PROJECT REPORT

TECHNO-ECONOMIC ANALYSIS OF JAGGERY PRODUCTION IN MAHARASHTRA

As a part of

TDSL 490: Supervised Learning – Analysis

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1. Introduction

Maharashtra is one of the leading producers of jaggery apart from sugar. Large numbers of jaggery production units are located in state. In Maharashtra, about 11 to 12 per cent sugarcane was being used for jaggery preparation during the year 2005-2006. Jaggery from Maharashtra is also well known for its quality, which has wide demand in international market.

Jaggery is used as traditional sweetener in India. The health importance of jaggery has been highlighted in literatures. Jaggery consumption is supposed to purify blood, prevents rheumatic afflictions and bile disorder [1]. The preventive action of jaggery on smoke-induced lung lesions suggests the potential of jaggery as protective agent for workers in industry in smoky environments. Magnesium found in jaggery strengthens the nervous system and potassium conserve the acid balance in the cells and combats acids and acetones. Jaggery is rich in iron and prevents anemia. Micronutrients present in jaggery have antitoxic and anti-carcinogenic properties.

![Fig: Different types of jaggery](image)

The importance of jaggery production is far and wide. It is one of the major occupations in rural Maharashtra. The production techniques have remained same for many years. With increasing demands the pressure on these units have increased. As a result unhygienic, inefficient production techniques are used. The use of chemicals has increased drastically.

Jaggery production has been neglected by research institute since long time. Today is dire need to study this production technique and bring about technological development in this region. This study is an attempt to study the processes used in jaggery production and highlight important aspects that needs solutions. We have supported our study with survey of jaggery producers from Kolhapur district. The analysis of this survey is also presented here.
2. Different types of processes of jaggery production

A. Single Pan Process (Kolhapur type):

Maharashtra has been one of the leading producers of jaggery in India since long time. Single pan method is most popular method for jaggery production. This is also known as Kolhapur Method. Unlike the four pan method this method employs only single pan. The rest structure is almost similar to four pan method. Bagasse is manually fed through fuel inlet into the furnace. These bagasse burns on a grid and provides heat to the pan kept above the furnace. The ash gets separated falls down from grid and is collected in ash pit. The ash pit is cleaned on regular basis.

The air flows from air inlet to chimney. The amount of air flow is critical in getting efficient consumption.

Fig: Single Pan Method (Ref: Prof. Narendra Shah, Presentation, 16 May, Kolhapur)

B. Four Pan Process (UP type):

Famous in Kedgaon village in Daund Taluka. This method is popular in Uttar Pradesh. In recent times with decreasing availability of labours the tendency of jaggery producer has been to sub-contract the plants to labourers from Uttar Pradesh. These labourers are skilled in using Four Pan method and consequently four pan method has become popular in these areas.
Process Flow:

The plants we visited used 4-pan process. Almost all the jaggary making units (Gurhal) in vicinity of kedgaon are using 4-pan process. The process could be briefly described as below:

1. After crushing the juice is sent to first pan. The main purpose of first pan is to settle the juice and remove any kind of solid or heavy impurities (Mud, molasses etc). Roughly the juice is kept in the pan for one hour.

2. The juice is then manually transferred to second pan. The main purpose of second pan is to remove Mali. Typically we have seen that the owners add lime. This neutralizes the juice and creates froth. The froth is "mali" and is removed manually. Bhendi extract (in form of powder) is used as coagulants for non-sugar agents.

3. Third pan basically removes any lime that could have been left from second pan. This is done by adding Phosphoric acid to the pan. Some "papdi" is also added for purpose of bleaching.

4. The purpose of fourth pan is basically to remove water. Some manufacturers add "Arend oil". This helps in coagulation. This liquid is brought to open pan and big lumps are formed while it is still hot. This liquid, if poured in buckets, take form of buckets when solidified.
C. Two Pan Process:

Crushing of cane is done with the help of bullock operated or power driven crushers to get the juice. The second unit operation in jaggery production is boiling and concentration of juice. It is performed in furnace where bagasse is used as main fuel. An efficient furnace should consume minimum bagasse then only it will be economical to the manufacturers directly and sugarcane grower indirectly, as the bagasse is a good raw material for paper and pulp industry, particle/ board industry and animal feed industry. From the above view point, a fuel efficient furnace needs to be operated. In different parts of the country, different types of furnaces are prevalent. Mostly the furnaces are of single pan and having low efficiencies. Therefore, extra fuels are required during operation. To overcome this problem, people have developed a two pan furnace to cater the need of jaggery producers.
When combustion occurred, boiling pan received heat and flue gases moved through chimney to escape. In this process, gutter pan also received some heat as it is kept over the flue gas passage. This was the advantage of the second pan (gutter pan). The temperature rise in the boiling pan is more than the gutter pan. It is due to this reason that the boiling pan is kept over the combustion chamber where burning of the fuel takes place. As a result, temperature of the boiling pan is higher.

We visited a two pan process in Karnataka. The plant aimed to use 1.5 kg to 1.6 kg of bagasse/kg of jaggery produced. One innovation which they achieved was to use entire components from stainless steel (SS304), including the heating pan. The conductivity of SS304 is less as compared to mild steel (MS). They have used fins of MS at the bottom of both the pans. The design for fins was done considering the fact that flue gas requires large area to transfer heat. The distance between fins is about 5 cm and thickness is 6mm. The height of chimney designed was about 12 meters. This is very large than conventional chimney heights.

Juice is crushed collected into underground SS304 tank. The capacity of this tank is about 4000 litres. Main purpose of this tank is to allow juice to settle and remove the impurities like mud. The tank also has inlet to flush water. This is used in order to clean the tank. When water is forced into tank at very high velocity it removes the mud that could be settled at the bottom of tank. This dirt is then made to flow into a cement tank which is at level below the level of settling tank. The cement tank is then cleaned manually.

When required, the juice is pumped to overhead tank using a SS304 pump. The juice is kept in overhead tank for about 20 minutes. This also performs work of settling tank. This tank is given a slope at bottom. The juice is taken out from higher outlet, and poured into preheater tank. The lower outlet is used to remove anything that might settled.
Preheater or gutter pan is the point when we start actually jaggery making process. Lime and Bhendi stem is added. Lime is to neutralize juice and bhendi powder is to help in coagulation. The Scum or “mali” is removed manually from preheater pan. The capacity of preheater tank is roughly 1500 litres.

The main pan or Boiling pan has capacity of about 1500 litres. The upper diameter is about 3.8 Meters and bottom diameter is about 3 meters. The tank is made up of stainless steel and has MS fins at bottom. Rahat (pedals) is assembled on the boiling pan for defrothing when the temperature of jaggery reaches about 105 degree Celsius. At striking temperature the jaggery is almost liquid and can be easily poured into cooling pit by opening value at bottom of boiling pan. The cooling pit is made of granite. Typically used material is stone or Kaddapa. Comparatively granite is strong, does not break and do not contaminate jaggery products.

Fig: Fins of boiling pan as seen from bottom. To the right are the holes for air flow (primary and secondary) and fuel inlet.
Fig: Preheater tank, chimney and a settling tank at right.

Fig: Underground setting tank.
We visited Mr. Ajit’s plant in Belgaum. He has intelligently used multiple effect evaporators in jaggery production. The idea of multiple effect evaporators is not new. It has been used in sugar industries and other such industries.

A multiple-effect evaporator is an apparatus for efficiently using the heat from steam to evaporate water. In a multiple-effect evaporator, water is boiled in a sequence of vessels, each held at a lower pressure than the last. Because the boiling temperature of water decreases as pressure decreases, the vapour boiled off in one vessel can be used to heat the next, and only the first vessel (at the highest pressure) requires an external source of heat.

In case of jaggery production our aim is to separate water from the juice. In traditional jaggery units we usually separate water by boiling it. The steam moves and also take along with it heat which is not used productively. The multiple effect evaporator identifies this problem by using the heat in the steam for productive use.

In this plant one significant advantage is that human interference is reduced considerably. The inefficiencies that could be due to this are therefore reduced. Also the jaggery coming out can be directly packed without exposure to atmosphere. It is also possible to completely avoid use of chemicals and use organic substance like Bhendi extract.

On an average daily crushing of about 30 tons of sugarcane produces 3.1 tons of jaggery. The juice, after filtration, is sent to clarification unit. In clarification vessels lime is added to neutralize juice. With help of steam juice is heated to about 80-90 degree Celsius. At this stage, manually the scum or Mali is removed and juice is sent to intermediate vessel. The
heating is continued in intermediate vessel as well. It is beneficial if the juice going inside the multiple effect evaporators is at high temperature. The use of intermediate vessel is primary as storage before the juice is sent to first effect.

The construction of effects is such that the juice passes through multiple pipes running parallel to the outer walls of evaporators. From the cross section of one of the evaporators it is clear how the inside of effect looks like. Heated steam is passed through the effects and move from the space between these pipes. Main purpose of steam is to provide heat to the juice moving along the pipes. The steam from this effect is used to heat juice is next effect. The temperature required in the effects is less than 100 degree Celsius. The First effect is at about 80 degree Celsius and second effect is at 60 degree Celsius.

The working of multiple effect evaporators depends on vacuum that is generated. In this particular plant about 600mm of Vacuum is generated using water jet vacuum generator. This vacuum depends on the speed at which water is forced through small holes. This vacuum is shared by the effects. If we increase number of effects the vacuum shared by each effect decreases and this limits from increasing number of effects.

To avoid loses due to conduction and convention use of glass wool and POP has been done extensively as insulators.

Fig: Preheater, the pipes carry steam to heat the juice. Also called as clarification vessel.
Fig: Intermediate Vessel

Fig: First Effect
Fig: Inside of First effect (Tube shell heat exchanger).

Fig: Second Effect
Fig: Boiler Plant

Fig: Fuel inlet for the boiler
3. Analysis of Survey

We did a survey of 60 jaggery producers to understand their needs and aspirations. The survey helps to identify where exactly should our efforts be concentrated in future in order to bring positive impact in life of jaggery plant owners.

We asked about 20 questions. The questionnaire is attached as appendix. Some of the interesting facts that came to light with this survey are discussed here.

The cost incurred by each jaggery owner is more or less same.

1. Diesel per day requirement is 10-12 litres
2. Daily consumption of electricity cost about 200-250 rupees.
3. The cost of chemicals required for jaggery production is about 1000-1500 Rs per day
4. Produced jaggery is supposed to be taken to markets by farmers. The cost for same is about 70 paisa per Kg. Total cost is about 500-600 rupees/day

The difference lies in aspects which require technical know-how. The recovery factor for farmers varies a lot. The farmers are from same geological reason which implies that the quality of sugar cane (in terms of sugar cane) is not much different. The mis-management of labourers also causes additional expenditure to some farmers. More such outcomes are discussed below.

1. **Average cane consumption:** The consumption of cane remains same across different production units. This is due to fact that the process employed is batch process and not favourable for scaling.

2. **Jaggery recovery factor:** Jaggery recovery factor is mainly dependent on crushing efficiency. Less amount of juice per ton of cane crushed causes less jaggery

![Cane Consumption Graph]
production. So there are in-efficiency in crushing which needs to be studied in greater detail

3. Usage of Bagasse: As per our expectation and studies in other parts of Maharashtra, it was identified that farmers are not aware of alternative use of bagasse. We need to work hard on this aspect and develop favourable atmosphere for an ecosystem in which bagasse could be of some value. We have explored briquetting dry bagasse as one of such alternative.

Are you aware of any Usage of Bagasse?

- Yes: 7%
- No: 78%
- Can't Say: 15%
4. **Excess Bagasse:** Ideally we expect that 1 Kg Jaggery production requires 1 Kg of dry bagasse. Assuming from 10 ton of cane we get around 1.75 tons of bagasse, we should expect on an average to get 700 Kg of excess bagasse. The actual amount of bagasse remaining does not match this numbers. Infact about 10 units do not save any bagasse. This clearly identifies the inefficiency in production process. We need to study on furnace design, feed rate, materials used for pans, etc. to increase efficiency. Only then it shall be possible to save bagasse and establish the briquetting plant.

![Estimation of Excess Bagasse](image)

5. **Problem with bagasse storing:** majority people face the problem while storing excess bagasse. Main difficulties are rain, storm and land. This could be solved if there is proper shed built for bagasse storage. Considering quantity of bagasse this is not feasible option. Briquetting is very good option. It reduces volume by compression of bagasse. It has high calorif value and is not affected by moisture.

![Problem For Storing Bagasse](image)
6. **Problems that need immediate solutions:** It is essential to know what problems are faced by people who are directly involved with this industry. Labour, variable markets are prominent highlights. Dependence on labour is one of the main reasons that not many people today prefer this job. Also there has been tendency to sub-contract the entire plant to workers from UP.

To make this industry flourish it is necessary to reduce this dependency. We should move towards more automated production. Multiple effect evaporators are one step in this direction. However bringing such drastic change in production technique is also not feasible. Instead we can look forward to use the present production techniques and do some changes and make them better.

Some suggestions in this direction:
- Automated harvesting using a tractor
- Use of sliders so that Jaggery could be poured into cooling pit without much labour force.
- Use of motor driven “rahat” to create froth
- Automatic juice extraction
- Mechanical fuel feeding mechanism

![Problems That need immediate Solutions](image)

7. **Will you work with IIT?** : Majority of farmers are willing to work with IIT. From our side we should reciprocate by devoting sufficient resources for development in this field. People are eager for a change and we have to bring it.
Would you like to work with IIT?

- Yes: 83%
- No: 0%
- Can't Say: 17%

You: Yes
4. Suggestions

From our visits to various jaggery units in Maharashtra we feel that a lot can be done from technological point of view to develop present production units. The suggestions can be divided into following major parts:

1. **Hygiene**

   General Outlook at hygiene is that production cost increases if we try to incorporate hygienic processes. Therefore most of the producers adhere to non-standard production processes and try to reduce production cost. Jaggery is used as sweetener in many food products. A sufficient chunk of population has jaggery as a part of daily diet.

   Sooner or later this industry is going to come under scanner of food department. It is essential that we start to incorporate changes today in order to avoid problems in future. Also, better quality jaggery will fetch good market price. For purpose of export the hygienic standard are to be strictly followed.

   We want to incorporate hygienic process without affecting too much on initial capital investment.

   a. Replacement with Stainless Steel (SS304):

      When crushed, juice is typically stored in underground cement or plastic tanks. We need to replace this storage tank with SS304 food grade quality stainless steel.

      The boiling pan is traditionally made up of mild steel (MS). The carbon content of MS is very large which needs to be replaced by low carbon content SS304. The thermal conductivity of SS304 is one fifth of MS. This loses can be reduced by adding MS fins at bottom of boiling pane. The increased surface area helps to absorb more heat per unit time.

      Other equipment such as pipes, motors should also use SS304. The cost of SS304 is large but in long run the use of stainless steel is must for modernization of jaggery plant.
Fig: Unhygienic conditions in four pan Jaggery production unit at Kedgaon, Daund

Fig: Underground Juice collection cement tank which needs to be replaced by a closed SS304 tank (Photo Courtesy: G. S. Nevkar)
b. Use of chemicals:

To make jaggery look yellow the use of lime and hydroxides has increased tremendously. We need to make use of organic products like Bhendi stem and reduce dependence on chemicals.

Another approach could be to use standard measuring units for chemicals. At present the chemicals are used based on some heuristic standards. We could analyse exact requirement of chemicals per batch and provide some containers or ready-made packaging with chemicals required for one batch. This could reduce extravagant use of chemicals.
2. Reduction of labour intensive processes:
From survey it is clear that the dependence on labour is proving detrimental for this industry. Manufacturer need to move towards more automated manufacturing techniques. There are few things that are already being done in this direction. Multiple effect evaporators provide an opportunity to completely automatize jaggery production. Even with present process we could make some technological changes and reduce labour dependence.

a. Use of Slider or tipping mechanism in case of Single pan units: After striking point is reached jaggery is transferred from boiling pan to cooling pit. This is labour intensive process. Such drudgery could be avoided by using contraptions like tipping mechanisms as shown in figure.

In some units the cooling pit is at some distance from boiling pan. Instead of moving it we can add sliders to help in easy movement and reduce labour dependence.

b. Harvesting: Mechanisation: of harvesting is essential as majority chunk of labourers are required for harvesting of cane. We need to research the area in collaboration with researchers from relevant background.

Use of tractors for harvesting sugar cane could also be explored.
3. Increase Efficiency: We are proposing mechanism to utilize excess bagasse by briquetting it. Due to inefficiencies in involved in process it is not possible for the units to save any bagasse. It is clear from survey that majority of units are run in inefficient manner.
a. Feed rate: it is observed that irrespective of type of method employed, the process of feeding the fuel remains more or less same. It is essential to provide constant fuel to keep the temperature in furnace constant.

If for some reason the fuel feeding is stopped, the cool air takes away heat from furnace and reduces furnace temperature. Extra amount of fuel is required to reach the temperature. This wastage could be stopped by mechanical feeder. This reduces labour dependence and also increases consistency in feed rate.

It is also essential to train the worker who feeds fuel to the furnace. Alternative arrangement has to be made when the worker takes break.

b. Control air draft: From work of Mr. Kiran Shiralkar (Ph.D. candidate, IIT Bombay) it is observed that air flow plays vital role in determining efficiency of furnace. He did analysis of two plants. The plant with larger length of air duct showed better efficiency. The reason is that larger length of air duct slows air flow by friction. This gives more time for flue gas to interact with the furnace walls and exchange heat. The heat is thus trapped inside furnace and comparatively less amount of heat is taken away by the flue gas.

### Comparison of two representative units

<table>
<thead>
<tr>
<th></th>
<th>Unit No.1 – Duct Length 31.5 Ft.</th>
<th>Unit No.2 – Duct Length 20 Ft.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Chimney ID- 1.6 Ft. and Ht. 15.5 Ft.</td>
<td>Chimney ID- 1.5 Ft. and Ht. 17 Ft.</td>
</tr>
<tr>
<td>Batch time</td>
<td>2 hrs</td>
<td>2.5 hrs</td>
</tr>
<tr>
<td>Bagasse consumption</td>
<td>1.2 kg</td>
<td>1.5 kg</td>
</tr>
<tr>
<td>Thermal Efficiency</td>
<td>50%</td>
<td>40 %</td>
</tr>
</tbody>
</table>

All in all, the inefficiency of unit-2 may be attributed to higher air draft that is probably caused by taller chimney and less pressure drop in shorter and straight furnace exhaust duct.

We should work for standardizing the plants. Using simulations we can develop plants which are efficient and saves fuel.

The heat carried away by flue gas is waste. This flue gas could be used to dry the bagasse. Quick drying of bagasse reduces land as well as labour requirement. One such plant has been set up at Ghunki.

Fig: Schematic of Bagasse drying unit at Ghunki.
5. Conclusion:

Farmers look forward to institutes like IIT to bring about changes in present technologies for jaggery production. Through survey and visits to different unit in Maharashtra we have realised the importance of technological development in this field. The potential for development in this field is immense. We can start with bringing smaller changes in process which will help the producers to give better product at cheaper price. The importance of jaggery and jaggery industries has already been highlighted.

Our final aim should be to bring complete automation in the jaggery industry. In short duration however we should think of developing the present process. With some alterations suggested we can make the producers happy and provide better quality product to consumer.

We have also identified areas for entrepreneurship. Increasing efficiency will help to save bagasse. This bagasse could then be used to make bio-mass briquettes. The market for low cost fuel is very large and this could serve as additional income source to farmers. We have discussed the feasibility of such and ecosystem in other report.
Appendix

युनायंटजबाबत सवर्जः

(१६ में २०१२)

व्यक्तिगत माहिती:

१. नाम:

२. पत्ता:

३. वय:

४. मोबाईल नंबर:

उत्पादन:

५. या व्यवसायात कधी पासून आहात? (किती वर्ष?)

६. उसाची गाढीष्प किती होते? (टण / प्रती दिवस)

७. गुळ उत्पादन (टण / प्रती दिवस)

८. वर्षासून अंदाजे किती दिवस उत्पादन करतात?

९. एका दिवसात किती बंच्खांड लिघातात? (आधान)

१०. तुम्ही कोणती पद्धत वापरतात? (कोल्हापूर (चाय पंप? कि युपी (दोन पंप))?

११. अंदाजे बगास प्रती दिन किती राहतो? (वाढवेला)

- बगास साठवण्यात काही अडचण येते का?
- जर उरलेला बगास या ब्रिकेटस बनवले तर तुम्हाला त्याचा काही उपयोग होईल का?

कमाई:

१२. गुळ कोण उचलतो?

१३. तुम्हाला जागेवर किती किंमत भेटते? (रुपये/किलो)

१४. अंदाजे मासिक/दिवसाचा धंदा किती होतो?

१५. गुळा व्यतिरिक्त काही विक्री होते का? (उदा: बगास वन्गारे)
१६. ऑफ सीज़न मध्ये जीविकेच्या काही साधन/ उद्योग आहे का?

१७. असेल तर त्यात प्राप्ती किती होते?

१८. देनंदिन उसाचा खर्च ? (रुपये/दिन )

१९. डॉजेल चा देनंदिन खर्च ? (रुपये/दिन )

२०. गुंहाझा लागणारा विजेचा अंदाजे खर्च ? मासिक/देनंदिन

२१. गुंहाझा साठी लागणारे मजुर - खर्च ?(रुपये/दिन )

२२. जागा भाडे - खर्च ? (वार्षिक )

२३. गुढ वाहतूक व्यापारी करतो कि गुरुळवाळे देतात ? जर तुम्ही करत असाल तर त्याचा खर्च किती असतो?

२४. इतर महत्त्वाचा खर्च- काय आणि किती?

इतर:

२५. आपल्या इष्टीने सदृश परीश्तीत गुरुळ गडांचे दोन महत्त्वाचे प्रश्न कोणते?

२६. बगासला बाहेर मार्केट असल्याची माहिती आहे का तुम्हाळा?

२७. आई. आई. टी. सारख्या संस्थे बरोबर काम करण्याची इच्छा आहे का?

- हो - नाही