

Optimum Carbonation System Design

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Introduction

For the past three years, Holly Sugar Corporation has done much research in the field of juice purification. These studies were conducted in the plants, on a pilot scale carbonation unit, and in the research laboratory. This paper presents a review of the results obtained² and draws conclusions which are applied in the design of a new carbonation system.

Summary

Carbonation Elimination and Juice Thermostability.

The research started with the investigation of three carbonation systems—A, B, and C, as shown in Figures 1, 2, and 3. System A is a classical carbonation system consisting of a progressive prelimer, a main-limer, and a carbonation tank. System B is the Benning Carbonation Tank, while System C is a split carbonation system which includes a stabilization tank, a primary defeco-carbonation tank, a main limmer, and finally a carbonation tank.

The results given in Table 1 show:

1. Carbonation elimination is the same for all three systems. This agrees with recently published findings of European experts on juice purification (1, 3, 9)³. Findings seem to indicate that differences in elimination could be attributed to mistakes in practical performances; *i.e.*, erroneous juice recirculation, etc.
2. The thermostability of juices was not achieved in systems A and C despite the long retention time of main-liming. The thick juice color produced from systems A and C was less than from system B, but the pH drop during evaporation was larger than system B juices. Later calculations made with analytical data from Holly Sugar Corporation non-sugar reports showed that Imperial Valley sugar beets in 1969 averaged a

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²Holly Sugar Corporation, Research Report No. 44.

³Numbers in parentheses refer to literature cited.

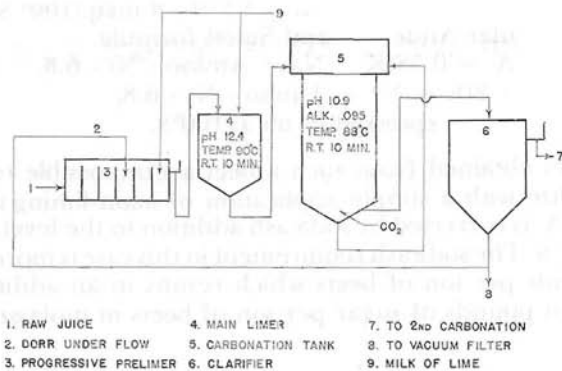


Figure 1.—Carbonation System A

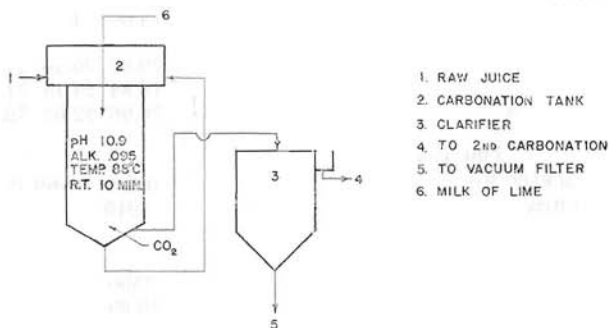


Figure 2.—Carbonation System B

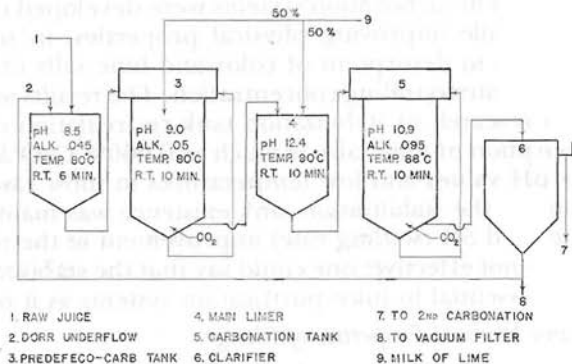


Figure 3.—Carbonation System C

beet effective alkalinity (B.E.A.) of - 8 meq./100° S. by using the popular Anderson and Smed formula:

$$\begin{aligned} \text{B.E.A.} &= 0.58(\text{K} + \text{Na} - \text{Amino} - \text{N}) - 6.8, \\ &8(\text{K} + \text{Na} - \text{Amino} - \text{N}) - 6.8, \\ &\text{expressed in meq./100°S.} \end{aligned}$$

Juices obtained from such a beet are impossible to thermo-stabilize with a simple application of main-liming unless the B.E.A. is corrected by soda ash addition to the level of 2 meq./100° S. The soda ash requirement in this case is more than two pounds per ton of beets which results in an additional loss of ten pounds of sugar per ton of beets in molasses.

Table 1.—Research results from the A, B, and C Carbonation Systems at the Carlton Plant in May and June, 1969.

	A	B	C	B
<u>Raw Juice</u>				
% Invert on Sugar	1.01	1.01	1.31	1.14
% Amino Acids on Sugar	4.09	4.09	5.05	5.35
% Carbonation Elimination	20.82	20.50	17.80	18.30
% Invert Destruction	78.84	24.15	71.09	24.01
% Amides Deamination	76.96	32.02	79.00	34.66
<u>Thin Juice</u>				
Lime Salts - % CaO/100 Brix	0.289	0.169	0.356	0.214
Color - units/100 Brix	1910	1580	3180	2370
<u>After Thin Juice Evaporation</u>				
Color - units/100 Brix	2500	3244	4219	4195
% Color Increase	30.89	105.31	32.70	77.00
pH drop (- Δ pH)	0.38	0.22	0.50	0.20

Erroneous Juice Recirculation.

In order to improve the physical properties of juices, a number of juice recirculations in carbonation systems were developed during the past 20 years. While improving physical properties, in some cases recirculation leads to desorption of color and lime salts caused by a simple decrease in surrounding concentration. The results which were obtained from research of stabilization tank recirculation conditions showed a desorption of lime salts as much as 0.060% CaO/100 Bx. In addition, low pH values and low temperatures in most cases lead to juice infection. As the stabilization tank existence was mainly for FK (filtration rate) and SK (settling rate) improvement at the time when flocculents were not effective, one could say that the stabilization tank is no longer as essential in juice purification systems as it once was.

Settling Aids and Physical Properties of Sludge.

Depending on brand name and method of application, flocculents can make enormous improvements in settling (SK) and filtering (FK)

properties of sludge with possible numerical values reaching 50 ft./hour for SK and less than 2 sec./cm.² for FK. The values are obtained by treating juices with one ppm flocculent which is properly prepared and thoroughly mixed with the juice in a graduated cylinder (less than 2.5% CaO O.B., alkalinity values in the range 0.060 - 0.120% CaO).

Research studies of plant scale flocculent application show that only 21.2% of the consumed flocculent is utilized as a settling aid. The remaining 78.8% is not utilized due to improper application; *e.g.*, lack of mixing with the juice. According to R. Kohn (6), the efficiency of flocculent utilization is mainly dependent on the way it is mixed with the juice before the flocculent begins to coalesce. This is very understandable, because high efficiency of flocculant utilization must be preceded by a high degree of absorption on the surface of the CaCO₃ particles. The coalescing of flocculent, even though it is accelerated by the presence of the Ca⁺⁺ ion, is not an instantaneous reaction and therefore five to eight seconds are available for mixing with the juice.

Precipitation and Separation of Colloids.

Research data (5) indicates that maximum carbonation elimination is achieved at an optimum alkalinity value or in the defined pH range 10.8 - 11.2. Contrary to this, precipitation of relatively soluble acids as malic and citric is increased as alkalinity increases (5, 8). The same is true with color and soluble lime salts adsorption. Tests results have also shown that an additional 15% color is adsorbed if the alkalinity is increased from 0.077% to 0.113% CaO. Consequently, from the standpoint of improving carbonation elimination, maximum advantages can be achieved by precipitation and separation of colloids in the first step of carbonation at the optimum alkalinity point. This will prevent juice deterioration by colloidal peptizate in further carbonation processing. The success of practical application of this idea is certain with the newly developed rapid clarifier (7). It should be stressed that the idea of colloidal separation as the initial carbonation step was applied for the first time in the Novi-Sad Carbonation System (10), but was not well accepted because of the unsolved problem of a fast and inexpensive method of sludge separation.

There is one more basic fact in support of colloidal separation. In the absence of colloids, the agglomeration of CaCO₃ particles is negligible. Thus, the surface of produced CaCO₃ in colloid free juice is increased, enlarging the degree of adsorption many fold.

Main-Limer

Main-liming is the process which promotes thermostable juice containing the required amount of natural alkalinity at existing

amino-N content. As previously mentioned, the optimum B.E.A. values are 2.0 meq./100°S or a numerical value of 1.8 if expressed as *Alkalinity Index* (4).

If the natural alkalinity level is low, largely due to the higher amino-N content in the case in California, main-limers could diminish juice quality unless sufficient soda ash is added. For beets with high amino-N levels or spoiled beets with high invert levels, the use of main-limers could lead to enormous soda ash requirements and should be avoided. While it is hoped that the beet quality will gradually improve, beets with B.E.A. values of less than 2 meq./100° S. should be processed without a main-limer. Stress should be placed on processing the beets as fast as possible. It is recommended that CaCl_2 be used in diffusion to decrease the expense of soda ash addition and at the same time improve the pressability of beet pulp (2).

In the Rocky Mountain Region where the beets are at the 10 B.E.A. level or more, conditions are highly favorable for the use of a main-limer. In conjunction with this, it seems wise to remove the alkali surplus through ion exchange with the NH_4^+ ion.

Optimum Carbonation System.

In designing a new carbonation system, the following guidelines are used:

- 1) to improve the chemical properties of the juice while the physical properties can be improved by flocculents,
- 2) to keep the system simple in performance and without sensitive spots—thus eliminating the biggest problems and mistakes in practical application,
- 3) to keep the capital investment for equipment as low as possible.

The recommended carbonation system is shown in Figure 4 and in the material balance flow scheme. A carbonation tank for coagulation could be made of the existing Benning tank. In the external doughnut where the alkalinity is 20% less than in the main tank, colloids of the raw juice are adsorbed on the CaCO_3 surface to some extent, depending on the mixing action. In the main tank, the alkalinity is maintained at the optimum value for colloid coagulation. Flocculent, 0.01% by weight, is added to juice in the mix tank. The mix tank has a six second retention time and the juice is agitated at 400 R.P.M.

The rapid clarifier is made by remodeling the old type clarifier trays. Mud is washed with limed water of pH 11.0 in order to avoid non-sugar desorption. The clarifier overflow and filtrate from the vacuum filters pass through the heater on the way to the main-limer. In the plants where the main-limer is not included in the carbonation system,

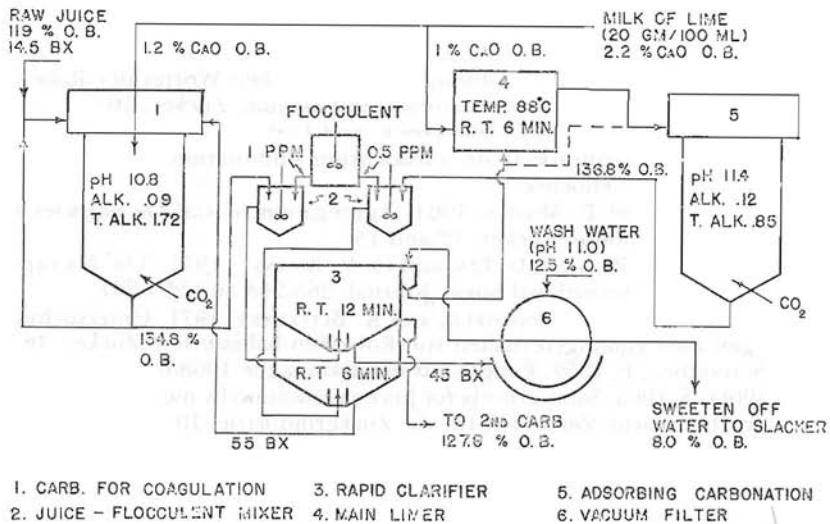


Figure 4.—Recommended Carbonation System

the overflow goes directly to the adsorbing carbonation tank. Consequently, the milk of lime in the latter case is fed directly into carbonation. Adsorbing carbonation should be controlled at the highest possible pH value. Colloidal properties of produced CaCO_3 contribute to better adsorption. Carbonated juices pass through the mixer tank for flocculent addition before entering the clarifier. The clarifier underflow is recycled to carbonation for coagulation.

Conclusion

This report has described a new carbonation system based on the latest trends in sugar beet processing:

1. declining beet quality resulting in an imbalance of amino-N content to natural alkalinity which requires selectivity in application of classical carbonation equipment.
2. development of flocculents placing more emphasis on the chemical rather than the physical properties of juices.
3. the incorporation of the latest designs in process equipment.

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Assumed Values for Calculation

I. Sugar Content in Cosettes	14.70%	O.B.*
II. Raw juice		
Sugar extracted	14.50%	O.B.
Solids extracted	17.25%	O.B.
Non-sugars	2.75%	O.B.
Acidity	0.03%	O.B.
III. Carbonation		
Elimination	31.00%	
Non-sugars removed	0.85%	O.B.
Sugar losses	0.10%	O.B.
Available CaO	2.20%	O.B.
Flocculent concentration (by weight)	0.01%	
A. Carbonation for Coagulation		
CaCO_3	3.68%	O.B.
Dry mud solids	4.53%	O.B.
Specific gravity of precipitate	2.20	gms/ml
Wet mud (50% solids)	9.26%	O.B.
Clarifier underflow (dry mud solids)	18.12%	on vol. %
B. Adsorbing carbonation		
Available CaO	1.0%	O.B.
CaCO_3	1.78%	O.B.
Specific gravity of CaCO_3	2.80	gm/ml
Clarifier underflow (dry mud solids)	22.25%	on vol. %

*Percent on Beets.

Flow Scheme with Material Balance

The two numerical values in each square, which are divided by a slash, express % weight on beets and liters per ton of beets.

