Influence of several agronomic, post-harvest and technological factors upon process ionic balance and consequently upon industrial yield.

Presented at the 2005 ASSBT conference (Factory operation session), Palm Springs, Ca, USA.

Emmanuel DUFFAUT(*) and Fernando MARTÍN DOMÍNGUEZ,
Azucarera Ebro, R&D center, C/Esperanza 10, Valladolid 47007, Spain..
(*) Contact: emmanuel.duffaut@aeasa.com

Abstract

Over the years 2002, 2003 and 2004 many experiments at different scales (industrial, pilot-plant, laboratory pilots) were finalized in both autumn and spring sown campaigns, that aimed at assessing the impact of different agronomic, post-harvest and technological factors upon process ionic balance (IO). The process ionic balance, which is determined through juice effective alkalinity, is a major factor that influences the sugar production yield. This study allowed to identify real and potential possibilities to improve IO. Also, new knowledge regarding the impact upon IO of the above-mentioned factors was obtained for both autumn sown beets and spring sown beets campaigns. The variation margins of effective alkalinity are exposed and in which way they are influenced by factors such as beet variety, nitrogen fertilization, irrigation, post harvest mechanical damage, time between harvest and slicing as well as diffusion and juice clarification parameters. Technical and economical results of preventive and corrective (NaOH addition) measures to obtain a positive ionic balance were compared. It was shown that (1) deficiency in alkalinity provokes an indirect melassigenic effect due to addition of NaOH, (2) that beet variety, beet diseases and nitrogen fertilization have an influence on IO, (3) that mechanical damage coupled with residence time and temperature alter IO as well as inappropriate beet washing, (4) that extraction (draft) and juice clarification parameters significantly affect effective alkalinity.

Introduction – Aim of the study.

It is well known that agronomic and post harvest conditions greatly influence the factory operations. For example, thick juice non-sugars and color loading along with its effective alkalinity which are three of the main parameters that condition good process operations in the sugar end are directly related to the quality of the beet being processed. Effective alkalinity (EA) or process ionic balance is the balance between the non-sugars that consume alkalinity (amino acids, reducing sugars) and those that produce it (Na^+, K^+). In case of deficit in EA caustic soda addition

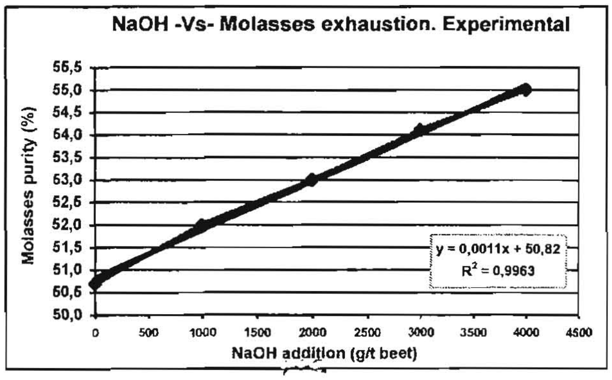

Figure 1.

then becomes necessary in order to limit lime salts formation and avoid a pH drop during evaporation, which would lead respectively to scaling in boiling pans and to sucrose inversion. Only, caustic soda addition is detrimental to the process for (1) sodium is strongly melassigenic (Figure 1), (2) it increases the final sugar ash content, (3) it increases color and (4) has a significant financial cost. Low effective alkalinity being a frequent problem in Spanish factories, therefore Azucarera Ebro launched a vast study at pilot plant scale to (1) identify the relation between EA and agronomic, post-harvest and process conditions, (2) determine the most influential of those parameters and (3) define equations to forecast EA from beet composition.

Material and methods.

On the agronomic point of view, the parameters taken into consideration were beet variety, harvesting date, nitrogen fertilization, irrigation, diseases and the post harvest conditions studied were field storage, and time between harvest and slicing. Process-wise, beet washing, extraction rate and pH profile in the prelimer were looked at.

A very thorough list of analysis were performed on the beets that were studied which included: purity, sucrose, glucose, fructose, raffinose, glutamine, betain, total and α-amino nitrogen, sodium, potassium, lactic acid, acetic acid, propionic acid, pH and dry substance. Those beets were subsequently entirely processed through a pilot plant station to obtain syrup using the same process as in a factory. EA was checked on the thin juice obtained and color and purity on thick juice. All the results presented below are average values of all the data obtained in the study.

Results & discussion.

1/ Agronomic factors.

1.1/ Beet variety and water stress.

It was observed that beet variety in normal growing conditions has a significant effect on the effective alkalinity, as it can be seen in figure 2, resulting in variations as high as 63 % in caustic

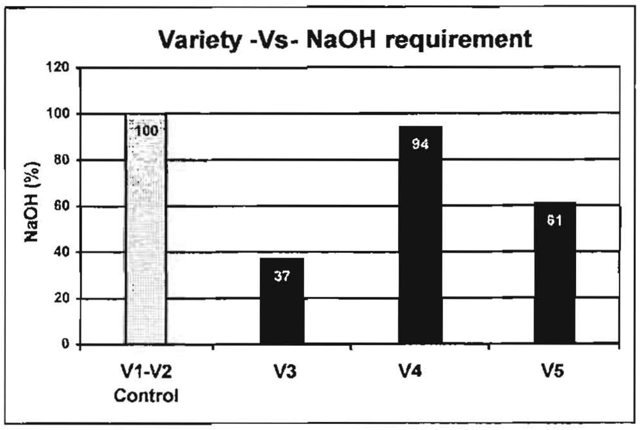

Figure 2

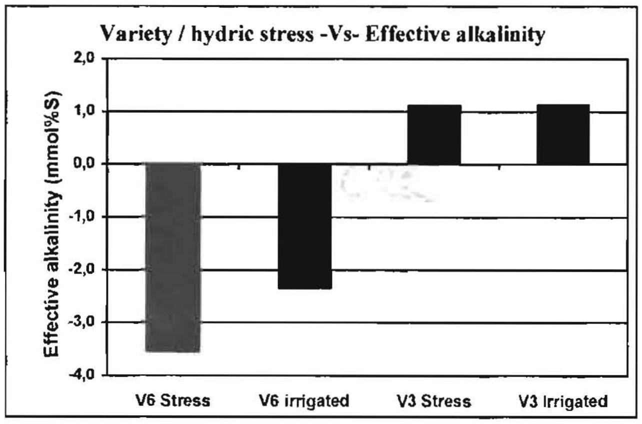

Figure 3

soda consumption. This is especially the case in the south of Spain where weather conditions are very drastic. Furthermore, in the south of Spain this parameter is also influenced to a certain degree by the amount of water received, to which each variety respond differently (Figure 3) in term of effective alkalinity. Therefore, beet variety associated to water supply condition appears to be an influential factor for EA improvement.

1.2/ Harvest date.

This is a very critical factor as can be seen in figure 4, specific to the South of Spain where excessive temperatures in the summer deteriorate the beets quickly. The obvious solution to this problem would be to start harvesting earlier to avoid the heat.

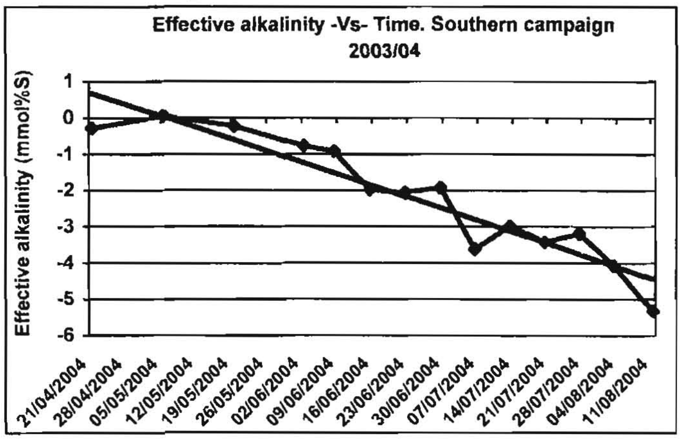

Figure 4

However, this can't be done for it would be to the growers great disadvantage economically speaking, since the beet would not have time to reach maturity and optimum sucrose concentration. The situation shown in figure 4 though has been greatly improved over the last 5 years by maintaining a constant crop treatment (ex: irrigation, pesticides) adapted to each field specific demand, up until one week before harvest. Also, factories capacity in the south has been increased in order to limit the length of the campaign and avoid processing too deteriorated beets.

1.3/ Field storage.

In the north of Spain, harvested beets are often momentarily stored by the field in small piles before being shipped to the factory, which generates steady beet degradation within a few weeks

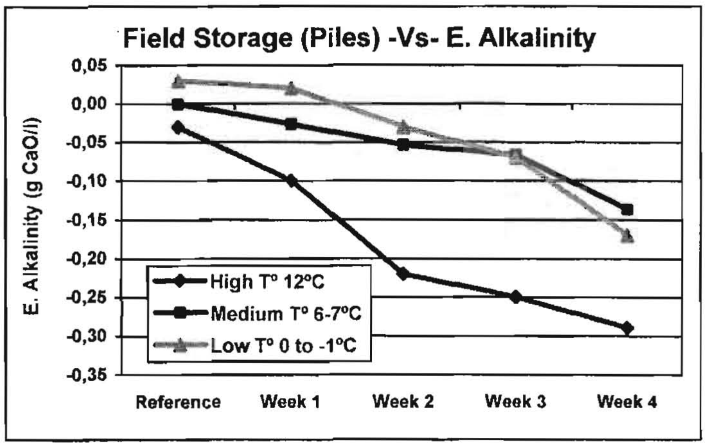

Figure 5

period that reflect on EA as it is shown in figure 5. Also, this deterioration is dramatically enhanced when the outside temperature increases.
One way to remedy to this problem could be to leave the beet in the ground instead. During the 2000/2001 campaign growers had to stop harvesting for about 40 days due to very important precipitations. When the campaign resumed, it was observed that overall beet quality had maintained quite well and that EA had only very slightly dropped (Figure 6). This characteristic, which has been confirmed during the following campaigns, will then allow to considerably reduce intermediate field storage, thus beet degradation, as well as to enlarge the harvesting campaign, optimizing therefore sugar production.

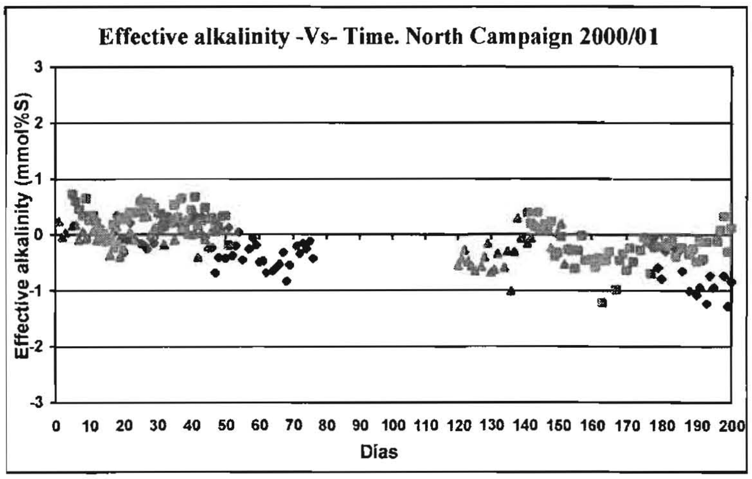

Figure 6

1.4/ Nitrogen fertilization and irrigation.

Nitrogen fertilization is detrimental to EA for it forms amino acids that consume EA (Figure 7) but is not a very critical parameter. However, on the other hand nitrogen is absolutely necessary for proper beet growth, which leads to a trade-off situation. The right nitrogen dosage must be found that allow the beet to develop and that gives acceptable EA in the process and thus an acceptable thick juice purity.

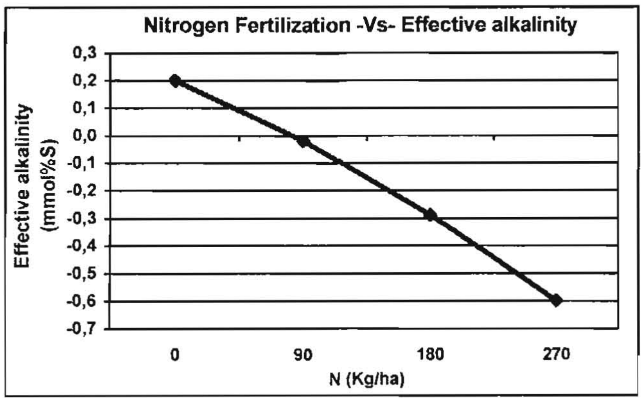

Figure 7

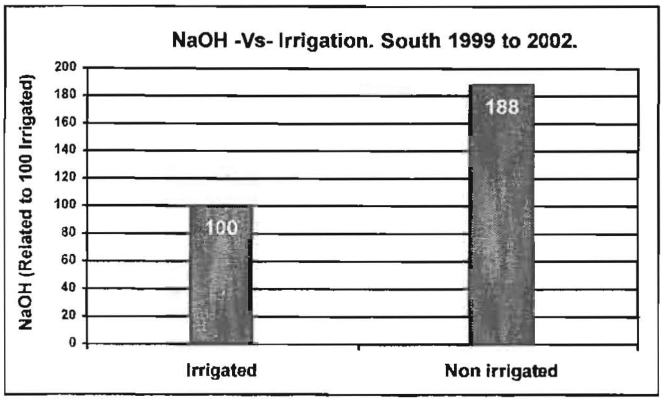

Figure 8

As we saw it in 1.1 irrigation has a certain influence on the impact of beet variety upon EA, but it also has a direct effect on EA as clearly stated in figure 8. Very important progress has been realized in that area in a very short time with the generalization of irrigation to almost each field and with the implementation of a state-of-the-art irrigation system that allows to deliver more efficiently the right amount of water to each parcel.

1.5/ Beet disease.

Beet diseases are of paramount importance when it comes to EA. Basically, beet infection, whatever the disease, induces sucrose degradation that leads to invert sugar formation causing great loss of EA (Figure 9, 10, 11) consequently increasing enormously caustic soda consumption.

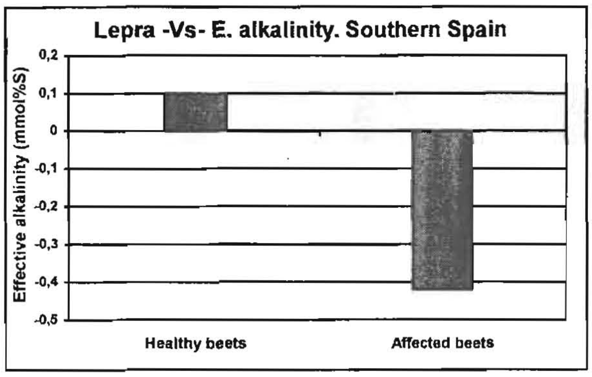

Figure 9

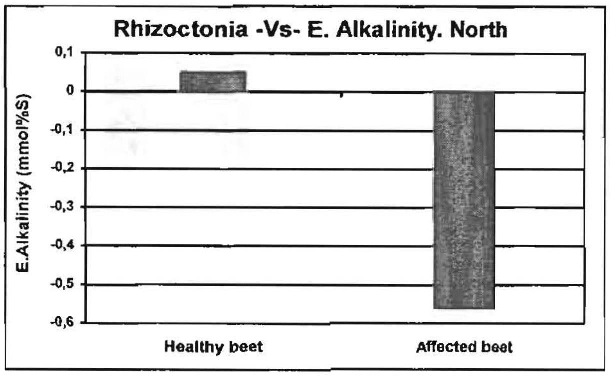

Figure 10

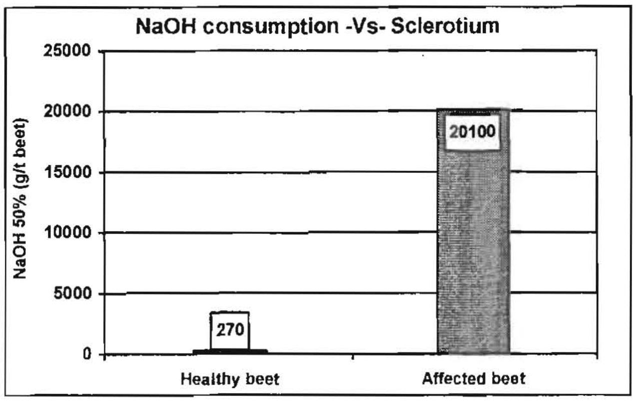

Figure 11

Beet variety selection, adequate pesticide treatment until harvest and fields turn-over among other factors have allowed to reduce significantly the occurrence of diseases but it still remains a problem especially in the south.

1.6/ Post harvest conditions.

There are two main post harvest parameter that greatly influence EA: mechanical damage prior to the plant and waiting time before slicing. They are especially critical in the south of Spain where outdoors temperatures can reach 45°C.

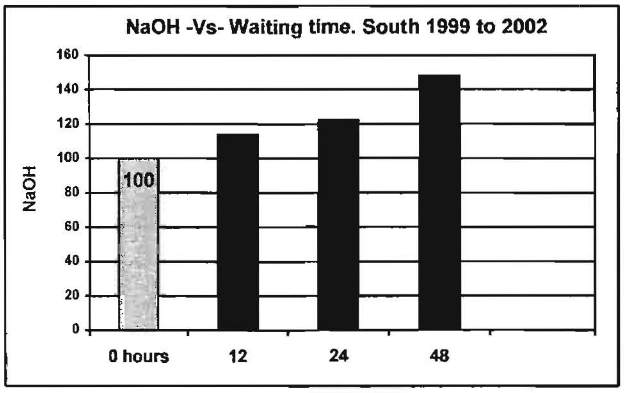

Figure 12

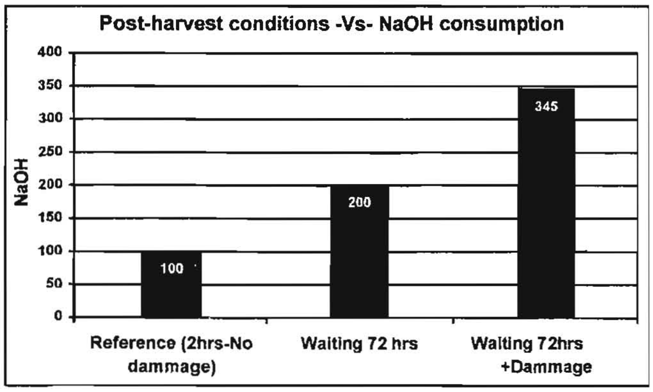

Figure 13

Figure 12 and 13, clearly show that waiting time only causes high level of degradation, which is dramatically increased when the beet has suffered mechanical damage. Along the last few years waiting time in the southern factories has been lowered to 12 hours maximum. However, damage still remains important and work is being conducted to limit it.

2/ Process factors.

2.1/ Beet washing.

As it can be seen on figure 13, final washing of beets plays an important role in EA. Figure 14 shows the increase in EA that was obtained at lab scale just by eliminating the dirty water surrounding the factory washed beet. This result was then confirmed at factory level when was added another nozzle ramp of clean water in the final washer (Figure 15).

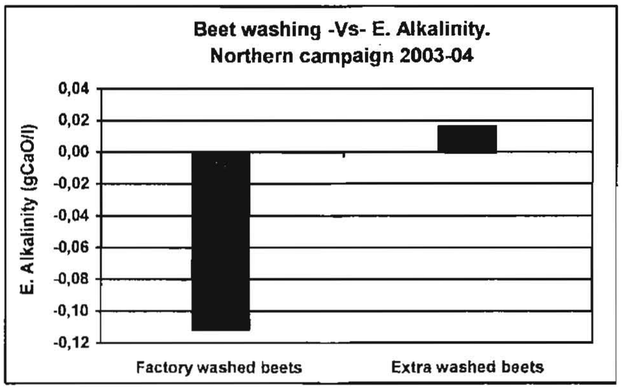

Figure 14

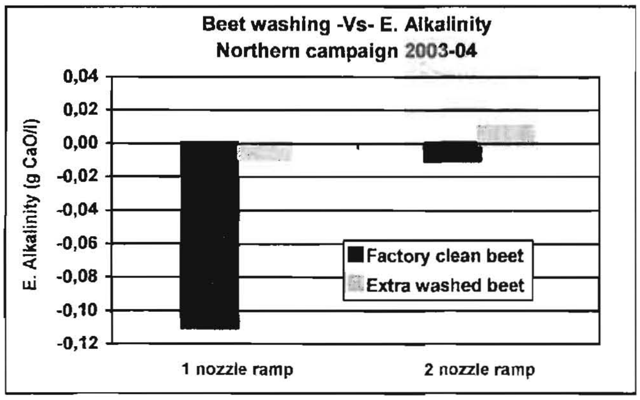

Figure 15

According to a more complete study realized in 2003/04, in the end a thorough final washing would allow to reduce the caustic soda consumption by 60 to 70 %. It would also allow to enhance the industrial yield by increasing thick juice purity (5%) and reducing its color (20%) and by reducing sugar ash content and turbidity.

2.2/ pH profile in prelimer.

Few years ago, in many factories filtration mud was recycled directly to diffusion juice for it was thought to better juice clarification. Therefore, the inlet pH of diffusion juice in the prelimer significantly increased causing EA in thin juice to drop (Figure 17). Obviously pH 10 is an extreme experimental situation and in reality pHs of 8.5-9 were usually observed.

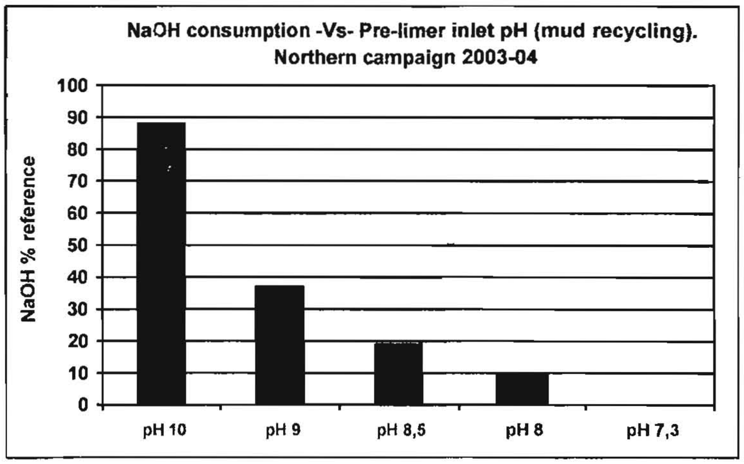

Figure 17

To prevent this from happening, in all factories, filtration mud is now gradually inserted into the prelimer as it is commonly done everywhere.

2.3/ Extraction.

Extraction rate is of course directly related to EA for the higher the draft, the higher the impurities content of diffusion juice. It was determined experimentally that rising the draft from 105% to 125% would triplicate caustic consumption. Here again an acceptable compromise has to be found between sugar and impurities extraction.

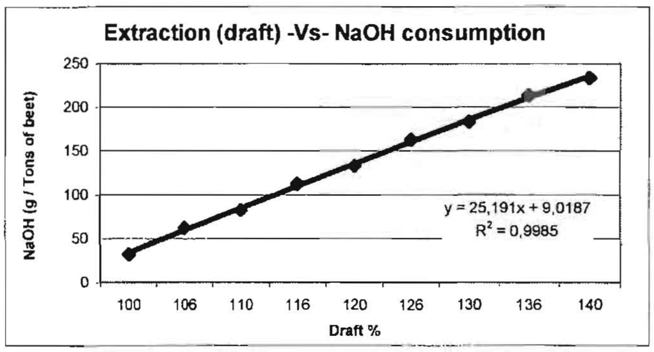

Figure 18

3/ Parameters improvement potential.

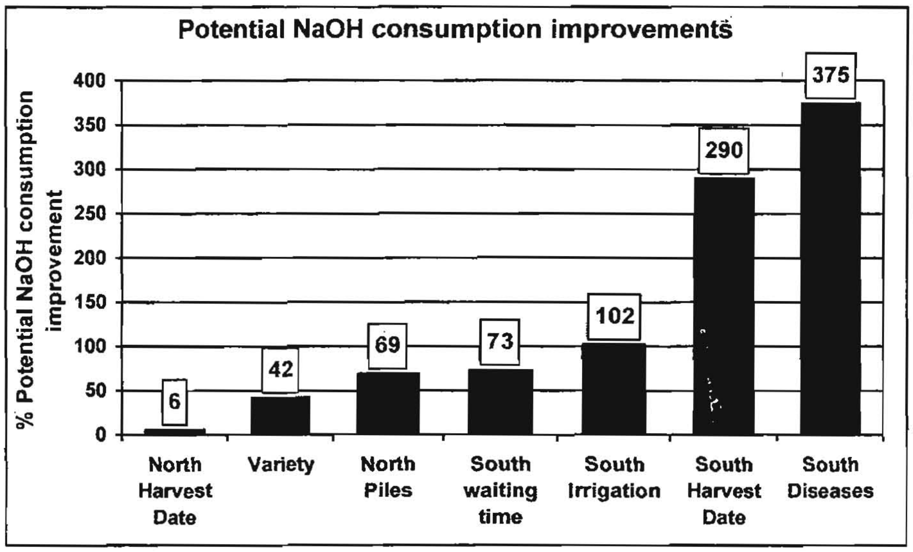

Figure 19

Figure 20 exposes the potential improvement on caustic soda consumption that would be induced by optimizing each mentioned parameter. As can be seen harvest date and beet diseases in southern Spain are clearly the two factors which optimization would lead to the higher improvement in EA, followed by irrigation and waiting time. The last two mentioned were the most optimized parameters over the last few years.

4/ Predictive equations.

Predictive equations for effective alkalinity in the process taking into account K+, Na+, reducing sugars and α-nitrogen content in the sugar beet were determined for both autumn sown beets (South) and spring sown beets (North).

North

$$w'_{AE} = 0{,}05.\ w'_{(K+Na)} - (0{,}29.\ w'_{Red} + 0{,}16.\ w'_{\alpha N}) + 0{,}93$$ (all variable in mmol % Sucrose)

South

$$w'_{AE} = 0{,}04.\ w'_{(K+Na)} - (0{,}30.\ w'_{Red} + 0{,}13.\ w'_{\alpha N}) + 0{,}08$$ (all variable in mmol % Sucrose)

These equations give a fairly precise indication of the EA that should be attained in normal conditions in the factory, and thus allow determining the theoretical amount of NaOH that needs to be added. The comparison with the factory value gives indication upon the good or bad functioning of the plant as well as the room for optimization.

Conclusion

Primarily, this study has allowed to identify the most influential agronomic and post harvest parameters upon process ionic balance and to quantify their impact. Subsequently, the real and potential possibilities for ionic process balance improvement in Spain were determined. Also, along the way new knowledge was gathered about those agronomic and post harvest factors.
Finally, it has initiated various industrial studies on preventive and corrective measures, which technical and economical results have been compared, that have resulted in factory process improvement (beet washing / irrigation / waiting time between harvest and plant).

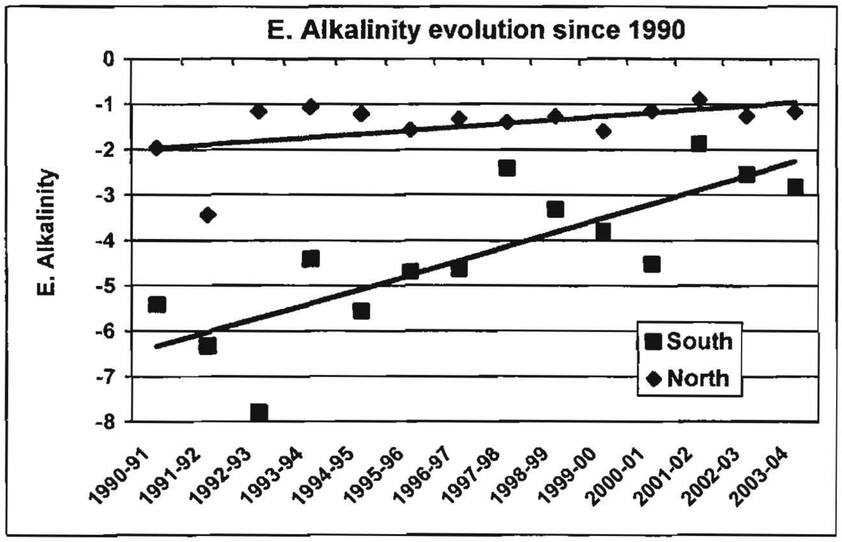

Figure 20