Proceedings STAI, Factory Processing
Vol. 82 (2024) : 267-276 doi: 10.69794/82SAC/978-81-969264-0-3/267-276

Recovery % Cane Estimation by Solid Balance and it's Application During Diversion of Syrup and B Heavy Molasses to Ethanol Production

Sunil Alappanavar[1]*, M.P. Manohar[2] and C.B. Patil[3]
[1]Corresponding Author; Lecturer Sugar Technology – S Nijalingappa Sugar Institute Belagavi-590 009
[2]Professor – Sugar Technology University of Mysore
[3]Director – S Nijalingappa Sugar Institute, Belagavi
S Nijalingappa Sugar Institute, Belagavi, Karnataka

Received : June 11, 2024; Accepted : June 28, 2024

ABSTRACT

The solid balance of a sugar factory helps in process control and also in establishing the massecuite and molasses % cane. A change in approach has evolved due to diversion of intermediate sugar house products to serve the feedstock requirement of a distillery. Due to this, factories are least bothered about solid balance calculation because of difficulties to calculate during the diversion period. But correct estimation helps to find out recovery % cane and recovery losses in intermediates products diversion. This paper discusses solid balance of different sugar factories which divert the clear Juice, syrup and B heavy molasses partially or completely for ethanol production and estimation of sugar recovery and recovery losses in syrup and B heavy molasses .

Keywords : Brix%, purity, solids in sugar, diversion of syrup and B heavy molasses, recovery losses.

INTRODUCTION

Recovery is the commercial sugar produced % cane. For judging the sugar factory performance and the raw material quality and quantity of sugar production recovery estimation is essential. Further to estimate the quantity of sugar present in the intermediate materials (stock taking) recovery estimation is very important. To calculate and control the losses recovery estimation is significant. There are many formulas/methods that are noted in literature to estimate the recovery % cane in the factory (Varma 1998)

Boiling house recovery means Sucrose (Pol) in sugar produced per cent Sucrose (Pol) in mixed juice. Basic boiling house recovery is the theoretical house recovery as calculated by the s-j-m formula in which j = gravity purity of mixed juice, s = 100 and m = recorded purity of molasses. The theoretical methods of calculations helps to cross check the practical methods. The main methods are java method, SJM method, etc.

SJM formula: This formula gives the theoretical recoverable available sugar (sucrose or pol) in the final product % sugar in the original material.

$$r = \frac{\{s(J-M)\}}{\{J(S-M)\}} * 100$$

Where, r = recovery or available sugar %, S = purity of final product

J = purity of original material, M = purity of the molasses produced.

Expected Recovery% cane =

$$CJ\%cane * Pol\%\ CJ * \frac{S(J-M)}{J(S-M)} - \text{Unknown losses}$$

At standard unknown losses is considered as 0.1% on cane.

*Corresponding Author email: snsibgm@yahoo.com, [1]sunilalappanavar@gmail.com

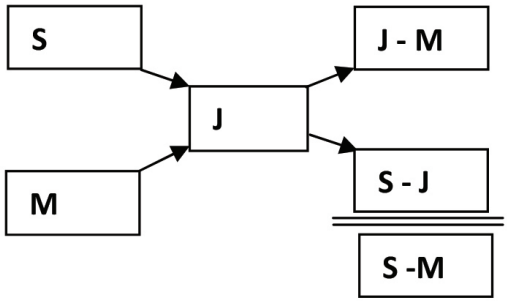
Crystallization is the main process of sugar recovery in the form of crystals, a small quantity of sucrose is lost in final molasses which can't be recovered economically. Good exhaustion in pans and crystallizers leads to a minimum loss in molasses and a high crystal yield. The molasses losses can always be ascertained with estimation of massecuite % canes, purity drop, massecuite crystal content and exhaustion (Hugot, 1986). The diversion of BH and Syrup to distillery has a bearing upon the crystallization process both qualitatively and quantitatively. The syrup diversion does not affect the quality of sugar but, results in decrease of the recovery % cane. But the BH diversion affects the purities and impacting the boiling house performance largely. An estimation of solid balance with varying solids of syrup and in absence of BH solids for C massecuite boiling is useful for controlling the sugar processing (Londhe and Khandagave, 2023).

MATERIALS AND METHOD

SJM method calculation requires correct estimation of pol% in the clear juice, and quantity estimation of clear juice. But this, method does not determines the other parameters like molasses % cane and its losses.

Generally, the solid balance of a pan floor is estimated by the well known 'Cobenze's Diagram', which is based on the proportion of purities. It is drawn as shown below and gives an idea of solids of syrup going into sugar and molasses which are originally present in the cane juice (Rein, 2007). As purity of sugar is considered as 100%, all solids in sugar are sucrose only, so solids proportion in sugar can be considered as recovery % cane.

Where, S is sugar purity, J is juice purity and M is molasses purity



(J-M) ÷ (S-M) is the proportion of solids going into sugar

(S-J) ÷ (S-M) is the proportion of solids going into molasses

$$\text{Solids going in sugar \% cane} = \text{Solids in CJ \% cane} \times \frac{(J-M)}{(S-M)}$$

$$\text{Where, solids is clear juice \% cane} = \frac{\text{CJ \% cane} \times \text{brix \% CJ}}{100}$$

There is no Solid losses from CJ to Syrup. So, solids is clear juice % cane = solids in syrup % cane

Relation between Solids in sugar % cane by Cobenze's diagram and Recovery % cane by SJM method:

To estimate the relation considered clear juice brix, pol and purity as JB, JP and J Sugar purity as S= 100, Final molasses purity as M

- *Recovery % cane by SJM method :*

$$\text{Expected recovery \% cane} = \text{CJ \% cane} * \text{Pol \% CJ} * \frac{S(J-M)}{J(S-M)} - \text{Unknown losses} \quad \text{----- \{1\}}$$

- *Solids in sugar % cane by solid balance (Cobenze's diagram) method:*

Solids in sugar % cane = CJ solids % cane * proportion CJ solids going to sugar

$$\text{Solids going in sugar \% cane} = \text{Solids in CJ \% cane} * \frac{(J-M)}{J(S-M)} \quad \text{---- \{2\}}$$

Divide and multiply the equation {2} by clear juice purity (J)

$$= \text{CJ \% cane x JB x } \left\{\frac{J}{J}\right\} \text{ x } \left\{\frac{(J-M)}{(S-M)}\right\} - 0.1 \quad - \{\text{where } J_B X J = J_p \text{ x}100\}$$

$$= \text{CJ \% cane x Pol \% CJ x } \frac{100}{J} \left\{\frac{(J-M)}{(S-M)}\right\} 0.1$$

$$= \text{SJM recovery \% cane} \quad \text{-------- \{1\}}$$

SJM recovery % cane = Solids in sugar % cane

Formula for estimation of recovery losses (By cobenze's diagram) in intermediate products diversion to ethanol production:

Recovery loss in BH diversion = Recoverable sugar solids in BH molasses

$$= \text{Solids in BH \% cane x } \frac{(J-M)}{(S-M)}$$

Where, J is B heavy purity, M as Final molasses purity 35.6 (Final molasses purity given by guidelines F. No. 4/1/2018-(BP&E) (Part) Government of India).

Recovery loss in syrup diversion = Recoverable sugar solids in syrup diverted

$$= \text{Solids in syrup \% cane diverted x } \frac{(J-M)}{(S-M)}$$

Where, J is syrup purity, M as final molasses purity 35.6.

Application solid balance to estimate recovery % cane in various conditions:

Authors have taken three season factory performance data of a sugar factory from technical efficiency report of Karnataka's sugar mills. Particularly data of season 2020-21 there is no diversion of syrup and B heavy, season 2021-22, Diversion of B heavy molasses and season 2022-23 diversion of syrup and B Heavy of the same factory. And applied the findings of the above solid balance which helps to overcome the calculation problems of recovery % cane, recovery losses and molasses % cane.

Case 1: No diversion of syrup and B heavy in season 2020-21

Table 1 : Factory performance parameters from RT8C of season 2020-21

Parameters	2020-21
Cane Crushed MT	331712.9
Clear Juice %cane	100.5%
Sugar Quantity MT	31446.29
Recovery In Sugar production	9.48
Quantity of CH produced	15570.3
CH molasses % cane	4.69

	Brix	Pol	Purity
Mixed Juice	13.41	10.69	79.72
Clear Juice	13.44	10.74	79.91
Syrup	63.26	50.45	79.75
A Heavy	78.35	57.94	73.95
A Light	72.78	62.44	85.79
B Heavy	84.03	42.02	50.01
C Light	80.24	50.25	62.63
C Heavy	86.57	28.15	32.52
CF Sugar	93	-	83
CA Sugar	95	-	93.5
B Sugar	96	-	96.8
AFS	98.9	-	98.5
AAS	99.96	99.88	99.91
A m/c	91.86	82.7	90.03
B m/c	94.29	70.06	74.3
C m/c	99.8	57.59	57.71

Solid balance by cobenze's diagram for season 2020-21

Sugar			
100		47.4	Solids in sugar % cane= 9.45
FM	79.91		
32.52	Syrup	20	Solids in FM % cane= 3.99
		67.4	
C For sugar			Solids in C m/c % cane= 7.96
83		25.2	
FM	57.71		Solids in Cfw sugar 3.97
32.52	C m/c	25.3	
		50.5	
C After sugar			Solids in in caw sugar 2.58
94		20.4	
CL	83		Solids in CL. 1.39
62.63	CFS	11	
		31.4	Solids in BH. 6.57
B sugar			
96.8		24.3	Solids in B m/c 13.66
BH	74.3		
50.01	B m/c	22.5	Solids in B sugar 7.09
		46.8	

A Fore Sugar			Solids in AH 13.66
98.5		16.1	
AH	90.03		Solids in A m/c 39.59
73.95	A m/c	8.47	
		24.6	Solids in AF sugar 25.93
A After Sugar			
99.91		12.7	Solids in sugar
AL	98.5		23.34
85.79	AFS	1.41	Solids in AL
		14.1	2.59

$$\text{So the recovery by SJM method} = 100.5 \times 10.74 \times \left\{ \frac{100X(79.91 - 32.52)}{79.91(100 - 32.52)} \right\} - 0.1$$

$$= 9.48$$

$$\text{Solids in sugar \% cane} = \text{CJ \% cane} \times \text{Brix \% CJ} \times \frac{(J-M)}{(S-M)} - 0.1$$

$$= 100.5 \times 13.44 \times \frac{79.91 - 32.52}{100 - 32.52} - 0.1$$

$$= 9.48.$$

$$\text{Final molasses \% cane} \frac{\text{Solids in final molasses}}{\text{(Brix \% final molasses)}} = \times 100$$

$$= \frac{3.99}{86.57} \times 100 = 4.61\%$$

So the recovery and final molasses % cane estimated solid balance are same as factory RT8c data. Further solid balance is used to calculate the all massecuite and molasses % cane in the above cases.

Case 2: Diversion of B heavy in season 2021-22

Factory had established 120 KLPD distillery plant attached to sugar plant for ethanol production, during the season 2021-22, factory diverted complete B Heavy molasses to storage for ethanol production. Some parameters from factory performance data RT8C are given below:

Table 3 : Factory performance data of season 2021-22

Parameters	**2020-21**		
Cane Crushed MT	471996.6		
Clear Juice %cane	106%		
Sugar Quantity MT	37715.3		
Recovery In Sugar production	7.99		
Recovery loss in B Heavy	1.5		
Total Recovery	9.49		
Quantity of BH produced	31340.57		
Diverted BH % cane	6.64		
Quality of CH produced	–		
	Brix	Pol	Purity
Mixed Juice	12.83	10.34	80.59
Clear Juice	12.84	10.33	80.49
Syrup	58.08	46.8	80.57
A Heavy	78.25	59.46	75.99
A Light	72.45	63.19	87.23
B Heavy	83.99	44.3	52.74
B Sugar	95.5	-	96.5
AFS	98.9	-	98.5
AAS	99.96	99.8	99.91
A m/c	91.58	81.177	88.64
B m/c	94.89	70.617	74.42

Solid balance by cobenze's diagram for season 2021-22

Sugar			
100		27.75	Solids in sugar
BH	80.5		7.70
52.7	CJ	19.42	Solids in BH
		47.17	5.39
B sugar			
96.5	B m/c	21.68	Solids in B- m/c
			10.69
BH	74.4		
52.7		22.08	Solids in B sugar
			5.29
		43.76	
AF Sugar			
98.5		12.65	Solids in AH

AH	88.6	99.96	10.69
76	A m/c	9.86	Solids in A m/c
		22.51	24.40
AA Sugar			Solids in AF sugar
99.9		11.27	
AL	98.5		Solids in sugar
87.2	AFS	1.38	12.21
		12.65	Solids in AL
			1.50

Table 5 : Recovery estimation by SJM method and solid balance method

	By SJM Method	By Solid Balance
Total recovery % cane	9.48	9.48
Recovery % in Sugar	7.99	7.98
Recovery loss in BH	1.48	1.47
BH % cane by solid balance		6.42%

So solid balance estimates the same recovery % cane and recovery losses in B heavy molasses diversion accurately as same as SJM formula.

Case 3: Diversion of partial syrup and complete B heavy in deason 2022-23

In the season 2022-23 factory had diverted partial syrup quantity of 29,140 MT *i.e.,* 6.06% on cane to attached 120 KLPD distillery plant and complete B heavy molasses to storage for ethanol production. The performance data and solid balance analysis are given below:

Table 6 : Factory performance data of season 2022-23

Parameters	**2022-23**		
Cane Crushed MT	482452.76		
Clear Juice %cane	107%		
Recovery In Sugar production	6.34		
Recovery loss in diverted Syrup	2.22		
Recovery loss in B Heavy	1.02		
Total Recovery	9.58		
Sugar Quantity MT	30599.20		
Quantity of Syrup diverted	29140.15		
Diverted Syrup % cane	6.06		
Quantity of BH produced	22578.79		
Diverted BH % cane	4.68		
	Brix	Pol	Purity
Mixed Juice	13.18	10.51	79.74
Clear Juice	13.21	10.54	79.78

Syrup	53.42	42.65	79.83
A Heavy	78.42	59.52	75.91
A Light	73.87	66.57	90.12
B Heavy	85.2	44.35	52.05
B Sugar	95.5	-	96.5
AFS	98.9	-	98.5
AAS	99.96	99.8	99.91
A m/c	91.56	80.75	88.2
B m/c	93.84	72.05	76.78

Solids bifurcation to sugar production and distillery:

As solids, pol (Sucrose %) of clear juice will remains same in syrup (Pete Rein 2007), so as syrup is diverted to distillery, for recovery calculations syrup quantity and quality parameters are considered for the calculations.

$$\text{Total quantity of clear juice produced} = \text{Cane crushed} \times \text{Clear juice \% cane}$$

$$= 482452.76 \times 107\%$$

$$= 516224.45 \text{ MT}$$

$$\text{Total quantity of syrup produced} = \text{Clear juice quantity} - \text{Evaporation quantity}$$

$$= 516224.45 - \frac{53.42\text{-}13.21}{53.42} \times 516224.45$$

$$= 508544.93 - 382789$$

$$\text{Total quantity of syrup produced} = 127654.8 \text{ MT}$$

$$\text{Total syrup \% cane} = \frac{\text{Quantity syrup produced}}{\text{Quantity of cane crushed}} \times 100$$

$$= \frac{127654.8}{482452.76} \times 100$$

$$\text{Total syrup \% cane} = 26.46\%$$

$$\text{Total solids in syrup \% cane} = \frac{(\text{Brix \% syrup} \times \text{syrup \% cane})}{100}$$

$$= 53.42 \times \frac{26.46}{100}$$

$$\text{Total solids in syrup \% cane} = 14.13\%$$

$$\text{Quantity syrup sent to distillery} = 29140.15 \text{ MT}$$

$$\text{Syrup to distillery \% cane} = \frac{\text{Syrup quantity to distillery}}{\text{Cane crushed}} \times 100$$

$$= \frac{29140.15}{482452.76} \times 100$$

$$\text{Syrup sent distillery \% cane} = 6.04\ \%$$

$$\text{Solids in syrup sent to distillery \% cane} = \frac{53.42 \times 6.04}{100}$$

$$\text{Solids in syrup sent to distillery \% cane} = 3.23$$

$$\begin{pmatrix}\text{Solids in syrup sent to pan}\\ \text{(Crystallization) \% cane}\end{pmatrix} = \begin{pmatrix}\text{Total solids in}\\ \text{syrup \% cane}\end{pmatrix} - \begin{pmatrix}\text{Solids in syrup sent}\\ \text{to distillery\% cane}\end{pmatrix}$$

$$= 14.13\text{-}3.23$$

$$\text{Solids in syrup sent to pan} = 10.90\%.$$

As Solids in syrup 14.13% but solids in syrup going to pan station is limited to10.90% by diversion of syrup solids of 3.23%. Calculating solid balance by the syrup solids as 10.69% in the calculation gives that exact recovery% cane going to achieve in the sugar production.

Table 7 : Solid balance by cobenze's diagram for season 2021-22

Sugar			Solids in syrup to pan station = 10.90
100		27.79	Solids in sugar 6.34
BH	79.839		
52.05	Syrup	19.96	Solids in BH 4.56
		47.75	
B sugar			
96.5	B m/c	24.73	Solids in B- m/c 10.27
BH	76.78		
52.05		19.72	Solids in sugar 5.71
		44.45	
AF Sugar			
98.5		12.29	Solids in AH 10.27
AH	88.2	99.96	
75.91	A m/c	10.30	Solids in A m/c 22.53
AA Sugar		22.59	Solids in sugar 12.26
99.88		8.38	
AL	98.5		Solids in sugar 10.52
90.12	AFS	1.38	
		9.76	Solids in AL 1.73

Table 8 : Recovery estimation by SJM method and solid balance method

	By SJM Method	By Solid Balance
Net recovery % cane	9.58	9.59
Recovery % in Sugar production	6.34	6.20
Recovery loss in Syrup	2.22	2.22
Recovery loss in BH	1.109	1.16
BH % cane by solid balance		5.25%

So solid balance estimates the correct recovery % cane and B Heavy % and recovery losses in B heavy and syrup accurately.

CONCLUSIONS

So the studies identify that relation between solids in sugar % cane estimated by solid balance to theoretical recovery % cane. So solid balance can be used for estimation of recovery. While diversion of intermediate compounds many factories unable to calculate the solid balance of their process. But the knowledge and correct method of analysis is very essential. Solid balance resolves the all problems about recovery calculation, losses estimation and massecuite, molasses % cane.

Solids in clear juice are not completely going to pan station during the diversion of syrup, As discussed in case 3, the bifurcation of solids in the syrup going to crystallization and to distillery is essential for solid balance calculation. So it helps to correct estimation recovery and other parameters. Further it helps to solve the problems related to sugar colour, B Heavy molasses purity and recovery estimations. Correct estimations are helps for the assessment of vapour and equipments required to pan station. After successful establishing of six years of ethanol blending policy still many factories are facing the issues in the correct mass balance of pan floor area. So these analytical and mathematical studies helps to resolve the issues caused during diversion period. And further requested technical bodies like NSI, VSI and STAI, SISTA and DSTA(I) bodies to further review these calculations and make new formulas which are suitable for current scenarios of the industry.

ACKNOWLEDGEMENT

Authors are extremely grateful to Chairman and governing council members of S Nijalingappa Sugar Institute, Belagavi for their encouragement to publish this paper.

REFERENCE

Hugot, E. (1986). Handbook of cane sugar engineering.

Karnataka Sugar Factories Technical performance report by SNSI 2020-21, 2021-22 and 2022-23.

Londhe M. B. and Khandagave R. B. (2023) Effect of B Heavy Molasses and Syrup diversion on boiling house efficiency parameters. *81st STAI Annnual convention*

Office memorandum from Ministry of consumer affairs, food and public distribution, Department of food and public distribution, Government of India; Mechanism for diversion/ sale of BH molasses/ CH Molasses / Cane juice/ sugar syrup / sugar used by sugar mills for production of ethanol guidelines ---- dated 21.12.2023

Peter Rein (2007). *Cane Sugar Engineering*. Sugar Industry International, Bartens., P. 752.

Varma, N.C. (1988). System of technical control for cane sugar factories in India. *Sugar Technologists' Association of India,* P. 299.