

INFLUENCE OF THIN JUICE pH MANAGEMENT ON THICK JUICE COLOR IN A FACTORY UTILIZING WEAK CATION THIN JUICE SOFTENING

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Introduction:

In beet sugar factories utilizing weak cation thin juice softening, soda ash addition to thin juice is utilized, usually in second carbonation, to pre-soften the thin juice to a suitable feed hardness for supply to the weak cation reactors. Downstream of the weak cation reactors, there is generally an addition of 50% caustic solution to counter the effect of H⁺ bleed from the freshly regenerated weak cation resin during the early portion of the reactor service cycle. If not precisely controlled, the post-reactor re-alkalization of the thin juice with 50% caustic solution may result in over-alkalization of thin juice leading to pH rise and an associated color rise in the juice during juice concentration. Over-dosing of soda ash and the excessive lowering of feed hardness to the softener reactors will similarly result in over-alkalization of the thin juice with the same effect during juice concentration.

The subject process control investigation was undertaken for the purpose of optimizing the pre-softening of thin juice while also achieving overall optimum pH management of thin juice with the aim of avoiding juice over-alkalization and the resulting associated color rise during juice concentration. A means of pre-alkalization control was developed and implemented satisfying both the pre-softening and the overall juice alkalization requirements leading to the complete elimination of the use of liquid caustic for post-reactor re-alkalization and the elimination of excessive color rise in evaporation due to unwanted pH rise. Optimum juice alkalization targets are maintained to achieve minimum color rise in juice concentration resulting in minimum thick juice color while also meeting the competing juice processing requirement for the production of soft thin juice.

Background and Methodology:

The Mini-Cassia Factory of The Amalgamated Sugar Co., LLC located in Paul, Idaho has undergone significant slicing capacity expansion in recent years. Due to various pressures on post expansion processing systems, the weak cation softening system has not routinely been capable of stable production of soft thin juice. As a result, it has been a process management strategy to over-dose soda ash to assure low juice hardness in the feed to the weak cation softener reactors. The established “normal” operation of the softening station called for the use of 50% caustic solution to adjust the pH of the juice exiting the reactors to a minimum of 8.8-9.2 pH. As a result of the combination of these operating practices, it was usually the case that there was a large pH increase from thin juice to thick juice even in spite of sulfitation of the thin juice prior to concentration in the evaporators.

It became apparent during the review of 2008-09 campaign operating data that, during juice concentration, a rather large increase in juice color was also associated with the pH increase. In fact, the degree of the increase in color appeared to be closely associated with the magnitude of the pH increase. Based on this observation, it was concluded that thin juice was being over-alkalized with excessive addition of soda ash and liquid caustic causing the pH rise and noted color rise.

The 2008-09 campaign data, shown in Figure 1, led to the development and evaluation of a modified operating strategy to achieve both reliable soft juice production and a significant reduction and/or elimination of excessive pH rise and the associated color rise during juice concentration.

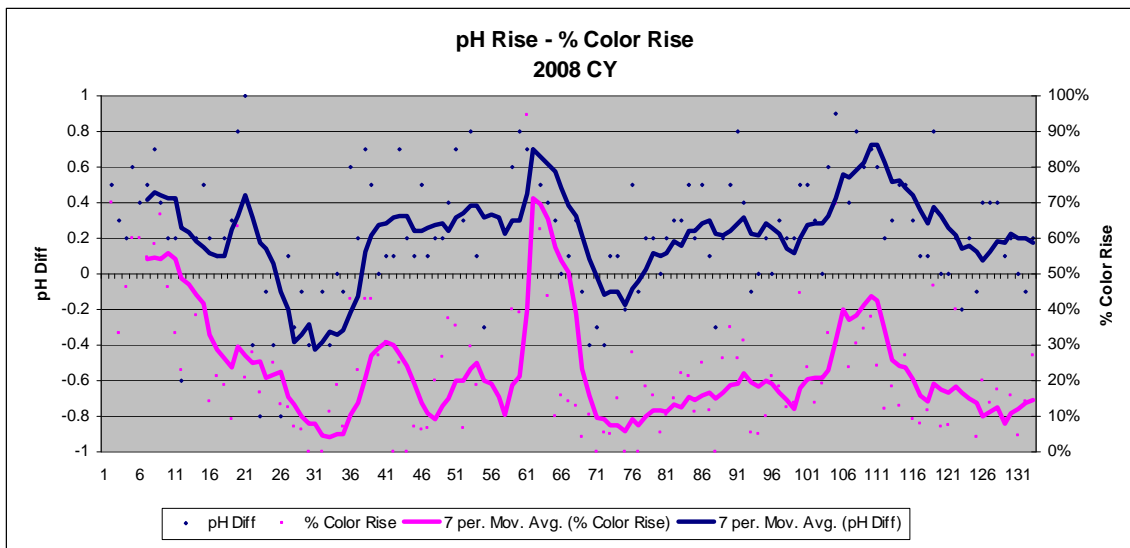


Figure 1

In the early portion of the 2008-09 campaign, up until day #50, juice purification received close scrutiny with a number operating target modifications made to preliming management and total lime addition for optimization of the purification process and improved juice quality. This period was followed by a plant power outage and recovery from day #60-70. The relationship between pH and color rise was first noted during the period up to day #50, when operations were relatively stable and purification performing well. Operations after the outage between day #75-131 proved quite stable from a slice rate and purification management perspective.

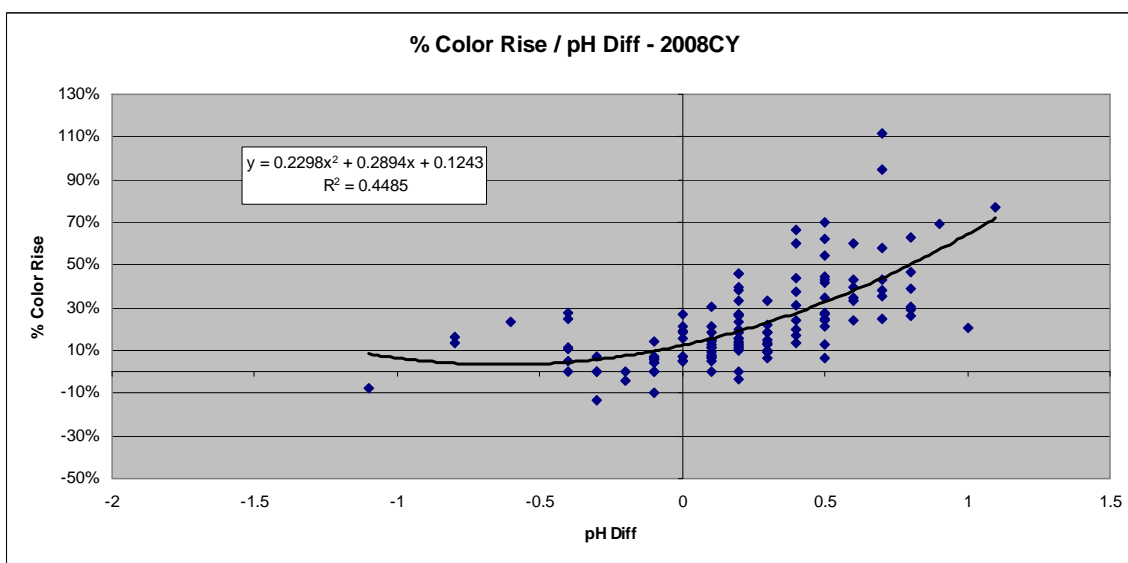


Figure 2

During this period, the relationship between pH rise and color rise in juice concentration was remarkably consistent. Figure 2 shows the regression analysis for % Color Rise as a function of pH increase in juice concentration. While the correlation coefficient is not high, it is clearly the case that there is an association of color rise and pH rise during juice concentration and that as much as 45% of the color rise in juice concentration is related to the pH stability of the juice during concentration. It is also noted that the lowest color rise is obtained when there is a slight drop in pH during juice concentration on the order of -0.5 pH.

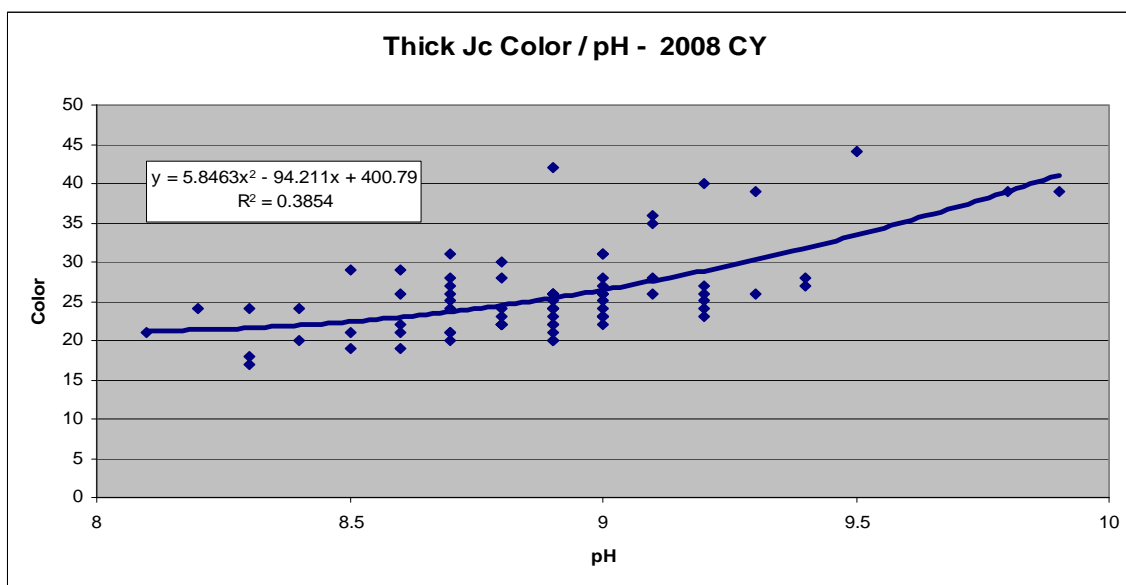


Figure 3

A regression analysis between final thick juice color and final thick juice pH indicates that the lowest thick juice color is produced roughly in the range of 8.0-8.7 pH. The regression shown in Figure 3 suggests that some of the influence on thick juice color relies on the final pH of the thick juice.

An additional regression analysis on juice color versus campaign day number, as shown in Figure 4, indicates as expected, a high dependence of process juice color on campaign day as well as a steady increase in color rise across the evaporators as the campaign progresses. The combined effects of campaign length (progressive deterioration of juice quality), pH stability across juice concentration (alkalization control) and final thick juice pH together appear to explain most of the variation in color and color rise.

Thus, campaign length notwithstanding, the color of thick juice has a significant dependence upon the degree of alkalization of the thin juice and on the final pH of the thick juice produced. A significant amount of the “scatter” noted in Figures 2 and 3 may be attributed to the effect of campaign length (operating day #) on the thick juice color and the noted color rise relative to the day associated with the data point. In a controlled experiment, the amount of scatter in the data points and the value of the calculated regression coefficients for these data would likely be significantly improved.

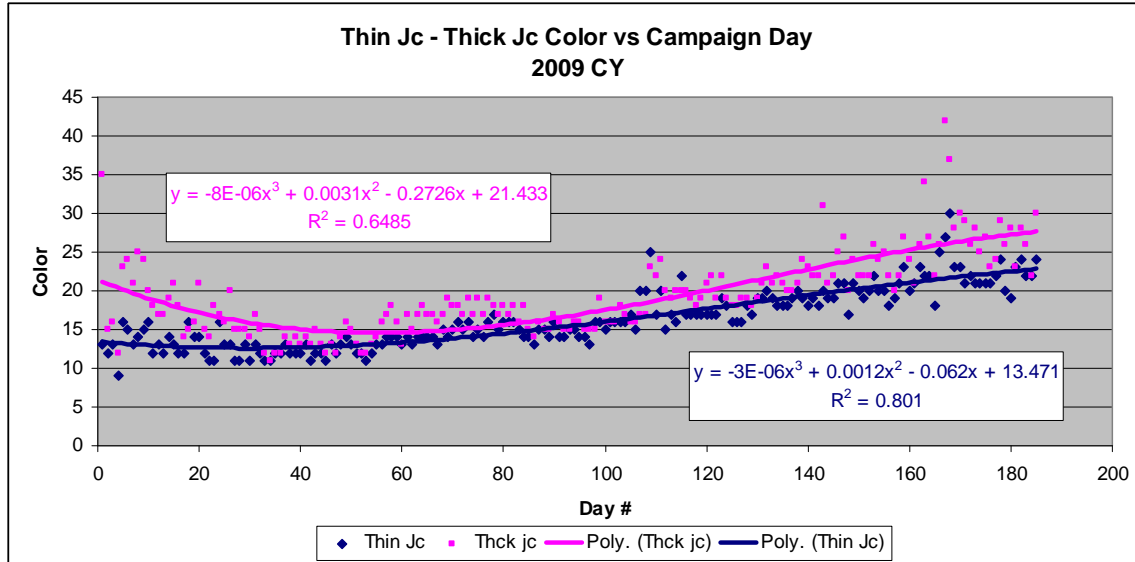


Figure 4

Based upon these observations, a means of thin juice alkalization control was devised to provide the necessary juice softening performance without over-alkalization of the juice and the associated pH and color rise across the evaporator. The primary elements of this control concept were based on the following assumptions.

1. With proper process management, 100% of the necessary juice alkalization could be accomplished solely with the addition of soda ash to juice purification (2nd carbonation). Thus, the post-reactor use of 50% caustic solution is likely to be unnecessary and could be discontinued entirely while the juice hardness supplied to the weak cation reactors would be at a minimum relative to the total required juice alkalization.

2. It was thought likely that the critical process management targets for juice hardness and pH management would change as the campaign proceeded from sound high quality beet to a beet having moderate deterioration and finally to significantly deteriorated beet after more than 100-120 days in storage.

3. Plant operators would be required to make timely and correct decision concerning the amount of soda ash to be added to the process based on not only the required hardness to the weak cation reactors but also relative to the thin juice / thick juice pH behavior during juice concentration as well as the final thick juice pH.

4. Very clear operating guidelines would be required to assure systematic decision making by the operating staff in order to routinely achieve satisfactory and optimized results for the possibly competing process objectives of soft juice production and minimum thick juice color at optimum pH.

Alkalization Control Matrix:

A process control decision matrix was developed to manage the various parameters necessary to achieve the optimum juice alkalization required to achieve both soft thin juice and low color thick juice. Shown in Figure 5.

Mini-Cassia Factory
Soda Ash Addition Decision Flow Chart

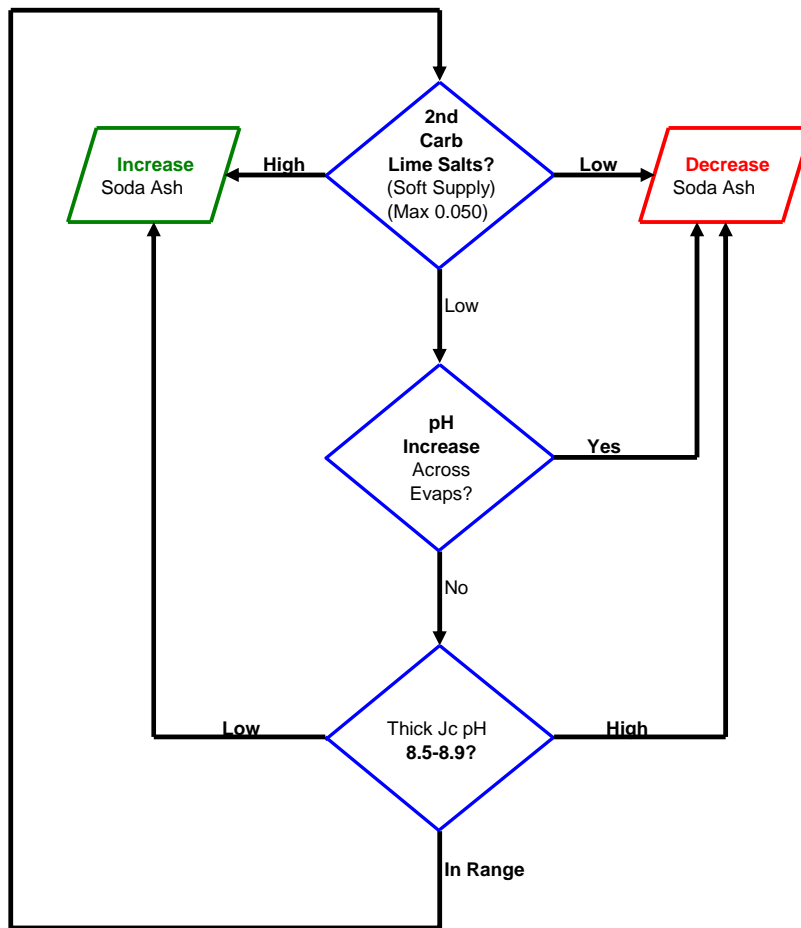


Figure 5

The essence of the control strategy embodied in this decision matrix is that the production of soft juice takes priority over other competing objectives. The elimination of pH increase across the evaporators takes second priority and the final pH of thick juice takes third priority. By systematically following the decision sequence, optimization of the process routinely occurs.

Plant operators were trained in the use of the process control flow chart and instructed to adjust the addition of soda ash to the process based upon process trends for filtered 2nd Carbonation and Softener Supply juice hardness and the difference in thin juice and thick juice pH as well as final thick juice pH as per the sequential decision flow diagram. Given the normal lag time in the process plus the time requirement for sampling and juice analysis, operators were cautioned against making adjustments based on individual data points. Stable process operation was stressed as well as the necessity of monitoring process trends and the strict avoidance of over-control which would introduce unwanted process variation. With some coaching and minimal training, operators were able to adjust quite easily to the modified control concept.

Operating Results and Discussion:

The control strategy was implemented on the 71st day of the 2009-10 campaign. By the 84th day, both juice hardness and pH increase across the evaporators were in the desired control range. Figure 6 shows the thin juice and thick juice pH along with the % color rise during juice concentration for the 2009-10 campaign period.

As noted in the graph, the average color rise in thick juice prior to adoption of the control strategy averaged 23% and included a period of low color rise where a pH increase across evaporation was absent. After the implementation of the new control strategy the average color rise

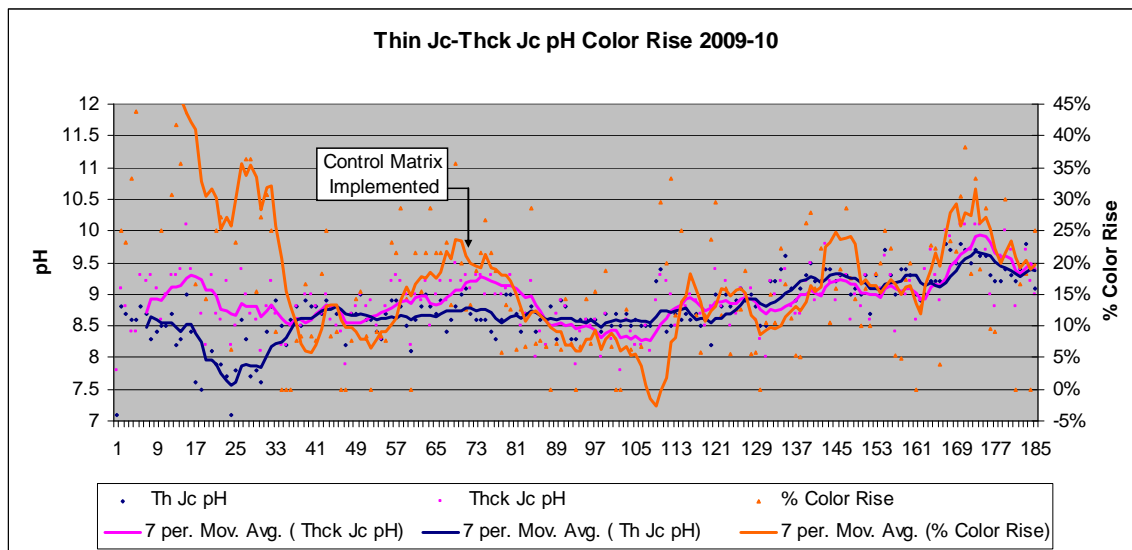


Figure 6

during juice concentration was reduced to 15% for the balance of the campaign period in spite of the processing of a relatively significant quantity of frost damaged beets during that processing period. Those periods of operation are quite evident where significant color rise was noted in spite of the absence of significant pH increase across the evaporators.

Regression analysis on pH difference between thin and thick juice and % color rise, as shown in Figure 7, indicates essentially the same relationship as in the 2008-09 campaign. The

regression analysis of thick juice color and thick juice pH, as shown in Figure 8, also indicates a similar relationship to the 2008-09 campaign but with a much higher correlation. This improvement in correlation is most likely the result of overall improved purification control and implementation of the juice alkalization management control strategy.

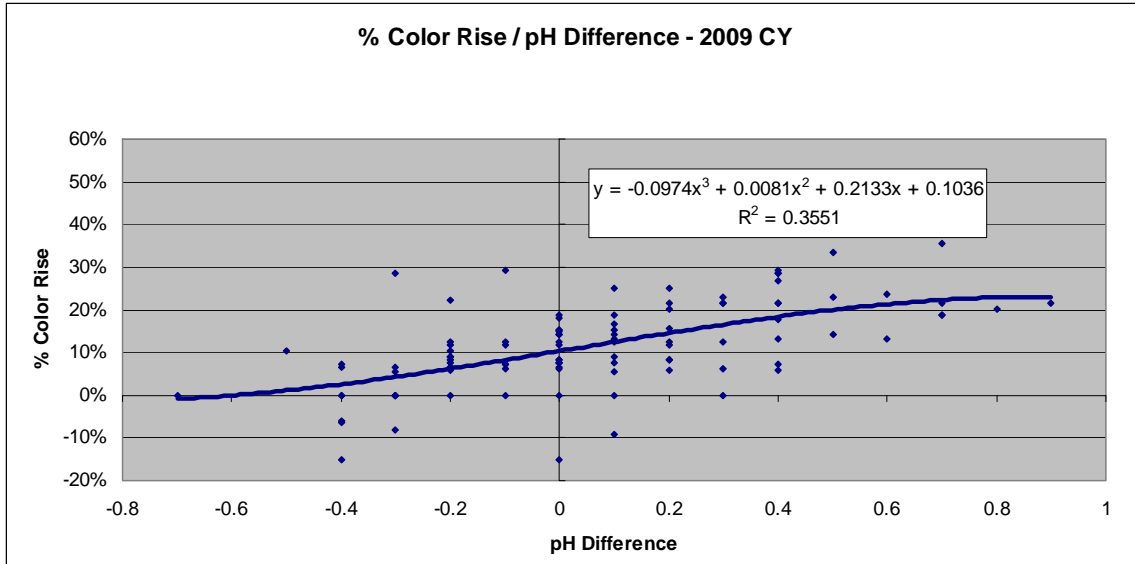


Figure 7

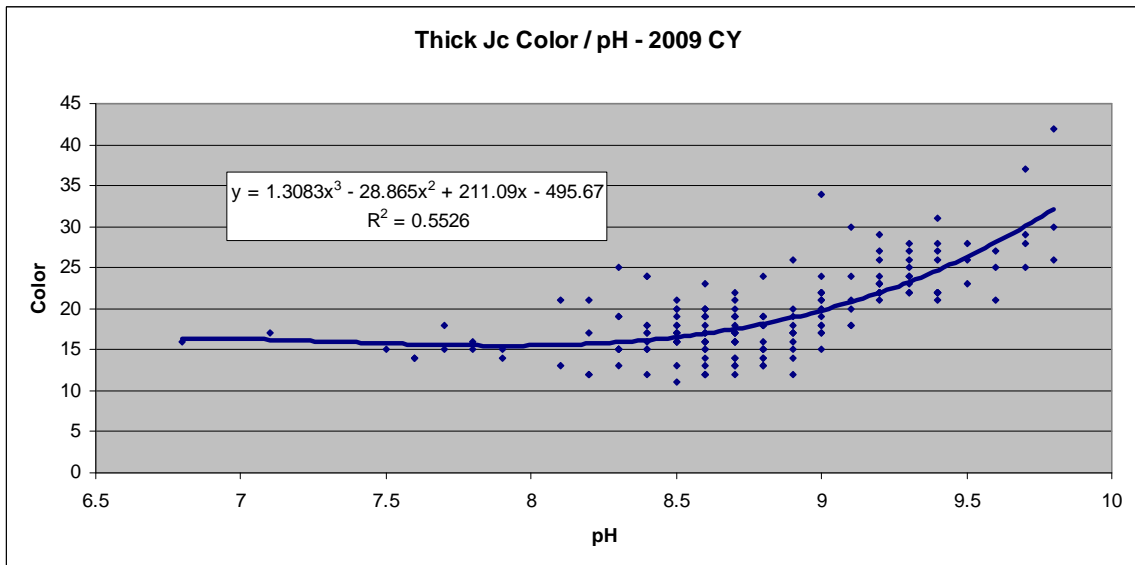


Figure 8

The lowest thick juice colors again appear to be approximately 8.5 pH with a range of 8.0-9.0 pH giving the lowest thick juice colors. It may be concluded thus that both the absence of pH increase in juice concentration and the final pH of the thick juice produced results in the production of thick juice with the lowest possible color.

Further refinement of the juice alkalization control strategy through additional operator training along with improvements to the soda ash delivery system prior to the 2010-11 campaign resulted in excellent control of thick juice color while producing the lowest thick juice color in the history of the Mini-Cassia factory. For the 2010-11 campaign, the percent color rise averaged approximately 21% or the equivalent of a 3 color unit color increase during juice concentration with a final thick juice color averaging 1700 ICUMSA through the 146th day of the campaign. Data points for the 2010-11 campaign are superimposed below on the thick juice color and thick juice pH (Figure 9) and for pH increase during juice concentration and % color rise (Figure 10) are similar to the previous campaign regressions and more tightly grouped in the optimum operating ranges.

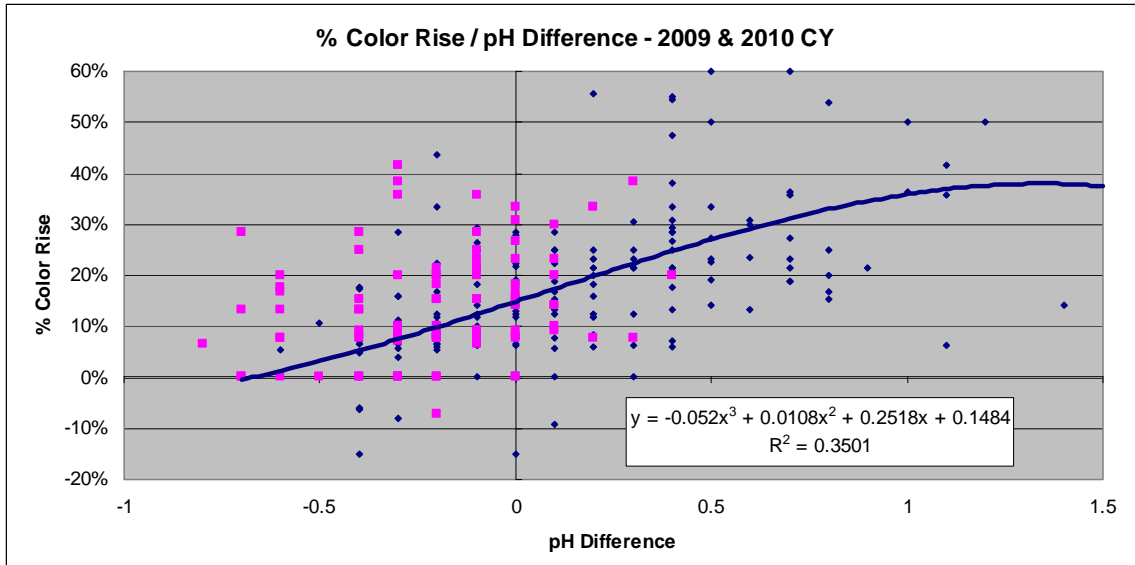


Figure 9

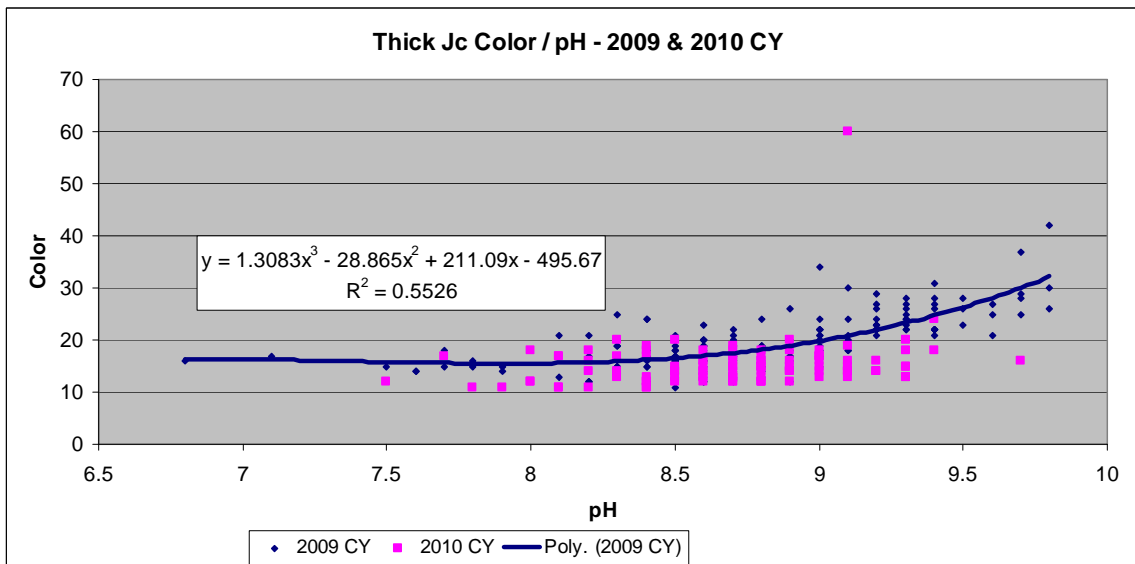


Figure 10

As compared to the previous two campaigns, the control of color rise in juice concentration and the final thick juice color are far superior to the previous two campaigns as shown in Figure 11.

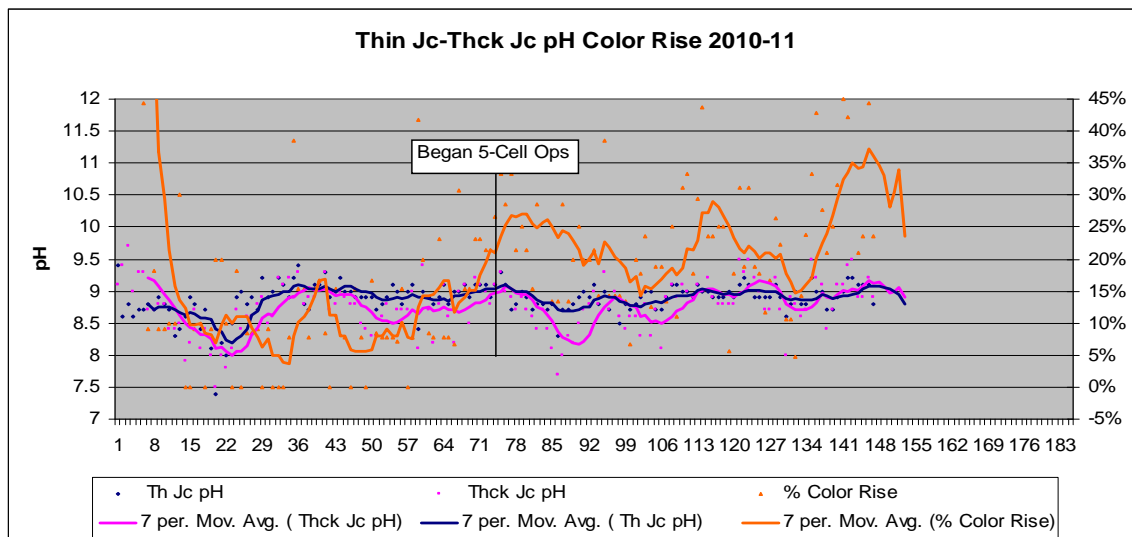


Figure 11

The noted improvement in juice pH and color management has been accomplished without any related deterioration in juice softening performance which, in fact, has improved as well as a result of accomplishing all thin juice alkalization during juice purification prior to weak cation treatment for final softening of the juice. The suspension of any pH adjustment after the weak cation juice softening reactors has had no measurable effect on the inversion of sucrose in final softening nor on the stability of juice colors in juice concentration or subsequent sugar end operations.

Conclusions:

1. In a factory operating weak cation thin juice softening, complete control of thin juice alkalization and lime salts control in softener supply may be accomplished through the strict, systematic control of soda ash addition. (It is not necessary to re-alkalize the effluent juice flow from the WIX (weak acid ion exchange) reactors with caustic addition to prevent inversion of sucrose.)
2. A rise in pH during juice concentration will have associated with it an increase in juice color. The greater the increase in pH the greater the degree of color increase. Such pH increase indicates excessive addition of soda ash and/or caustic solution to the process.
3. The optimum pH difference between thin juice and thick juice is in the range of -0.5 to 0.0 to achieve the lowest % color rise during juice concentration.
4. The optimum thick juice pH is in the range of approximately 8.20-8.70 pH to obtain the lowest color of thick juice.