A BOILING HOUSE RECOVERY FORMULA INDEPENDENT OF JUICE QUALITY

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Abstract

A corrected reduced boiling house recovery (CRB) is derived by using SJM recoveries and a molasses target purity based on the analysis of mixed juice. The approach corrects satisfactorily for the effect of juice quality and allows meaningful comparisons to be made. It also generates data which correlate well with the usual Target Purity Difference figures. The assumptions used are highlighted and the need to use sucrose rather than pol based data is stressed.

Introduction

It is generally accepted that recoveries are affected by juice quality, particularly purity. The comparison of Boiling House Recoveries (BHR) from different factories can therefore be less meaningful if juice qualities are different. The Corrected Reduced BHR (CRB) is proposed in order to provide a fair means of assessing boiling house work and has the primary requirement of being independent of mixed juice purity. A further intention is that as far as possible only those elements within the control of process management should be reflected in the CRB.

Basic Principle

An interesting concept was suggested by Rouillard[1] and Rein[2]. This involves the use of an SJM recovery using the molasses purity calculated from the target purity formula derived by Rein and Smith[3] in 1981 and reviewed by Ravnö and Lionnet[4] in 1982, but based upon mixed juice (MJ) rather than molasses analysis. Thus, a molasses target purity, M_t* is given by

$$M_t = 33{,}9 - 13{,}4 \log_{10} \frac{(\text{Fructose} + \text{Glucose in MJ})}{(\text{Ash in MJ})} \quad \ldots\ldots (1)$$

and the target boiling house recovery can now be calculated using the actual juice and sugar purities, together with the value of M_t

$$\text{Target BHR} = 100. \frac{S_a (J_a - M_t)}{J_a (S_a - M_t)} \quad \ldots\ldots (2)$$

For the derivation of CRB, sucrose losses in filter cake, all undetermined sucrose losses and the molasses loss in excess of the level determined by the mixed juice quality, are deemed to be within the control of process management.

CRB represents the boiling house recovery that would be achieved if the identified "controllable losses" had been incurred with mixed juice of standard quality.

The following standard qualities have been used in the derivation:-

- Mixed juice purity (Sucrose/brix, J_s) : 85,0
- Mixed juice $\frac{\text{Fructose} + \text{Glucose}}{\text{Ash}}$: 0,8
- Sugar purity (Pol/(100 - moisture), S_s) : 99,5

* See Nomenclature for definition of terms/symbols.

These standards have been chosen to illustrate the approach. Obviously, any other relevant values may also be used.

In correcting for mixed juice purity, the CRB formula uses in the first instance, a similar approach to that of Gundu Rao[5,6] where the difference between two calculated molasses losses (one at the actual mixed juice purity and one at 85 purity) is added to the actual BHR:-

Gundu Rao's recovery = $BHR_a + (100 - SJM_a) - (100 - SJM_{85})$

Gundu Rao, in effect assumes that the same purity molasses (actual) will be made from any purity juice. His correction only allows for the different quantities of non-sucrose in mixed juice.

The equivalent correction in the case of CRB is

$$CRB = BHR_a + (100 - SJM_t) - (100 - SJM_s) = BHR_a + SJM_s - SJM_t \quad \ldots\ldots (3)$$

The application of this correction to actual recoveries would adequately compensate for the effect of mixed juice purity only if the target molasses purity was exactly met. This is not expected to occur often. The efficiency of molasses exhaustion is usually measured in terms of purity units approaching a target (TPD_t). While TPD_t accurately reflects work done by the boiling house, the impact of a unit of molasses purity on BHR is dependent on the mixed juice purity. Thus a factory with a high mixed purity can afford to be less efficient in molasses exhaustion, for the same BHR, than a low purity factory, as shown in Table 1.

Table 1

BHR Units/TPD Unit at different mixed juice purities

	Factory 1	Factory 2
S_a	99,5	99,5
J_a	88	80
(G + F)/A	0,8	0,8
M_t	35,2	35,2
BHR when $TPD_t = 0$	92,8	86,7
BHR when $TPD_t = 5$	91,1	83,5
Difference	1,8	3,2
BHR Units/TPD unit	0,35	0,64

To overcome this bias a further correction has been added to the formula to reduce the value of a TPD_t unit to that which it would have if the mixed juice had been at 85 purity. The correction is calculated from the difference between the "Actual effect of a TPD_t unit and the Effect of a TPD_t unit at the standard quality."

i.e. $(SJM_t - SJM_a) - (SJM_s - SJM_{s+TPD_t})$

The CRB formula now becomes

$$CRB = BHR_a + SJM_s - SJM_t + SJM_t - SJM_a - SJM_s + SJM_{s+TPD_t}$$

which simplifies to

$$CRB = BHR_a - SJM_a + SJM_{s + TPD_t} \quad \ldots\ldots\ldots (4)$$

or using the standard values

$$CRB = BHR_a - 100.\frac{S_a\,(J_a - M_a)}{J_a\,(S_a - M_a)} + \frac{49{,}8 - TPD_t}{0{,}5493 - 0{,}008543.TPD_t} \quad \ldots\ldots (5)$$

Some examples are given in Table 2.

Table 2

Calculation of CRB

MJ purity	TPD_t	CRB
90	1	91,96 − 3,56 − 0,16 = 88,24
90	2	91,70 − 3,56 − 0,33 = 87,81
90	3	91,42 − 3,56 − 0,49 = 87,37
85	1	88,24 − 0 + 0 = 88,24
85	2	87,81 − 0 + 0 = 87,81
85	3	87,37 − 0 + 0 = 87,37
80	1	84,06 + 4,00 + 0,18 = 88,24
80	2	83,44 + 4,00 + 0,37 = 87,81
80	3	82,81 + 4,00 + 0,56 = 87,37

Industrial Results

CRB versus mixed juice purity - monthly industrial data

CRB values were calculated monthly for the last two seasons and regressed against mixed juice purity. The results are given in Table 3.

Table 3

CRB versus mixed juice purity

Mill	1984/85		1985/86	
	Corr. coeff.	n	Corr. coeff.	n
ML	0,44	9	0,67	8
PG	0,42	9	0,31	8
UF	− 0,62	8	0,36	7
EN	− 0,01	9	0,52	8
FX	− 0,04	7	− 0,30	7
AK	0,08	9	0,53	7
DL	− 0,01	9	− 0,19	8
MS	0,28	9	0,67	7
ME	0,14	9	− 0,12	7
GD	0,19	9	0,54	8
GH	− 0,29	9	0,41	8
NB	− 0,48	9	0,45	8
UC	0,29	9	0,82	7
IL	0,47	9	0,23	6
SZ	0,77	7	0,95	8
UK	0,42	9	− 0,12	8

Except at SZ and at UC (1985/86) the correlation coefficients are not statistically significant. In addition, some are negative. These results therefore indicate that the approach is promising.

TPD_t versus TPD

TPD_t is given by the formula:—

TPD_t = Molasses actual purity − M_t

TPD_t was regressed against the usual TPD for the monthly data from all the mills over the last two seasons. The results are shown in Table 4.

Table 4

TPD_t versus TPD, monthly mill results, 1984/85 and 1985/86 seasons treated together

	$TPD_t = a + b.TPD$		n	r
	a	b		
PG	1,4	1,0	15	0,95
UF	4,2	0,6	13	0,79
EN	3,0	0,9	15	0,94
FX	2,8	0,7	12	0,64
AK	0,6	1,2	15	0,87
DL	3,9	0,6	15	0,85
MS	0,8	1,1	14	0,86
ME	2,3	0,9	15	0,87
GD	2,2	0,9	15	0,99
GH	2,0	1,0	15	0,89
NB	1,5	1,2	15	0,69
UC	3,6	0,7	15	0,73
IL	2,1	0,9	15	0,87
SZ	1,8	0,8	15	0,84
UK	3,3	0,6	15	0,65

In all cases, as is expected, TPD_t is strongly related to TPD, TPD_t being about two units higher than TPD.

These results indicate that TPD_t is as meaningful as the usual TPD and could replace it.

Molasses target purity, mixed juice based (M_t) versus the usual molasses target

The relation between the two target molasses purities follows the trend found in the previous section. Thus, strong relationships between these two quantities also exist, with the mixed juice based target being about two units lower than the usual one.

The results for the data from the last two seasons are given in Table 5.

Table 5

Molasses target purities based on mixed juice M_t and based on the usual molasses analyses

$M_t = a + b$ (Usual target)			Average values		
	n	r	M_t	Usual mol target purity	Difference
ML	15	0,96	31,6	33,4	1,8
PG	15	0,95	33,2	34,7	1,5
UF	13	0,84	34,6	37,1	2,6
EN	15	0,91	32,3	34,8	2,5
FX	12	0,88	33,5	35,0	1,5
AK	15	0,97	32,9	34,3	1,4
DL	15	0,95	31,8	34,2	2,4
MS	15	0,97	32,6	33,9	1,3
ME	14	0,92	31,6	33,7	2,0
GD	15	0,91	32,2	33,4	1,2
GH	15	0,96	32,5	34,5	2,0
NB	15	0,89	31,0	33,4	2,4
UT	15	0,76	34,8	31,8	3,0
IL	15	0,90	34,7	32,9	1,8
SZ	15	0,96	33,3	34,3	1,0
UK	15	0,85	32,6	35,0	2,4

M_t = Target molasses purity based on mixed juice analysis
Usual target = Target molasses purity based on final molasses analysis.

Discussion

The corrected reduced boiling house recovery discussed in this paper is given by equation 5.

This may be simplified algebraically to show that CRB depends only on the TPD, cake and undetermined losses if the non-sucrose ratio is unity. This is not unexpected.

The approach has been shown, both theoretically and statistically, to yield results generally independent of juice quality. This therefore makes the comparison of CRB values more meaningful. Apart from the sulphated ash analysis in mixed juice, no further sampling or analyses are required from what is already being done on a routine basis.

The approach includes some important assumptions, particularly as far as the use of the target purity formula is concerned. Qualitatively there is no doubt that the formula is correct. Quantitatively, however, it is necessary to assume firstly that the values of the slope and of the intercept in the target purity equation obtained from the exhaustion of final molasses apply equally when mixed juice analyses are used instead in the calculation; and secondly that there is no bias among mills, geographical areas or seasons. These points could, in principle, be checked by exhausting mixed juice but the experimental difficulties are considerable. It is well established that the TPD formula has been found to be satisfactory in a number of sugar producing countries. In addition, the results obtained here are very encouraging. It is therefore concluded that a meaningful approach has been obtained.

It should also be stressed that it is essential to use sucrose analyses (by GC for example) and not pol values in the approach given here, not only because the target purity formula is based on sucrose data but also because of the known differences in the pol/sucrose ratios for mixed juice and final molasses.

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REFERENCES

1. Rouillard, EEA (1984). Personal communication.
2. Rein, PW (1984). Personal communication.
3. Rein, PW and Smith, IA (1981). Molasses exhaustibility studies based on sugars analysis by gas-liquid chromatography. *Proc. S. Afr. Sug. Technol. Ass.* 55: 85-91.
4. Ravnö, AB and Lionnet, GRE (1982). Exhaustion performance yardsticks in the South African sugar industry. *Proc. S. Afr. Sug. Technol. Ass.* 56: 46-50.
5. Hugot, E (1972). *Handbook of cane sugar engineering.* 2nd Ed. p. 786.
6. Huang Shi-Yang. (1984). Reduced boiling house recovery ESG. *Sug. J.* April 1984: 12-14.

NOMENCLATURE

CRB	: Corrected Reduced Boiling house recovery.
BHR_a	: Actual boiling house recovery, as reported by a factory (sucrose based).
SJM_a	: Actual SJM, as calculated with factory reported data (sucrose based).
SJM_{85}	: An SJM using factory data, but a mixed juice purity equal to 85.
SJM_t	: Target recovery, calculated using actual sugar and juice purities but using M_t for the molasses purity.
SJM_s	: A standard SJM recovery obtained by using the standard values of sugar, juice and molasses purities.
SJM_{s+TPD_t}	: An SJM recovery using the standard values for mixed juice and sugar purities but with molasses purity equal to the sum of the standard purity and the TPD_t. (i.e. $M = M_s + TPD_t$).
S_s	: A sugar purity which has been selected as a standard value.
J_s	: A mixed juice purity which has been selected as a standard value.
M_s	: A standard final molasses purity calculated from the target purity formula but using a selected standard value for (fructose + glucose)/ash in mixed juice.
S_a	: Actual sugar purity, as reported by a factory.
J_a	: Actual mixed juice purity, sucrose/brix, as reported by a factory.
M_t	: Target final molasses purity, as calculated from the target purity formula, but using mixed juice analyses.
TPD_t	: A target purity difference given by the difference between the actual final molasses purity and a target molasses purity as calculated by the target purity formula, but using mixed juice analyses.