HAZARD ANALYSIS AND CRITICAL CONTROL POINTS EVALUATION IN THE MANUFACTURING PROCESS AND STORAGE OF JAGGERY

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CERTIFICATE

This is to certify that the thesis entitled '**HAZARD ANALYSIS AND CRITICAL CONTROL POINTS EVALUATION IN THE MANUFACTURING PROCESS AND STORAGE OF JAGGERY'** submitted in partial fulfilment of the requirements for the degree of **Master of Technology** in **Agricultural Engineering** with major in **Process and Food Engineering** of the College of Post-Graduate Studies, G. B. Pant University of Agriculture & Technology, Pantnagar, is a record of *bona-fide* research carried out by **Ms. Sweta Mishra**, Id. No. **31869**, under my supervision, and no part of the thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of this investigation have been acknowledged.

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CERTIFICATE

We, the undersigned, members of the Advisory Committee of **Ms. Sweta Mishra**, Id. No. **31869**, a candidate for the degree of **Master of Technology** in **Agricultural Engineering** with major in **Process and Food Engineering,** agree that the thesis entitled **'HAZARD ANALYSIS AND CRITICAL CONTROL POINTS EVALUATION IN THE MANUFACTURING PROCESS AND STORAGE OF JAGGERY'** may be submitted in partial fulfillment of the requirements for the degree.

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

4.39	Sulphated Ash Content of fresh jaggery samples (phase-II)	
4.40	Reducing Sugar Content of jaggery samples (phase-II)	
4.41	Sucrose Content of jaggery samples (phase-II)	
4.42	Total Sugar Content of jaggery samples (phase-II)	
4.43	Moisture Content of jaggery samples (phase-II)	
4.44	Color of jaggery samples (phase-II)	
4.45	pH of jaggery samples (phase-II)	
4.46	True Density of jaggery samples (phase-II)	

LIST OF PLATES

NOMENCLATURE

Symbols:

%	Per cent
^0C	Degree Centigrade
N	Normal
ρ	Density

Abbreviations:

ANOVA	Analysis of Variance
BIS	Bureau of Indian Standard
CCP	Critical Control Point
cm	centimeters
d.b	dry basis
et al.	and others
etc.	et cetera, and so forth
Fig.	Figure
FSO	Food Safety Objectives
g	Gram
g/cc	Gram per Cubic Centimeter
GMP	Good Manufacturing Practice
h	Hour
HACCP	Hazard Analysis and Critical Control Point
H_2SO_4	Sulphuric Acid
Hcl	Hydrochloric Acid
i.e.	that is
ISI	Indian Standard Institution
Kg	Kilo gram
l	liter
m	meter

Max	Maximum
mg	Milligram
Min	Minimum
min	Minute
ml	Milliliter
mm	Millimeter
O.D	Optical Density
ppm	Parts per million
viz.	namely, in other words
w/v	weight/volume

1 Introduction

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)**.

Due to extensive scale of food production, even a single failure in hygiene control may affect a large numbers of consumers. Hence, quality of food has to be controlled and maintained. In today's global market quality and safety have become competitive edge for enterprises producing goods and providing services like food industries **(Sohrab, 1997)**. Consideration of quality is peremptory more now than ever before owing to global competition. With global competition increasing, companies must establish dynamic forward looking cultures of quality to survive in the global village of the business world. Importing countries have begun to impose stringent quality standards more in the area of safety aspects. Hence, in order to increase the export demand for our products, it is essential that quality of Indian food products should be good.

Moreover, good quality food has become intense concern of the consumers. Good quality refers to physico-chemically, microbiologically sound, nutritious and more close to natural foods without preservatives and colors **(Rao, 1997)**. Thus, to meet global demand of better quality and hygienic foods an effective and rational means of assuring food safety from harvest level upto consumption level is required. Traditional surveillance of end products to control safety may fail to detect unsafe batches of food and microbiological testing of end products is also time consuming and expensive.

Preventive measure "Hazard Analysis and Critical Control Point evaluation" can serve as an important tool for safety management that can ensure that system used, produces a standard acceptable product with respect to nutrition, purity and wholesomeness **(Mehta *et al*. 2002)**. It is a careful balance between the scientific approach that emphasizes the need for the system to be effective in controlling the food safety hazards and the pragmatic approach that recognizes the need for the system to be practical and cost effective.

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 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)**.

HACCP systems are designed to prevent the occurrence of potential food safety problems by assessing the inherent hazards attributable to a product or a process, determining the necessary steps that will control the identified hazards and implementing active managerial control practices to ensure that the hazards are eliminated or minimized. HACCP represents an important food protection tool supported by Standard Operating Procedures, employee training and other prerequisite programs that small independent businesses as well as national companies can implement to achieve managerial control of hazards associated with foods.

The HACCP approach is being increasingly employed in the food industries all over the world, particularly in large manufacturing operations. But due to several constraints like lack of proper infrastructure and distribution network coupled with widespread consumer unawareness about the cost effective quality control system like HACCP system, small and/or less developed businesses are unable to produce good quality hygienic foods.

Jaggery occupies an important role in rural diet, post harvest cottage industry and agricultural economy of India. At present about 50-60% of the total sugar production is used for manufacturing jaggery and khandsari products. India produces more than 70% of the total jaggery production of the

world. Over 3 million people earn their livelihood from jaggery and khandsari sector **(Statistics, Indian Sugars, December 2002)**. Since, the demand of this traditional least expensive nutritive sweetener is increasing this industry would continue playing its role in processing of sugarcane at rural level for the production of sweeteners and in addition this will also create better employment opportunity to people in rural areas. 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. Since, most of the jaggery is produced at village level, there is poor or no quality control. For this efforts must be directed towards the manufacture of high quality jaggery, free from contaminants.

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.

2 Review of Literature

Jaggery industry is the most widespread cottage industry in India. Jaggery being a low cost traditional, eco-friendly and nutritive sweetener holds a good export potential. Most of the jaggery produced is consumed in raw form and it has overall nourishing effects on health. Being a nutritive sweetener, it has a potential use in developing energy foods on large scale. So, inorder to sustain market potential as well as to obtain healthy sweetener, it is necessary to enhance the quality of jaggery. Since jaggery is mostly produced at the rural level, the quality control system to be used should be cost-effective and efficient one. HACCP system offers a viable alternative. Although HACCP analysis has been applied to various food industries in India, the scientific literature pertaining to such process is very limited. The literature has been reviewed in the following parts:

2.1 Need for quality control in Food industries

Notermans and Borgdorff (1997) investigated the need for production of safe food and presented the global perspective of food borne diseases. According to their investigations food borne illnesses are among the most widespread problems of our contemporary world. The illnesses are toxic or infectious by nature and are caused by agents that enter through ingestion of contaminated food or water. The causative agents can be chemical or biological. Because of high frequency of occurrence of such illnesses, the

socio-economic impact is very high. Therefore, in most countries safe food production is of prime concern and legislation has been developed to ensure the safety of food and because of globalization of production of raw food materials, use of new food-processing technologies, changing eating habits, the issue of production of safe food is a highly dynamic one.

Rao (1997) emphasized the need for quality control in food processing industries. According to him poor quality standards are root cause of food borne illnesses and more natural and organic food instead of genetically modified food is more important. He stressed on the fact that there is a need to produce more from a progressively diminishing land resource. Hence, improving and stabilizing productivity to meet these needs is a must. In addition there is an urgent need for improving the quality of food in terms of protein content and equitable distribution amongst all classes of our society. He concluded that quality improvement is a continuous process and can be controlled if pre and post harvest operational measures, storage and packaging are looked with care. Fair degree of acceptability of Indian food products can be achieved, if normal care and attention is bestowed.

Premavalli (2000) studied the standardization systems for quality control. He defined quality as the composite of those 'characteristics' that differentiate individual units of a product and have significance in determining the degree of acceptability of that unit by the buyer. According to him in general, the quality control is the maintenance of quality at levels and tolerance acceptable to buyer, minimizing the cost for vender. But, from scientific angle,

the overall quality refers to technological, physical, chemical, microbiological, nutritional and sensory parameters to achieve the wholesome food. He worked on national and international quality standardization systems which revealed that all these systems emphasized on checking the quality and enforcement of HACCP. He focused on product specifications, microbiological method specifications, methods of analysis of specified parameters and other hygienic codes and specifications mentioned in BIS, AGMARK, ISO, Codex Alimentarius Commission which are to be followed inorder to control the quality.

Sohrab (2000) analyzed the need for quality standards for food and the modern trends in these standards (ISO 9000:2000).He reported that the global economy today centres round technology, quality and international competitiveness. Standardization encapsulates technological results and becomes a vehicle for technology transfer, while quality is the key for facilitating trade and satisfying customers. He concluded that the ISO 9000 Quality Management System standards combine these two. It provides an overall improved competitiveness, as it ensures control, consistency, assurance of high standards, improved productivity and most importantly improved quality.

Omaye (2002) evaluated the food supplement safety and suggested that evaluation and management of quality of dietary supplement should be practiced inorder to make them safe for consumers.

Taylor (2002) focused on the objectives of food safety system. According to him food safety systems are required to reduce food borne diseases and maintaining public confidence in food safety and food supply systems. Moreover, people want the peace of mind that comes to them by knowing that their food is safe and those involved in the food processing system have done everything it is reasonably possible to do to make the food safe.

Zwietering (2004) emphasized on the need of food safety objectives in order to control quality of food. His study revealed that the concept of food safety objectives (FSO) is very strong in that it may make food safety transparent and quantifiable. This brings a major advantage in that one can ensure food safety at the process where it is the most effective in meeting the overall integrated objective. He in his study gave a practical overview about the derivation of FSOs from population health goals and product group health objectives and how these FSOs can be used to assign the responsibilities over various parts of food processing stages.

Kumar *et al*. (2005) studied the importance of quality and process control in the food industry. Their study revealed that the aim of quality control is to achieve as good and as consistent a standard of quality in the product being produced as is compatible with the market for which the product is designed. According to them quality control is the sum of all those controllable factors that ultimately influence positively or negatively the quality of the finished product e.g. selection of raw materials, processing methods,

packaging, methods of storage distribution etc. The use of good and sound raw material is of primary importance for achievement of the required end product of consistent quality. They concluded that traditional quality control is completely unable to eliminate quality problems, thus a preventive strategy based on thorough analysis of prevailing conditions which ensures that objectives of the quality assurance programme are met which is recommended for food industry.

2.2 Jaggery industry- an important cottage industry

2.2.1 Forms of jaggery

Jaggery is commonly produced in three forms viz. powder jaggery, liquid jaggery and solid jaggery.

Powder jaggery

The powder jaggery is produced by heating the acidified juice (pH: 6 to 6.2) by adding lime as clarificant. The charge is boiled up to striking point of 118 -120°C and the hot mass is allowed to cool along with thorough mixing for a few minutes. This thick mass is then spread on aluminum tray or cement platform and allowed to cool for few minutes without stirring. This helps in good crystal formation. At the time of solidification the mass is stirred with wooden scrapers to get the powdered *gur* **(*Anonymous*, 1996).**

Liquid jaggery

For manufacturing liquid jaggery the juice is put in settling tank in .which potassium-alum crystal strainers are dipped for half a minute for rapid

sedimentation of soil particles etc. The clear juice is then transferred to a boiling pan on the furnace where the pH is adjusted to 5.8 -6.0 by adding lime. After some time, Deola mucilage and phosphoric acid are added for clarification. The striking temperature of 105 to 106 °C results in good keeping quality, the microbial growth and crystallization are also minimized at this striking point. The manufacturing conditions for liquid jaggery as reported by **Patil *et. al.* (1993)** are slightly different. The pH of the juice ranges from 6.5 to 7.0 and Bhindi mucilage in used for coagulation. The striking is done at 105°C (60 to 70° Brix) and the syrup is collected in the container.

Solid jaggery

Chockalingam (1985) reviewed the *gur* manufacturing in Tamilnadu. He recommended that extracted juice should be converted to jaggery within 8 - 12 hours to avoid inversion of sugar and than lime be added to juice. Juice is boiled by filling up to one third of the height of the pan. He described five stages in preparation of jaggery as boiling of juice as defection, evaporation, concentration, cooling and moulding.

Pandey and Narain (1993) reported that solid jaggery is obtained by striking at a temperature of 115 -117 °C which corresponds to 90°C Brix. The semi-liquid mass is then poured into containers of standard shape and size and the semi-liquid mass solidifies into solid jaggery after cooling.

Table 2.1 AGMARK Grades for Jaggery

Grade designation	Special characteristics		General characteristics
	Color	**Texture**	➢ No bleaching agents should be used. ➢ Should be in the form of solid lumps with firm consistency-not sticky or plastic. ➢ Should be free from baggase, dirt and other impurities (if present should be less than 1% by weight) ➢ Should be dried to such an extent as reasonably to maintain its color, consistency and weight ➢ Should not bear any signs of superficial sweet or mould ➢ Should be sweet to the taste and not possess a sour, salty or other objectionable flavor.
Special	Golden	Granular	
A-I	Dark golden	Either granular or smooth	
A-II	Light brown	Either granular or smooth	
B	Brown	Either granular or smooth	

Table 2.2 BIS Specifications for jaggery

The specifications of the composition of jaggery as per BIS (IS 12923:1990) are:-

Sl.No.	Constituent	% Jaggery weight	
		A-I	**A-II**
1.	Sucrose (min)	80%	70%
2.	Reducing Sugar (max)	10%	20%
3.	Moisture (max)	5%	7%
4.	Water insolubles (max)	1.5%	2%
5.	Sulphated Ash (max)	3.5%	5.0%
6.	Ash insoluble in dil.Hcl (max)	0.3%	0.3%
7.	Total ash (max)	1.1%	2.0%
8.	Free Sulphur Dioxide (max)	50 ppm	50 ppm

2.2.2 Future aspects and export potential

Shahi *et al.* (2002) studied the future aspects jaggery industry and reported that the value added products of sugarcane should be promoted as cottage industry. These products i.e. jaggery, powder jaggery, sugarcane juice concentrate, rab, vinegar, reori, gazak, chikki, patti etc.are not only nutritious but also have great potential in international market.

Singh and Shahi (2002) studied the prospects of jaggery and khandsari industry in India and proposed that by 2020 AD the requirement of sweetener would be 40 kg/head/year owing to growing population. Thus, our country would need at least 54 million tones of sweeteners, of which 40% is assumed to be met by jaggery and khandsari sector. Hence, this sector would continue play significant role not only in processing of sugarcane at rural level but will also create employment opportunities in countryside area. Moreover, this cottage industry has scope for additional small scale industries making different value added and diversified products which contributes to its high export potential

2.3 Factors affecting quality of jaggery

2.3.1 Factors affecting quality of sugarcane juice

Shinde *et al.* (1982) studied the change in chemical properties of sugarcane juice during boiling and found out that there was an increase in specific gravity and decrease in p^H particularly at later stages of boiling. A sharp rise in reducing sugars was noted during last stage of boiling. This rise in reducing sugars was attributed to the solution phase inversion due to rise in

acidity and high temperature during boiling and it could affect the storability of jaggery.

Solomon *et al*. (1990) studied the post harvest changes in sugarcane juice quality and reported that in harvested cane the losses due to sucrose inversion were accelerated after 72 h of storage. There was increase in reducing sugars and total soluble solids whereas, cane weight and purity declined. They concluded that storage of sugarcane results in increase in inversion of sucrose and loss of moisture; hence sugarcane should be crushed fresh or within 72 h of storage.

Jadhav *et al*. (2001) studied the effect of staling of sugarcane on juice and jaggery quality. Their studies revealed that maximum losses of 7.8% were recorded in the staling time of 48 h in the month of march. The juice quality studies showed decrease in nonreducing sugar but increase in reducing sugar with advancement in staling time from 0-48 h. the deterioration in jaggery quality was observed after 24 h of staling of cane.

2.3.2 Effect of clarificants on quality of jaggery

Clarification is done after preheating the strained juice inorder to remove the soluble impurities in the form of scum and mud. **Agarwal *et al*. (1985)** classified the clarificant into vegetative and chemical clarificant. The commonly used vegetative clarificants are Deola, Bhindi, Sukhai, Semal, Bel and Falsa barks and Groundnut and Castor seeds. Lime water, sodium bicarbonate, sodium carbonate, sodium bisulphate, sodium hydrosulphite and alum were the chemical clarificants used.

Agarwal and Ghosh (1983) studied the effect of clarificant on keeping quality of jaggery and indicated that jaggery prepared with lime had best storability followed by that prepared with deola extract.

Javalekar *et al*. (1985) studied the effect of different clarificants on physical properties of jaggery and found out that groundnut seed milk was as good as hydros in improving the color of jaggery. Excessive use of chemical clarificant hydros (sodium hydrosulphite) had an adverse effect on p^H, sugar content and color of jaggery. There was reduction in sugar content and fall in p^H. The quantity of hydros used to improve the color was reported to be from 200-500g, whereas only 35g of hydros per boiling pan should be used inorder to keep the SO_2 content below 70 ppm-its permissible limit.

Lal *et al*. (1986) studied the effect of clarificants on the quality of jaggery prepared from ladged cane and found that 150g Deola mixed with five litre water per 400 kg of juice was most suitable for improving the quality of jaggery made from ladged cane.

Londle and Yadav (1989) reported that quantities of lime required for clarification increased with the increased stale of time of cane. They reported increased acidity of juice in stale cane and observed that in fresh cane juice lime requirement was 25 ml/l while after 120 hours the lime requirement reached 36 ml/l of juice.

Mungare *et al*. (2000) discussed the use of various vegetative clarificants used for cane juice clarification for making good quality jaggery having less color. Clarification efficiencies of ten common vegetable-based

clarifying were evaluated during three seasons of sugarcane production. Following clarification, percentage of scum removed, reducing and non-reducing sugar contents of jaggery, color, P^H and moisture content of fresh and stored jaggery were determined and compared. Overall, mucilage from okra was the best out of the clarificants examined, although none of those used markedly improved shelf life of jaggery.

2.4 Storage studies of jaggery

Ingle and Kanwade (1982) studied the effects of storability on quality of jaggery. They examined the changes in quality of jaggery stored in two types of storage structures. For this purpose they compared jaggery cones wrapped with Hessian with unwrapped jaggery and shape, color, moisture content, bulkdensity, reducing and non-reducing sugar were noted. It was observed that the bulk density, moisture content and reducing sugar percentage increase with increased relative humidity. The shape was deformed and color was changed from brownish yellow to dark brown at higher relative humidity values.

An attempt was made by **Agarwal and Ghosh (1984)** to devise a cheap storage method for storage of jaggery during monsoon months and the jaggery stored in pits was evaluated for its keeping qualities. The results showed that jaggery kept fairly well in the godown designed by them and seems to be in better than storage pit made in open because jaggery was free from any fungal growth.

Banerji *et al.* (2001) studied moisture absorption in jaggery with different levels of reducing sugars under storage. They examined three types of

jaggery samples with reducing sugar levels 0-5%, 5-10% and greater than 10% respectively and calculated their moisture absorption at different time intervals. They concluded that jaggery with reducing sugar content higher than 10% should not be stored, while jaggery with reducing sugar less than 5% is most suitable for storage.

2.5 Packaging aspects of jaggery

Shinde *et al*. (1983) studied the effect of form and color of polythene (wrapping material) on keeping quality of jaggery. Their study indicated that the polythene film of any form and color prevented the absorption of moisture, inversion of non-reducing sugars and ultimately the liquidity of jaggery. If colorless polythene is used then it has to be covered with grass cover to reduce deterioration of color of jaggery during storage. The black polythene, jute cloth lined with colorless and black polythene could be used directly without grass cover to avoid marked deterioration of color of jaggery as well as the absorption of moisture and liquidity during storage.

According to **Annual report of IISR, Lucknow (1992-93)** types of packaging materials that can be used for packaging of jaggery were found out to be double coverings of butter paper, single wrapping with glazed paper, single cellophane wrapping and polythene sheets.

According to **Annual report of IISR, Lucknow (1997-98)** effect of packaging for storage of jaggery has been studied. The data showed that all the jaggery samples stored in cold storage remained satisfactory during monsoon

than that stored in ordinary store and aluminium foil was found to be superior of all other packing materials.

2.6 HACCP evaluation as efficient quality control system

Bauman (1974) studied the importance of HACCP concept and hazard categories. According to him in an effort to keep units cost low, food manufacturers and processors have tended toward more automatic and high-speed processing equipment. In order to increase product palatability and acceptance, there has been a trend toward minimum processing times and temperatures. Formulations designed to reduced preparation time by the homemaker to the absolute minimum are commonplace in the market and many of these are complex in composition. These complications have brought various risks regarding food safety. Control can be obtained and maintained through the diligent, intelligent application of HACCP principles and identification of control points that are critical to food safety.

Studies of **Notermans *et al*. (1995)** emphasized the importance of HACCP in quantitative risk assessment. According to them several approaches have been proposed for reducing the risk of foodborne disease. These included surveillance of foods and foodborne diseases. Surveillance of foods to control their quality, based on inspection and testing of the end product, also has drawbacks. It may fail to detect some contaminated batches and since it is only possible to test a small number of units from a batch, unsafe units may be missed, leading to the false assumption that the whole batch is safe. To improve the situation, training in good manufacturing practices (GMP) has

been introduced. Since GMP is only a qualitative approach and is largely subjective, it has been extended by introducing HACCP system. With HACCP, control procedures are directed at specific operations that are crucial in ensuring the safety of foods and the effects on product contamination can be quantified.

Sohrab (1997) in his investigations of quality management system described HACCP system as a well established concept in food safety, identifies specific hazards and provides preventive measures for their control to ensure the safety of food. HACCP is a tool to assess hazards and establish control systems that focus on preventive measures rather than relying mainly on end product testing. It is now widely embraced by the food industries and by the government regularity agencies around the world as a most cost effective means of minimizing the occurrence of identifiable foodborne biological, chemical and physical hazards and maximizing product safety.

Adams (1998) emphasized HACCP as a process control tool of choice. In his studies he described HACCP as a tool that describes a logical sequence for thinking through a known process, considering where the likely sources of nonconformances could arise and then taking appropriate action in advance in order to prevent these "bad things" from happening. With a food safety focus, the nonconformances take the form of microbiological, chemical and physical contamination.

Bhat and Vasanthi (2000) studied the quality evaluation of agricultural produce and reported that the significance of microbial foodborne diseases in

the health and economic sectors together with an increase in global food trade is necessitating the use of newer approaches that are cost effective and efficient in the management of a safe food supply like HACCP system. Major food safety issues in many countries relate to contamination due to the presence of microorganisms, filth, mycotoxins, pesticide residues, food additives and environmental conditions. They suggested that out of various safety management approaches, HACCP is the most widely used tool. The HACCP system is a cost-effective management tool for food safety assurance that can be applied to all sections of the food chain from primary production to processing, manufacturing, distribution and retail to the point of consumption. Food safety systems based on HACCP principles have been successfully applied in food processing plants, retail food stores and food service operations.

Giese (2000) has emphasized on optimizing processes for quality and safety. His study revealed that since 1997, there has been a 19% overall decline in incidence of bacterial food borne infections and these reflect simple annual fluctuations which is concurrent with several interventions, including implementation of mandated good agricultural practices on farms and increased consumer awareness. Ensuring food safety requires that everyone from farm to table assume responsibility for producing and preparing safe food. Good Manufacturing Practices or GMPs are basis for producing safe and wholesome food product but they are expensive. Hence, new HACCP-based models can serve the purpose.

Investigations of **Busta (2002)** revealed that the food safety objectives coupled with HACCP approach offers alternative transparent determination in risk management. FSO defines the expected level of control that must be achieved to meet the appropriate level of consumer protection. He concluded that by using FSOs intertwined with HACCP program, goals for improving food safety can be translated into quantitative terms that both regulatory agencies and industry can use to control potential hazards.

2.7 HACCP evaluation in some food processing industries

Bryan (1981) conducted hazard analysis of food service operations. He evaluated specific hazards and identified the critical control points as handling after coking, hot-holding of cooked foods, improper cooling, reheating, serving and packaging, time-temperature control, cleaning of kitchenware and equipment surfaces and hygiene of workers.

Synder (1981) worked on quality assurance of food service system. His observations on sanitation quality revealed that inadequate hot holding, infected persons or poor hygiene, inadequate cleaning were the causes of poor quality food. Critical control points identified were time and temperature, hand washing, surface cleaning and purchasing control in each of these causes. Quality control indicators were cooling of food, temperature of refrigerators during high voltage operations, quantity and temperature of leftovers.

Adams (1990) incorporated the HACCP approach in the meat and poultry inspection process. While applying HACCP, inspection is divided into slaughter and processing operations because the animal-disease implications

are associated with slaughter and the greater degree of mechanization is associated with processing. Processes like inspection of carcass and internal organs after slaughter operation, carcass cut-up steps, handling of raw meat and poultry and packaging step are considered to be critical steps. He suggested that handling procedures must be sanitary, contact surfaces must be clean and the environment should not introduce foreign materials or microorganisms.

Bryan (1990) applied the HACCP approach to ready-to-eat chilled foods. He developed a HACCP model for chilled potato salad. His study revealed hazards associated during various processes like procurement of raw materials, handling during peeling and removing shells from eggs and cooling. Various critical points to be controlled were cooking eggs, formulating, mixing, cooling and cold storage.

Bryan (1990) worked on hazard analysis of retail food and restaurant operations. He studied various steps responsible for causing hazards. According to his investigation, hazards varied depending on the food source, methods to prepare foods, conditions during storage and display and the interval between heating and consumption. He classified different foods prepared in these operations into categories of food service systems and certain critical control points applied to each system. He sited certain examples like cooking as critical control point for Cook/Hold hot systems, chilling as critical control point for Cook/Chill and Cook/Freeze systems etc.

Garrett *et al.* (1990) analyzed the use of HACCP for seafood surveillance and certification. They developed a generic model for cooked

shrimp and identified critical control points as sanitation equipments and processing facilities.

Stauffer (1991) studied the quality assurance in cereal plants. He applied HACCP principles to the plant and found out various hazards and critical control points associated with it. According to him various hazards associated were extraneous matters, filth, molds and mycotoxins. The critical control points identified were grain quality, tramp metal, moisture and packaged weight. He concluded that improper stacking, sloppy warehousing, cuts and punctures from forklift trucks and rough treatment during transportation, poor rotation of stock, storage with odor emitting chemicals and infestation by pests should be avoided inorder to control the quality.

Sudershan *et al.* (1997) applied HACCP system in manufacturing process of khoa in two districts of Andhra Pradesh. Their studies indicated that khoa is often contaminated with pathogenic bacteria like *staphylococcus aureus* & *bacillus cereus* to unacceptable levels at various levels of production. Critical control points identified were handling by many food handlers, longer duration of storage and use of soil for cleaning utensils. They concluded that providing cold storage facilities at village levels, proper air tight packaging and educating the dairy farmers regarding possible contamination can reduce microbial hazards from khoa based sweets.

Bhat *et al.* (1998) studied the use of HACCP system in coffee industry. Their studies revealed that coffee production involves series of processes which if not controlled may lead to mould growth and mycotoxin production.

According to them HACCP system helps to identify and control such critical processes that are susceptible to mould growth and deterioration of coffee quality. They identified critical control points for cherry coffee processing as drying stage at which fruits are heaped up and internal temperature can increase which can become conducive to mould growth and for parchment coffee preparation identified critical control points were pulping, demucilaging, washing and drying stages. They observed that ochratoxin contamination and mould counts were high in cherry processed coffee than in parchment coffee.

Bolton *et al*. (1999) worked on reduction of pork carcass contamination by applying HACCP principles to it. He identified the critical control point in a generic HACCP model for pork slaughter as trimming operation. He suggested that trimming with sanitized knife and removal of faecal material significantly reduce contamination and dramatically lower total bacterial count.

Jaiswal (1999) studied the quality control aspects in chocolate industry. According to his studies fermentation of cocoa beans which is required for flavor development in chocolates is often associated with microbial contamination. He conducted different hazard analysis and enlisted different physical hazards as pieces of metal, stone, glass and chemical hazards as mycotoxin and aflatoxin. He identified critical control points as roasting, raw material screening and storage stages. He suggested that moisture content during the storage should be maintained at 6-8.5% to prevent mould growth with 8% being critical level.

Jaiswal (2000) conducted hazard analysis in frozen foods. According to him faster freezing processes such as newer liquid nitrogen and carbon dioxide freezing certainly improve food quality and offer less microbial destruction than the conventional slower freezing methods. The response of micro-organisms to freezing depends on many factors such as the kind of microorganism and its state, the freezing rate, freezing temperature and time and kind of food. The critical control points for frozen food processing identified (as a whole) includes maintenance of equipments, utensils and other physical facilities, cleaning and sanitation, personal hygiene practices, pest control infestations, microbiological population control and time and temperature control. The critical control points vary with raw materials and may include some or all of the above mentioned points. He concluded that everyone in food system from food manufacturers to consumers must recognize the need for controlling microbiological hazards.

Park and Lee (2003) developed HACCP plan to be applied to soybean curd and verified its effectiveness. They investigated four soybean curd workshops for thee months and conducted hazard analysis. They identified critical control points as selection procedure and refrigeration procedure in non-wrapped soybean curd.

Sarkar *et al*. (2005) applied HACCP approach for safe ice-cream production. Their studies revealed that poor quality of ice-creams is due to inferior quality ingredients, improper quality control, improper packaging material, poor cleaning & sanitation and unhygienic handling. They identified

different critical control points as pasteurization of ice-cream mix, time-temperature combination for the ripening of pasteurized mix, use of unpasteurized ingredients, contact of pasteurized products with work surfaces that may be a source of microbial contamination and the final temperature at which product is stored. He suggested introduction of effective public health regulations to enforce the adoption of hygienic methods in the production and sales of needs to be considered.

Soriano *et al*. (2005) applied HACCP system to salads served in the restaurant of Valencia University of Spain. They analyzed the potential hazards and critical points by taking salad samples from 19 restaurants with a central kitchen. The critical control points were receiving of raw materials, storage at room temperature and refrigeration, mixing, refrigerated display and washing with disinfectants.

2.8 Microbial Hazards associated with some food industries

Ito (1974) assessed microbiological critical control points in canned foods. According to him critical control points must indicate those points where lack of control may cause a potential public health hazard. His studies revealed that critical control points of canning operations vary with the product packed and retort system used to fill and seal containers. He suggested that microbiological critical control points are the areas which allow the survival of *clostridium botulinum* in these kinds of foods and containers.

Peterson and Gunnerson (1974) identified microbiological critical control points in frozen foods. According to them rates of freezing and thawing

have critical influence on microbial survival in frozen foods and time required for freezing is a critical factor to be controlled. They suggested that main critical control points for frozen food processing may vary with the products and include equipment sanitation, employee personal hygiene, facility sanitation and management, raw material control and storage, time of freezing and water quality.

Studies of **Notermans *et al*. (1994)** revealed the identification of potentially hazardous microorganisms by applying HACCP principles. According to him the first step is to establish the hazardous organisms associated with a particular food product. An approach is presented here that permits identification of potentially hazardous bacteria. It is based on a list of all those bacteria that are known to cause foodborne diseases in man. Following an evaluation of raw materials, the production process, possibilities for contamination, deletions from or additions to the list were made. For the organisms that are retained, it is necessary to determine whether or not they have caused foodborne disease involving identical or related food products. Where this is not the case, the organism can be deleted. In case of doubt, an organism should not be deleted from the list of potentially hazardous agents.

Biss and Hathway (1995) examined microbiological and visible contamination of lamb carcasses. According to their report the effective design and implementation of HACCP systems for fresh meat is dependent on identification of those process steps that determine most of the contamination on the carcass and institution of appropriate critical limits. Eight groups of 25

lamb carcasses of different preslaughter presentation statuses were subjected to excision sampling at multiple sites for microbiological contamination and detailed examination for visible contamination. Levels of visible contamination in different categories had a variable pattern and carcasses derived from unwashed lambs had markedly higher rates of faecal contamination. They concluded that visible contamination should be used as a critical parameter to monitor microbiological hygiene on carcasses and it would be more appropriate to effect HACCP-based process control by monitoring the preslaughter presentation status of the animals, along with correct operating procedures at pelting and appropriate communication loops rather than using on-line monitoring of the product itself for visible contamination.

Garrett *et al.* (1997) developed a holistic approach to seafood safety and natural marine resource issues by applying HACCP principles with new risk analysis studies. They grouped the hazards associated with seafoods as environmentally induced, process induced, distribution induced and consumer induced hazards. Moreover, loss of habitat and ecosystem degradation threatens the future viability of fisheries. They concluded that protecting, conserving and restoring the health and safety of fisheries resources is a must.

Larson *et al.* (1997) evaluated the microbiological hazards from vegetables in modified atmospheric packaging. They examined vegetables like cabbage, broccoli, carrots and green beans. The ability of clostridium botulinum types A, B and E spores to grow and produce botulinal toxin was investigated in these vegetable samples. Botulinal toxin was detected only in

lettuce and broccoli. They identified the factors effecting toxigenesis as P^H and oxygen level.

Tauxe *et al*. (1997) studied the microbial hazards and emerging safety issues associated with food products. Their investigations revealed that recent outbreaks of foodborne disease associated with fresh produce have raised concern that these foods may be an increasing source of foodborne infections. They concluded that to prevent foodborne diseases associated with fresh produce, it is necessary to prevent initial contamination, to decontaminate or pasteurize potentially contaminated foods and to prevent additional contamination and amplification of pathogens throughout the processing chain. Proper sanitation is crucial at all levels in the fresh produce chain. This includes using only adequately treated manure as fertilizer, providing proper sanitary systems and hand washing facilities for the workers, using clean equipment and transportation vehicles, good hygiene in the processing facilities and in the kitchen and taking measures to prevent cross contamination.

Leoni *et al*. (2003) analyzed critical control points in the production and distribution line of fresh vegetable products. They suggested a method to evaluate the microbiological quality of fresh vegetables to be consumed raw, using as critical control point the microbiological analysis of the water used to wash them. The survey carried out examining 35 water samples collected from the washing tanks of a factory where various vegetable products are processed and packaged. Fecal coliforms were present in 42.9 % of the washing water, E.coli in 40%, enterococci in 77.1% and anti- E.coli phages in 11.4%. The

finding of fecal indicators shows that some producers use irrigation water contaminated by wastes mainly of human origin. They concluded that microbiological monitoring of the washing waters is a must to control the safety of fresh vegetables.

Sipola and Liepins (2004) conducted microbiological evaluation of manufacturing process of casein. They examined eighteen samples of pasteurized milk and eighteen samples of good casein for Coliform bacteria and genus of salmonella isolation. In five cases the number of microorganisms was increased above the permissible standard in both the pasteurized milk and casein. Coliform bacteria were isolated in three skim milk samples. They suggested that Coliform bacteria should be included as the critical control point.

2.9 HACCP evaluation in some places other than food industries

Rajalaksmi (1983) assessed the microbiological quality of ice-creams sold in Hyderabad city. She examined three hundred and one samples collected from hotels, restaurants, ice cream parlors and local vendors. The samples were assessed for standard plate count, coliforms and for pathogens. Her study revealed that only 58 (19.4%) were within ISI specifications for SPC and Coliform counts. *Staphylococcus aureus* was isolated from 20.3% samples and Escherichia colli from 7% samples. She concluded that slab ice cream sold in hotels was superior to other varieties sold by local vendors. Poor quality of the cups, cones wrappers, repeated handling and unhygienic surroundings are significant factors contributing microbiological infections.

Sarada and Begum (1991) analyzed the microbiological quality of ice creams sold in Bangalore city. They examined one hundred and twenty samples of ice creams in cups, cones, bars and lollies from hotels, parlors and local vendors for standard plate count and coliforms. According to their report microbiologically no significant differences were found between samples from hotels, parlors and local vendors. The counts were comparatively less in lollies than in ice creams. Out of total samples collected for the study, only 47 samples for standard plate count and 74 for coliforms were meeting the standards prescribed by Bureau of Indian Standards. The poor quality of the cups, cones and wrappers used in packing, repeated handling and unhygienic surroundings are the factors responsible for heavy load of microorganisms.

Ali and Spencer (1995) conducted hazard analysis and evaluated critical control points in school food programs in Bahrain (U.K.). They conducted hazard analyses in 16 school canteens in the state of Bahrain, to determine the possible sources and modes of contamination. They observed that foods were prepared in advance long (6h or more) before they were consumed. Holding of foods at room temperature for long time have allowed germination of bacterial spores and multiplication of microbes, hence showing a massive increase in bacterial counts, reaching a critical level. They identified critical control points as preparation of food long before consumption, holding the food at room temperature and physical touching of food products.

Bryan *et al*. (1996) evaluated hazards associated with holding and reheating of foods at vending sites in a small town in Zambia. They conducted

hazard analyses at 11 cooked-food-vending sites and related food vending operations in a small-town market of Zambia. The analyses consisted of observations and time-temperature measurements during preparation of food, holding foods on display, after their reheating at the vending sites and collecting samples of the leftovers foods after reheating and holding at intervals throughout the day and testing them microbiologically in the laboratories. According to them the critical control points varied with food, preparation steps and during holding and display, but in most cases they were cooking, holding after cooking and reheating.

3 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 controled 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.

The details of HACCP principles and materials and equipments used in the experimental procedures are presented below:

3.1 Materials

The material of main concern was the jaggery. Samples of fresh jaggery were taken during survey of every unit. Jaggery samples of stored unit were collected from different sections which are separated according to storage period of jaggery. For preparation of jaggery raw material was sugarcane.

3.2 Plan of work

The details of HACCP plan is described below:

3.2.1 Principles of HACCP

For the development of HACCP plans to work on, following steps and principles were followed.

Pre-requisite program: Pre-requisite programs are practices & procedures prior to or during implementation of HACCP system which includes:

- Assemble the HACCP team.
- Describe the product.
- Identify the intended use.
- Develop a flow diagram that describes the process.
- On site confirmation of the flow diagram.

HACCP Principles: After these pre-requisite programs have been completed the seven HACCP principles to be followed are

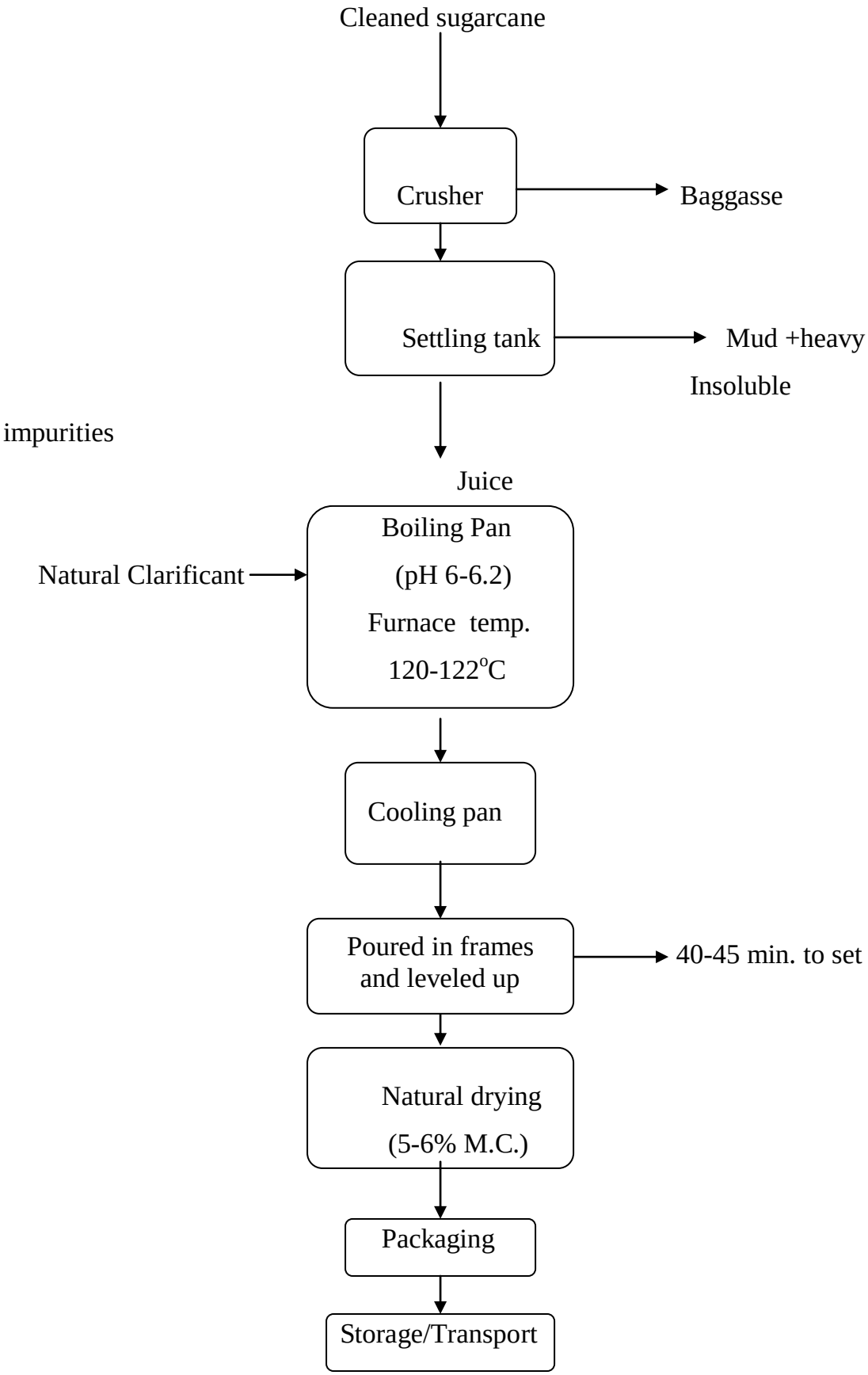
1. Conduct a hazard analysis to identify potential hazard(s) associated with food production at all stages from raw material procurement, processing, manufacture upto storage and distribution and to identify different preventive measures for their control.
2. Determine the critical control points (CCP) i.e. the points/procedures/ operational steps that can controlled to eliminate the hazard(s) or minimize its likelihood of occurrence. A step means any stage in food production including raw materials, their receipt, transport, processing storage, etc.

3. Establish critical limit(s) which must be met to ensure the CCP is under control.
4. Establish a system to monitor control of the CCP by scheduled testing or observations.
5. Establish the corrective action to be taken, when monitoring indicates that a particular CCP is under control.
6. Establish procedures for verification, including supplementary tests and procedures to conform that the HACCP system is working efficiently.
7. Establish documentation concerning all procedures and records appropriate to these and their applications.

3.2.2 Product Description

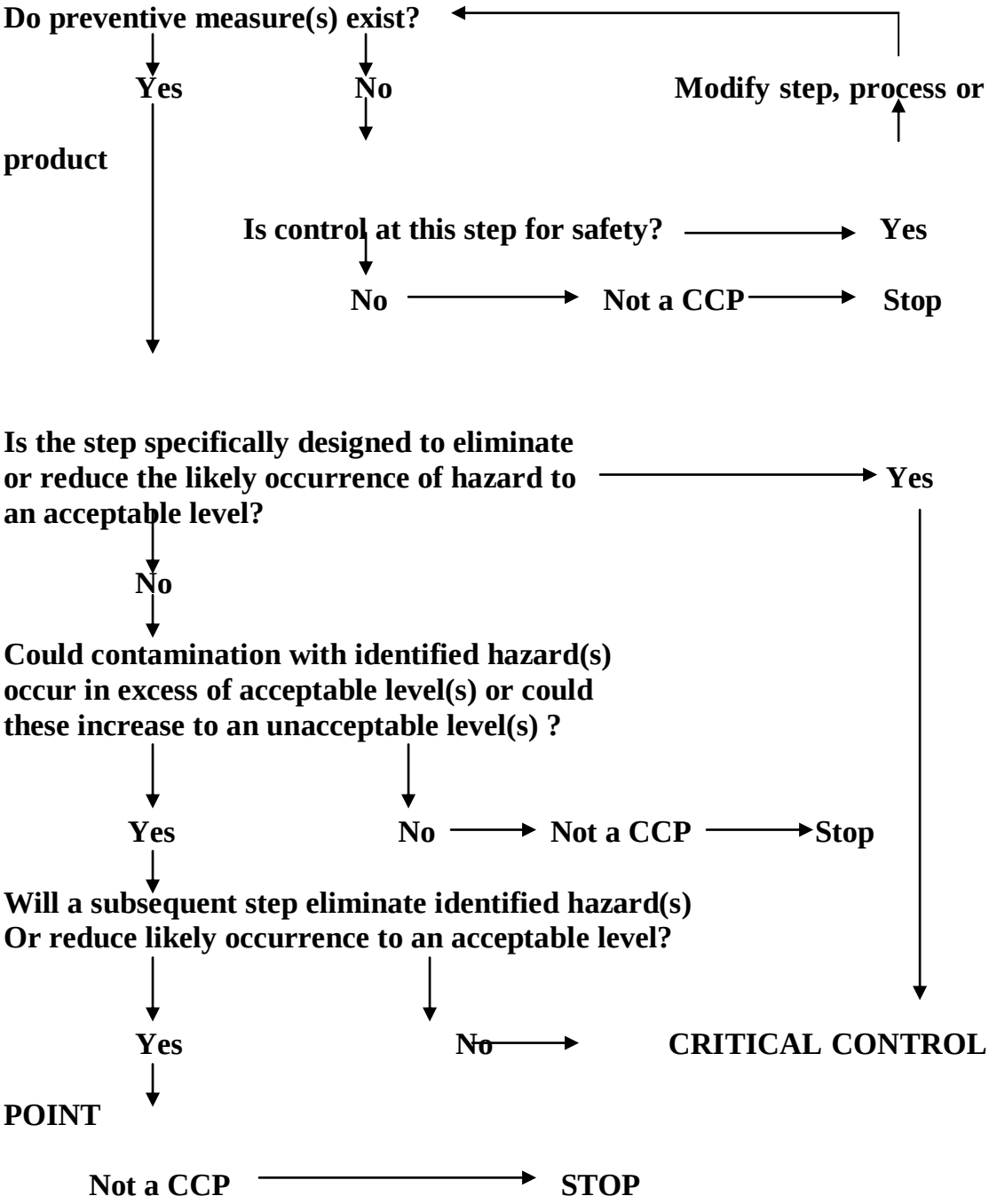
1. Product description – Jaggery
2. How the product is to be used – Direct consumption & or in some modified form
3. Packaging – Sold openly
4. Where the product will be sold – in Uttaranchal
5. Labelling instructions – nil
6. Special distribution control – freshly sold
7. who will be consuming the product – persons of all age

3.2.3 Process Flow Diagram for manufacturing Jaggery



3.2.4 Decision tree approach for deciding critical control points

HACCP Design Tree to Each Step With Identified Hazards



3.3 Measurement Techniques

3.3.1 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.

3.3.2 True Density

True density was determined using toluene displacement method. Two litre measuring cylinder was filled with one liter of toluene. A lump of jaggery was weighed and immersed in toluene and the change in volume was noted **(Anon., 1986)**.

Calculation

$$\rho_g = \frac{\rho_{gt} \times \chi_1}{\text{Weight of the volume displaced by the sample, g}}$$

ρ_g = True density, g/cc

ρ_{gt} = Density of the toluene, g/cc

χ_1 = Weight of the sample, g

3.3.3 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).**

3.3.4 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 was added to expel the air. The content was titrated rapidly with 0.02 N standard iodine solution using starch as indicator **(Ranganna, 1986)**.

Calculation

1 ml of 0.02 N iodine solution = 0.64 mg of sulphur dioxide

$$\text{Sulphur dioxide in ppm} = \frac{Titre \times 0.64 \times 1000}{Weight\ of\ sample}$$

3.3.5 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.

Assessment of surface cleanliness

Squares of 900cm^2 area were drawn on the surface of juice storage tank, open pan (used to cool jaggery) and jaggery wrapping cloth separately. Then the swabs were rubbed over these areas and then transferred again to the tube with distilled water. The tube was shaken and the water inside it was taken as sample for enumeration of microbial count using plate count agar.

3.3.6 Coliform Count

Preparation of sample

13 g of jaggery was weighed and dissolved in 100 ml of sterilized distilled water. This solution was used as sample for enumeration of microorganisms.

Preparation of media

35.965 g of Eosin Methylene Blue agar was weighed and added to a container having 1000ml distilled water. The solution was boiled with continuous stirring. The boiled agar solution was filled in the conical flasks, plugged with cotton, covered with an aluminium foil and then tied with a thread. Then the flasks were sterilized in the autoclave at 15psi for 15 minutes.

Enumeration of coliforms

1ml of sample solution was pipetted into three sterile petridishes. The agar media was cooled to 44-46°C and added to petridishes aseptically. The plates were incubated at 32°C for 4 days and colonies were counted.

3.3.7 Yeast and Mould Count

Preparation of sample

The process is same as above mentioned in 3.3.6.

Preparation of media

The process is same as above mentioned in 3.3.6 except the type and weight of agar taken. For enumeration of yeast and moulds 39 g of Potato Dextrose agar was taken. pH of agar solution was adjusted at the time of usage to 3.5±0.1 using 10% tartaric acid.

Enumeration of yeasts and moulds

Plates were prepared and incubated according to above mentioned process and colonies were counted.

3.3.8 Total Plate Count

Preparation of sample

The process is same as above mentioned in 3.3.6.

Preparation of media

For enumeration of total plate count, 23.5 g of Standard Methods agar (Plate Count agar) was taken. pH of agar solution was adjusted after boiling to 7.0±0.2. Rest of the process is same as above mentioned in 3.3.6.

Enumeration of total colonies of microorganisms

The process mentioned in 3.3.6 was repeated for preparing plates and counting of colonies.

3.4 Proximate composition

3.4.1 Moisture Content (IS12711:1989)

About 5g of the sample was weighed in previously dried and weighed petridish with tight fitting cover. Dish was placed in the vacuum oven maintained at 70±1°C for 10hrs, then cooled and weighed till the difference between two consecutive weighing is less than 1 mg.

Calculation

Moisture, percent by $Mass = \frac{100 \times (M_1 - M_2)}{(M_1 - M)}$

Where,

M_1= mass, in g, of the dish with the material before drying;

M_2= mass, in g, of the dish with the material after drying to constant mass and

M = mass, in g, of the empty dish.

3.4.2 Total Ash Content (IS12711:1989)

5g of the prepared sample was ignited in a tared, clean and dry silica dish. On complete ignition it was kept in a muffle furnace at 500 ±10°C until gray ash resulted. The silica dish was ignited, cooled and weighed at one-hour intervals until the difference between two consecutive readings was less than 1 mg.

Calculation

Total ash (on dry basis), percent by $Mass = \frac{(M_2 - M_1) \times 10000}{(M_1 - M) \times (100 - W)}$

Where,

M_2=mass, in g, of the dish with the ash;

M= mass, in g, of the empty dish;

M_1= mass, in g, of the dish with the material taken for the test and

W= percent moisture in the sample

3.4.3 Acid Insoluble Ash Content

To the ash contained in the silica dish (from the previous test), 25 ml of dilute hydrochloric acid (5N) was added and the dish was heated on a water bath for 10 minutes. The contents of the dish were filtered through the whatman filter paper no.42 and washed till washings become free of acid. Subsequently dish is ignited over a burner for complete charring and then transferred to the muffle furnace at 550 ±10 °C until gray ash resulted. The

silica dish was ignited, cooled and weighed at one-hour intervals until the difference between two consecutive readings was less than 1 mg.

Calculation:

Acid insoluble ash (on dry basis), percent by $Mass = \frac{(M_2 - M) \times 10000}{(M_1 - M) \times (100 - W)}$

Where,

M_2= mass, in g, of the dish with the ash;

M = mass, in g, of the empty dish;

M_1= mass, in g, of the dish with the material taken for the test and

W= percent moisture in the sample.

3.4.4 Water Insoluble Ash Content

To the ash contained in the silica dish (from the previous test), 25 ml of distilled water was added and the dish was heated on a water bath. Then the contents of the dish were filtered through the whatman filter paper no.42 and washed with 50 ml of hot water thoroughly. Subsequently dish is ignited over a burner for complete charring and then transferred to the muffle furnace at 550 ±10 °C until gray ash resulted. The silica dish was ignited, cooled and weighed at one-hour intervals until the difference between two consecutive readings was less than 1 mg.

Calculation

Water insoluble ash (on dry basis), percent by $Mass = \frac{(M_2 - M) \times 10000}{(M_1 - M) \times (100 - W)}$

Where,

M_2= mass, in g, of the dish with the ash;

M = mass, in g, of the empty dish;

M_1= mass, in g, of the dish with the material taken for the test and

W= percent moisture in the sample.

3.4.5 Sulphated Ash Content

5g of the prepared sample was ignited in a tared, clean and dry silica dish. To this 5 ml of 10% sulphuric acid was added and evaporated. On complete ignition it was kept in a muffle furnace at 500 ±10°C until gray ash resulted. The silica dish was ignited, cooled and then again 3 ml of 10% sulphuric acid was added. Then it was again evaporated on hot water bath until the sulphuric acid is volatilized. Again the dish was transferred to muffle furnace and heated at 500 ±10°C until gray ash resulted.The silica dish was cooled and weighed.

Calculation

Sulphated ash (on dry basis), percent by $Mass = \frac{(M_2 - M) \times 10000}{(M_1 - M) \times (100 - W)}$

Where,

M_2= mass, in g, of the dish with the ash;

M = mass, in g, of the empty dish;

M_1= mass, in g, of the dish with the material taken for the test and

W= percent moisture in the sample.

3.4.6 Reducing Sugars, Total sugar and Sucrose Content

Lane and Eynon (**AOAC, 1983**) method was followed by estimation of reducing sugar, total sugar and sucrose content of jaggery (**Majumdar and Bose, 1985**).

Preparation of the extract

50 g of the sample was added to 400 ml water and neutralized with NaOH (1N)using phenolphthalein indicator. It was boiled gently for 1 hr and the volume was made to 500 ml after cooling. It was filtered through whatman filter paper no.4. 100ml of the extract was taken in 500ml volumetric flask and 2 ml of neutral lead acetate was added followed by addition of 200 ml of water. The solution was kept undisturbed for 10 min and excess lead was precipitated with potassium oxalate solution. Distilled water was added to make up the volume.

Titration

10 ml of Fehling solution (A+B) was taken in 250 ml conical flask. It was gently heated to boil on a hot plate followed by addition of sugar extract from the burette till the color of the extract turned brick red. Few drops of methylene blue were added as indicator.

For estimation of total sugars, 50 ml of extract were taken in a 250 ml flask. 10 ml of hydrochloric acid (1+1) were added to it and kept for 24 hr at room temperature. The solution was then neutralized and volume made to 25 ml by addition of distilled water. The solution was then titrated against Fehling solution as in reducing sugars. Factor for Fehling solution was determined by titrating it against a standard solution of invert sugar.

Calculation

$$\% \text{ Reducing sugars} = \frac{mg of Invert sugar \times Dliution \times 100}{Titre \times Weight or Volume of the Sample \times 100}$$

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

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

3.5 Equipments Used

A brief description of the equipments used in the experiments is described in this section.

3.5.1 Weighing Balance

Precisa make electronic digital balance with maximum capacity of 200g (e = 0.01 g) was used for weighing.

3.5.2 Incubator

New Brunswick make incubator with temperature range of 0-100°C and speed 0-500 rpm was used for incubation of plates.

3.5.3 Colorimeter

Systronics make photoelectric colorimeter with wavelength range of 380-630 nm was used to estimate the color of jaggery solution.

3.5.4 pH Meter

Systronics make digital pH meter was used to estimate the pH of jaggery solutions.

3.5.5 Vacuum Oven

Macro Scientific works make vacuum oven with a temperature range of 0-250C and pressure range of 0-760 mm was used to determine moisture content of jaggery samples.

3.5.6 Muffle Furnace

Narang Scientific works make muffle furnace with digital temperature control was used for ashing of jaggery samples.

3.5.7 Laminar Flow Bench

Mac Scientific works make laminar flow bench of size 1200 X600 X 600 mm was used to provide aseptic environment during pour plating.

4 Results and Discussions

Hazard analysis was carried out during the manufacturing process and in the storage unit of jaggery in order 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). Samples were drawn during the process, starting from crushing of juice upto the storage of jaggery. Samples of baggase, fresh juice, clarified juice and fresh jaggery were drawn. These samples were further analyzed in the laboratory to check whether they meet the levels as specified by BIS or not. The samples collected in the survey during first week of January is designated as phase-1, that collected in the survey during first week of February is designated as phase-2 and the samples collected during first week of march is designated as phase-3. After the survey of jaggery manufacturing units, one storage unit was surveyed to find out the hazards associated with it if any. Samples were collected from each section of godown and were analyzed in the laboratory. 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:

4.1 Description of Jaggery units as reflected from survey reports

4.1.1 Survey Schedule

Six jaggery manufacturing units were surveyed three times during first week of January, first week of February and during first week of March in the nearby areas i.e. in Rudrapur and Kanakpur. Five units from different areas of Rudrapur city (one unit of mallik colony, one unit of singh colony and three units of bhurarani) and one unit of Kanakpur were surveyed. Besides this one unit that manufacture jaggery from molasses located at Beripadav was also surveyed in the last week of December. One storage unit for jaggery at Haldwani was surveyed in the last week of March.

4.1.2 Process Description with onsite observations

1. Raw material procurement

Suganecanes of different varieties i.e. Co 1148, Cos 687, CoJ 64, Co 1158, Cos 8118, Cos 8016, Cos 7918 etc.were procured from nearby farmers. The leaves of sugarcanes were removed manually and these sugarcanes were either stored or crushed immediately. It was observed that sugarcanes were stored in the harvesting season. It is a common practice to store sugarcanes for later use when plenty of them are not available. The duration of storage varied from 4-8 days in all the units.

2. Extraction of sugarcane juice

Two-roller crusher made up of high grade iron was used for juice extraction. The extracted juice was either used fresh or stored in an open juice storage tank for further use. The juice was filtered through double

Plate 1. Storage of sugarcane juice in open storing tank

Plate 2. Cooling of jaggery in an open pan

wire mesh so that baggase get separated. Then the filtered juice was transferred to the first boiling pan through an iron pipe for clarification. It was observed that the juice settling tank the boiling pans were washed with locally available raw acid or detergents at night. Hence, there are chances of contamination through detergents residues, metal parts of pipe and baggase. After crushing baggase was dried and used as fuel for furnace.

3. Clarification of filtered juice

The filtered juice was clarified in two boiling pans. For clarification of juice usually extracts of deola (natural clarificant) was used. In some units lime was also added to enhance clarification. Castor oil was used to reduce scum formation. This clarified juice was then transferred to the third boiling pan.

4. Concentration of clarified juice

Clarified juice was concentrated in the third boiling pan. In this pan hydros (chemical clarificant) was added to lighten the color of the finished jaggery. In almost all the units it was observed that the amount of hydros used was much more (more than 50 g per pan) than that of recommended limit (35 g per pan). This may be health hazardous.

5. Cooling of jaggery

Concentrated jaggery was cooled in an open pan. After this semisolid jaggery was wrapped in wet cloth to mould it into shape of bheli or made ladoos with hand. There are therefore, chances of contamination

Plate 3. Jaggery wrapped in wet cloths (moulds) in unhygienic conditions

Plate 4. Jaggery stored open in unhygienic conditions

of jaggery through hand, wrapping cloth and from dust, dirt, baggase and flies.

6. Storage and transportation

The cooled jaggery was either stored in open stacks or transported to local market and storage units (godowns). Open stacking of jaggery may deteriorate the quality of jaggery through contamination with rodents, flies, bees etc.

***** During the survey of Beripadav unit it was observed that the jaggery was manufactured from molasses and sold for human consumption. But this practice should be avoided because this type of jaggery is not fit for human consumption and should be used as cattle feed. The results of analysis of proximate composition of jaggery manufactured in Beripadav unit is presented in A-4.

4.2 Hazards identified during the manufacture of jaggery

The hazards assessed are presented in the Table-4.1.

4.2.1 Physical Hazards

As observed during the survey of different units the physical hazards associated with during the manufacture of jaggery were pieces of metal, polythene pieces, nails, hairs, baggase, dust and dirt. These hazards when present in the juice or get entered into the process at any time will not get damaged and remain as it is in the end product i.e. jaggery. Hence, these may cause health hazards. During the analysis of jaggery of Mallik colony unit the

presence of hairs was observed. To check the entry of these hazardous substances inspection is a must which is mostly avoided.

4.2.2 Chemical Hazards

According to the observations made during survey chemical hazards enlisted in the process of manufacture of jaggery were leakage of lubricants from crushers, excessive use of chemical clarificant and residues of acids and detergents used for cleaning the pans. Lubricants may leak and mix up with the juice; hence, the crushers should be properly lubricated to avoid any leakage. Excessive use of chemical clarificant affects the physical and chemical characteristics of jaggery and causes liquification during storage. Hence, the use of chemical clarificant should be minimized. Moreover, pans should be properly washed after the use of acids or detergents for cleaning.

4.2.3 Biological Hazards

Flies, rodents and ants are the sources of biological hazards. As jaggery is kept in open during cooling and during storage these hazards are predominant. Moreover, contamination of pathogens through hands during preparation of jaggery bhelies and laddoos are obvious. Jaggery can also be contaminated with pathogens through spit of workers and through environmental contaminants. These hazards can be avoided if proper hygiene is maintained by the workers. Jaggery should be cooled under hygienic conditions.

Table.4.1. 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.

4.3 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:

4.3.1 Physical Properties

4.3.1.1 Moisture Content

Moisture contents of the jaggery samples taken from six units varied from 9.72-12.6 % (d.b) for phase-1, from 10.97-12.01% (d.b) for phase-2 and from 10.66-13.13% (d.b) for phase-3. It was observed that none of these were within specified limits (5% d.b.) in all the three phases of the experiment. This is confirmed from the Fig.4.1, 4.9, 4.17. The reason assigned to this is time of sampling. The jaggery samples taken were fresh samples which were further dried but the specifications shows the moisture content after proper drying which caused deviation from the specifications.

4.3.1.2 Color

The color of jaggery was obtained in terms of optical density. In the first phase of experiment optical density of jaggery varied from 0.21 to 0.46. In the second phase of experiment it varied from 0.19 to 0.44 and in the third phase it varied from 0.21 to 0.32.

4.3.1.3 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.

4.3.1.4 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.

4.3.2 Chemical Properties

4.3.2.1 Total ash content

Total ash contents of jaggery samples taken during first phase of the experiment varied from 2.17%-3.18 %(d.b), during second phase of the experiment varied from 2.07%-3.18 % (d.b) and during third phase of experiment varied from 2.19%-3.35 % (d.b). None of these were within specifications (1.1% d.b) as confirmed from the fig 4.2, 4.10, 4.18.

4.3.2.2 Acid Insoluble Ash content

Ash contents insoluble in dilute Hcl, of jaggery samples obtained during first phase of the experiment varied from 0.02% to 0.04% (d.b), during second phase of the experiment varied from 0.03%-0.09%(d.b) and during third phase of experiment varied from 0.02%-0.12%(d.b). All of these were found out to be within specifications (0.3% d.b). This is confirmed from the fig.4.3,4.11,4.19.

4.3.2.3 Water Insoluble in Ash content

Ash contents insoluble in water, of jaggery samples obtained during first phase of the experiment varied from 0.61% to 0.79%(d.b), during second phase of the experiment varied from 0.81%-1.01%(d.b) and during third phase of experiment varied from 0.84%-1.17%(d.b). All of these were found out to be within specifications (1.5% d.b) as confirmed from the fig.4.4, 4.12, 4.20.

4.3.2.4 Sulphated ash content

Sulphated ash contents of jaggery samples obtained during first phase of the experiment varied from 2.53% to 3.02% (d.b), during second phase of the experiment varied from 2.61%-3.24%(d.b) and during third phase of experiment

varied from 2.59%-3.19%(d.b). Samples collected from Kanakpur unit for all the three phases of experiments deviate from the specifications but all others were found out to be within specifications (3.5% d.b) as shown in fig.4.5, 4.13, 4.21. The reason may be the difference in the variety of sugarcanes used.

4.3.2.5 Reducing Sugar content

Reducing sugar content of jaggery samples taken during first phase of the experiment varied from 11.7%-12.41%, during second phase of the experiment varied from 12.15%-13.25% and during third phase of experiment varied from 13.25%-15.9%. None of these were within specifications (Max.10%) as confirmed from the fig 4.6, 4.14, 4.22. The reason assigned to this high reducing sugar content of jaggery is staling of sugarcane juice or storage of sugarcane or the addition of excess clarificant like hydros. A controlled sample prepared in one of the unit without addition of hydros which is used to lighten the color of jaggery with all other process conditions remaining the same. When reducing sugar 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 shows the probability of addition of excess hydros as a reason for high reducing sugar content of the end product **(Javalekar *et al.*, 1985)**. Moreover, during the survey it was observed that sugarcanes are stacked and stored for 4-8 days or more owing to high production of sugarcane. As reviewed from literature, in harvested cane the losses due to sucrose inversion accelerated after 72 h of storage and reducing sugar content increased remarkably **(Solomon *et al.*, 1990)**. This staling

of sugarcanes also contributes to addition of more amount of clarificant **(Londle and Yadav 1989)**. From survey it was observed that particularly during summer season, the sugarcanes were crushed early in the morning and the juice was used after 7-9 hours of storage in open settling tank. This may also cause inversion of sugar and increase in reducing sugars.

4.3.2.6 Sucrose content

Sucrose content of jaggery samples taken during first phase of the experiment varied from 73.26%-74.4 %, during second phase of the experiment varied from 71.41%-73.43 % and during third phase of experiment varied from 68.53%-72.49 %. None of these were within specifications (min.80%) as confirmed from fig.4.7, 4.15, 4.23.The reasons assigned to this is same as above discussed in the section of reducing sugar.

4.3.2.7 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.50ppm) 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.

4.3.3 Microbiological Studies

4.3.3.1 Assessment of cleanliness of surfaces

Swab tests of three different areas i.e. juice storage tank, open pan (used to cool jaggery) and jaggery wrapping cloth were done. The results revealed that the colony count per 900 cm^2 area was maximum for wrapping cloth i.e.380cfu.The colony count per 900 cm^2 area for juice storage tank was 180 cfu and 220 cfu for the cooling pan. It is therefore concluded that cleaning is not satisfactory and may cause microbial contamination.

4.3.3.2 Microbiological counts

The microbiological quality of fresh jaggery samples is better in terms of Coliform count but shows remarkably high total plate count. The Coliform counts varied from 0-1 for samples of all the three phases of different units (Table 4.3). The total plate count was remarkably high for fresh jaggery and varied from 4-13 for phase-1, from 5-13 for phase-2 and from 8-15 for phase-

Plate 5. Swab Test of cooling pan

Plate 6. Swab Test of wrapping cloth

Plate 7. Enumeration of micro-organisms

Table.4.2 RESULTS OF PHYSICAL AND CHEMICAL TESTS, 0-DAYS(* OD at 540 nm)

PHASE	TESTS	Rudrapur mallik colony	Rudrapur Singh colony	Rudrapur Bhurarani unit-I	Rudrapur Bhurarani unit-II	Rudrapur Bhurarani unit-III	Kanakpur unit
I	Total ash content,%	3.187	2.175	2.296	2.353	2.282	2.943
	Acid insoluble ash,%	0.03	0.032	0.047	0.048	0.148	0.02
	Water insoluble ash,%	0.675	0.621	0.788	0.654	0.799	0.614
	Sulphated ash,%	3.02	3.251	3.18	2.537	2.991	3.808
	Reducing Sugar,%	11.9	11.63	11.7	12.13	12.41	11.25
	Sucrose,%	74.4	74.71	74.82	73.65	73.26	75.53
	Total Sugar	86.3	86.34	86.52	85.78	85.67	86.78
	Moisture content (d.b. %)	12.6	10.94	12.45	11.07	11.29	9.72
	Colour (O.D.*)	0.32	0.47	0.21	0.40	0.31	0.46
	pH	5.50	5.43	5.40	5.41	5.35	5.55
	True density(g/cc)	1.562	1.441	1.586	1.569	1.645	1.496
	Free sulphur dioxide,ppm	94.32	93.22	97.04	91.68	95.89	87.04
II	Total ash content,%	3.187	2.075	2.304	2.423	2.293	2.491
	Acid insoluble ash,%	0.039	0.035	0.043	0.040	0.098	0.041
	Water insoluble ash,%	0.931	0.823	0.943	0.861	1.012	0.812
	Sulphated ash,%	3.10	3.24	3.20	2.61	3.15	3.82
	Reducing Sugar,%	12.25	12.41	13.01	12.71	13.25	12.15
	Sucrose,%	73.25	73.61	71.41	73.20	71.9	73.43
	Total Sugar	85.5	86.02	84.42	85.91	85.15	85.58
	Moisture content (d.b. %)	11.92	10.97	12.01	11.82	11.17	11.85
	Colour (O.D.*)	0.34	0.36	0.19	0.42	0.32	0.44
	pH	5.26	5.13	5.22	5.24	5.24	5.27
	True density(g/cc)	1.571	1.433	1.592	1.572	1.650	1.498
III	Total ash content,%	3.350	2.324	2.197	2.415	2.274	2.542
	Acid insoluble ash,%	0.040	0.039	0.045	0.043	0.121	0.028
	Water insoluble ash,%	0.875	0.892	1.009	0.856	1.171	0.847
	Sulphated ash,%	3.12	3.19	3.13	2.59	2.87	3.76
	Reducing Sugar,%	15.01	13.63	15.25	15.90	15.10	13.25
	Sucrose,%	69.31	71.79	68.53	68.72	71.2	72.49
	Total Sugar	84.32	85.42	83.78	84.62	86.3	85.74
	Moisture content (d.b. %)	12.2	12.33	10.66	12.05	13.13	10.29
	Colour (O.D.*)	0.22	0.29	0.32	0.31	0.29	0.21
	pH	4.43	4.41	4.46	4.42	4.49	4.71
	True density(g/cc)	1.552	1.446	1.579	1.568	1.642	1.491

Table.4.3 Coliform count of fresh Jaggery samples –CFU at 32°C

UNITS	PHASE-I	PHASE- II	PHASE -III
Rudrapur mallik colony	0	0	0
Rudrapur Singh colony	0	0	0
Rudrapur Bhurarani unit-I	1	1	1
Rudrapur Bhurarani unit-II	1	1	1
Rudrapur Bhurarani unit-III	1	1	1
Kanakpur unit	0	1	0

Table 4.4. Total Plate count of fresh Jaggery samples –CFU at 32°C

UNITS	PHASE -I	PHASE -II	PHASE -III
Rudrapur mallik colony	68	74	72
Rudrapur Singh colony	83	56	64
Rudrapur Bhurarani unit-I	44	56	77
Rudrapur Bhurarani unit-II	96	63	39
Rudrapur Bhurarani unit-III	49	35	66
Kanakpur unit	53	48	44

Table 4.5 Yeast and Mould count of fresh Jaggery samples –CFU at 32°C

UNITS	PHASE -I	PHASE -II	PHASE -III
Rudrapur mallik colony	10	12	13
Rudrapur Singh colony	13	9	15
Rudrapur Bhurarani unit-I	12	13	12
Rudrapur Bhurarani unit-II	9	12	9
Rudrapur Bhurarani unit-III	13	12	8
Kanakpur unit	4	5	11

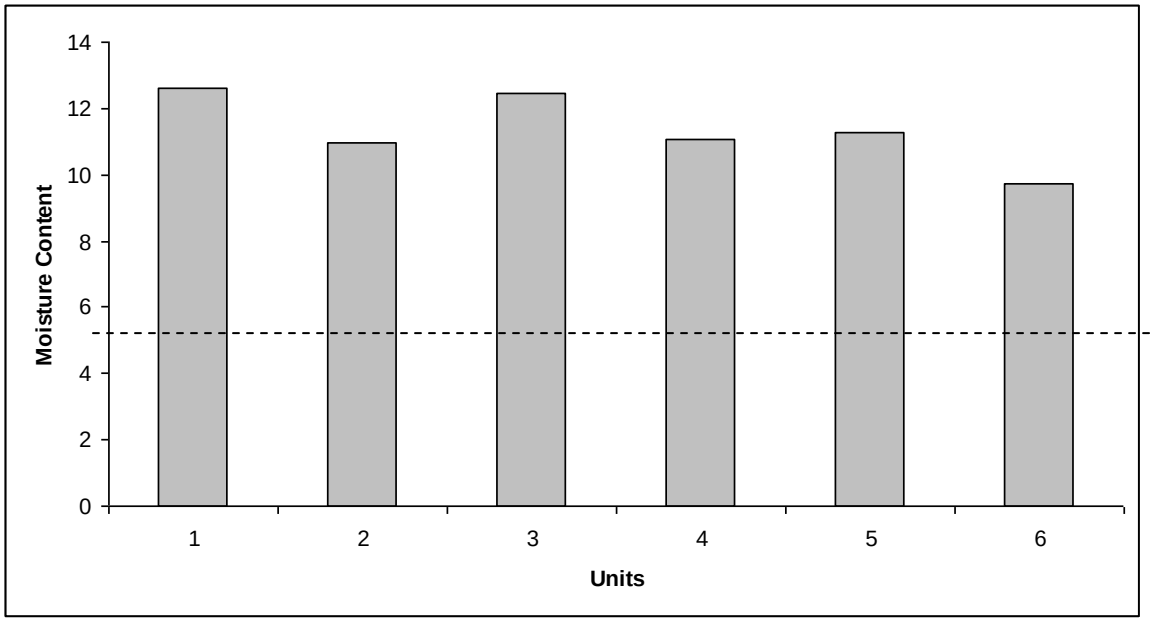


Fig.4.1 Moisture Contents of fresh jaggery samples (phase-I)

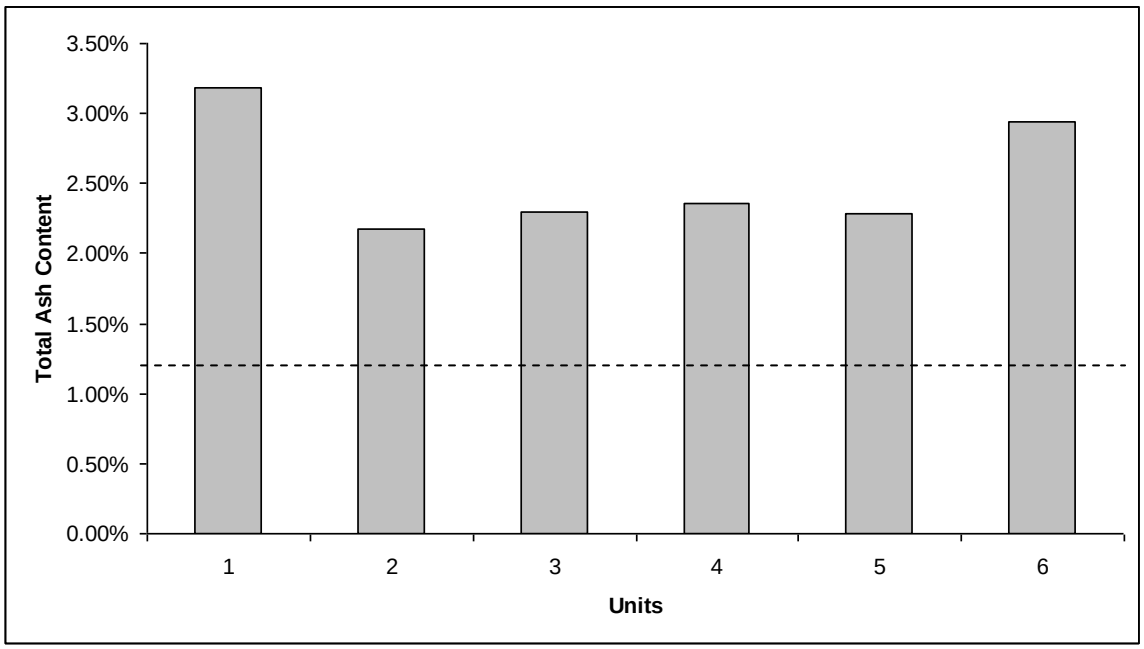


Fig 4.2. Total Ash Content of fresh jaggery samples (phase-I)

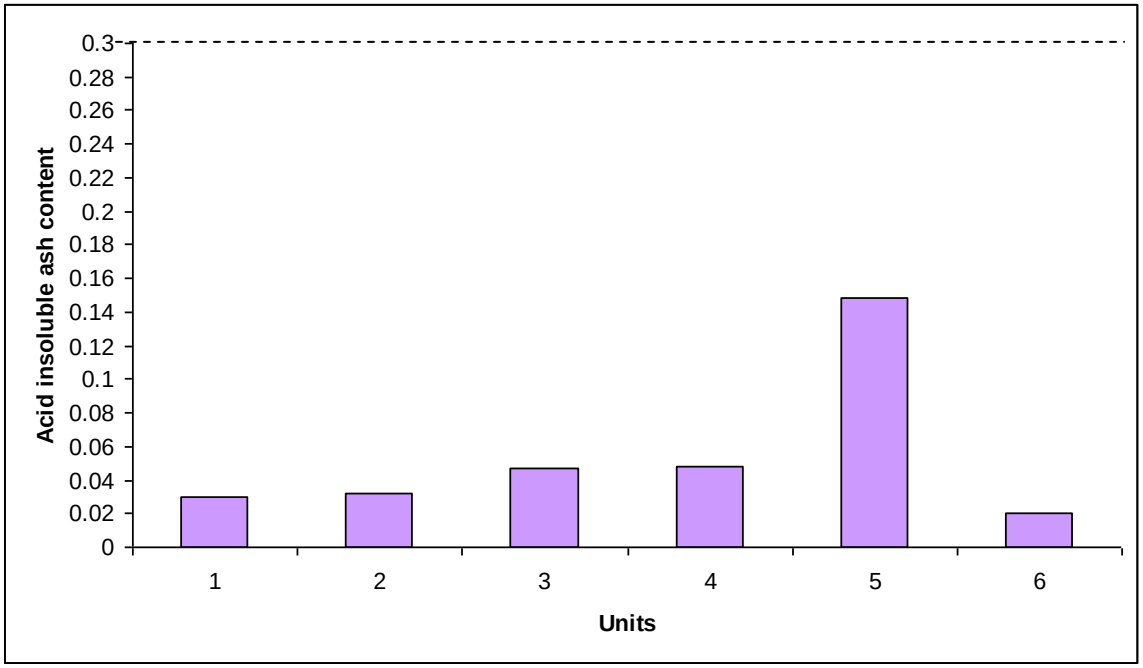


Fig 4.3. Acid Insoluble Ash Content of fresh jaggery samples (phase-I)

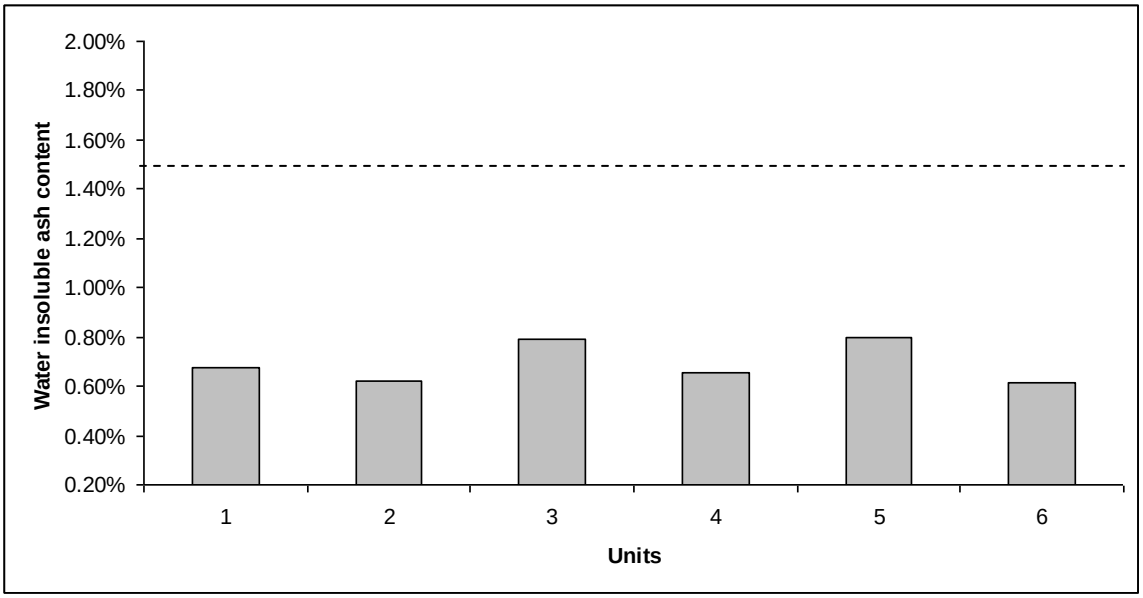


Fig 4.4. Water Insoluble Ash Content of fresh jaggery samples (phase-I)

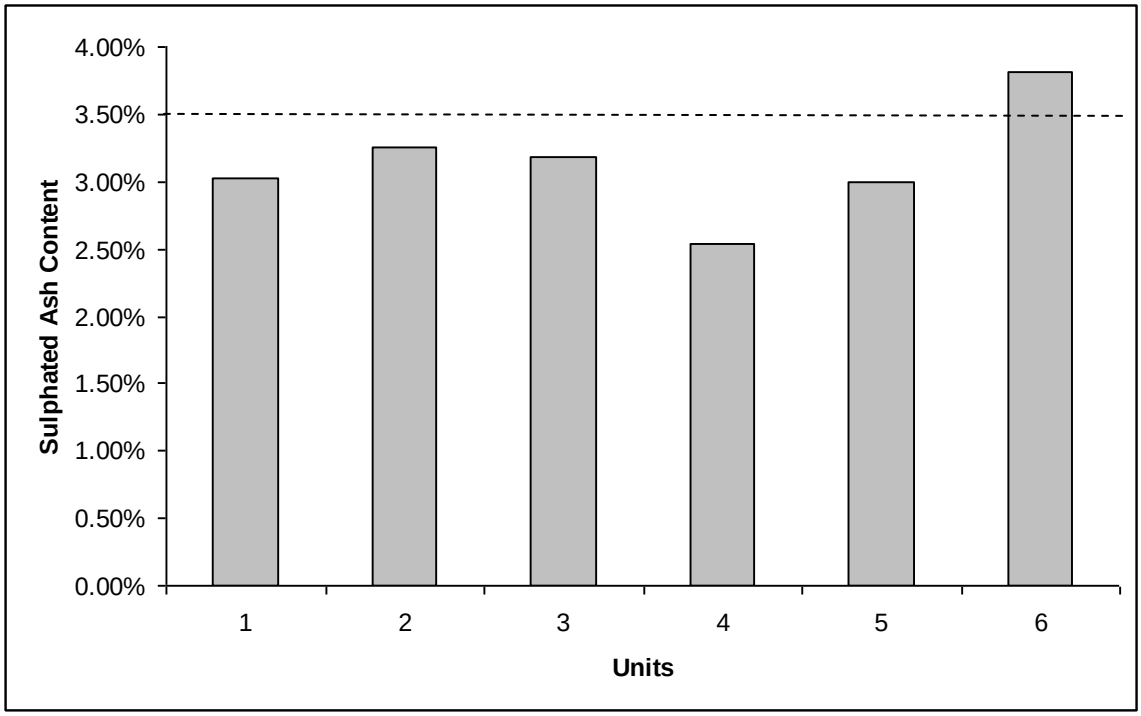


Fig 4.5. Sulphated Ash Content of fresh jaggery samples (phase-I)

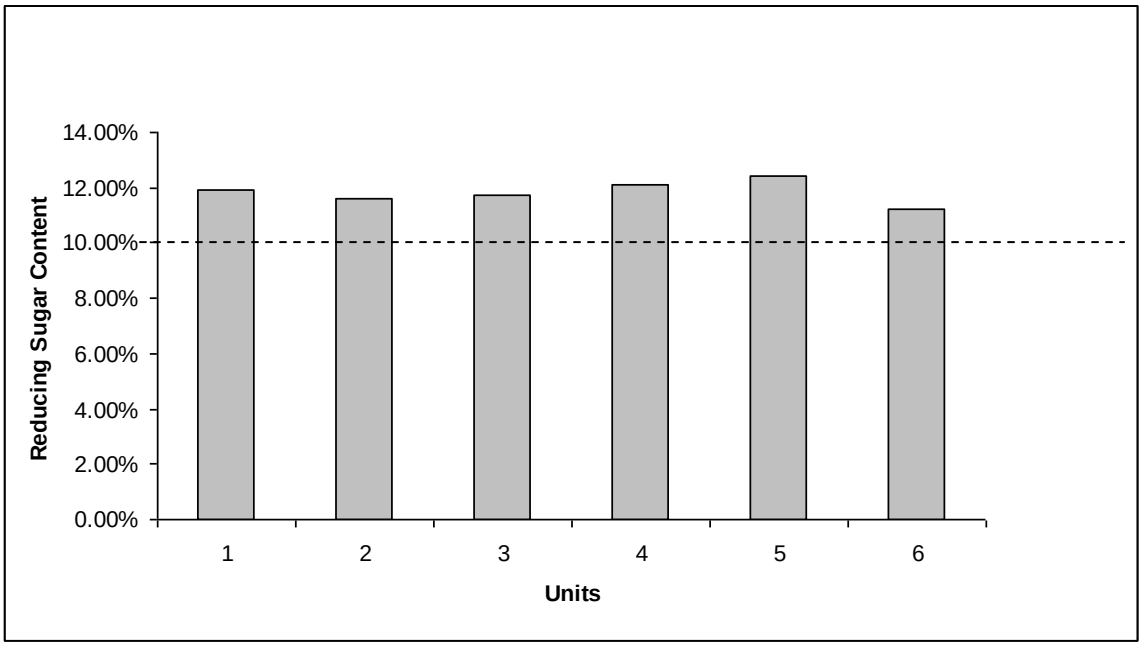


Fig 4.6 Reducing Sugar Content of fresh jaggery samples (phase-I)

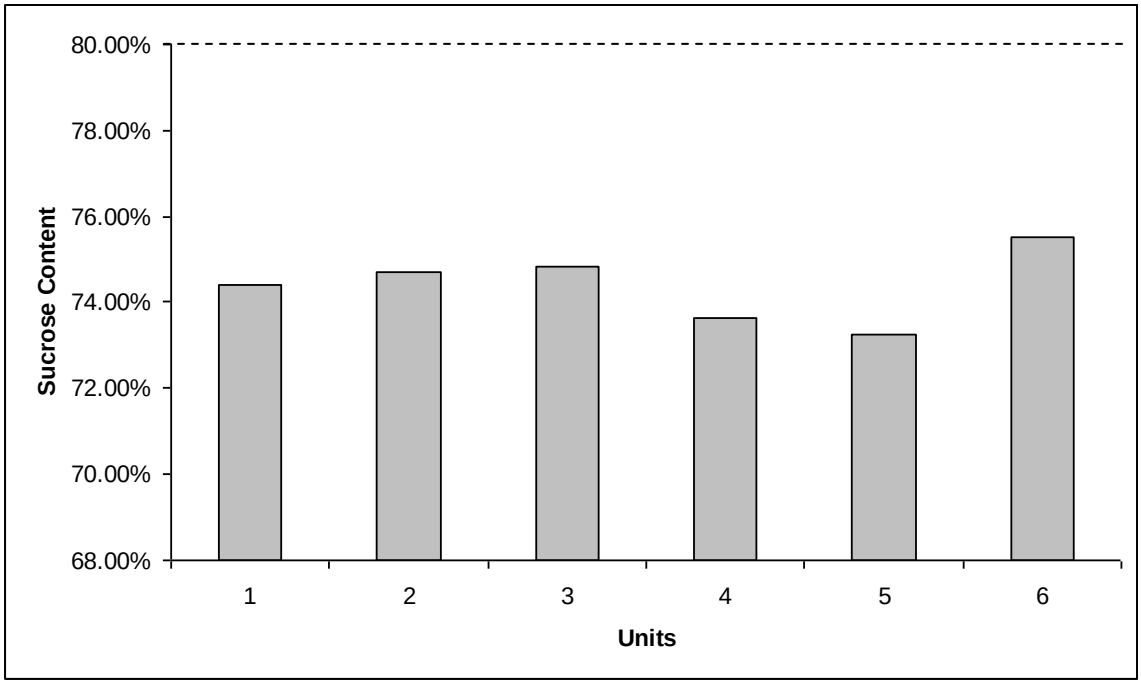


Fig 4.7. Sucrose Content of fresh jaggery samples (phase-I)

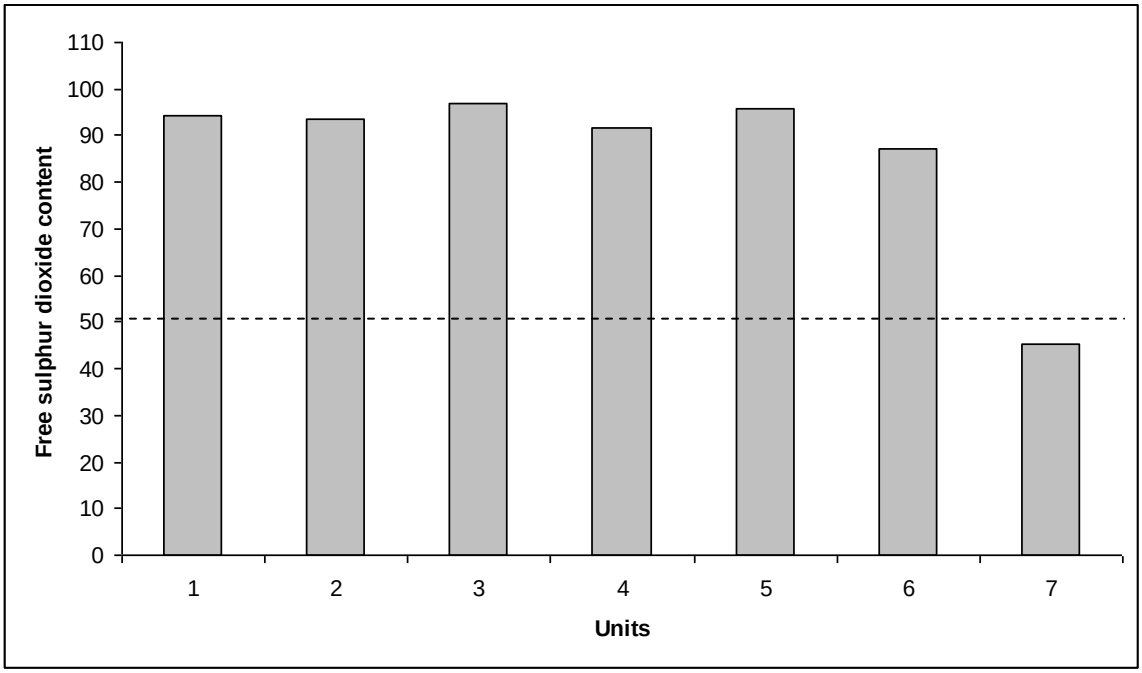


Fig 4.8. Free sulphur dioxide Content of fresh jaggery samples (phase-I)

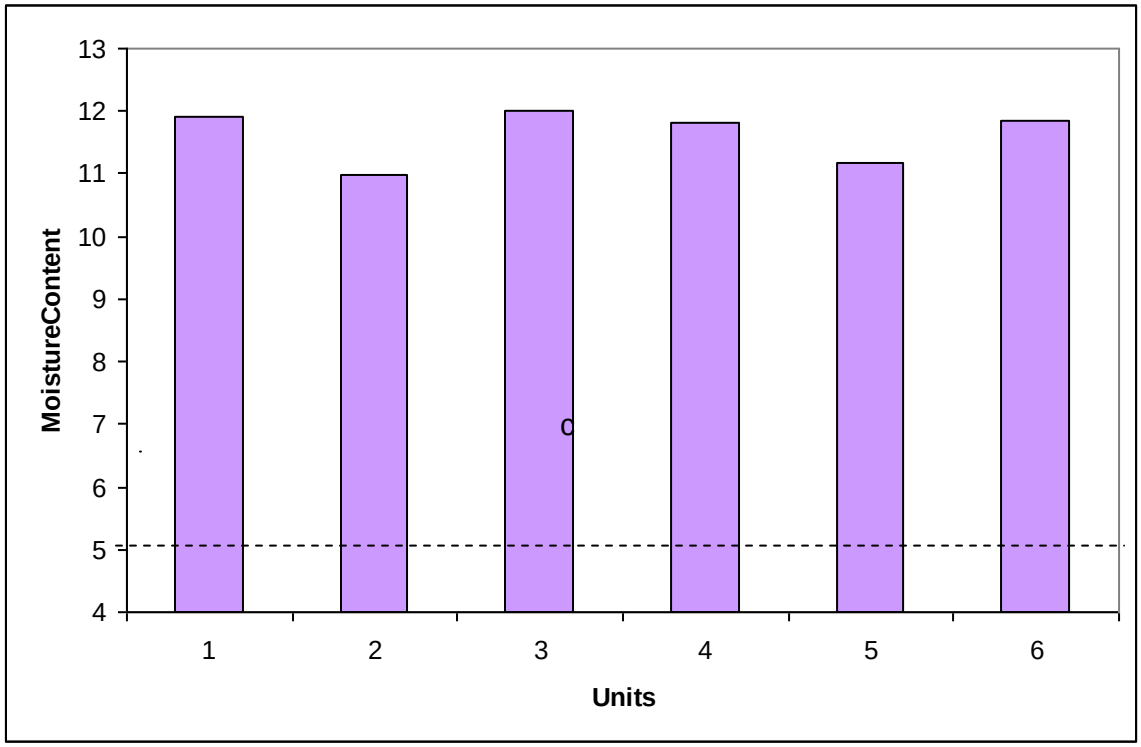


Fig.4.9 Moisture Contents of fresh jaggery samples (phase-II)

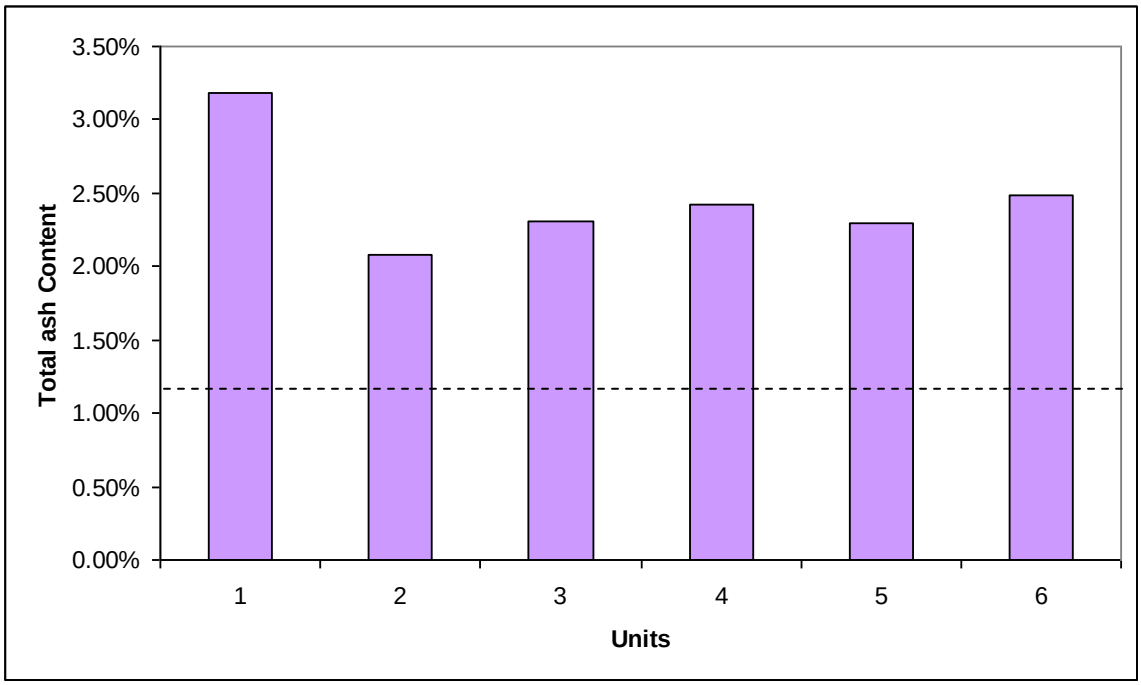


Fig 4.10. Total Ash Content of fresh jaggery samples (phase-II)

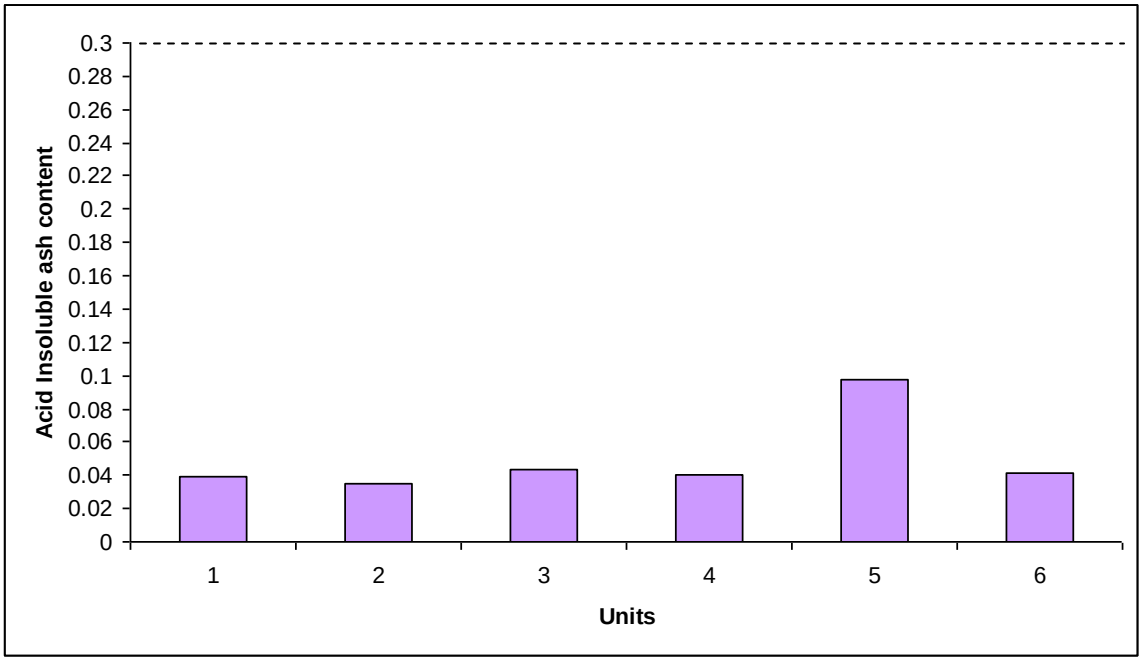


Fig 4.11. Acid Insoluble Ash Content of fresh jaggery samples (phase-II)

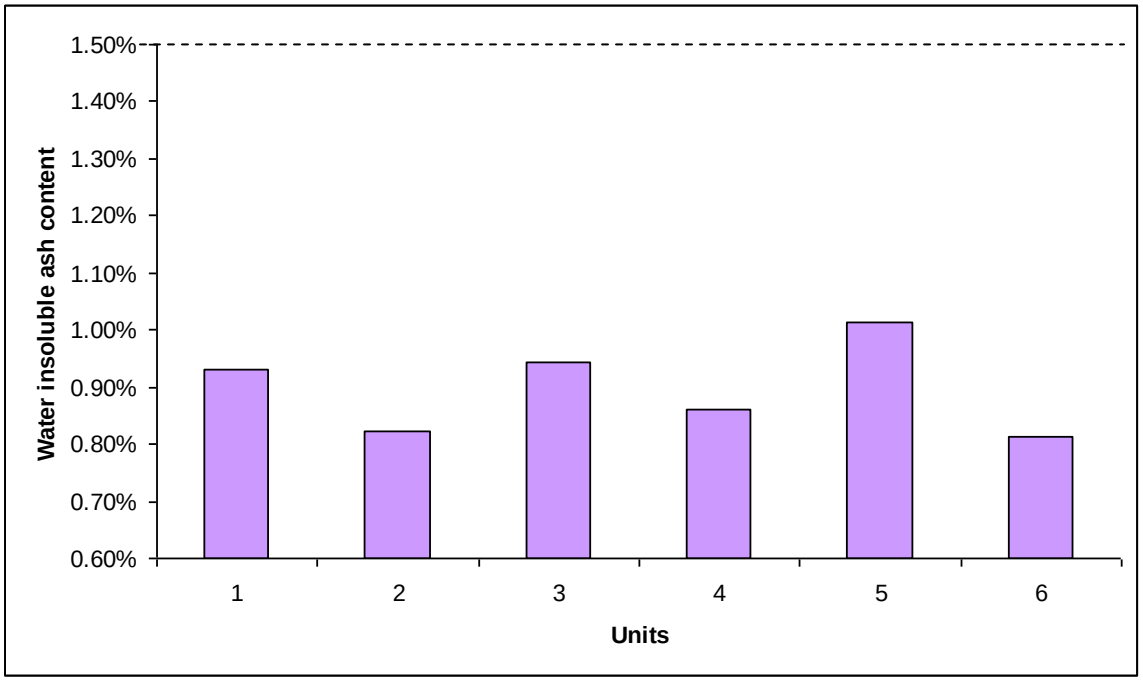


Fig 4.12. Water Insoluble Ash Content of fresh jaggery samples (phase-II)

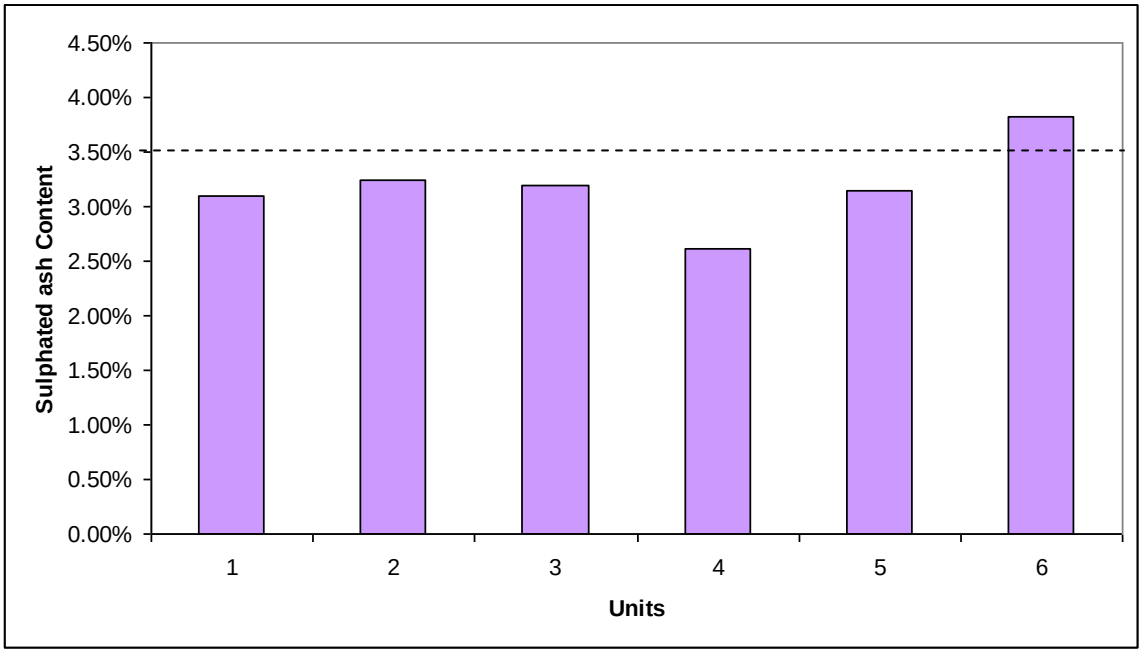


Fig 4.13. Sulphated Ash Content of fresh jaggery samples (phase-II)

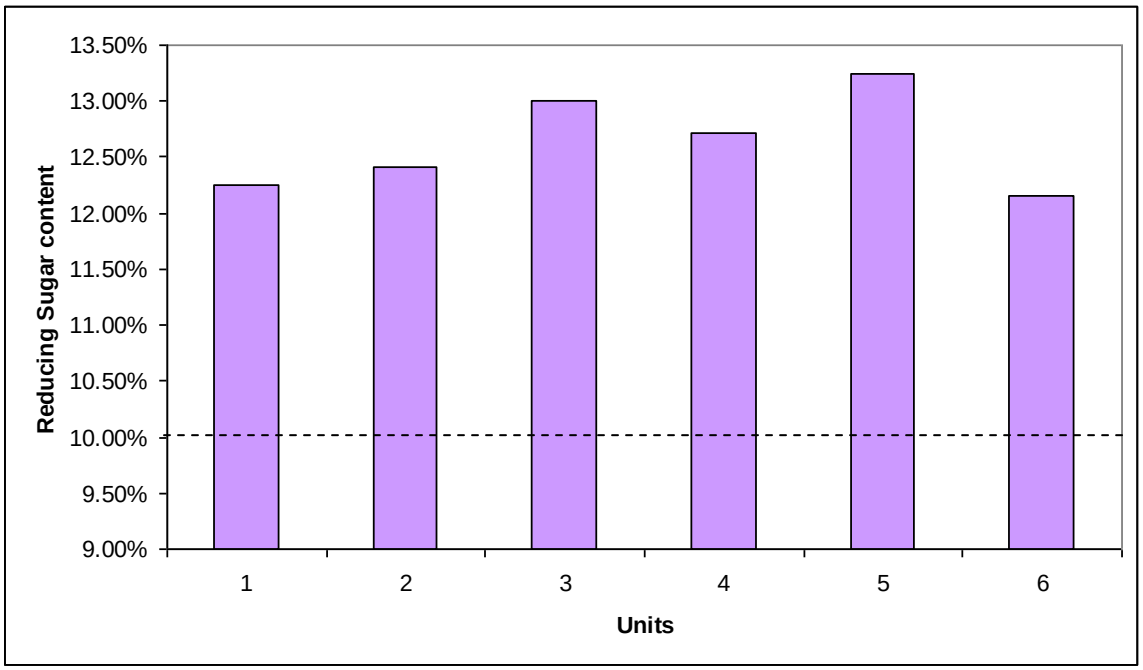


Fig 4.14. Reducing Sugar Content of fresh jaggery samples (phase-II)

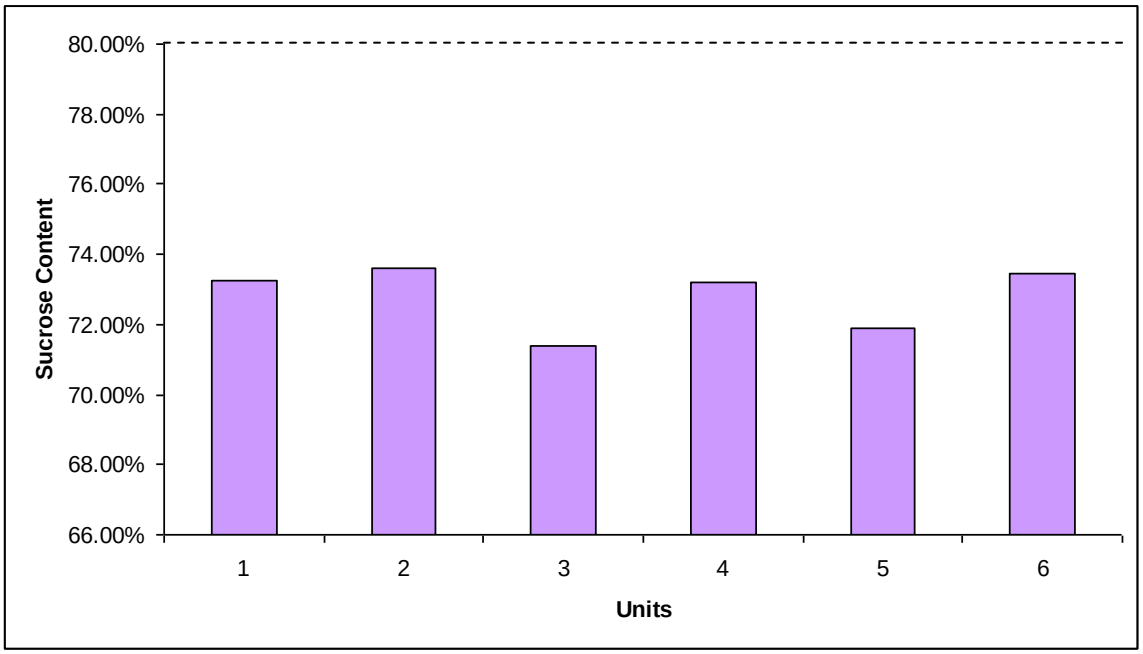


Fig 4.15. Sucrose Content of fresh jaggery samples (phase-II)

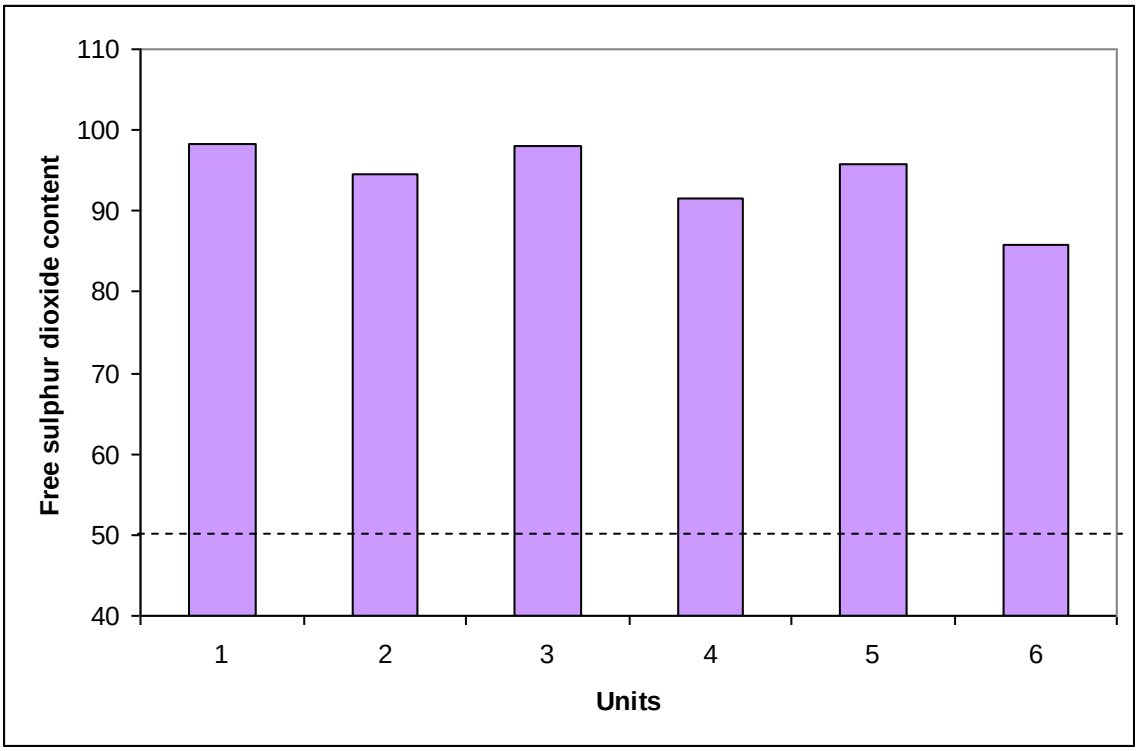


Fig 4.16. Free sulphur dioxide Content of fresh jaggery samples (phase-II)

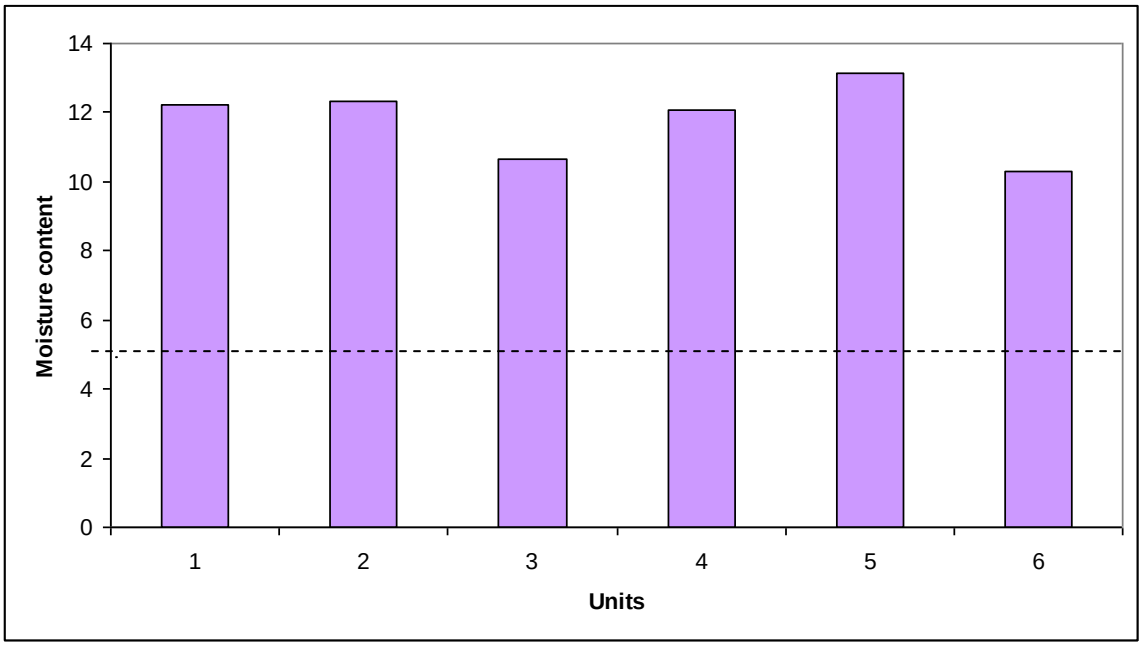


Fig.4.17 Moisture Contents of fresh jaggery samples (phase-III)

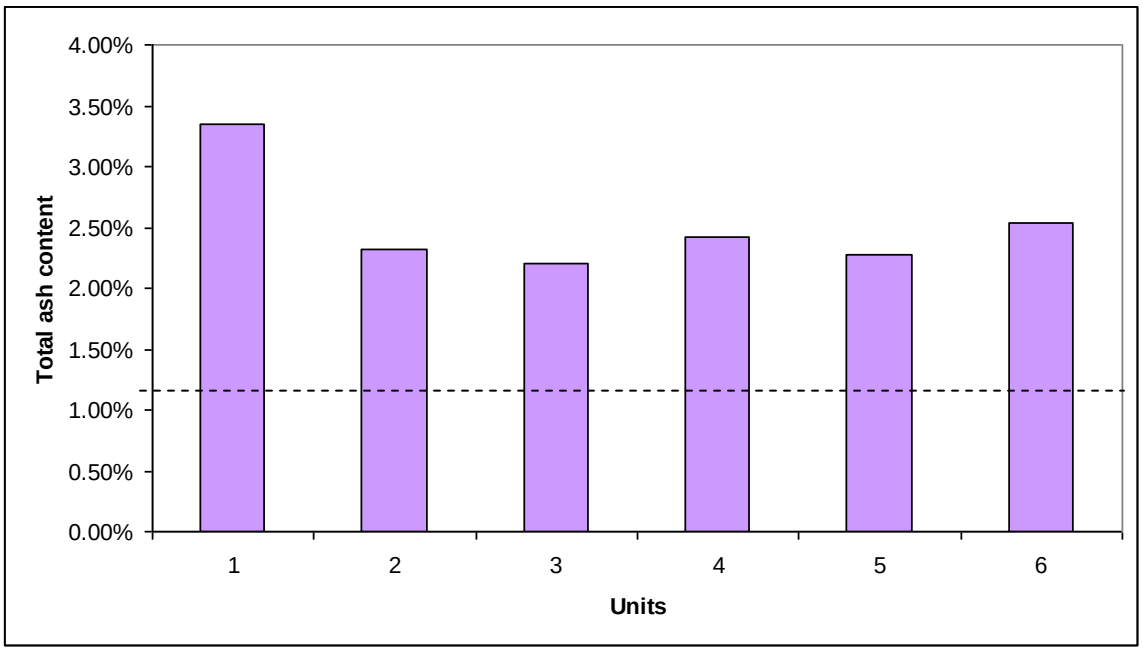


Fig 4.18. Total Ash Content of fresh jaggery samples (phase-III)

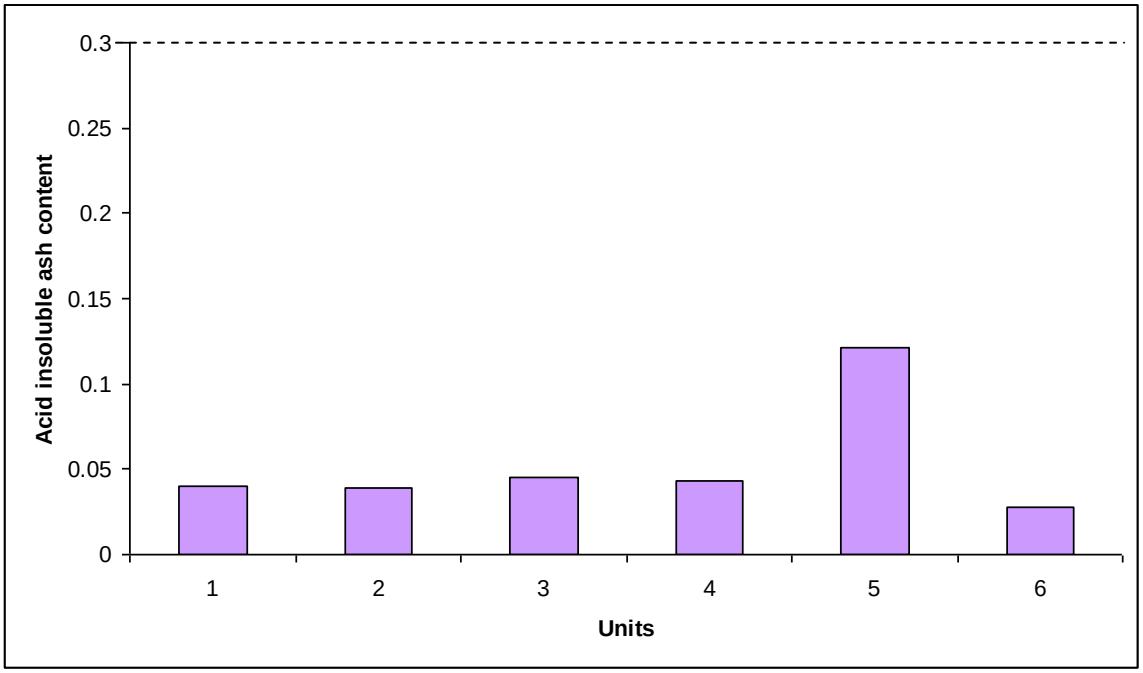


Fig 4.19. Acid Insoluble Ash Content of fresh jaggery samples (phase-III)

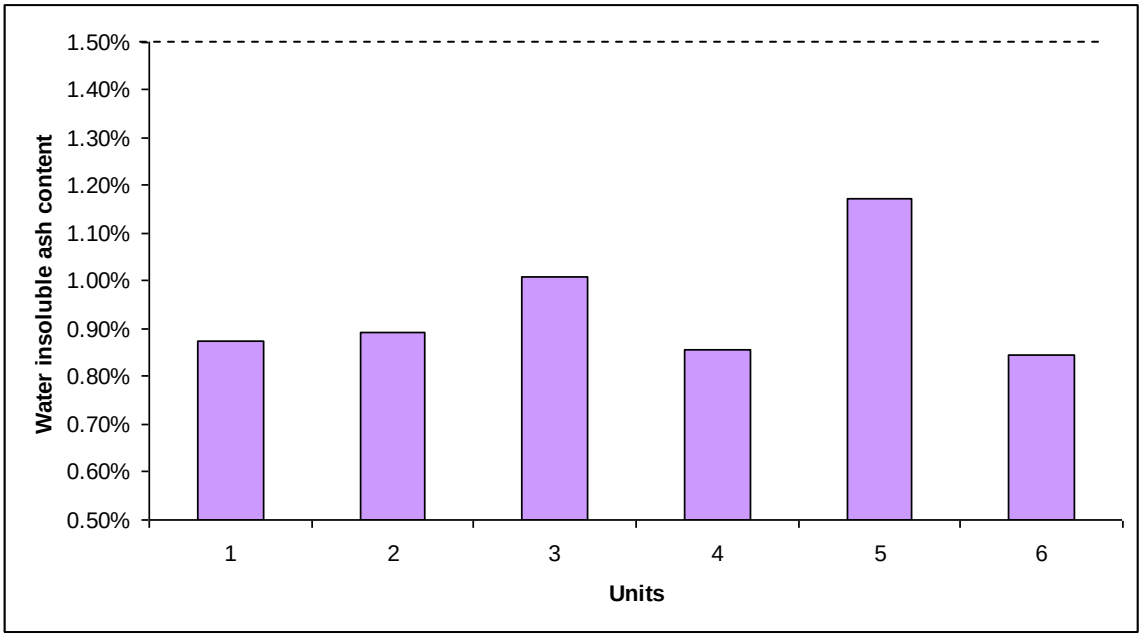


Fig 4.20. Water Insoluble Ash Content of fresh jaggery samples (phase-III)

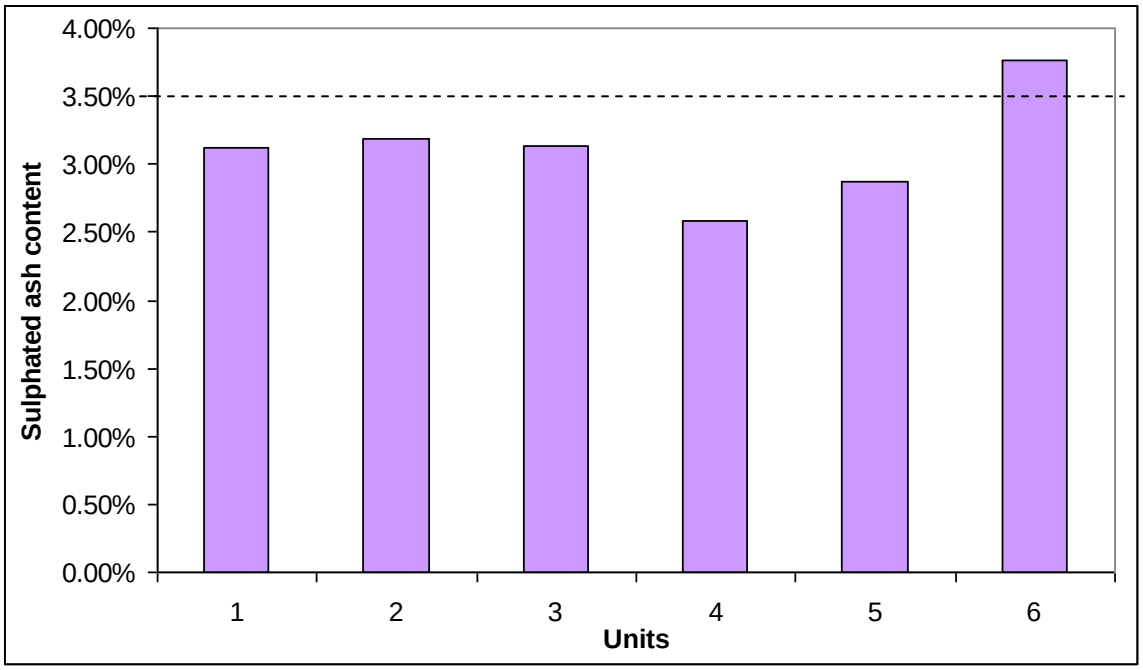


Fig 4.21. Sulphated Ash Content of fresh jaggery samples (phase-III)

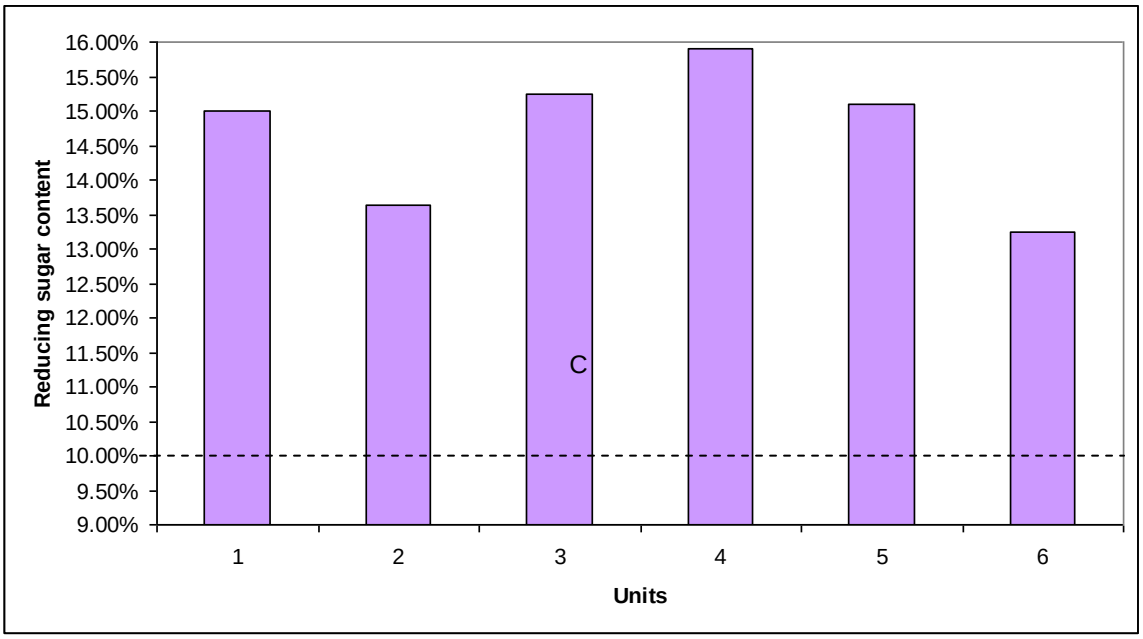


Fig 4.22 Reducing Sugar Content of fresh jaggery samples (phase-III)

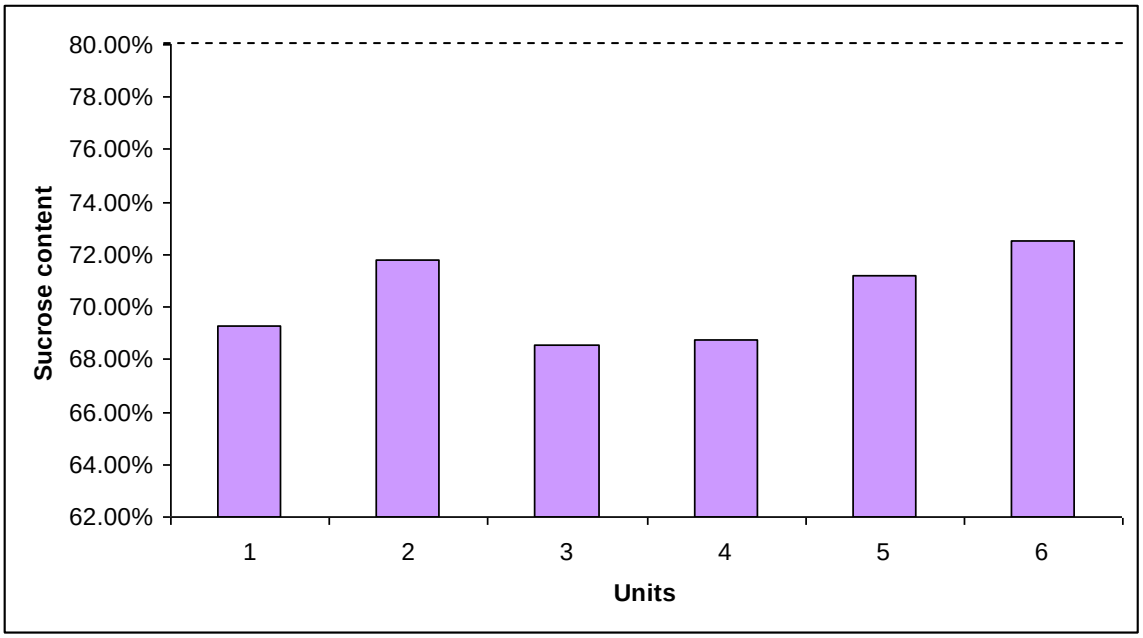


Fig 4.23. Sucrose Content of fresh jaggery samples (phase-III)

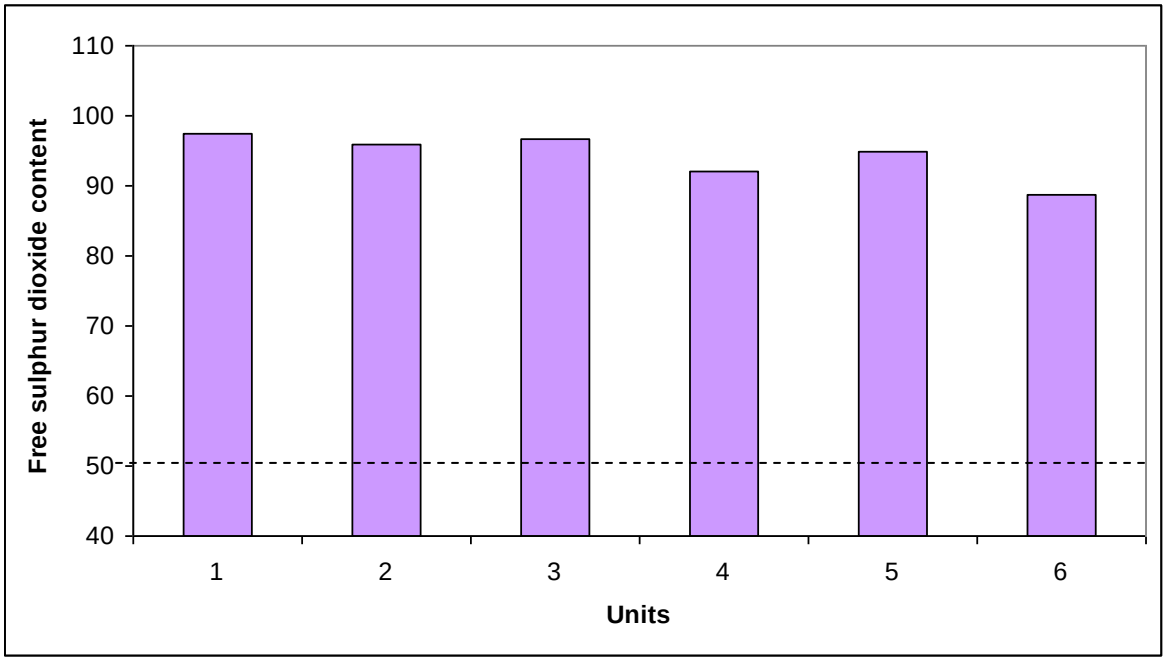


Fig 4.24 Free Sulphur dioxide Content of fresh jaggery samples (phase-III)

3(Table 4.4). The yeast and mould count varied from 2-4 for phase-1, from 2-5 for phase-2 and phase-3 samples (Table 4.5).

4.4 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.

4.4.1 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.

4.4.2 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.

4.4.3 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.

4.5 Control limits for Critical Control Points

4.5.1 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.

4.5.2 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.

4.5.3 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.

4.6 Analysis of Storage Unit

4.6.1 General Description of Storage unit

One jaggery storage unit was surveyed to assess the hazards associated during the storage. The storage unit was a concrete roofed godown with storage capacity of approximately 120 Quintal jaggery per room. There were five well-ventilated sections. Jaggery in the form of bhelis, were stacked in blocks on wooden batterens (to allow the air to pass in). Each block was separated from other by a passage of 0.6-0.9m. Jaggery lumps which were in the form of laddoos were stored in jute bags. Two exhaust fans were provided in one of the section but other sections were ventilated by opening of doors. There was no provision for maintenance of humidity and temperature which is a must. Some of the bhelis were wrapped in newspaper to avoid liquification. Jaggery which was prepared during the month of October and November were sold earlier to avoid

any losses due to biochemical changes but jaggery produced after February were stored as they have good storability. Some of the jaggery lumps in the section where proper ventilation was not provided were spoiled. The traders prefer horizontal stacking instead of vertical stacking.

4.6.2 Compatibility of the storage unit with the specification codes

According to Indian Standards certain codes are specified for the storage of jaggery. According to the code stack height should not be more than 1.5m, length of the stack should not be more than 9m and breadth of the stack should not be more than 6m, which is maintained in the unit. This is done to avoid the collapse of the bottom jaggery bhelis. The codes stressed that jaggery being a hygroscopic commodity should be kept air tight, this is maintained by closing the door airtight. The only criteria not met by the storage unit were maintenance of temperature and humidity.

4.6.3 Hazards associated with the storage unit

The hazards assessed during the survey of storage unit are described under the following categories:

4.6.3.1 Physical Hazards

The physical hazards assessed were color impairment such as darkening, loss of body texture through liquification and disintegration and weight loss due to hydration, breakage and separation of molasses. All these contribute to loss of quality in jaggery. These losses can be overcome if jaggery is loaded and unloaded properly and maintenance of proper ventilation with proper humidity level.

4.6.3.2 Biological Hazards

Houseflies, bees, ants, wasps and rodents are source of biological hazards. These hazards cause remarkable losses in the quality of jaggery. This can be avoided by proper hygiene practices. During storage some jaggery get liquefied and show mold growth, hence can be a source of contamination. To avoid such contamination of other jaggery samples, such samples should be discarded.

4.7 Comparison of proximate composition of samples of storage units with that stored under laboratory conditions

The jaggery samples of storage unit at different sections were collected and various parameters which contribute to its physical and chemical properties were analyzed in the laboratory. The results of physical and chemical tests are presented in comparative form in Table 4.6-4.8 and Fig 4.25-4.45. Samples of all the phases were stored in laboratory conditions (wrapped in polythene). Tests were conducted to evaluate their proximate composition at 30 days, 45 days and 60 days of storage. The results thus obtained were compared with the data obtained from the samples of storage unit. The results of various tests conducted are discussed in the following paragraphs:

4.7.1 Physical Properties

4.7.1.1 Moisture Content

Two jaggery samples “A &D” were taken from the sections where jaggery was stored for 30 days, “B&C” from the sections where jaggery was stored for 45 days, “E” from the sections where jaggery was stored for 60 days and their moisture content were compared with the moisture content of samples stored at

laboratory conditions taken at 30 days, 45days and 50 days. Moisture content of stored samples 'A'&'D' were 7.48% and 5.74% (d.b) respectively whereas moisture contents of laboratory samples varied from 9.10-11.42 % (d.b) for phase-1 samples , from 9.05-11.21%(d.b) for phase-2 and from 9.28-11.69 %(d.b) for phase-3 after 30 days. The data of stored samples shows a slight variation from data of laboratory samples. Moisture content of stored samples 'B'&'C' were 6.53% and 5.72% respectively whereas moisture contents of laboratory samples varied from 8.82-10.86 % (d.b) for phase-1, from 9.24-10.54 % (d.b) for phase-2 and from 8.78-11.75 % (d.b) for phase-3 after 45 days. Moisture content of stored samples 'E' was 4.47% whereas moisture contents of laboratory samples varied from 9.03-10.42 % (d.b) for phase-1, from 8.03-10.13 % (d.b) for phase-2 and from 8.01-11.01 % (d.b) for phase-3 after 60 days. Samples stored in laboratory conditions show high moisture because the samples were not dried and stored in the polythene as it is. It was observed that one of the samples of phase-3 taken from Bhurarani was liquefied after 45 days.

4.7.1.2 Color

The color of stored samples 'A'&'D' were found out to be 0.13 whereas the color of laboratory samples after 30 days of storage varied from 0.26-0.52 for phase-1, from 0.28-0.48 for phase-2 and from 0.18-0.33 for phase-3. The color of stored samples 'B'&'C' were found out to be 0.10 and 0.26, whereas the color of laboratory samples after 45 days of storage varied from 0.28-0.52 for phase-1, from 0.30-0.52 for phase-2 and from 0.19-0.32 for phase-3. The color of stored samples 'E' was found out to be 0.27 whereas the color of laboratory samples

after 60 days of storage varied from 0.31-0.54 for phase-1, from 0.40-0.54 for phase-2 and from 0.16-0.28 for phase-3. The laboratory samples of phase 1 and 2 show a increase in optical density with increase in time of storage but the samples of phase-3 shows the reverse trend. The reason for this could not be attributed. The laboratory samples show slight variation in color from stored samples.

4.7.1.3 True Density

The true density of stored samples 'A'&'D' were found out to be 1.42 and 1.44 g/cc respectively, whereas the true density of laboratory samples after 30 days of storage varied from 1.442-1.645 g/cc for phase-1, from 1.436-1.596 g/cc for phase-2 and from 1.406-1.633 g/cc for phase-3 .The true density of stored samples 'B'&'C' were found out to be 1.37and 1.54 g/cc, whereas the true density of laboratory samples after 45 days of storage varied from 1.450-1.647 g/cc for phase-1, from 1.436-1.656 g/cc for phase-2 and from 1.312-1.673 g/cc for phase-3. The true density of stored samples 'E' was found out to be 1.55 g/cc whereas the true density of laboratory samples after 60 days of storage varied from 1.450-1.647 g/cc for phase-1, from 1.436-1.657 g/cc for phase-2 and from 1.119-1.633 g/cc for phase-3. The laboratory samples show an increase in true density with increase in time of storage for all samples of phase 1 and 2 but phase-3 samples show the reverse trend. The laboratory samples show slight variation in true density from stored samples.

4.7.1.4 pH of N/2 Jaggery Solution

The pH of stored samples ‘A’&’D’ were found out to be 5.41 and 5.45 respectively, whereas the pH of laboratory samples after 30 days of storage varied from 5.26-5.49 for phase-1, from 5.11-5.23 for phase-2 and from 5.21-5.41 for phase-3. The pH of stored samples ‘B’&’C’ were found out to be 5.39 and 5.48, whereas the pH of laboratory samples after 45 days of storage varied from 5.24-5.48 for phase-1, from 5.09-5.20 for phase-2 and from 5.19-5.35 for phase-3. The pH of stored samples ‘E’ was found out to be 5.22 whereas the pH of laboratory samples after 60 days of storage varied from 5.21-5.45 for phase-1, from 5.07-5.19 for phase-2 and from 5.10-5.52 for phase-3. There is decrease in pH with increase in time for phase 1 and 2 but phase-3 show increase in pH.The laboratory samples show slight variation in pH from stored samples.

4.7.2 Chemical Properties

4.7.2.1 Total ash content

The total ash content of stored samples ‘A’&’D’ were found out to be 1.863% and 1.84% respectively, whereas the total ash content of laboratory samples after 30 days of storage varied from 2.499-3.389% for phase-1, from 2.428-3.381% for phase-2 and from 2.544-3.861% for phase-3. The total ash content of stored samples ‘B’&’C’ were found out to be 1.281% and 1.446%, whereas the total ash content of laboratory samples after 45 days of storage varied from 2.479-3.573% for phase-1, from 2.361-3.574% for phase-2 and from 2.614-3.638% for phase-3. The total ash content of stored samples ‘E’ was found out to be 1.452% whereas the total ash content of laboratory samples after 60

days of storage varied from 2.499-3.389% for phase-1, from 2.229-3.612% for phase-2 and from 2.907-3.184% for phase-3. The laboratory samples show an increase in total ash content with increase in time of storage. The laboratory samples show high ash content as compared to stored one.

4.7.2.2 Acid Insoluble Ash content

The ash content insoluble in dil.Hcl of stored samples 'A'&'D' were found out to be 0.202% and 0.197% respectively, whereas that of laboratory samples after 30 days of storage varied from 0.118-0.128% for phase-1, from 0.116-0.182% for phase-2 and from 0.112-0.297% for phase-3. The ash content insoluble in dil.Hcl of stored samples 'B'&'C' were found out to be 0.078% and 0.192%, whereas that of laboratory samples after 45 days of storage varied from 0.220-0.296% for phase-1, from 0.215-0.376% for phase-2 and from 0.170-0.448% for phase-3. The ash content insoluble in dil.Hcl of stored samples 'E' was found out to be 0.189% whereas that of laboratory samples after 60 days of storage varied from 0.311-0.418% for phase-1, from 0.308-0.411% for phase-2 and from 0.246-0.529% for phase-3. The laboratory samples show an increase in ash content insoluble in dil.Hcl with increase in time of storage. The laboratory samples show high ash content insoluble in dil.Hcl as compared to stored one.

4.7.2.3 Water Insoluble Ash content

The ash content insoluble in water of stored samples 'A'&'D' were found out to be 0.758% and 0.706% respectively, whereas that of laboratory samples after 30 days of storage varied from 0.601-1.048% for phase-1, from 0.410-0.843% for phase-2 and from 0.727-0.952% for phase-3. The ash content

insoluble in water of stored samples ‘B’&’C’ were found out to be 0.413% and 0.709%, whereas that of laboratory samples after 45 days of storage varied from 0.592-1.136% for phase-1, from 0.452-0.896% for phase-2 and from 0.401-0.956% for phase-3. The ash content insoluble in water of stored samples ‘E’ was found out to be 0.712% whereas that of laboratory samples after 60 days of storage varied from 0.610-1.211% for phase-1, from 0.411-0.932% for phase-2 and from 0.147-0.948% for phase-3. The laboratory samples show high ash content insoluble in water as compared to stored one.

4.7.2.4 Sulphated ash content

The sulphated ash content of stored samples ‘A’&’D’ were found out to be 2.66% and 2.446% respectively, whereas that of laboratory samples after 30 days of storage varied from 2.856-4.107% for phase-1, from 3.010-4.112% for phase-2 and from 3.344-4.548% for phase-3. The sulphated ash content of stored samples ‘B’&’C’ were found out to be 1.876% and 2.169%, whereas that of laboratory samples after 45 days of storage varied from 2.779-3.932% for phase-1, from 2.972-3.981% for phase-2 and from 3.171-4.098% for phase-3. The sulphated ash content of stored samples ‘E’ was found out to be 2.18% whereas that of laboratory samples after 60 days of storage varied from 2.893-3.874% for phase-1, from 2.813-3.887% for phase-2 and from 3.060-4.578% for phase-3. The laboratory samples show high sulphated ash content as compared to stored one.

4.7.2.5 Reducing Sugar content

The reducing sugar content of stored samples ‘A’&’D’ were found out to be 13.38% and 13.26% respectively, whereas that of laboratory samples after 30 days of storage varied from 11.42-12.53% for phase-1, from 12.32-13.52% for phase-2 and from 11.36-13.10% for phase-3. The reducing sugar content of stored samples ‘B’&’C’ were found out to be 15.33% and 15.02%, whereas that of laboratory samples after 45 days of storage varied from 11.97-12.59 % for phase-1, from 12.46-13.76% for phase-2 and from 10.72-12.15% for phase-3. The reducing sugar content of stored samples ‘E’ was found out to be 15.98% whereas that of laboratory samples after 60 days of storage varied from 12.01-12.65% for phase-1, from 12.51-13.89% for phase-2 and from 9.69-10.75% for phase-3. The laboratory samples show an increase in reducing sugar content with increase in time of storage except samples of phase-3. The laboratory samples show low value of reducing sugar content as compared to stored one. This may be due to inversion of sugar in store or may be due to high reducing sugar content initially.

4.7.2.6 Sucrose content

The sucrose content of stored samples ‘A’&’D’ were found out to be 73.65% and 72.51% respectively, whereas that of laboratory samples after 30 days of storage varied from 72.88-75.11% for phase-1, from 70.91-73.14% for phase-2 and from 73.65-76.97% for phase-3. The sucrose content of stored samples ‘B’&’C’ were found out to be 69.21% and 67.51%, whereas that of laboratory samples after 45 days of storage varied from 72.53-74.86% for phase-

1, from 70.54-72.89% for phase-2 and from 76.14-78.99% for phase-3. The sucrose content of stored samples ‘E’ was found out to be 65.93% whereas that of laboratory samples after 60 days of storage varied from 72.21-74.52% for phase-1, from 70.32-72.68% for phase-2 and from 78.84-81.53% for phase-3. The laboratory samples show a decrease in sucrose with increase in time of storage due to inversion of sucrose during storage. But phase-3 samples show reverse trend. The laboratory samples show high sucrose content as compared to stored one.

4.7.3 Microbiological Properties

The microbiological quality of fresh jaggery samples is better in terms of Coliform count but shows remarkably high total plate count. As the time of storage increases the microbiological count decreases. The microbiological counts for stored samples are presented in Table.4.9-4.11. The Coliform counts for samples ‘A’&’D’ were 1 and 2 respectively whereas that of laboratory samples after 30 days of storage varied from 1-2 for phase-1, from 1-3 for phase-2 and from 0-4 for phase-3. The coliform count for samples ‘B’&’C’ were noted as 0 and 1 respectively whereas that of laboratory samples after 45 days of storage were nil for all the phases. The coliform count for sample ‘E’ was 1 whereas that of laboratory samples after 60 days of storage were nil for all the phases. The total plate count for samples ‘A’&’D’ were 81 and 116 respectively whereas that of laboratory samples after 30 days of storage varied from 44-73 for phase-1, from 45-94 for phase-2 and from 54-110 for phase-3.. The total plate count for samples ‘B’&’C’ were noted as 35 and 70 respectively whereas that of

laboratory samples after 45 days of storage varied from 24-66 for phase-1, from 29-67 for phase-2 and from 32-68 for phase-3. The total plate count for sample 'E' was 60 whereas that of laboratory samples after 60 days of storage varied from 14-38 for phase-1, from 11-43 for phase-2 and from 14-44 for phase-3.. The yeast and mould count for samples 'A'&'D' were 12 and 14 respectively whereas that of laboratory samples after 30 days of storage varied from 7-21 for phase-1, from 10-26 for phase-2 and from 5-13 for phase-3. The yeast and mould count for samples 'B'&'C' were noted as 10 and 13 respectively whereas that of laboratory samples after 45 days of storage varied from 5-12 for phase-1, from 6-12 for phase-2 and from 5-9 for phase-3.. The yeast and mould count for sample 'E' was 7 whereas that of laboratory samples after 60 days of storage varied from 2-7 for phase-1, from 3-7 for phase-2 and from 2-7 for phase-3.. Microbiological studies revealed that microbial load decreases with storage.

FLOW DIAGRAM FOR MANUFACTURE OF JAGGERY (GUR)

Sugarcane is taken & its leaves are removed manually, stored (*,D,=>)

or fed to crusher

↓

Juice is poured into tank through a wire mesh, stored (*,O)

or directly poured into the pan

↓

Filtered juice goes to first boiling pan through pipe (O,D)

↓

Clarificant deola is added (O,D)

↓

Semi clarified Juice is poured in second boiling pan (O,D,□)

↓

Scum is removed manually and more deola is added to juice in pan(=>,O,□)

↓

Castor oil and Hydros is added (*, O)

↓

Boiling juice is transferred to next boiling pan & more Hydros and Castor oil is added (=>,O)

↓

Juice is concentrated in the pan (O,□)

↓

Semi-solid mass is poured into open cooling pan (O,=>,D, □)

↓

Jaggery is now made into balls of particular weight by hand OR wrapped in wet cloth to make jaggery bricks of particular weight(O,=>, □)

↓

Cold jaggery is stacked and transported to market or storage unit (=>,S)

*** CCP**

=> TRANSPORTATION

D DELAY

O OPERATION

□ EXAMINATION

S STORAGE

Table. 4.6 Proximate Composition of Samples of Storage unit (*OD at 540 nm)

	Samples from storage unit				
Tests	**A-30 days**	**B-45 days**	**C-45 days**	**D-30days**	**E-60 days**
Total ash content	1.863	1.281	1.446	1.84	1.452
Acid insoluble ash	0.202	0.078	0.192	0.197	0.189
Water insoluble ash	0.758	0.413	0.709	0.706	0.712
Sulphated ash	2.66	1.876	2.169	2.446	2.18
Brix(°)	5.4	5.2	4.6	5.0	4.6
Reducing Sugar	10.38	11.73	11.52	10.26	12.38
Sucrose	75.65	73.21	72.52	76.21	68.73
Total Sugar	86.03	84.94	84.04	86.47	81.11
Moisture content (d.b.%)	7.48	6.53	5.72	5.74	4.47
Colour(O.D.*)	0.13	0.10	0.26	0.13	0.27
pH	5.41	5.39	5.48	5.45	5.2

Table.4.7 RESULTS OF PHYSICAL AND CHEMICAL TESTS, 30-DAYS(* OD at 540 nm)

PHASE	TESTS	Rudrapur mallik colony	Rudrapur Singh colony	Rudrapur Bhurarani unit-I	Rudrapur Bhurarani unit-II	Rudrapur Bhurarani unit-III	Kanakpur unit
I	Total ash content,%	3.389	2.527	2.793	2.543	2.499	3.122
	Acid insoluble ash,%	0.112	0.116	0.118	0.119	0.148	0..3
	Water insoluble ash,%	0.728	0.410	0.522	0.479	0.799	0.752
	Sulphated ash,%	3.376	3.520	3.661	2.856	3.212	4.107
	Reducing Sugar,%	12.02	11.82	11.93	12.20	12.53	11.42
	Sucrose,%	73.99	74.12	74.31	73.07	72.88	75.11
	Total Sugar	86.01	85.94	86.24	85.27	85.41	86.53
	Moisture content (d.b. %)	11.24	10.62	11.42	10.44	10.71	9.10
	Colour (O.D.*)	0.36	0.52	0.26	0.46	0.36	0.48
	pH	5.47	5.40	5.38	5.36	5.26	5.49
	True density(g/cc)	1.583	1.442	1.587	1.571	1.645	1.499
	Free sulphur dioxide,ppm	3.389	2.527	2.793	2.543	2.499	3.122
II	Total ash content,%	3.381	2.428	2.873	2.682	2.512	2.799
	Acid insoluble ash,%	0.118	0.120	0.124	0.128	0.215	0.123
	Water insoluble ash,%	1.048	0.610	0.656	0.592	1.114	0.926
	Sulphated ash,%	3.512	3.714	3.8210	3.010	3.662	4.112
	Reducing Sugar,%	12.32	12.66	13.39	12.98	13.52	12.47
	Sucrose,%	72.89	73.14	70.91	72.86	70.99	73.01
	Total Sugar	85.21	85.8	84.3	85.84	84.51	85.48
	Moisture content (d.b. %)	10.04	9.05	11.21	10.03	9.72	9.98
	Colour (O.D.*)	0.36	0.40	0.28	0.48	0.36	0.47
	pH	5.23	5.11	5.19	5.21	5.22	5.23
	True density(g/cc)	1.571	1.436	1.596	1.573	1.654	1.499
III	Total ash content,%	3.861	2.837	2.898	2.959	2.682	2.884
	Acid insoluble ash,%	0.286	0.297	0.112	0.135	0.253	0.142
	Water insoluble ash,%	0.811	0.844	0.727	0.796	0.952	0.886
	Sulphated ash,%	3.344	3.414	3.455	4.268	4.548	4.21
	Reducing Sugar,%	13.10	11.72	11.75	12.16	11.36	11.37
	Sucrose,%	73.65	76.13	73.75	75.49	76.97	75.69
	Total Sugar	86.75	87.85	85.5	87.65	88.33	87.06
	Moisture content (d.b. %)	9.426	11.07	9.285	11.6	12.32	11.69
	Colour (O.D.*)	0.18	0.25	0.32	0.33	0.31	0.19
	pH	5.23	5.21	5.26	5.23	5.30	5.41
	True density(g/cc)	1.512	1.406	1.574	1.559	1.633	1.419

Table.4.8 RESULTS OF PHYSICAL AND CHEMICAL TESTS, 45-DAYS(* OD at 540 nm)

PHASE	TESTS	Rudrapur mallik colony	Rudrapur Singh colony	Rudrapur Bhurarani unit-I	Rudrapur Bhurarani unit-II	Rudrapur Bhurarani unit-III	Kanakpur unit
I	Total ash content,%	3.573	2.479	2.614	2.716	2.576	3.210
	Acid insoluble ash,%	0.215	0.273	0.265	0.234	0.376	0.222
	Water insoluble ash,%	0.773	0.485	0.497	0.452	0.896	0.733
	Sulphated ash,%	3.476	3.672	3.718	2.972	3.591	3.981
	Reducing Sugar,%	12.19	12.01	12.0	12.27	12.59	11.98
	Sucrose,%	73.16	73.91	74.06	72.92	72.53	74.86
	Total Sugar	85.35	85.92	86.1	85.19	85.12	86.84
	Moisture content (d.b. %)	10.51	10.14	10.86	9.62	9.83	8.82
	Colour (O.D.*)	0.39	0.52	0.28	0.47	0.38	0.52
	pH	5.45	5.39	5.37	5.32	5.24	5.48
	True density(g/cc)	1.583	1.450	1.587	1.574	1.647	1.501
	Free sulphur dioxide,ppm	3.573	2.479	2.614	2.716	2.576	3.210
II	Total ash content,%	3.574	2.361	2.511	2.916	2.596	3.123
	Acid insoluble ash,%	0.220	0.281	0.273	0.296	0.339	0.286
	Water insoluble ash,%	1.136	0.683	0.656	0.592	1.120	0.943
	Sulphated ash,%	3.10	3.24	3.20	2.61	3.15	3.82
	Reducing Sugar,%	12.46	12.87	13.52	13.21	13.76	12.68
	Sucrose,%	72.64	72.83	70.54	72.59	70.76	72.89
	Total Sugar	85.1	85.7	84.06	85.8	84.52	85.57
	Moisture content (d.b. %)	9.63	8.72	10.54	9.71	9.24	9.56
	Colour (O.D.*)	0.39	0.44	0.30	0.52	0.40	0.52
	pH	5.20	5.09	5.17	5.18	5.19	5.20
	True density(g/cc)	1.573	1.436	1.597	1.575	1.657	1.499
III	Total ash content,%	3.638	2.614	2.633	3.064	2.787	3.021
	Acid insoluble ash,%	0.299	0.310	0.170	0.330	0.448	0.228
	Water insoluble ash,%	0.819	0.851	0.401	0.799	0.956	0.864
	Sulphated ash,%	3.171	3.241	3.444	3.858	4.098	3.959
	Reducing Sugar,%	12.15	10.77	10.91	11.19	10.42	10.72
	Sucrose,%	76.14	78.62	76.61	78.21	78.99	78.33
	Total Sugar	88.29	89.39	87.52	89.4	89.41	89.05
	Moisture content (d.b. %)	8.972	10.64	8.78	11.05	11.75	10.78
	Colour (O.D.*)	0.18	0.25	0.28	0.32	0.29	0.19
	pH	5.20	5.19	5.17	5.26	5.35	5.41
	True density(g/cc)	1.673	1.567	1.324	1.312	1.386	1.312

Table.4.9 RESULTS OF PHYSICAL AND CHEMICAL TESTS, 60-DAYS (*liq-liquified)

PHASE	TESTS	Rudrapur mallik colony	Rudrapur Singh colony	Rudrapur Bhurarani unit-I	Rudrapur Bhurarani unit-II	Rudrapur Bhurarani unit-III	Kanakpur unit
I	Total ash content,%	3.621	2.315	2.582	2.793	2.622	3.298
	Acid insoluble ash,%	0.323	0.311	0.333	0.308	0.411	0.319
	Water insoluble ash,%	0.819	0.513	0.411	0.519	0.932	0.716
	Sulphated ash,%	3.266	3.332	3.516	2.893	3.110	3.874
	Reducing Sugar,%	12.31	12.13	12.18	12.33	12.65	12.01
	Sucrose,%	73.01	73.62	73.94	72.84	72.21	74.52
	Total Sugar	85.32	85.75	86.12	85.17	84.86	86.53
	Moisture content (d.b. %)	10.18	9.98	10.42	9.03	9.55	8.69
	Colour (O.D.*)	0.39	0.54	0.31	0.54	0.40	0.54
	pH	5.44	5.36	5.32	5.29	5.21	5.45
	True density(g/cc)	1.605	1.450	1.587	1.574	1.647	1.502
	Free sulphur dioxide,ppm	3.621	2.315	2.582	2.793	2.622	3.298
II	Total ash content,%	3.612	2.229	2.471	2.893	2.654	3.220
	Acid insoluble ash,%	0.311	0.328	0.342	0.369	0.418	0.321
	Water insoluble ash,%	1.211	0.718	0.610	0.711	1.135	0.914
	Sulphated ash,%	3.331	3.545	3.679	2.813	3.435	3.887
	Reducing Sugar,%	12.51	13.01	13.74	13.46	13.89	12.82
	Sucrose,%	72.31	72.56	70.32	72.28	70.43	72.68
	Total Sugar	84.82	85.57	84.06	85.74	84.32	85.5
	Moisture content (d.b. %)	9.11	8.03	10.13	9.14	8.95	9.19
	Colour (O.D.*)	0.40	0.46	0.34	0.54	0.40	0.54
	pH	5.19	5.07	5.16	5.16	5.14	5.17
	True density(g/cc)	1.573	1.436	1.599	1.575	1.657	1.499
III	Total ash content,%	2.907	2.356	2.339	3.184	Liq..	3.163
	Acid insoluble ash,%	0.529	0.332	0.246	0.451	Liq.	0.318
	Water insoluble ash,%	0.978	0.859	0.147	0.821	Liq.	0.840
	Sulphated ash,%	4.578	3.060	3.427	4.358	Liq.	3.657
	Reducing Sugar,%	9.69	9.92	10.75	10.36	Liq.	9.7
	Sucrose,%	81.09	81.33	78.84	80.41	Liq.	81.53
	Total Sugar	90.78	91.25	89.59	90.77	Liq.	91.23
	Moisture content (d.b. %)	11.01	10.83	8.01	10.32	Liq.	9.61
	Colour (O.D.*)	0.28	0.24	0.23	0.31	Liq.	0.16
	pH	5.40	5.13	5.10	5.30	Liq.	5.52
	True density(g/cc)	1.197	1.633	1.203	1.119	Liq.	1.202

Table 4.10 RESULTS OF MICROBIOLOGICAL TESTS OF STORED SAMPLES OF PHASE-I

		Storage unit samples		Samples stored in lab. Conditions					
Days	**Tests**	**A**	**D**	**K**	**S.C**	**M-I**	**M-II**	**M-III**	**M.C**
30 days	**Total Plate Count**	81	116	56	62	44	59	73	48
	Coliform Count	1	2	1	1	1	1	2	2
	Yeast and Mould Count	12	14	9	7	12	16	21	10
		B	**C**	**K**	**S.C**	**M-I**	**M-II**	**M-III**	**M.C**
45 days	**Total Plate Count**	35	70	28	31	24	40	66	39
	Coliform Count	0	1	0	0	0	0	0	0
	Yeast and Mould Count	10	13	6	5	9	10	12	6
60 days		**E**		**K**	**S.C**	**M-I**	**M-II**	**M-III**	**M.C**
	Total Plate Count	60		16	14	16	25	38	27
	Coliform Count	1		0	0	0	0	0	0
	Yeast and Mould Count	7		2	3	3	5	7	2

*** K** represents Kanakpur unit, **S.C** represents Singh colony unit, **B-I**, **B-II** and **B-III** represents Bhurarani units and **M.C** represents Mallik colony unit.

Table 4.11 RESULTS OF MICROBIOLOGICAL TESTS OF STORED SAMPLES OF PHASE-II

		Storage unit samples		Samples stored in lab. Conditions					
Days	**Tests**	**A**	**D**	**K**	**S.C**	**M-I**	**M-II**	**M-III**	**M.C**
30 days	**Total Plate Count**	81	116	53	68	45	76	94	66
	Coliform Count	1	2	1	1	2	1	3	1
	Yeast and Mould Count	12	14	10	17	14	14	19	26
		B	**C**	**K**	**S.C**	**M-I**	**M-II**	**M-III**	**M.C**
45 days	**Total Plate Count**	35	70	49	53	29	36	67	50
	Coliform Count	0	1	0	0	0	0	0	0
	Yeast and Mould Count	10	13	7	8	10	6	12	10
60 days		**E**		**K**	**S.C**	**M-I**	**M-II**	**M-III**	**M.C**
	Total Plate Count	60		15	21	11	24	39	43
	Coliform Count	1		0	0	0	0	0	0
	Yeast and Mould Count	7		4	3	3	5	7	6

*** K** represents Kanakpur unit, **S.C** represents Singh colony unit, **B-I**, **B-II** and **B-III** represents Bhurarani units and **M.C** represents Mallik colony unit.

Table 4.12 RESULTS OF MICROBIOLOGICAL TESTS OF STORED SAMPLESOF PHASE-III

		Storage unit samples		**Samples stored in lab. Conditions**				
Days	**Tests**	**A**	**D**	**K**	**S.C**	**B-I**	**B-II**	**M.C**
30 days	**Total Plate Count**	81	116	66	103	110	54	56
	Coliform Count	1	2	1	4	1	1	0
	Yeast and Mould Count	12	14	13	13	12	5	10
		B	**C**	**K**	**S.C**	**B-I**	**B-II**	**M.C**
45 days	**Total Plate Count**	35	70	32	33	68	44	50
	Coliform Count	0	1	0	0	0	0	0
	Yeast and Mould Count	10	13	5	6	7	6	9
60 days		**E**		**K**	**S.C**	**B-I**	**B-II**	**M.C**
	Total Plate Count	60		14	23	44	36	30
	Coliform Count	1		0	0	0	0	0
	Yeast and Mould Count	7		2	3	5	3	7

*** K** represents Kanakpur unit, **S.C** represents Singh colony unit, **B-I** and **B-II** represents Bhurarani units and **M.C** represents Mallik colony unit. **B-III** values are not written as it was liquefied.

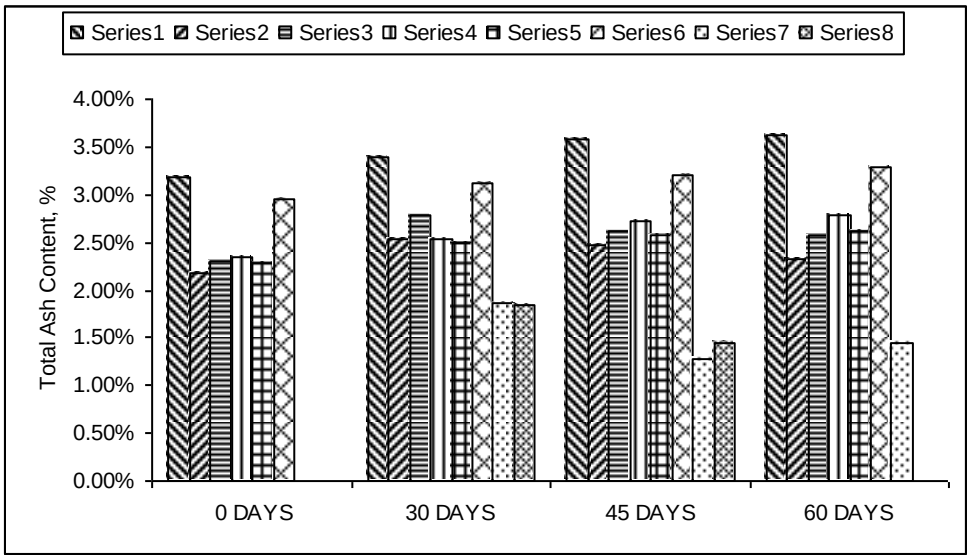


Fig4.25. Total Ash Content of jaggery samples (phase-I)

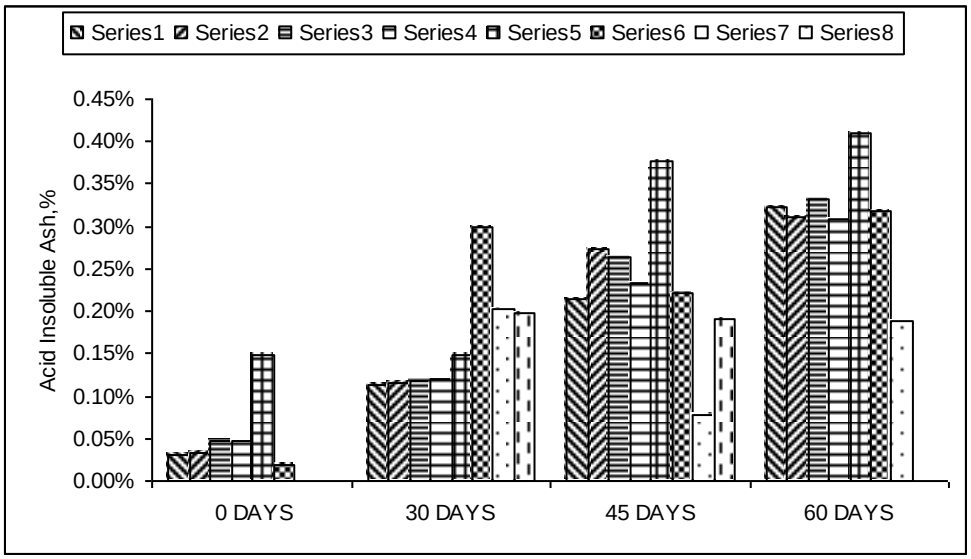


Fig4.26. Acid Insoluble Ash Content of jaggery samples (phase-I)

* Series 1-6 represents Units 1-6 . 7 and 8 represents A, D for 30 days and B,C for 45 days data. For 60 days 7 represents sample E

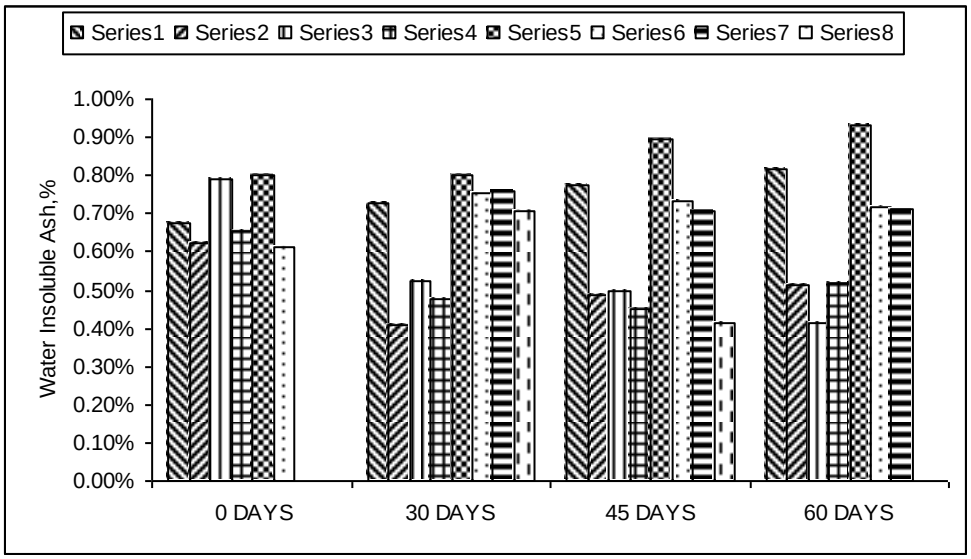


Fig4.27. Water Insoluble Ash Content of fresh jaggery samples (phase-I)

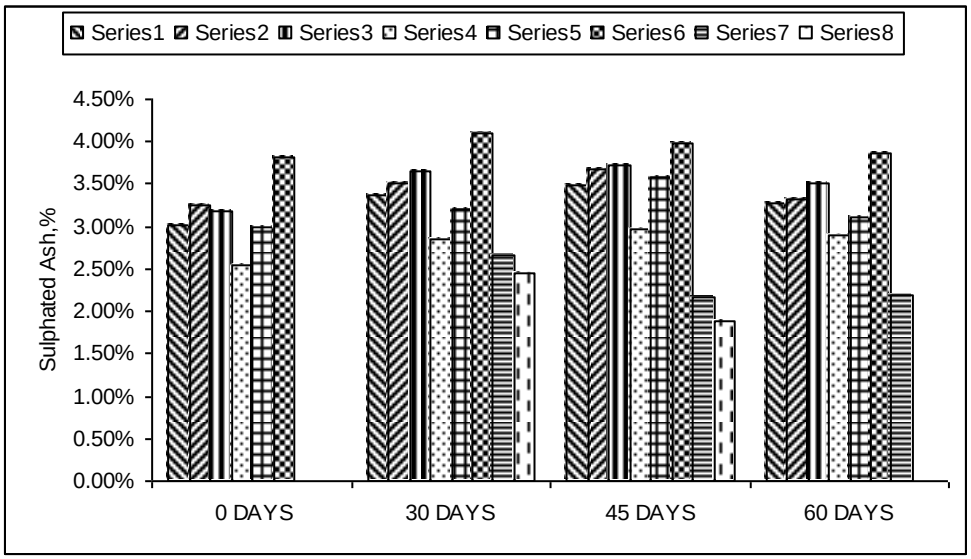


Fig4.28. Sulphated Ash Content of fresh jaggery samples (phase-I)

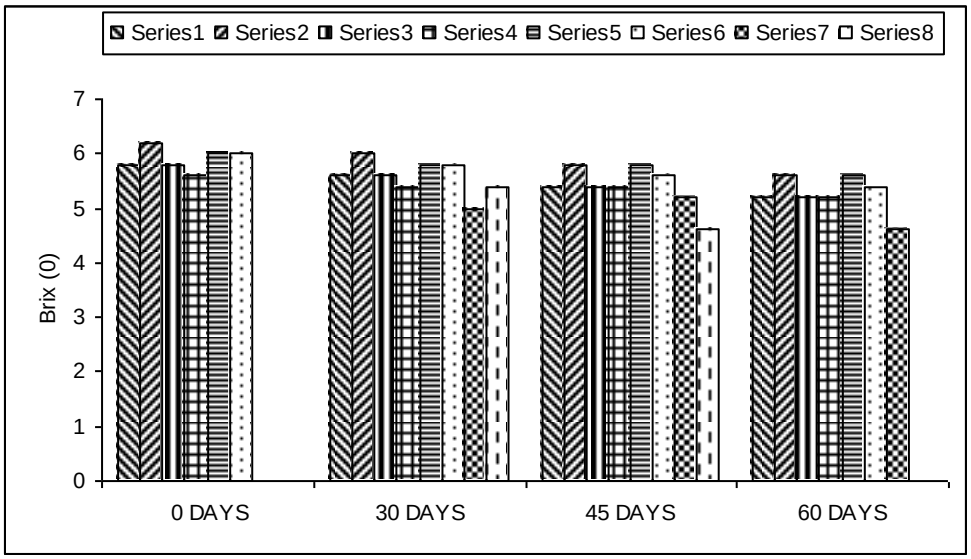


Fig4.29. Reducing Sugar Content of jaggery samples (phase-I)

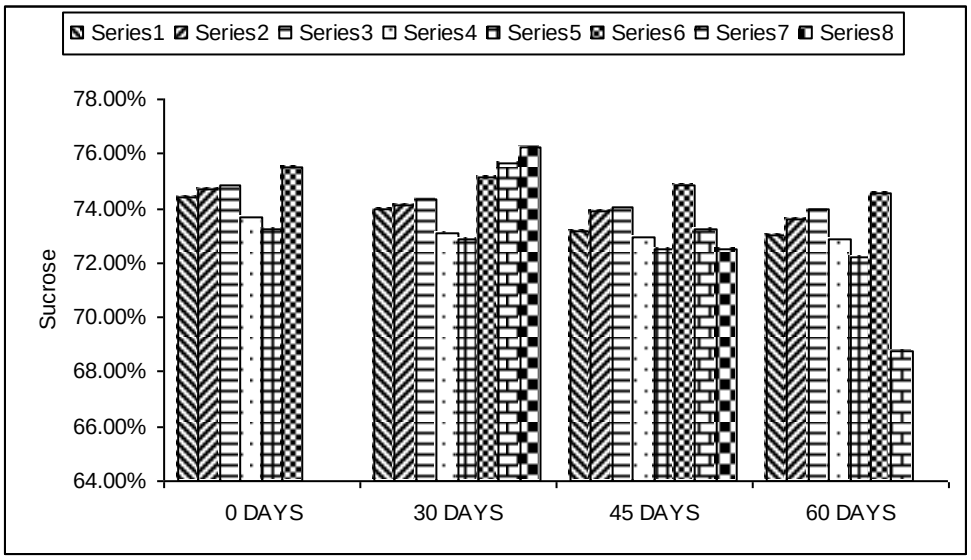


Fig4.30. Sucrose Content of jaggery samples (phase-I)

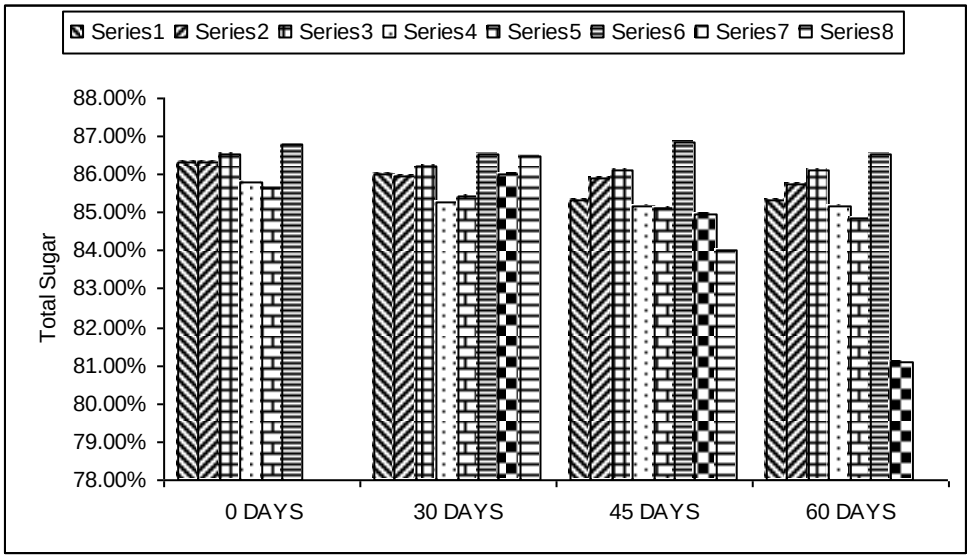


Fig4.31. Total Sugar Content of jaggery samples (phase-I)

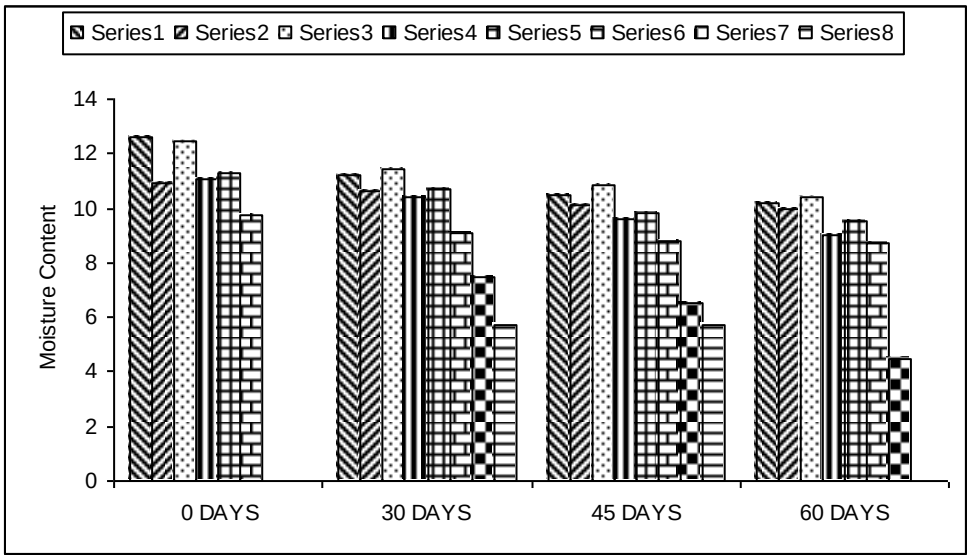


Fig4.32. Moisture Content of jaggery samples (phase-I)

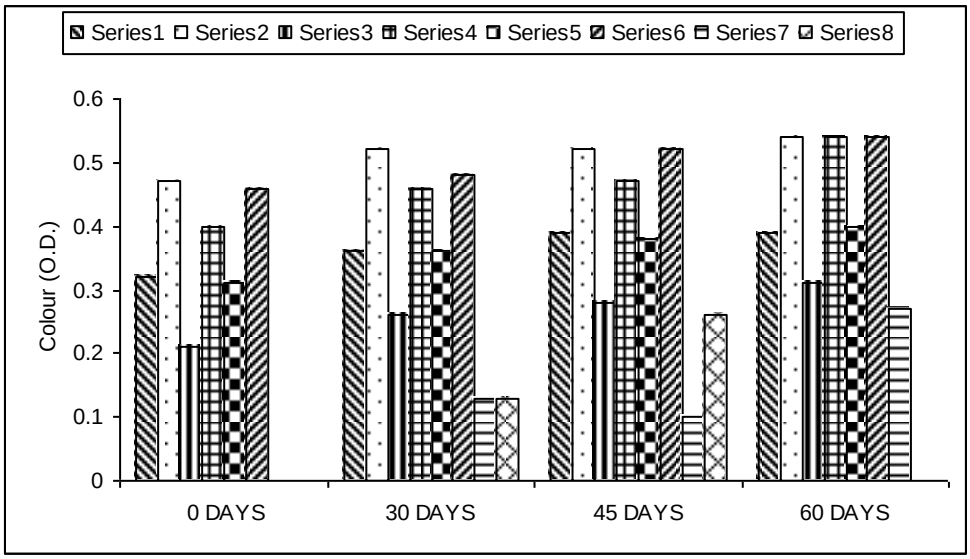


Fig4.33. Color of jaggery samples (phase-I)

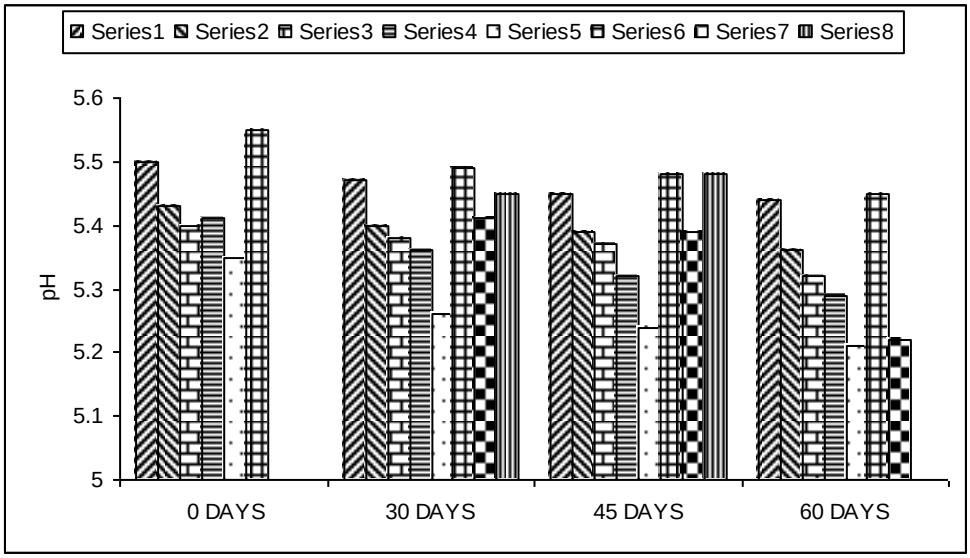


Fig4.34. pH of jaggery samples (phase-I)

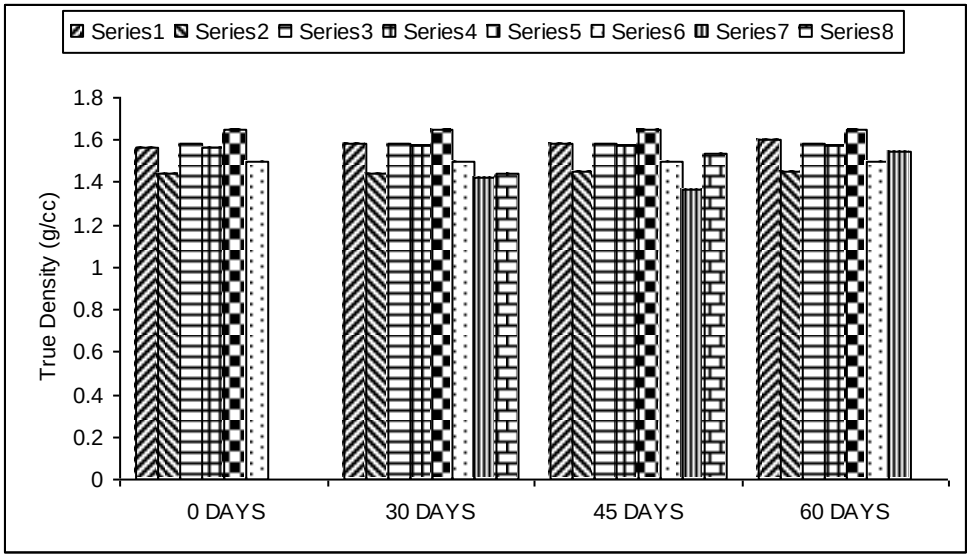


Fig4..35. True Density of jaggery samples (phase-I)

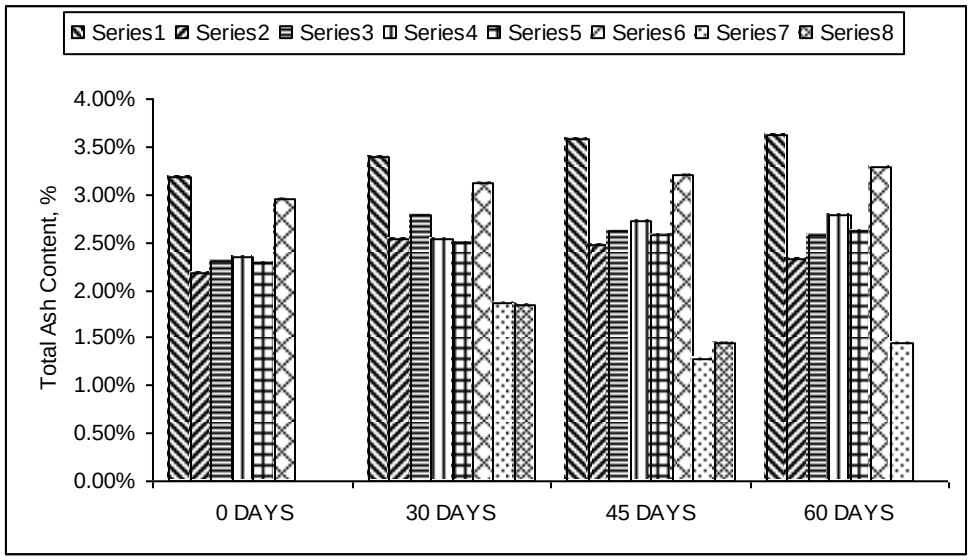


Fig.4.36 Total Ash Content of jaggery samples (phase-II)

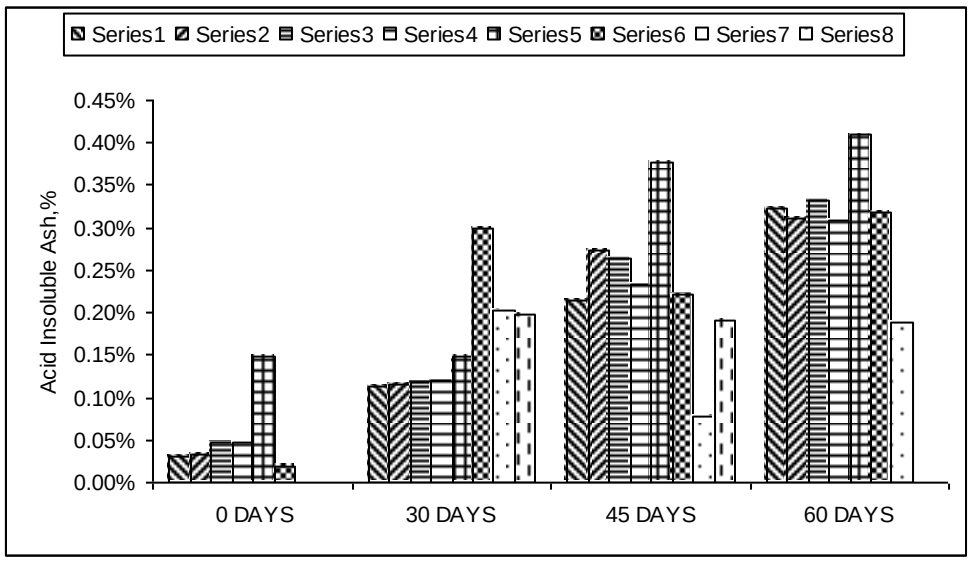


Fig.4.37 Acid Insoluble Ash Content of jaggery samples (phase-II)

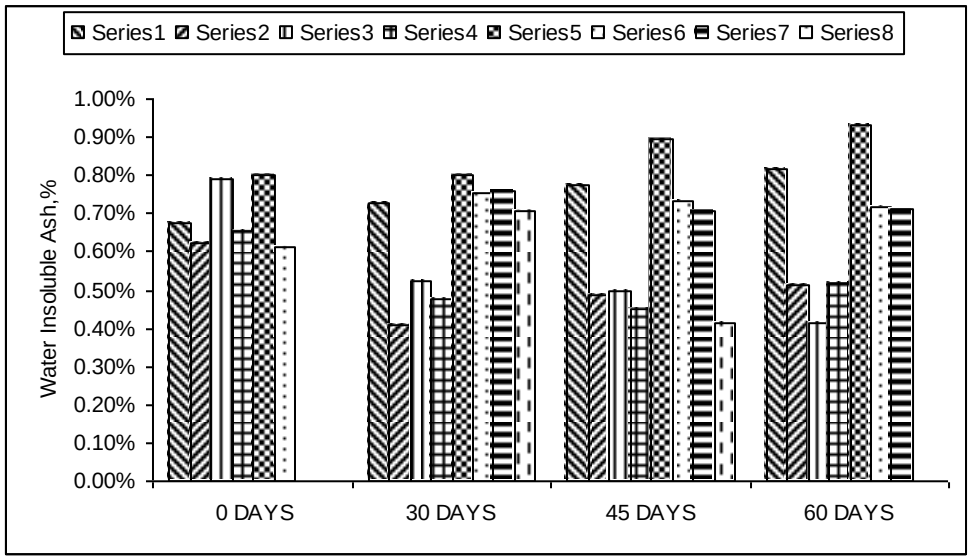


Fig.4.38 Water Insoluble Ash Content of fresh jaggery samples (phase-II)

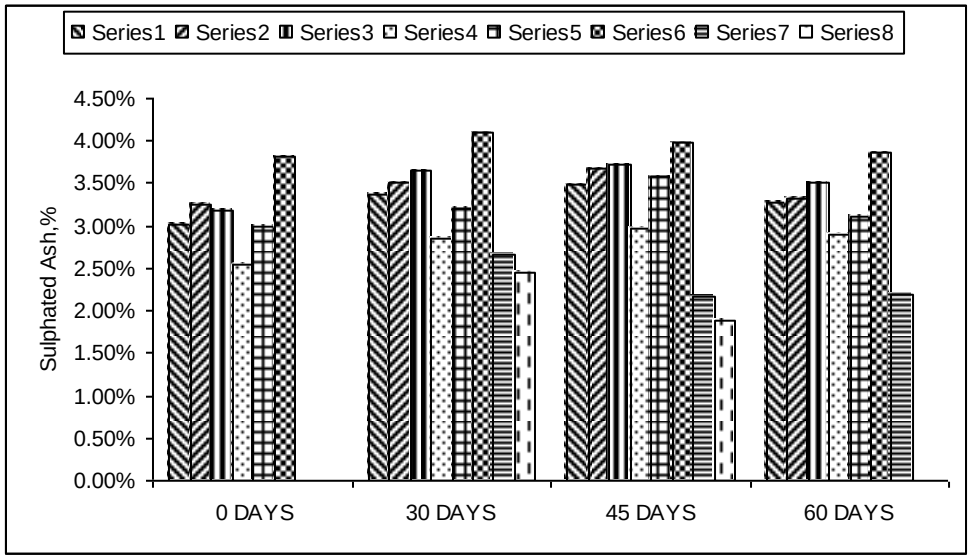


Fig.4.39 Sulphated Ash Content of fresh jaggery samples (phase-II)

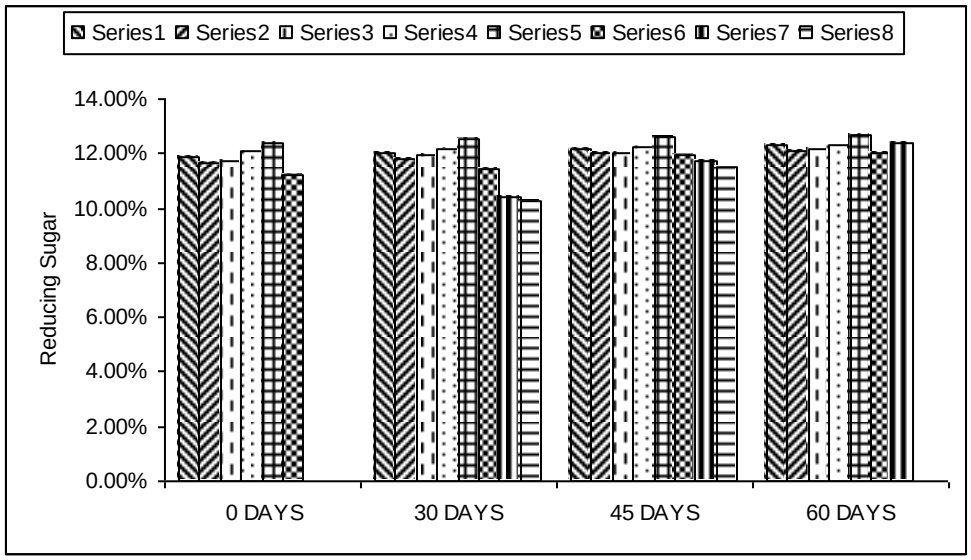


Fig.4.40 Reducing Sugar Content of jaggery samples (phase-II)

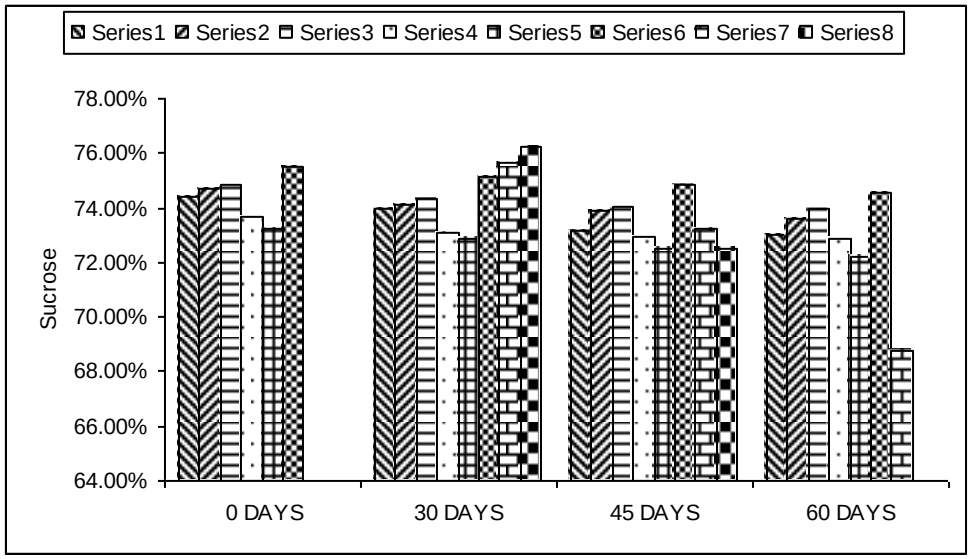


Fig4.41. Sucrose Content of jaggery samples (phase-II)

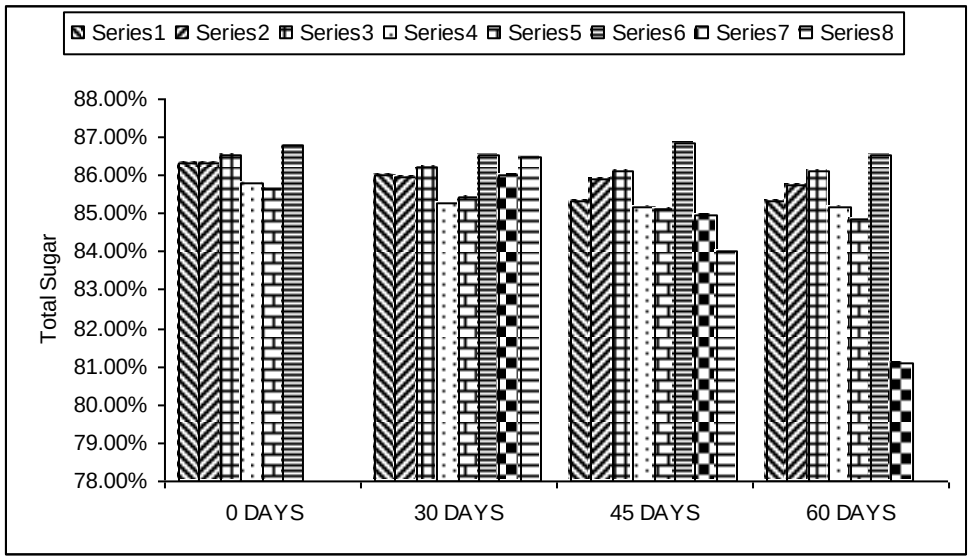


Fig4.42. Total Sugar Content of jaggery samples (phase-II)

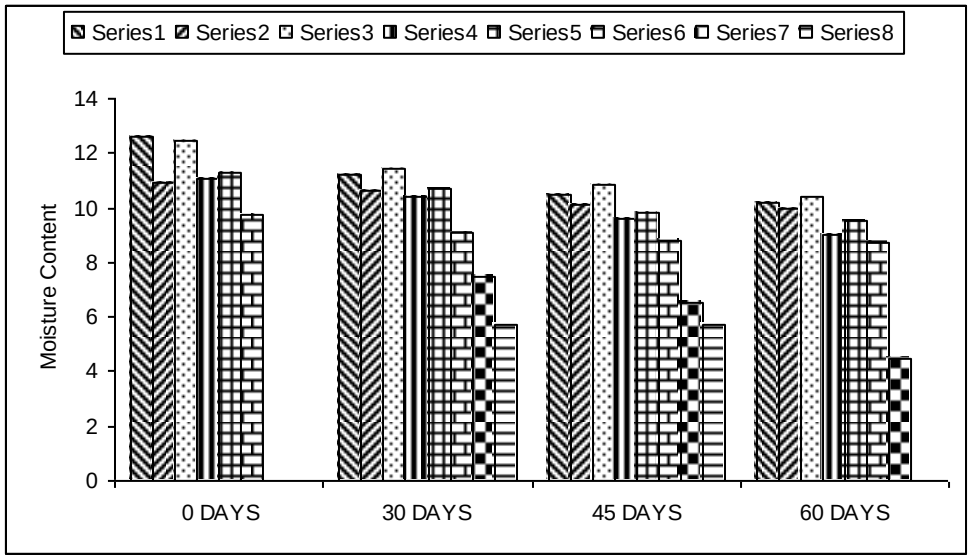


Fig4.43. Moisutre Content of jaggeryu samples (Phase II)

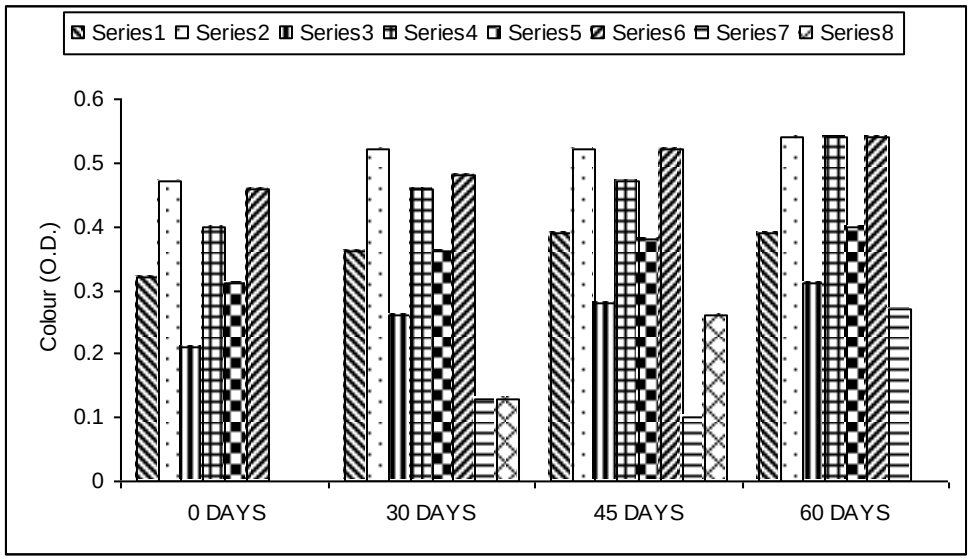


Fig.4.44 Color of jaggery samples (phase-II)

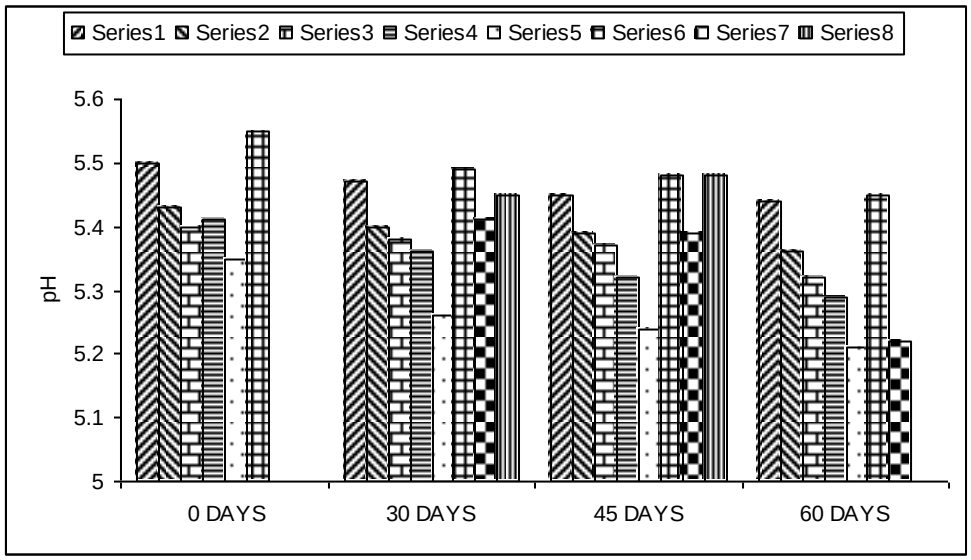


Fig.4.45 pH of jaggery samples (phase-II)

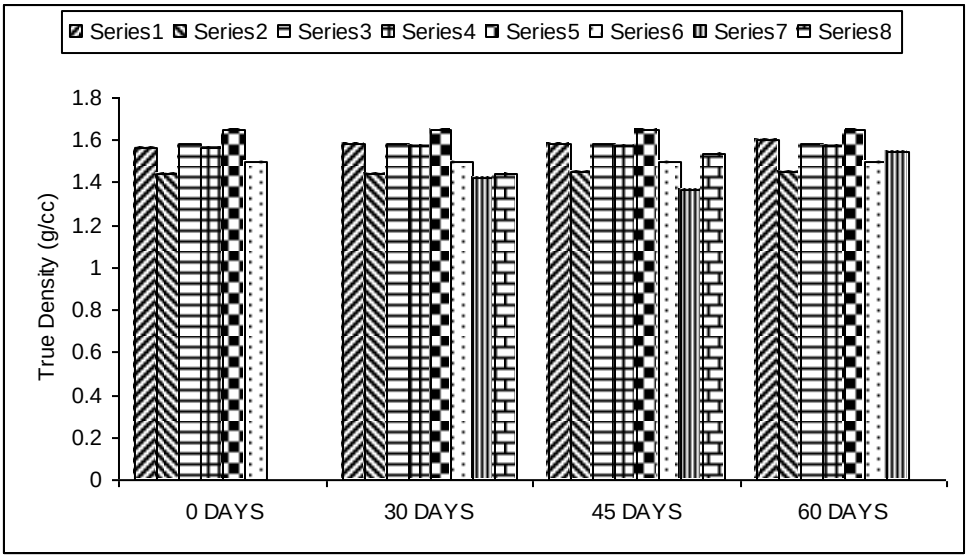


Fig4.46. True Density of jaggery samples (phase-II)

6 Summary and Conclusions

Jaggery is considered to be best of all sugarcane preparations. It promotes digestion and has on overall nourishing effects on health. Jaggery occupies an important role in rural diet, post harvest cottage industry and agricultural economy of India. India produces more than 70% of the total jaggery production of the world. Jaggery and khandsari sector provides employment to over 3 million people. Since, the demand of this traditional, least expensive, nutritive sweetener is increasing, this industry would continue playing its role in processing of sugarcane at rural level for the production of sweeteners and in addition this will also create better employment opportunity to people in rural areas. Being an eco-friendly sweetener, with additional nutritive value, jaggery holds good export potential. To sustain the market and export potential of jaggery, it is imperative that the jaggery quality is enhanced. Since, most of the jaggery is produced at village level, there is poor or no quality control. Hence a cost effective, simple and useful food safety management system is needed to improve the quality of jaggery.

Preventive measure "Hazard Analysis and Critical Control Point evaluation" can serve as an important tool for safety management that can ensure that system used, produces a standard acceptable product with respect to nutrition, purity and wholesomeness. 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 is a careful balance between the scientific approach that emphasizes the need for the system to be effective in controlling the food safety hazards and the pragmatic approach that recognizes the need for the system to be practical and cost effective. The HACCP system of food protection is being increasingly employed in large manufacturing operations but due to widespread consumer unawareness small and/or less developed businesses are unable to adopt HACCP to produce good quality hygienic foods.

Research on the application of HACCP system has been limited. Application of HACCP has been confined to some food industries like coffee industry, ice-cream industry etc. However, HACCP system has not been applied to less developed industries like jaggery manufacturing units. Hence, there is a great need to study the quality control aspects to manufacture good quality jaggery.

The present research therefore was directed towards identifying various potential hazards, deciding the critical control points among the operational steps and their control limits.

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). Samples were drawn during the process, starting from crushing of juice upto the storage of jaggery. These samples were further analyzed in the laboratory to check whether they meet the levels as specified by BIS or not. After this, one storage unit was surveyed to find out the hazards

associated with it if any. Samples were collected from each section of godown and were analyzed in the laboratory. The results thus obtained were compared with that of samples stored in the laboratory conditions and the variations were noted. The samples were also tested to estimate the microbiological status of jaggery samples at different time intervals and it can be observed from the results that fresh jaggery samples show more microbiological load than stored ones. None of the samples show heavy load of coliforms. The data obtained from swab test for assessment of cleanliness of surface, revealed that microbiological contamination was maximum from the cloth used to wrap the jaggery to mould it into different shapes.

Based on survey reports of hazard analysis and results of analysis of jaggery in the laboratory, the following conclusions could be drawn:

1. 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 jaggery.
2. The results of proximate analysis of composition of jaggery revealed that in all the three phases of experiments, total ash content, reducing sugar content, sucrose content and free sulphur dioxide content were not within the limits i.e. 1.1%(max.), 10%(max.), 80%(min.) and 50ppm respectively as specified

by BIS. The results revealed great variations from the specifications. The samples taken from storage units vary slightly from the samples stored in laboratory conditions. To avoid such variations from specifications proper manufacturing steps should be followed.

3. Storing of sugarcane long (4-8 days) before use resulted in losses due to inversion of sucrose, remarkable increase in reducing sugar content and requirement of excess clarificant. All these deteriorate the quality of jaggery, hence this step is considered to be critical. It is recommended that sugarcanes should be used within 72 hours of storage to prevent losses.

4. Use of sugarcane juice stored for 7- 9 h is usual practice during summer season. This resulted in inversion of sucrose and remarkable changes in its proximate composition. Hence, this step is considered as critical from quality point of view and need to be controlled. It is recommended that sugarcane juice should not be stored for more than 2 hours to prevent inversion.

5. 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).

Literature Cited

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.L.; Dua,S.P.; Dubey,V. and Dixit,G.S.1985. A resume of workdone for manufacture and storage in: Proceedings of National Seminar-cum-Group Discussion on jaggery manufacture and storage. pp-67-71.

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.

Anonymous. 1996. A report on accomplishment of AICRP on processing, handling and storage of jaggery and Khandsari.

Anonymous. 1992-93. Jaggery Packaging. Annual Report of Indian Institute of Sugarcane Research.pp-103.

Anonymous. 2001-02. Study of effect of gur storage methods and packaging materials on gur quality attributes. Annual Report of Indian Institute of Sugarcane Research.pp-50.

Anonymous.1998. Hazard analysis and critical control point principles and application guidelines. *Journal of food protection*. **61:**762-775.

Banerji, R.; Nandlal.; Ramsevak. and Madan, V.K.2001. Studies on moisture absorption in jaggery with different levels of reducing sugar under storage. *Indian Journal of Sugarcane Technology*. **16(2):** 85-87.

Bauman,H.E.1974. The HACCP concept and microbiological hazard categories. *Food Technology*. **28:**30-34.

Bhat, R.V.and Vasanthi, S.1998. Mould damaged coffee-Its implication on human health and prevention through HACCP system. *Indian Coffee*.**62:**3-4.

Bhat,R.V. and Vasanthi,S.2000. Meeting International Trade requirements of agricultural produce by a quality evaluation approach. *Indian Food Industry*. **19(2):**135-138.

Biss,M.E. and Hathaway,S.C.1995. Microbiological and visible contamination of lamb carcasses according to preslaughter presentation status: Implications for HACCP. *Journal of Food Protection*. **58(7):**776-783.

Bolton,D.J.; Oser,A.H.; Cocoma,G.J.; Palumbo,S.A. and Miller, A..J.1999. Integrating HACCP and TQM reduces pork carcass contamination. *Food Technology*. **53(4):**40-42.

Bryan, F.L.1990. Hazard Analysis and Critical Control Point (HACCP) systems for retail food and restaurant operations. *Journal of food protection*. **53(11):**978-983.

Bryan, F.L.1981. Hazard Analysis of food service operations. *Food Technology*.**34:**78-87.

Bryan,F.L.; Jermini,M.; Schmitt,R.; Chilufya,E.N.; Michael,M.; Matoba,A.; Mfume,E. and Chibiya,H.1997. Hazards associated with holding and reheating foods at vending sites in a small town in Zambia. *Journal of Food Protection*. **60(4):**391-398.

Bryen,F.L.1990. Application of ready-to-eat chilled foods. *Food Technology*. **44(7):**70-76.

Busta,F.2002. Food Safety Objectives aid in risk management. *Food Technology*. **56(3):**24.

Chockalingam, B. 1985. Gur manufacturing in TamilNadu -A review. In: Proceeding of National Seminar -cum -group discussion on jaggery manufacture and storage. 94-98.

Garrett,E.S.and Hudak-Roos,M.1990. Use of HACCP for seafood surveillance and certification. *Food Technology*. **44(7):**159-164.

Garrett,E.S.; Jahncke,M.L. and Tennyson,J.M.1997. Microbiological hazards and emerging food safety issues associated with seafoods. *Journal of Food Protection.* **60(11):**1409-1415.

Giese,J.2000. Optimizing processes for quality and safety. *Food Technology*. **54(9):**88-91.

Ingle,N.J. and Kanwade,L.R.1982. Effect of storability on quality of jaggery. *Indian Sugar*.15-18.

IS:12923:1990. Specifications for composition of jaggery. Indian Standard Institution, New Delhi.

IS:6151:1976. Specifications for storage management code. Indian Standard Institution, New Delhi.

Ito, K.1974. Micribiological critical control points in canned foods. *Food technology*, **29 (2)**:46-48.

Jadhav,H.D.; Mungare, T.S.; Patil, J.P.; Hasure, R.R.; Jadhav,B.S. and Jaswant Singh.2001. Effect of staling of sugarcane on juice and jaggery quality. *Cooperative Sugar*. **32(10):**821-825.

Jaiswal, A.K.1999. Quality control in chocolate industry. *Indian food Industry.***18(2)**:94- 97.

Jaiswal, A.K.2000.Hazard analysis in frozen foods. *Indian Food Industry.* **19(2)**:129-134.

Javalekar,D.R.; Shinde,B.N. and Randive.S.J.1985. Use of different clarificants in jaggery making-Effect on physical properties. *Indian Sugar*. **35(3):**193-199.

Javalekar,D.R.; Shinde,B.N. and Randive.S.J.1985. Use of different clarificants in jaggery making-Effect on chemical properties. *Indian Sugar*. **35(4):** 253-260.

Kulshreshtha,M. and Singh,A.2006. Measurement techniques for jaggery properties.pp-22.

Kumar,P.; Dewani; Susheel and Jayaprakasha,H.M.2005. Quality and Process control in the food industry. *Bevarage and Food World*. **32(10):**19-21.

Lal,U.; Srivastava,S.C.; Sharma,R.K. and Verma.S.K.1985. Effects of clarificants on quality of gur prepared from lodged cane. *Bhartiya Sugar*:41-49.

Larson,A.E.; Johnson,E.A.; Barmore,C.R. and Hughes,M.D.1997. Evaluation of the Botulism hazard from vegetables in modified atmosphere packaging. *Journal of Food Protection.* **60(10):**1208-1214.

Leoni, E.; Legnani, P.P.; Corradini, N. and Lucano, A.2003. Analysis of Critical Control Point in the production and distribution line of fresh vegetable products. *Industrie-Alimentari* (Italy). **42(424):** 361-366.

Londle, M.H.and Yadav,S.Y.1989. Effect of stale cane on clarification. *Bhartiya Sugar*:27-29.

Majumdar, G. and Bose, S. 1985. A review on the methods of reducing sugars-reduction methods. *Indian Sugar* :349-353.

Mehta, A.; Ranote, P.S. and Bawa, A.S.2002. Indian fruit processing Industry-quality control aspects. *Indian Food Industry*. **21(1):**37-40.

Mungare,T.S.; Jadhav,H.D.; Patil,J.P.; Hasure,R.R.; Jadhav,B.S. and Singh,J.2000. Clarification technique for producing quality jaggery. *Cooperative Sugar*. **32(4):**283-285.

Notermans, S.; Zwitering, M.H. and Mead, G.C.1994. The HACCP concept: Identification of potentially hazardous micro-organisms. *Food Microbiology*. **11(3):**203-214.

Notermans, S.; Gallhoff, G; Zwietering, M.H. and Mead, G.C.1995. The HACCP Concept: specification of criteria using quantitative risk assessment. *Food microbiology*. **11(5):**397-408.

Notermans, S.; Gallhoff, G; Zwietering, M.H. and Mead, G.C.1995. Identification of critical control points in the HACCP system with a quantitative effect on the safety of food products. *Food microbiology*. **12(2):**93-98.

Notermans,S. and Borgdorff,M.1997. A Global perspective of foodborne disease. *Journal of food protection*. **60(11):**1395-1399.

Omaye.S.T.2002. Evaluating food supplement safety. *Food Technology*. **56(11):**23.

Pandey, J. P. and Narain, M. 1993. Background paper on technology of gur manufacture and storage. In: Proceeding of the workshop on University Industry Collaboration, March 1-2, Pantnagar.

Park, W.H. and Lee, S.H.2003. The application of HACCP system to soybean curd and its effectiveness. *Journal of Food Hygiene and Safety*. **18(4):** 202-210.

Patil, J. P.; Jadhav, H. P.; Hasadnis, A. B.; Singh, Jaswant; Wandre, S. S. and Hasene, R. R. 1993. Research Bulletin of liquid jaggery (Kakvi).Kolhapur, MS 416005.

Peterson, A.C. and Gunnerson, R.E.1974. Microbiological critical control points in frozen foods. *Food Technology*. **28:**37-44.

Premavalli, K.S.2000. Standardization systems for quality control of foods. *Indian Food Industry*. **19(2):**116-128.

Rajalakshmi.1983. The microbiological quality of ice-creams sold in Hyderabad city. *Journal of Food Science and Technology*. **20(2):** 19-20.

Ranganna, S. 1986. Handbook of Analysis of Quality Control of Fruit and Vegetable Products; 2nd Ed; Tata Mc Hill Publication, New Delhi.

Rao, C.B.J.1997. Food Processing and need for quality control. *Indian Food Industry*. **16(1&2):**58-62.

Sarada,M. and Begum, M.1991. The microbiological quality of ice-creams sold in Bangalore city. *Journal of Food Science and Technology*. **28(5):** 317-318.

Sarkar, S.; Pal, R.; Das, S.; Jaiswal, P.; Adhikari, A.K. and Sur, A.2005. HACCP approach for safe ice-cream production. Indian Food Industry. **24(1):**64-66.

Shahi,H.N.; Singh,J. and Singh,P.2002. Products from sugarcane juice. *Indian Farming*. **51(2):** 57-58.

Shinde,B.N.; Marathe,A.B. and Kadam,S.K.1982. Changes in specific gravity,pH, reducing and non-reducing sugars during boiling of sugarcane juice for preparation of jaggery. *Indian Sugar*. **32(2):**89-93.

Shinde,B.N.; Marathe,A.B.; Javalekar,D.V. and Kadam,S.K.1983. Effect of form and colour of polythene-The wrapping material on keeping quality of jaggery during storage. *Indian Sugar*. **32(12):**937-940.

Singh,J.and Shahi,H.N.2002. Jaggery and Khandasari industry in India. *Indian Farming*. **51(2):** 59-60.

Sipola,G. and Liepins,E.2004. Microbiological evaluation in the manufacturing process of casein at the critical control points. Jelgava (Lativa). LLU VMF.

Snyder,O.P.1981.A Model Food Service Quality Assurance system. *Food Technology*. **34:**70-76.

Sohrab.2000. The quality standards for the new millennium ISO9000:2000. *Indian Food Industry*. **19(2):**98-106.

Sohrab.1997.HACCP through ISO 9000 quality management system. *Indian food Industry*. **16(3):**37-47.

Solomon,S.; Srivastava,K.K.; Bhatnagar,S.and Madan,V.K.1990. Post harvest changes in invertase activity and juice quality in sugarcane. *Indian Sugar*. **39(12):** 895-898.

Soriano,J.M.;Prieto,I.; Molto,J.C. and Manes,J.2005. A review of the application of the HACCP system to salads served in the restaurant of Valencia University. International Journal of Food Science and Technology. **40:**333-336.

Statistics.2002. *Indian Sugar.* **52(9):**134-135.

Stauffer,J.E. Quality assurance in cereal plants. *Cereal Foods World*. **36(1):**11-26.

Sudershan, R.V.; Rao, R.N. and Bhat, R.V.1997. Concepts of HACCP and traditional Food Industry-a case study of khoa. *Indian Food Industry,* **16(4)**:40-45.

Tauxe,R.; Kruse,H.; Hedberg,C.; Potter,M.; Madden,J. and Wachsmuth,K.1997. Microbial hazards and emerging issues associated with produce: A preliminary report to the National Advisory Committee on microbiologic criteria for foods. *Journal of Food Protection.* **60(11):**1400-1408.

Taylor.M.R.2002. Reforming food safety:A model for future. *Food Technology*. **56(5):**190-194.

Zwitering,M.2005. Practical considerations on food safety objectives. URL: www.google.com

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			

* Significant at 1% probability level

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

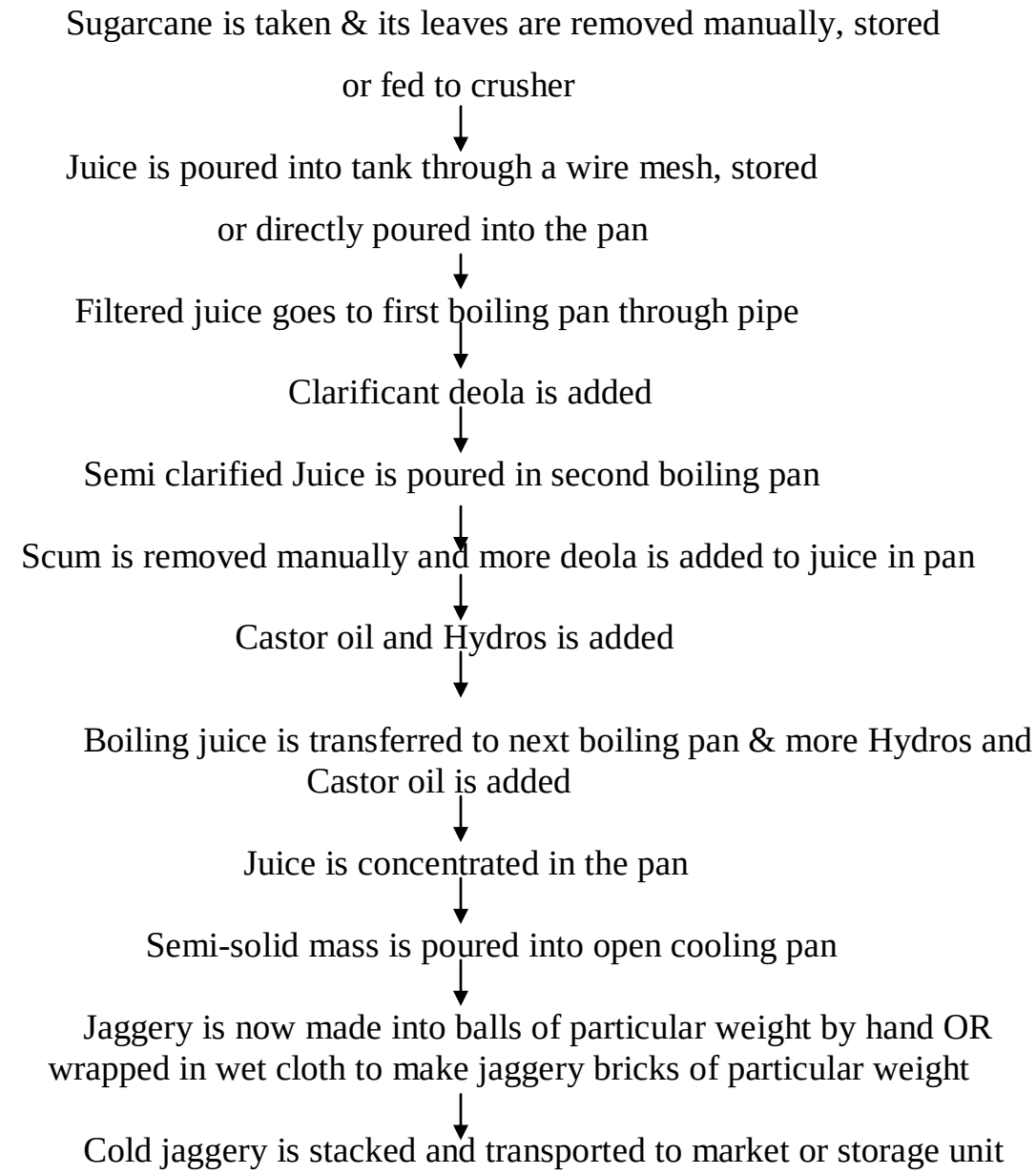
Appendix A-4. Data obtained after analysis of proximate composition of molassine jaggery manufactured in beripadav unit

TESTS	VALUES
Moisture content (d.b.%)	16.9827
Colour	0.77
pH	5.81
True Density(g/cc)	1.732
Total ash content (%)	4.95
Acid insoluble ash content (%)	0.249
Water insoluble ash content (%)	0.019
Sulphated ash content (%)	3.2
Reducing Sugar content (%)	30.85
Sucrose content (%)	12.63
Total Sugar content (%)	43.48

Appendix B-1. HAZARD IDENTIFICATION TABLE

STEPS						
	Physical		Chemical		Biological	
	Hazards	Preventive measures(if any)	Hazards	Preventive measures(if any)	Hazards	Preventive measures(if any)
1.Procurement of raw materials						
2. Extraction of sugarcane juice						
3. Clarification of filtered juice						
4. Concentration of clarified juice						
5.Cooling of jaggery						
6. Storage of jaggery						
7. Transportation						

Appendix B-2. FLOW DIAGRAM FOR MANUFACTURE OF JAGGERY (GUR)



***** **CCP**

=> **TRANSPORTATION**

D **DELAY**

O **OPERATION**

□ **EXAMINATION**

S **STORAGE**

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ABSTRACT

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Title HAZARD ANALYSIS AND CRITICAL CONTROL POINTS EVALUATION IN THE MANUFACTURING PROCESS AND STORAGE OF JAGGERY

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).

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