMUs listed as score in this table will give the information about how much inputs can be decreased or outputs can be increased to improve the performance of DMUs and hence sets the target of improvement for inefficient DMU. Another significant feature deserving attention is that some of the DMUs which have scored 1 also have better benchmark strength i.e., they act as benchmarks to other underperforming DMUs, whereas few other DMUs despite scoring 1, did not act as benchmarks for other inefficient units. Thus they can be considered as weakly efficient DMUs which require attention to improve their performance.

Table 3: Projected decreases or increases in inputs and outputs

<table>
<thead>
<tr>
<th>Decision Making Units</th>
<th>Score</th>
<th>Benchmark Strength</th>
<th>X1</th>
<th>X2</th>
<th>X3</th>
<th>Y1</th>
<th>Y2</th>
<th>Y3</th>
<th>Y4</th>
</tr>
</thead>
<tbody>
<tr>
<td>D1</td>
<td>0.88</td>
<td>0</td>
<td>3631</td>
<td>0.43</td>
<td>4.06</td>
<td>1226.8</td>
<td>0.18</td>
<td>0.88</td>
<td>0.06</td>
</tr>
<tr>
<td>D10</td>
<td>1.00</td>
<td>0</td>
<td>1.72</td>
<td>1.43</td>
<td>1.00</td>
<td>0.18</td>
<td>0.88</td>
<td>0.06</td>
<td></td>
</tr>
<tr>
<td>D11</td>
<td>1.00</td>
<td>4</td>
<td>1.72</td>
<td>1.43</td>
<td>1.00</td>
<td>0.18</td>
<td>0.88</td>
<td>0.06</td>
<td></td>
</tr>
<tr>
<td>D12</td>
<td>0.85</td>
<td>0</td>
<td>1533</td>
<td>0.82</td>
<td>2.91</td>
<td>540.17</td>
<td>0.22</td>
<td>0.89</td>
<td>0.04</td>
</tr>
<tr>
<td>D13</td>
<td>1.00</td>
<td>3</td>
<td>1.72</td>
<td>1.43</td>
<td>1.00</td>
<td>0.18</td>
<td>0.88</td>
<td>0.06</td>
<td></td>
</tr>
</tbody>
</table>
The DEA analysis established that 10 MSME units are most efficient. They comprise D11, D21, D13, D14, D22, D23, D19, D28, D3 and D4. Another 14 units are weakly inefficient and remaining 11 units are inefficient. This approach utilized the input and output values of the efficient units calculated the target inputs or output values. The score gives the percentage decrease in input values and decrease in output values. For instance DMU D1 has score 0.88 indicates it has to reduce or increase its input or output values by 12% respectively. D10 is a DMU having efficiency score 1 but is not a benchmark for any of the inefficient DMUs and hence it is a weakly efficient DMU. DMUs D11 and D21 are most efficient and each of them are benchmarks for 4 peer DMUs. The improvement potential of the inefficient DMU is portrayed in Figure 1.

![Figure 1: Improvement potential of inefficient DMUs](image-url)
DEA results showed that over 30% of the surveyed units have improvement potential. When the actual and target values for inputs and outputs are observed, it can be found that there is a potential for reduction in input or enhancement of output. For instance DMU1 is an inefficient unit requires overall input reduction or increase in output by 12%. Its targeted raw material reduction is 15%, water savings is 12% and energy consumption reduction is 7%. Its targeted increase in cashew kernel output is 12%, recycle enhancement by over 38%, boost in renewable energy use by 16% and employment generation capability improvement by 16%. The results demonstrate that on input reduction side an average, raw material usage in these units could be reduced to a tune of 9%, energy by 7% and water usage up to 15%. On output enhancement category the production efficiency could be enhanced by 6%, onsite recycling by 20% and renewable energy usage by over 12%.

7. Conclusions
CP strategy in industries can be practiced through various approaches like input modification, clean technology adoption, practicing efficient processes, reuse, recycling and sometimes just by housekeeping. In many instances some inexpensive modifications in existing practices leads to considerable improvements in better resource utilization and less environmental damage. However, adoption of CP strategy has taken the backseat especially in MSMEs as benefits of this strategy and potential opportunities to do so are not widely known. This research work tried to benchmark the existing processes in cashew processing MSME units and brought out that there is significant scope in improving inefficient operations of MSMEs. Further, it should not be mistaken that performance of efficient MSME units are flawless but they are only relatively better and they can also further improve their performance as a continuous improvement exercise. Further, MSME development institutions may derive important policy implications from the study results to fine tune the policy instruments to make CP initiatives more attractive and fruitful.

References

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