Optimization of a Cane sugar - Bioethanol Producer

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Abstract- Kenana Sugar Company is an integrated factory that produces both raw sugar and ethanol. This study is to determine a means for optimizing the cane sugar- bio ethanol production. Looking for the optimum operating conditions and, targeting the most feasible and the best solution consistent with the constraints imposed on the study case. Linear programming optimization method is used to maximize a linear objective function, subject to a set of constraints the linear program model was solved using MathCAD 14.Three areas were explored to see their effect on the objective function these were: changing the production rate of ethanol, effects of raw sugar price changes, effects of molasses price changes and possible production rates that can be obtained.

From the analysis of data it has been found that the molasses producedby Kenana sugar company will meet to need of the ethanol plant up to $24.975*10^6$ Liter/year, and when the price of raw sugar falls to beyond 1200SDG/ton some of the raw sugar can be diverted towards production of ethanol, however for low molasses prices Kenana sugar company can use all the molasses produced for ethanol production.

I. INTRODUCTION

Integrated Sugar and Ethanol Factory Process

The sugar cane factories can be classified into three main categories: Production of raw sugar alone, Production of ethanol or to be an integrated factory that produces both raw sugar and ethanol.

In Sudan the third option is being attempted while for example 80% of the factories in Brazil belong to third category. Large factories - crushing more than five hundred thousand tons of cane each season- usually belong to the third category. The use of both molasses and cane juice to produce ethanol is only economically feasible in factories belonging to the third category [1].

In integrated factories, cane is crushed at a mill that produces both sugarcane juice-which is rich in sucrose- and bagasse.Bagasse is used to meet the energy demand of the entire factory. The juice is split into two streams sending one for raw sugar production and the other to the ethanol distillery. Molasses, which is a byproduct of raw sugar production, is then sent as additional feedstock to the distillery. The yield of ethanol from fermentable sugars in molasses is almost identical to the yield from fermentable sugars in cane juice[2].

Linear programming optimization method is used to maximize the income from both operations. A linear objective function was developed[3], [4], subject to a set of constraints.The model was solved using Mathcad 14 and the input data used for the program was collected from the sugar and the ethanol factories.

The collected data is shown below and inputted for the solution of the optimization model.

II. M ATERIAL AND METHOD

The following diagram is the set up of the unit .Showing the input and output streams .

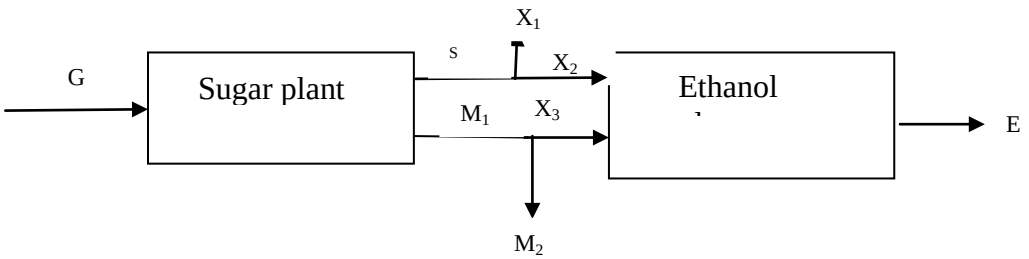

Figure 1:block diagram forinput and out put streams

The above notations were used in writing the model program
Where:-

G cane crushed ton/day
S sugar production ton/y
M1 molasses production ton/y
M2 molasses to be bought ton/y
E ethanol plant annual production capacity liter/year(the design capacity)
$x_1$sugar to local market ton/y
x_2 sugar for ethanol production ton/y
x_3 molasses for sale (export) ton/y
x_4 molasses to ethanol production ton/y
x_5 molasses bought from markets (x 's in tones year)
$P_s$sugar selling price per ton
P_m Selling price per ton local molasses
P_{mo} price per ton foreign molasses
Z1 Ethanol production Liter per ton sugar
Z2 Ethanol production Liter per ton molasses
Peth Ethanol selling price per liter
Ps.x1 income from the sale of sugar

Z1peth.x2income from the sale ethanol produced by processing sugar

Pm.x3 income from the sale of molasses

Z2peth.x4 income from the sale ethanol produced by processing sugar

Pmo.x5 payment of buying foreign molasses

Mathcad program:

Total income= Ps.x1 + Z1peth.x2 + Pm.x3 + Z2peth.x4 +(Z2peth.x5 + Pmo.x5)

Objective function to maximize income:

Y(x1, x2, x3,x4,x5) =Ps.x1 + Z1peth.x2 + Pm.x3 + Z2peth.x4 + (Z2peth.x5 + Pmo.x5)

Constraints:

X1+x2 –s ≤ 0

X3+x4 –M1 ≤ o

Z1x3+ z2 (x4 +x5) –E ≤ 0

Production limit:

o≤ x1 ≤ s , o≤ x2 ≤ s , o≤ x3 ≤M1 , o≤ x3 ≤M1, o≤ x3 ≤M1

Data input:

$E = 56..10^6$ P_s =5600 p_m = 600 P_{mo} = 620

Z_1 =550 z_2 =268 P_{eth} =3.78

The model is thus ready to be solved and investigated. The software MATHCAD-14 is used for solution [5].

III. RESULT AND DISCUSSIONS

Results and Three cases and scenarios will be looked into

. **Case One:**

Analysis of changing ethanol production rate Ethanol plant to work at different capacities in range 5*106 -100*106 liters per year

Summary of the results are shown in Table 1 and plotted in Figures 2: and (3).

Case Two:

Effect of sugar selling price changes

i) For sugar selling price change in range 1200-7840 SDG per ton when the ethanol plant is working at its full production capacity of 65*106 liters per year

Summary of the results are shown in table 2:

ii) For sugar selling price change in the range 1200-7840 SDG per ton when the ethanol plant is working at production capacities of 25*106 , 45*106 and 65*106 liters per year

Summary of the results are shown in table 3:and plotted in Figure1:

Case Three:

Effect of foreign molasses selling price changes

i) Foreign molasses changes in the range 372-868 SDG per ton when the ethanol plant is working at its full production capacity of 65*106 liters per year.

Summary of the outputted results are shown in Tables 4:

ii) Foreign molasses selling price change in the range 372-868 SDG per ton when the ethanol plant is working at production capacities of 25*106 , 45*106 and 65*106 liters per year

Table 2: Result for Effect of different capacity on ethanol plant

Production capcity*(10^6) Ton/year	X1*10^5 Ton/year	X2 Ton/liter	X3 Ton/year	X4*10^4 Ton/liter	X5 ton/year	Mneed*10^4 Ton/year	Income x10^9SDG
5	3.043	2.47*10^{-4}	7.45*10^4	1.87	0	1.87	1.77
10	3.043	4.99*10^{-4}	5.59*10^4	3.73	0	3.73	1.7
20	3.043	0	1.86*10^4	7.46	0	7.46	1.79
24.975	3.043	0	0	9.32	1.29	9.32	1.80
25	3.043	0	0	9.32	94.6	9.32	1.80
30	3.043	0	0	9.32	1.88*10^4	11.9	1.81
50	3.043	0	1.47*10^{-11}	9.32	9.34*10^4	18.66	1.84
65	3.043	0	0	9.32	14.93*10^4	24.25	1.86
75	3.043	0	0	9.32	18.67*10^4	27.99	1.87
85	3.043	0	1.42*10^{11}	9.32	22.4*10^4	31.72	1.89
100	3.043	0	0	9.32	27.99*10^4	37.31	1.91

Molasses need =Molasses Sold + Molasses convert to ethanol +Molasses bought

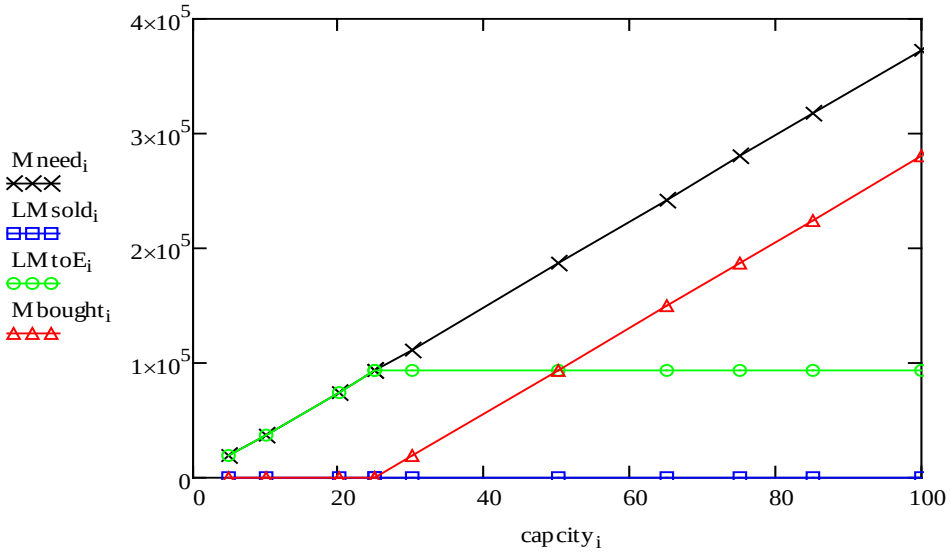

Figure 2 Relation between capcity and molasses(sold,bought,need,to ethanol production)

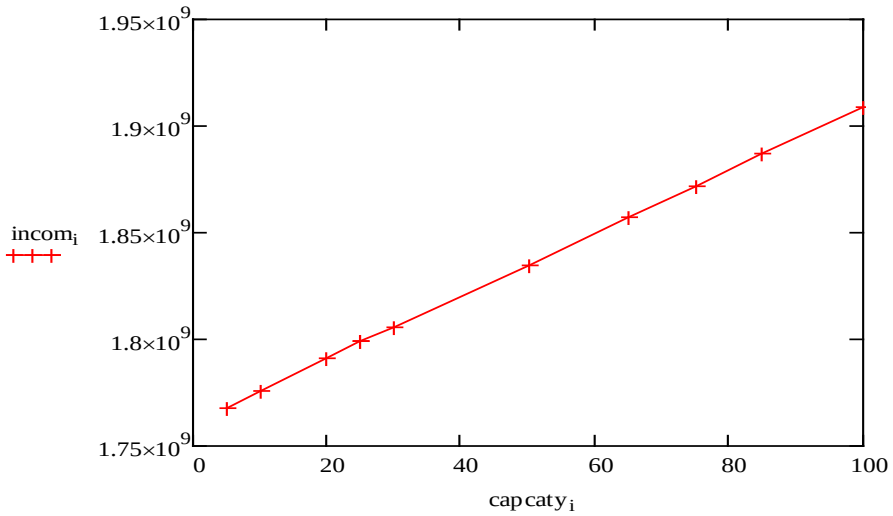

Figure 3: Relation between capcity and income

Table 3: Result for different sugar selling price in ethanol plant

Priceof sugar SDG	X1*10^5 Ton/year	X2 Ton/year	X3 Ton/year	X4*10^4 Ton/year	X5*10^5 Ton/year	Mneed*10^5 Ton/year
1200	1.862	1.182	932*10^4	0	0	0.525
3360	3.043		1.24*10^{-11}	9.32	1.493	2.425
3930	3.043	0	0	9.32	1.493	2.425
4480	3.043	0	1.13*10^{-11}	9.32	1.49**3**	2.425
5040	3.043	0	7.12*10^{-12}	9.32	1.493	2.425
5600	3.043	0	1.42*10^{-11}	9.32	1.493	2.425
6260	3.043	0	0	9.32	1.493	2.425
6720	3.043	0	0	9.32	1.493	2.425
7220	3.043	0	1.07*10^{-11}	9.32	1.493	24.25
7840	3.043	0	-355*10^{-12}	9.32	1.493	2.425

Table 4: Result for different capacity of ethanol plant in income

Sugar price SDG	Income incapcity25*10^6 SDG/ ton	Income incapcity45*10^6 SDG/ ton	Income incapcity65*10^6 SDG/ ton
3360	1.117	1.146	1.349
3930	1.29	1.32	1.517
4480	1.458	1. 472	1.687
5040	1.628	1.658	1.76
5600	1.799	1,828	1.857
6260	2	2.029	2.058
6720	2.14	2.169	2.198
7220	2.292	2.321	2.35
840	2.48	2.51	2.539

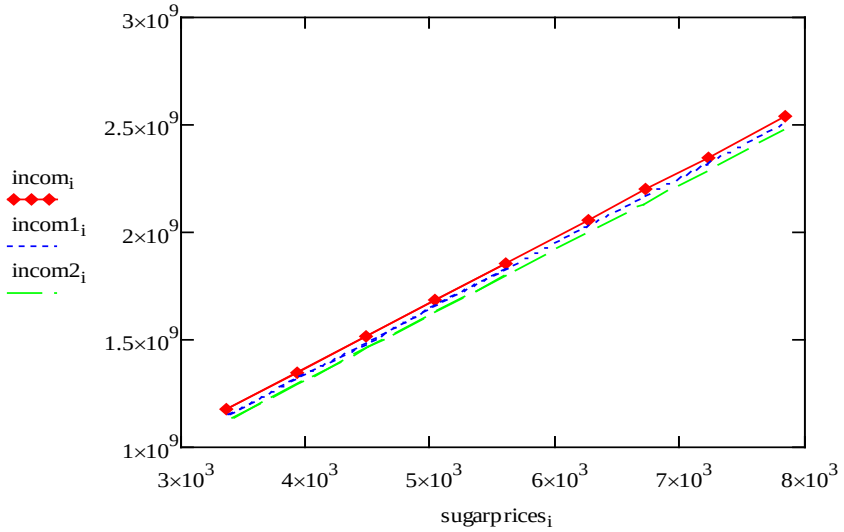

Figure4:relation of deferent of Sugar prise and incom atdifferent capacity

Table5: Result for different price foreign Molasses in Ethanol plant

forgen molasses price SDG/ton	X1*10^5 Ton/year	X2 Ton/year	X3 Ton/year	X4 Ton/year	X5*10^5 Ton/year	Mneed *10^5 Ton/year	Income *10^9 SDG/Ton
372	3.043	0	9.32*10^4	2.13*10^{-11}	2.425	3.3569	1.916
434	3.043	0	9.32*10^4	7.11*10^{-12}	2.425	3.3569	1.901
496	3.043	0	9.32*10^4	7.11*10^{-12}	2.425	3.3569	1.886
558	3.043	0	9.32*10^4	2.13*10^{-11}	2.425	3.3569	1.875
620	3.043	0	1.42*10^{-11}	9.32*10^4	1.493	2.425	1.857
682	3.043	0	7.11*10^{-12}	9.32*10^4	1.493	2.425	1.848
744	3.043	0	1.42*10^{-11}	9.32*10^4	1.493	2.425	1.839
806	3.043	0	0	9.32*10^4	1.493	24.25	1.83
868	3.043	0	0	9.32*10^4	1.493	2.42	1.82

Table 6: result for different priceof foreign Molasses in income

forgone molasses price SDG/ton	Income incapacity25*10^6 SDG/ton	Income at capacity 45*10^6 SDG/ton	Income incapcity65*10^6 SDG/ton
372	1.82*10^9	1.868*10^9	1.916*10^9
434	1.814*10^9	1.857*10^9	1.901*10^9
496	1.808 *10^9	1.847*10^9	1.86*10^9
558	1.803 *10^9	1.837*10^9	1.875*10^9
620	1.799 *10^9	1.828*10^9	1.857*10^9
682	1.799 *10^9	1.823*10^9	1.848*10^9
744	1.799 *10^9	1.819*10^9	1.839*10^9
806	1.799 *10^9	1.814*10^9	1.83*10^9
868	1.799 *10^9	1.81*10^9	1.82*10^9

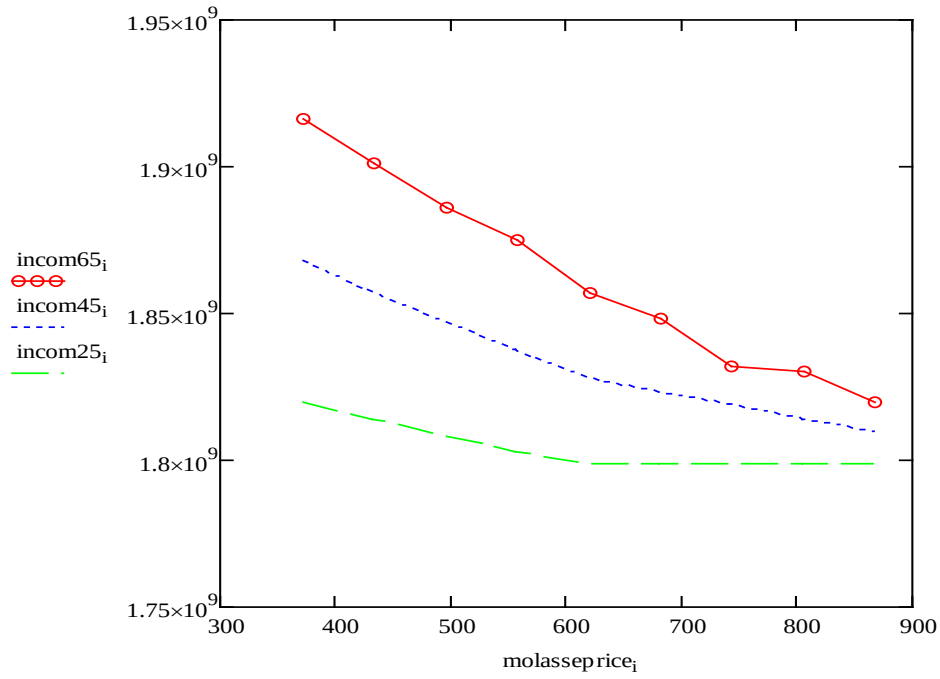

Figure 5: relation between foreign molasses price and income at different capcity(25,45,65 ton/year)

Optimization Results dissections:-

The effect of different capacity of ethanol plant and from figure2 molasses produce by Kenana sugar company will meet to need the ethanol plant up to (24.975*10^6) Liter/year., From figure 3 the income is proposal linearly with production rate of ethanol., When the price of sugar falls beyond 1200SDG/ton it is feasible to convert 1.182 x10^5 ton of sugar to ethanol.

From table5: when the price of foreign molasses decrease the value of molasses bought rise to 2.425x10^5 ton/year instead of 1.493x10^5 ton/year at high capacity for production ethanol ,in otherwise this leads to an increase the income., when the price of foreign molasses increase Kenana ethanol factory uses total local molasses for ethanol production. , increasing the capacity (form 25 to 45to 65)*10^6 ton/year for different values of foreign molasses selling price leads to an increase the income.

IV. CONCLUSIONS

It is conclusions that the integration of sugarcane and bio ethanol factories is very importance and advantage to decrease the production cost of ethanol because there is law value of transportation cost and raw material is available.

And the quality and quintets of the final molasses in factory depends on the quantity of non-sugar solids in the cane entering the mill and the manufacturing system used form the stag of mill extraction.

Then when the properties of molasses is good and high efficiency of fermentation and distillation processes theses lead to increase quantity and production high concentration of ethanol.(99.8%) this means less percentage of ethanol is losses and carry out in vinasse (by product of ethanol industries) in other wise thesis good effects to decrease environ mint impact of vinasse .

Linear programming has been used to determine the maximum income when it used the local and foreign molasses and selling price of sugar and ethanol in Kenana sugar factories and ethanol factories. Three cause can be used in optimize.

different production rate capacity of ethanol plant, different selling price of sugar, different price of foreign molasses.

Output of the optimization allayed molasses produce by Kenana sugar company will meet to need the ethanol plant up to ($24.975*10^6$) Liter/year.

and where the selling price of sugar decrease Kenana sugar company convert apart of sugar to ethanol manufactories or if it increase theses effect only in the income linearly.

similar where the price of foreign molasses change decrease theses effect only on the income or if it increase Kenana uses all molasses production to manufactories ethanol and the value of foreign molasses falls.

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