IJTA © Serials Publications

National Academy of Agricultural Science (NAAS) Rating : 3.03

Hazard Analysis and Critical Control Points Evaluation in the Manufacturing Process and Storage of Jaggery

P. K. Omre*1, Sweta Mishra* and Suman Singh*

***ABSTRACT:** Jaggery occupies an important role in rural diet, post harvest cottage industry and agricultural economy of India. Being an eco-friendly sweetener, with additional nutritional value, jaggery holds good export potential. To sustain the market and export potential of jaggery, it is imperative that the jaggery quality is enhanced. Some efficient and cost effective quality control systems like Hazard Analysis and Critical Control Point (HACCP) evaluation is being increasingly adopted in developed industries for quality improvement but it failed to reach the cottage industries. Hence, there is a strong need to develop a cost effective quality control plan using HACCP approach to improve the quality of jaggery. Therefore, this study was undertaken to identify various potential hazards and to decide the critical control points with their control limits among operational steps.*

A HACCP plan was developed to assess various hazards associated with the process of jaggery manufacture by the application of seven principles and pre-requisite programs of HACCP system. For this purpose six different jaggery units were surveyed. Units were surveyed in three phases from December upto March. Samples drawn during the manufacturing process were further analyzed in laboratory to ensure whether they meet the limits specified for their proximate composition by BIS or not. After this one storage unit for jaggery was surveyed to identify various hazards associated with it. Samples were drawn from its various sections and compared with the samples stored in the laboratory conditions. A controlled sample was manufactured in one of the unit without using any chemicals, under the same process conditions and its results were compared with other samples to know the effects of chemicals.

In the hazard analysis conducted various hazards assessed were classified as physical, chemical and biological hazards. Metal pieces, hairs, nails, dust were sources of physical hazards; leakage of lubricants, use of excessive chemicals, residues of detergents were sources of chemical hazards and flies, rodents and ants were sources of biological hazards. The results of proximate analysis of composition of jaggery revealed great variations from the specifications. The critical control points were identified as storage of sugarcanes for long time, storage and late processing of sugarcane juice and exhaustive use of chemicals during preparation of jaggery. The control limits recommended to control these steps are to use sugarcanes within 72 hours of storage, to process the sugarcane juice within 2 hours and to use 35 g of hydros per pan to keep the sulphur dioxide content below 50 ppm (specified limit).

Food safety is a top priority among the food manufacturers everywhere in the world. Foodborne diseases cause considerable morbidity and mortality throughout the world. It is estimated that in India about seven million people a year are affected with food borne illness of which almost 700 have proved to be fatal **(Jaiswal, 1999)**.Outbreaks of food borne illnesses remind us that there are compelling reasons for proactive control of food safety at all stages of food production i.e. procurement, processing, packaging and storage **(Jaiswal, 2000)**.

HACCP system of process control was developed from the Pillsbury company's effort to produce safest food for consumption of astronauts as per requirements of National Aeronautics and Space

* Professor, M. Tech. and Ph.D Scholar Deptt. of Post Harvest Process and Food Engineering, Govind Ballabh Pant University of Agril. & Tech., Pantnager 263145 (UK) India. *E-mail: pkomre@rediffmail.com*

Administration in 1960 **(Giese, 1999)**. Hazard analysis and critical control point (HACCP) is a safety management system using the approach of controlling hazards at critical points in food production and in all levels of food handling to prevent food safety problems. It is a world wide recognized systematic and preventive approach that addresses biological, chemical and physical hazards through anticipation and prevention rather than through end product inspection and testing. It aims to identify problems before they occur and establish measures for their control at stages in production that are critical for ensuring the safety of the food **(Notermans *et al.*, 1995)**.

Literature search indicates that HACCP approaches have been applied to various food industries like chocolate industry, ice-cream industry, coffee industry, meat industry etc., but not in less developed cottage industries like jaggery manufacturing units.

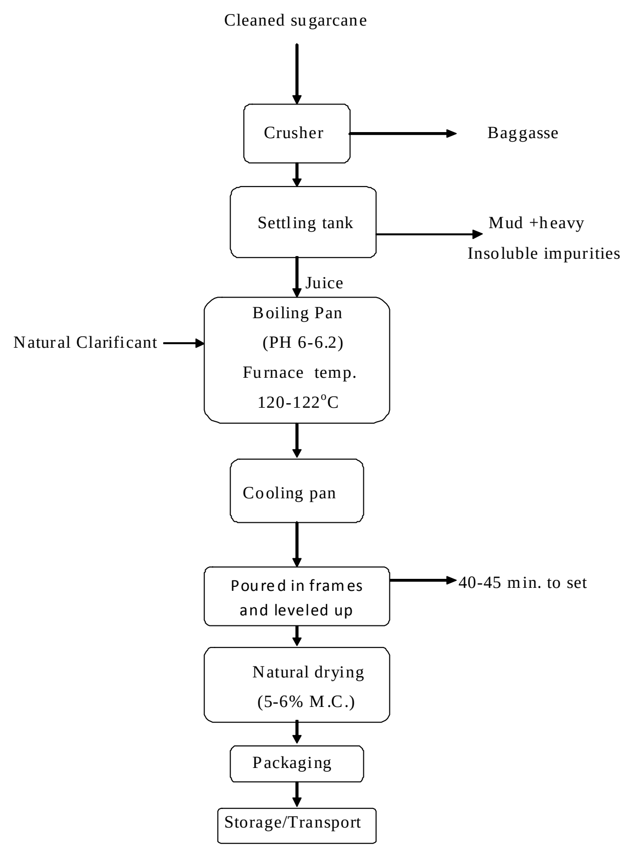
In the context of the above arguments, there is a strong need to develop a cost effective quality control plan using HACCP approach to improve the quality of jaggery. Therefore this study was undertaken with the following objectives:

1. To identify various potential hazards in jaggery manufacturing process.
2. To decide the critical control points among the operational steps.
3. To decide the control limits for the critical control points.

MATERIALS AND METHODS

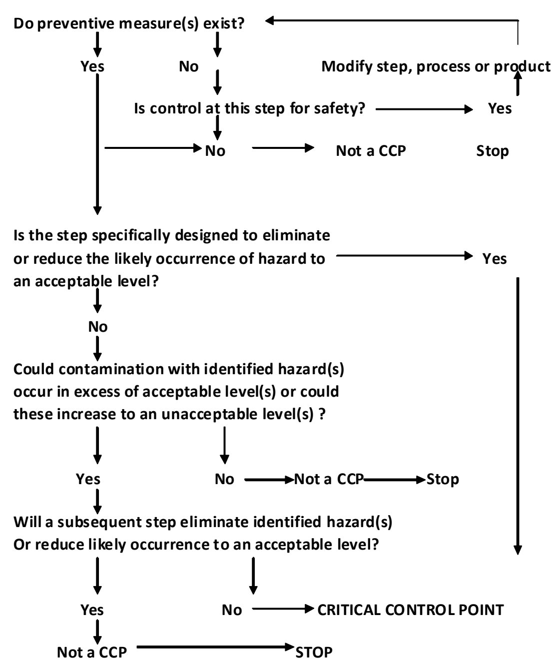
A HACCP plan was developed to assess various hazards associated with the process of jaggery manufacture by the application of seven principles and pre-requisite programs of HACCP system. For this purpose six different jaggery units were surveyed. Units were surveyed in three phases from December upto March. Samples drawn during the manufacturing process were further analyzed in laboratory to ensure whether they meet the limits specified for their proximate composition by BIS or not. After this one storage unit for jaggery was surveyed to identify various hazards associated with it. Samples were drawn from its various sections and compared with the samples stored in the laboratory conditions. A controlled sample was manufactured in one of the unit without using any chemicals, under the same process conditions and its results were compared with other samples.

Process Flow Diagram for manufacturing Jaggery



Decision tree approach for deciding critical control points

<u>*HACCP Design Tree to Each Step With Identified Hazards*</u>



Measurement Techniques pH

13 g of jaggery was weighed and dissolved in 100 ml of distilled water to make jaggery solution (N/2). pH of this solution was determined using pH meter.

True Density

True density was determined using toluene displacement method. **(Anon., 1986)**.

Optical Density

A 13% (w/v) solution was made and filtered through Whatman No.2 filter and was taken. Optical density was estimated by colorimeter at 540 nm. **(IS: 6287 – 1985).**

Free Sulphur dioxide Content

Jaggery solution was made by dissolving 25 g of jaggery in 250 ml distilled water to estimate free sulphur dioxide content **(Kulshreshtha and singh, 2006)**. 50 ml of this jaggery solution was acidified with 5 ml dilute sulphuric acid. Then 0.5 g of sodium carbonate as added to expel the air. The content was titrated rapidly with 0.02 N standard iodiwne solution using starch as indicator **(Ranganna, 1986)**.

Swab Test Preparation of swab

The swab consists of cotton wool which was bound at the end of a metal wire. The other end of the wire was looped. The swab was immersed in a test tube with distilled water. The test tube was plugged with cotton, sterilized in the autoclave at 15 psi for 20 min and then used for enumeration of microorganisms.

% Sucrose = (%Total invert Sugars - % Reducing sugars originally present) X 0.95

% Total Sugar = (% Reducing sugars + % Sucrose)

RESULTS AND DISCUSSIONS

Hazard analysis was carried out during the manufacturing process and in the storage unit of jaggery inorder to find out the potential hazards and to identify the critical points to be controlled. For this purpose six units were surveyed three times (Jan-Mar). The results thus obtained were compared with that of samples stored in the laboratory conditions and the variations were noted. A brief discussion of experimental results is presented in the following paragraphs:

Hazards identified during the manufacture of jaggery

The hazards assessed are presented in the Table

Hazards Identified and Preventive Measures for Jaggery Manufacture

Sl.No.	*Steps*	*Identified Hazards*	*Preventive measures*
1.	**Reception of raw material**	Losses due to inversion of sugar due to staling of stored sugarcane	Sugarcane should be crushed within 24 hours of procurement.
2.	**Juice extraction**	Contamination through leakage of lubricants from crushers	Crusher gears should be properly lubricated and tightened.
3.	**Passage of sugarcane juice to settling tank**	Entry of metal parts	Rusting of pipes should be avoided.
4.	**Storage of sugarcane juice**	➢ Entry of Baggase, dust, dirt, polythene pieces. ➢ Staling of stored juice due to inversion of sugar. ➢ Residues of cleaning detergents left.	➢ Physical contamination should be avoided, stored juice should be covered. ➢ Juice should be used within 2-3 hours of crushing. ➢ Tank should be properly cleaned.
5.	**Clarification of sugarcane juice**	➢ Excessive use of chemical clarificant ➢ Use of castor oil in excess.	➢ Addition of chemical clarificant should be less than 35g per pan. ➢ Addition of castor oil should be avoided.
6.	**Cooling of jaggery**	Entry of flies nails hairs, Baggase, dust, dirt, polythene pieces.	Open cooling of jaggery should be avoided or cooled under hygienic conditions.
7.	**Preparation of different shapes of jaggery**	Microbial contamination through hands, wrapping cloth and from surroundings.	➢ Hands should be properly washed ➢ Wrapping cloth should be properly cleaned ➢ Environmental contamination should be avoided.
8.	**Storing of jaggery before sale**	Contamination through rodents, ants, bees.	Open stacking should be avoided; Jaggery should be properly packed and stored.

Results of different tests of end products

The end product i.e. jaggery samples of different units were analyzed in the laboratory to check whether its composition is compatible with the specifications given by BIS or not. Various parameters which contribute to its physical and chemical properties were analyzed. The results of various tests for proximate composition of fresh jaggery of all the three phases are presented in Table 4.2. From the ANOVA Table A-1-3, it is confirmed that the units have significant effect on the variation in the data pertaining to proximate composition of jaggery. The reason may be assigned to the variation in the process of manufacture. The results of various tests conducted are discussed in the following paragraphs:

True Density

True density of jaggery obtained in the first phase of the experiment varied from 1.49 g/cc-1.64 g/cc. In the second phase of experiment it varied from1.49 g/cc-1.65 g/cc and in the third phase it varied from 1.44 g/cc-1.64 g/cc.

pH

pH of N/2 jaggery solution varied from 5.35-5.55 in the first phase of the experiment, 5.13-5.27 in the second phase of the experiment and 4.41-4.71 in the third phase of the experiment. pH of juice decreased during boiling **(Shinde *et al.*, 1982)**. This contributed to low pH of jaggery. pH values of different jaggery samples when compared with the pH value of controlled sample (where no chemical clarificant was added) show variation. The controlled sample has higher pH. Hence, the cause may be the effect of clarificant added **(Javalekar *et al.*, 1985)**. The cause of low pH may also be to the variety of sugarcane used

Free Sulphur dioxide content

Free Sulphur dioxide content of jaggery samples taken during first phase of the experiment varied from 87.04-97.04 ppm, during second phase of the experiment varied from 85.91-98.32 ppm and during third phase of experiment varied from 88.62-97.49 ppm. None of these were within specifications (max .50 ppm) as confirmed from fig. 4.8, 4.16, 4.24. The reason may be excess use of hydros to lighten the color of jaggery. A controlled sample was prepared in one of the unit without addition of hydros with all other process conditions remaining the same. When free Sulphur dioxide content of all the samples were compared with that of the controlled sample, it was observed that the controlled sample does not deviate from specifications but all other samples deviate from specifications. This confirms that addition of hydros (sodium hydrosulphite) in excess is responsible for high sulphur dioxide content of jaggery. From literatures it was found that the quantity of hydros to be used for the purpose should be less than 35 g per boiling pan to keep the sulphur dioxide content below 50 ppm the permissible limit of sulphur dioxide content in jaggery **(Food Adulteration Rules 5, promulgamated by the Government of India) (Javalekar *et al.*,1985).** Survey of all the units confirms that none of the unit use hydros below 40 g per pan. Hence, the sulphur dioxide content is more than specified which should be avoided as it can affect human health adversely.

Process steps and Critical Control Points

The critical control points were decided by using HACCP decision tree. During the process of jaggery manufacture the following operations are important for food safety management.

Raw material storage

In the process of jaggery manufacture the main aim is to produce jaggery of high quality. Quality of jaggery depends on the variety of sugarcane available, time upto which it is stored and time of crushing of sugarcanes. From survey it was found that particularly during winter season the availability of sugarcane is more than the processing capacity of units, hence amount left after processing is stored. However, staling of canes is less during winter than that of summer season **(Jadhav *et al*, 2001)**. The storing time for sugarcane varied from 4-8 days in the six units surveyed. According to literature, the staling of sugarcane results in the inversion of sugar, increase in amount of reducing sugar and decrease in sucrose content **(Solomon *et al.*, 1990)**. Hence, this step is considered as critical and must be controlled during the manufacture of jaggery.

Storage of sugarcane juice

In the process of manufacture of jaggery, quality of jaggery depends on the time upto which the fresh sugarcane juice stored before processing. From survey it was found that particularly during summer season owing high heat and inconsistency of jaggery in settling during day time the workers crush the canes and fill the juice in the storage tank for preparation of jaggery during the night time. The storing time varies from 7-9 h in the six units surveyed. Literature reviewed suggests that sugarcane juice suffers inversion and remarkable changes in its composition if stored more than 2h. Hence, this step is considered to be critical for quality of jaggery and must be controlled.

Exhaustive Use of Hydros

Quality of jaggery is judged by its color, hardness, texture, sucrose and invert sugar content etc. The prices are fixed in the local market on visual appearance i.e. color and texture of jaggery by the local dealer. The color being the main criteria for fetching good price, therefore, farmers strive hard to get golden yellow color for his product. Hydros (sodium hydro sulphite i.e.$Na_2S_2O_4$) is most commonly used in jaggery making areas for the purpose. However, its use lead to the change in color, fall in pH, reduction in sugar content and watering of jaggery during storage **(Anjal and Tagare, 1972)**. From the survey of six units it was observed that it is a usual practice to use more than 50 g of hydros per pan which is more than recommended i.e.35 g. This excess use of hydros also resulted in the high amount of sulphur dioxide content than permitted. Hence, this step is considered to be critical and needs control.

Control limits for Critical Control Points Control limits for time of storage of raw material

From the survey it is revealed that the storing time for sugarcane varied from 4-8 days in the six units surveyed. This staling of sugarcane results in the inversion of sugar, increase in amount of reducing sugar and decrease in sucrose content. Hence, this step is considered as critical. According to the literature, the post harvest changes in sugarcane juice quality in harvested cane and the losses due to sucrose inversion were accelerated after 72 h of storage. To avoid such losses in quality in terms of increased reducing sugar and decreased sucrose content the sugarcanes should be used fresh if possible and should not be stored more than three days.

Control limits for time of storage of sugarcane juice

Due to high heat and inconsistency of jaggery in settling during day time the workers crush the canes and store the juice which causes inversion of sugar and changes in juice composition. The storing time varied from 7-9 h in the six units surveyed. Hence, this step is considered to be critical to maintain the quality of jaggery. To avoid such changes in juice quality, the juice should be used fresh as far as possible and in worst case should not be stored more than two hours.

Control limits for amount of hydros to be used

Farmers use hydros exhaustively to lighten the color of jaggery in order to increase its market value. This results in the change in color fall in pH, reduction in sugar content and watering of jaggery during storage. From the survey of six units it was observed that it is a usual practice to use more than 50 g of hydros per pan which is more than recommended i.e.35 g. This excess use of hydros also resulted in the high amount of sulphur dioxide content than permitted i.e. 50 ppm. Hence, this step is considered to be critical. Thus, in order to make the jaggery safe to eat the sulphur dioxide content needs to be minimized. For this purpose the use of hydros should be restricted to 35 g / pan.

CONCLUSION

Based on survey reports of hazard analysis and results of analysis of jaggery in the laboratory, the following conclusions could be drawn:The hazards assessed during the manufacture and storage of jaggery were classified as physical, chemical and biological. Metal pieces, hairs, nails, dust were sources of physical hazards; leakage of lubricants, use of excessive chemicals, residues of detergents were sources of chemical hazards and flies, rodents and ants were sources of biological hazards. Thus, hygienic conditions should be maintained in the unit and its surroundings inorder to avoid any contamination to the jiggery. Exhaustive use of chemical clarificant i.e. Hydros (sodium hydro sulphite i.e.$Na_2S_2O_4$) to lighten the color of jaggery to increase its market value has resulted in remarkable increase in free sulphur dioxide content beyond specified limits which is health hazardous. Hence, this step is critical from health point of view. It is recommended that 35 g of hydros per pan should be used to keep the sulphur dioxide content below 50 ppm (specified limit).

REFERNCES

A. O. A. C., (1969), Official methods of analysis, edited by Horwitz, H. Associationof Official Analytical Chemists, Washington, **16**(1&2): 58-62.

Adams C. E., (1998), Maximising value from HACCP: Managing food safety for the business, *Food Australia*, **50**(7): 332-335.

Adams C. E., (1990), Use of HACCP in meat and poultry inspection, *Food Technology*, **44**(5): 169-170.

AGMARK Grades, Sugarcane Gur (Jaggery) Grading and Marking Rules.

Agrawal M. P., and Ghosh A. K., (1983), Effect of cane maturity, nitrogen fertilization, clarificants and additives on keeping quality of Gur, *Indian Sugar*, **33**(2): 97-104.

Agrawal M. P. and Ghosh A. K., (1984), Designing and evaluation of godowns for storing jaggery by small farmers, *Indian Sugar*, **34**(6): 505-507.

Ali A. A. and Spencer N. J., (1996), Hazard Analysis and Critical Control Point evaluation of school food programs in Bahrain, *Journal of Food Protection*, **59**(3): 282-286.

Anonymous, (1986), A report on investigations of gur storage and handling.

Kulshreshtha M., and Singh A., (2006), *Measurement techniques for jaggery properties*, pp. 22.

Appendix A-1

ANOVA- summary table for variation among the units

Source of variation	*Degree of freedom, d.f.*	*Sum of squares, S.S.*	*Mean Sum of squares, M.S.S.*	*F Calculated*	*Critical difference at 1% Level*
		Total ash content			
Units	5	2.896138	.5792277	1046.99*	.6082583
Error	10	.5536497	.5536497		
Total	17	3.407097			
		Acid insoluble ash content			
Units	5	.3341050	.1601651	40038.23*	.1056062
Error	10	.1668930	.6682101		
Total	17	.3373250			
		Water insoluble ash content			
Units	5	.1035150	.2070300	3899.943*	.5956045
Error	10	.5308539	.5308539		
Total	17	.3918810			
		Sulphated ash content			
Units	5	2.579661	.5159322	3392.677*	.3187833
Error	10	.1520723	.1520723		
Total	17	2.888382			

* Significant at 1% probability level.

Appendix A-2
ANOVA- summary table for variation among the units

Source of variation	*Degree of freedom, d.f.*	*Sum of squares, S.S.*	*Mean Sum of squares, M.S.S.*	*F Calculated*	*Critical difference at 1% Level*
Free Sulphur dioxide content					
Units	5	190.4740	38.09479	6094.671*	.2043752
Error	10	.625050	.6250508		
Total	17	190.7188			
Reducing sugar content					
Units	5	2.472738	.4945475	3038.352*	.3298037
Error	10	.1627684	.1627684		
Total	17	2.781250			
Sucrose content					
Units	5	10.22917	2.045833	654.6735*	.1445085
Error	10	.3124967	.3124967		
Total	17	10.53125			
Total sugar content					
Units	5	2.734375	6.3731	1049.998*	.5899570
Error	10	.5208343	1.0239		
Total	17	3.015625			

Appendix A-3
ANOVA- summary table for variation among the units

Source of variation	*Degree of freedom, d.f.*	*Sum of squares, S.S.*	*Mean Sum of squares, M.S.S.*	*F Calculated*	*Critical difference at 1% Level*
Moisture content					
Units	5	17.03866	3.407731	104893.6*	.1473427
Error	10	.3248751	.3248751		
Total	17	17.31543			
Color					
Units	5	.1459609	.2919218	42.37395*	.6785069
Error	10	.6889179	.6889179		
Total	17	.4053273			
pH					
Units	5	.8034261	.1606852	73.81317*	.3814095
Error	10	.2176918	.2176918		
Total	17	.3928833			
True density					
Units	5	.7746887	.1549377	2648.42*	.625253
Error	10	.5850196	.5850196		
Total	17	.3658371			

* Significant at 1% probability level