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## Effects of Lime on Some Properties of Cossettes Cut From Frozen-Thawed Sugarbeets

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### INTRODUCTION

Currently the processing of sugarbeets involves cutting cossettes (thin strips) from fresh beets and thicker slabs from frozen or thawed beets prior to countercurrent extraction with hot water. Lime as  $\text{Ca}(\text{OH})_2$  is then added to the extract or "raw juice" at the beginning of a series of purification steps with many possible options.

An alternative to this approach would be  $\text{Ca}(\text{OH})_2$  addition to the sugarbeet tissue as a first step. Recent research on the effect of liming of sugar beet tissue on subsequent extraction and dewatering (3, 8, 12) was motivated by a need to reduce the current high use of energy in American sugarbeet processing plants and thus reduce processing costs. That research was carried out with fresh beets and cold stored beets ( $\sim 1^\circ\text{C}$ , < 4 days) and showed that liming of cossettes could result in:

1. A potential reduction in overall lime consumption.
2. Reduction of diffusion juice colloids and color.
3. Slightly lower purities of the resultant thin juice due, at least in part, to formation of methanol and acetate.
4. A reduced diffusion rate.
5. An increase in dry pulp yield.
6. Decreased thermal energy requirements for pulp drying due to the higher total solids content of the pulp press cake.

Of the cossette liming methods examined, the best re-

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sults were obtained by dipping the cossettes in a slurry of about 2%  $\text{Ca}(\text{OH})_2$  (calculated as  $\text{CaO}$ ) in thin juice for 2 to 5 minutes at  $20^\circ\text{C}$  followed by a drain period such that the total treatment time from the initial contact with the lime slurry was 10 to 15 minutes (3). Lime consumption was less than 1% of the beet weight (calculated as  $\text{CaO}$ ). Potential energy savings in pulp drying were calculated to be 50% or more of current energy consumption.

Up to 20% of U.S. beet sugar is produced from beets which have been intentionally frozen to extend the length of the processing year (6). The temperature and time that sugarbeet tissue remains frozen, along with the conditions of thawing, determine the degree of freeze damage and the irreversibility of that damage (1, 2, 7). Frozen beets at U.S. plants are kept at  $-20^\circ\text{C}$  to  $-35^\circ\text{C}$  where freeze damage is irreversible, cells are ruptured and the elastic modulus of thawed tissue is reduced (10). Slabs are cut from these beets because cossettes would be too mushy to handle in the diffusion and dewatering operations. Although the low surface to volume ratio of slabs is detrimental to rapid diffusion of sucrose, the increased diffusion coefficient of sucrose in the frozen-thawed (FT) beet tissue (9) compensates and has made beet slabs more useful than cossettes for the conventional extraction of frozen beets. Slabs minimize disintegration and improve the flow in the diffuser.

Liming of fresh beet tissue prior to diffusion toughens the tissue, markedly improving dewatering characteristics (8). If the same is true for frozen beet tissue, it may be possible to process frozen cossettes satisfactorily and gain the diffusion and dewatering advantages of cossettes.

This paper explores the effects of  $\text{Ca}(\text{OH})_2$  addition to cossettes cut from frozen-thawed (FT) sugarbeet tissue on parameters which may be important for evaluating the practicality of replacing slabs with treated cossettes.

## MATERIALS AND METHODS

Beet Form

Cossettes were cut with a pilot plant cossette cutter designed and constructed at this laboratory. Twenty nine division Konigsfeld knives were used with a 2 1/4 mm "back" setting and a 2 1/2 mm "up" setting.

Freezing Conditions

Since the properties of frozen-thawed sugarbeet tissue are dependent on the intensity and duration of freezing and on the thaw rate (1, 2, 7), all frozen beets used in this work were frozen at  $-17^{\circ}\text{C}$  for a minimum of 64 hours and were thawed by leaving them at room temperature overnight in order to insure irreversible tissue damage and a worst case condition for the thawed tissue.

Beet Liming

Cossettes were limed by one of two methods: 1. Cossettes were mixed with dry powdered lime ( $\text{Ca}(\text{OH})_2$ ), either in a double cone mixer or a pill coater, for 2 to 3 minutes. Good contact of  $\text{Ca}(\text{OH})_2$  with beet tissue was obtained in this time period without excessive breakage of cossettes. For the remainder of the total treatment time (12 or 27 min), the cossettes were held in the mixer at the appropriate temperature without mixing. 2. Cossettes were dipped into a thin juice- $\text{Ca}(\text{OH})_2$  slurry (TJS) for several minutes, then removed and drained. The cossettes were held for the remaining time at the same temperature as the slurry. The slurries, containing 1% to 4% lime, expressed as  $\text{CaO}$ , were made by diluting thick juice to 15° Brix with tap water and adding an appropriate amount of  $\text{Ca}(\text{OH})_2$ . It should be noted that results with fresh beets reported in Figures 1 and 2 were from earlier experiments (8) where control fresh cossettes were brought to thermal equilibrium in air in sealed polyethylene bags, to prevent dehydration. The controls for the FT beets were "treated" in thin juice (TJ) without lime in a manner identical to the TJS-dipped cossettes.

Shear and Dewatering Tests

Shear tests were carried out with a L.E.E.-Kramer

Shear Press (L.E.E. Inc., Washington, D.C) usually fitted with a 3000 lb. (13,345 N) proving ring. One hundred gram cossette samples were placed into the standard shear-compression cell, and sheared at a power rate of travel of 1/4 in. per second.

Static dewatering tests were carried out with two presses. For small samples and lower pressures, the Succulometer, a small hydraulic press made by the United Company, Westminster, Maryland, was used. A force of 3,266.6 Newtons was applied to a round die with an inner diameter of 5.72 cm for a pressure of 1272 KPa (185 psi) which was applied for 10 minutes. A Carver Laboratory Hydraulic Press with a cage attachment (Fred S. Carver, Inc. Menomonee Falls, Wis.) was used for higher pressures. A total force of 5000 lbs or 22,240 N was applied to a 8.89 cm die, to obtain a pressure of 3,585.0 KPa (520 psi) for 5 minutes. All dewatering tests with limed cossettes were with beet samples which had been limed at 21°C. Each test was run at least three times.

#### Yield of Dry Pulp Solids

Cossettes treated either with dry  $\text{Ca}(\text{OH})_2$  (1% as CaO on the beets) or in thin juice-lime slurry (2.0% and 4.0% calculated as CaO) were weighed, placed in 20-mesh stainless steel wire baskets (20.5 cm x 23.0 cm x 3.7 cm) and suspended in 75°C running water. After extraction for a given time period, pulp was removed, dried in a forced draft oven for 16 hours at 110°C and weighed to determine the pulp total solids content. Experimentally, it was determined that 20-mesh wire baskets prevented pulp losses through the screen. Sucrose in the dry pulp was determined by extracting the sugar with ethanol by the standard AOAC method followed by colorimetric analysis of the total sugar as recommended by Dubois et. al.(5). Calcium was determined by atomic absorption using a Perkin Elmer 303 AA spectrophotometer on samples prepared by a modified dry ashing method (4).

The dry pulp solids content, the weight of insoluble solids without the unextracted sugar or the calcium added

in the liming process, was calculated by subtracting the sugar and calcium contents from the total dry solids.

#### Sugar Extraction Rates

Cosettes were extracted by placing three hundred gram batches of cosettes in 20-mesh wire baskets in 75°C running water. Cosettes were removed from extraction at 1, 2, 4, 6, 8 and 10 minutes. Weight of dried extracted cosettes and sugar yield was determined using methods previously described.

### RESULTS AND DISCUSSION

#### Shear Strength of Tissue

The results of shear strength tests carried out with fresh and with FT cosettes TJS-dipped for a 15 minute equilibration time at several temperatures and lime concentrations, for both unextracted and extracted cosettes, are given in Figures 1 and 2, showing:

1. Much higher shear strength for all unextracted samples over extracted samples.
2. Higher shear strengths for all lime treated unextracted beets treated at 22°C or lower compared to those of untreated controls (Figure 1).
3. An unanticipated increase in shear strength for thawed

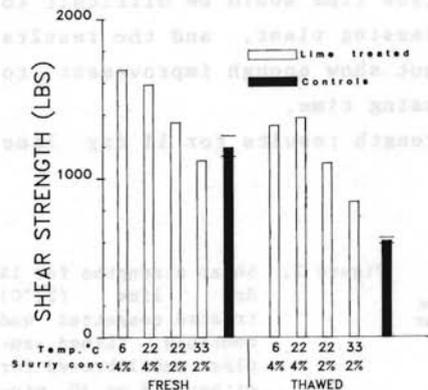


Figure 1. Shear strength for unextracted cosettes. (Slurry limed samples equilibrated for 15 minutes.)

extracted control over the of "fresh" extracted control cosettes (Figure 2).

4. Higher shear strength after 2% TJS treatment than after 4% TJS treatment for fresh and FT cosettes

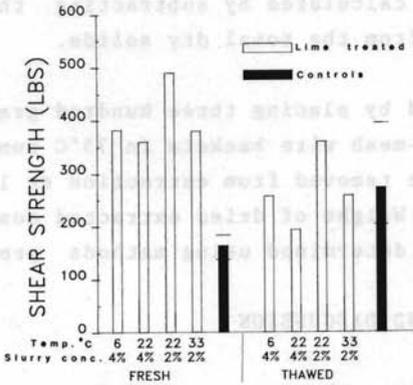


Figure 2. Shear strength for cossettes extracted at 75°C for one hour. (Slurry limed samples equilibrated for 15 minutes.)

which were slurry treated at 22°C and extracted for one hour at 75°C (Figure 2), even though the 4% treatment produced higher shear strength for unextracted cossettes (Figure 1).

It could be that the higher concentration of lime within the tissue of the cossette at the time of contract with 75°C extraction water takes more time for removal and thus causes some alkaline degradation during the extraction.

Results for lime treated cossettes with a total equilibrium time of 30 minutes were not included in Figures 1 and 2. The increased reaction time would be difficult to achieve in a sugarbeet processing plant, and the results were inconsistent and did not show enough improvement to warrant the increased processing time.

Figure 3 shows shear strength results for 1% dry lime

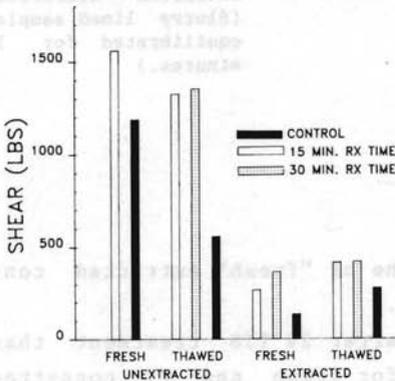


Figure 3. Shear strengths for 1% dry lime (22°C) treated cossettes and controls. (Limed samples equilibrated for either 15 or 30 minutes.)

treated cossettes (22°C), for both fresh and previously frozen cossettes. For both lime treated cossettes and controls an increase in the shear strength of the thawed extracted cossettes over the fresh extracted cossettes can be observed.

Dewatering of Limed Beet Pulp

Figures 4 and 5 show the effects of pressing extracted pulp of slurry-limed or control cossettes. Liming of cossettes facilitated dewatering and resulted in higher press cake solids content in all experiments. While current factory practice with screw presses results in a pressed pulp of about 22% solids, experiments with the laboratory hydraulic presses were at relatively low pressures and achieved less than 15% total solids content for pressed pulp from fresh "control" cossettes.

In Figures 4 and 5 it is also evident that the 4% TJS treatments resulted in lower press cake solids content than the 2% TJL treatments, just as the 4% treatments resulted in lower shear strengths than the 2% treatments for similarly treated extracted cossettes (as shown in Figure 2). Pressed pulp total solids contents are almost as high with limed FT cossettes as with limed fresh cossettes in Succulometer experiments (Figure 4), and are perhaps higher than the solids content of the limed fresh pressed pulp in the Carver press experiments (Figure 5). Figure 2 however, shows a lowered shear strength in the extracted

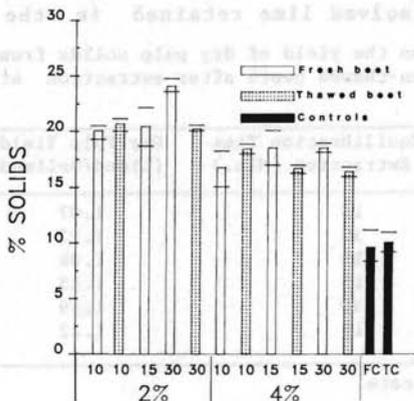


Figure 4. Comparison of Succulometer press cake solids for cossettes cut from both fresh and frozen-thawed beets and subsequently treated with either 2% or 4% lime slurry at 21°C for either 10, 15 or 30 minutes, followed by extraction.

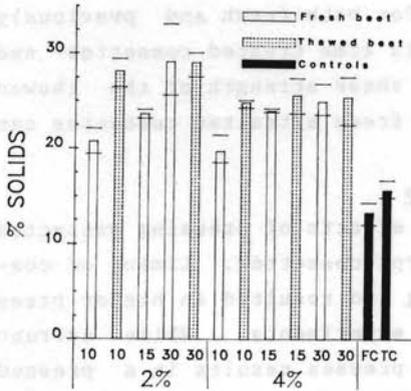


Figure 5. Comparison of Carver press cake solids for cossettes cut from both fresh beets and frozen-thawed beets and subsequently treated with either 2% or 4% lime slurry at 21°C for 10, 15 or 30 minutes, followed by extraction.

limed FT cossettes compared to the extracted limed fresh cossettes, indicating that shear strength is not a good indicator of dewatering characteristics in making cross comparisons between fresh and FT cossettes.

#### Yields of Pulp Dry Solids

Results presented in Table 1 show that the solids retained in extracted pulp increased by as much as 22% compared to the control for thawed beets dipped in 2% TJS slurry, although results were consistently lower than those obtained with fresh beets, where the ratio was about 1.30 (3). Pulp yields were even lower for beets dipped in 4% TJS slurry.

The lower pulp yields of extracted cossettes treated with 4% slurry is possibly explained by the presence of larger quantities of undissolved lime retained in the

Table 1. Effect of slurry liming on the yield of dry pulp solids from cossettes cut from frozen-thawed beets after extraction at 75°C for one hour\*.

Slurry Lime Conc. (%CaO)	Dip Time (Min.)	Total Equilibration Time Before Extraction (Min.)	Dry Pulp Yield (Limed/Ulimed)
4	6	15	1.07
4	6	30	1.17
4	10	15	1.06
2	3	15	1.15
2	3	30	1.19
2	10	15	1.22

\*Samples run in duplicate or triplicate.

cracks of cossettes, where they may continue to react with beet pectin during the 75°C extraction, leading to pectin degradation and subsequent reduced pulp yields. In itself, freezing does not affect the solids retained in extracted pulp, for there was no difference between fresh cossettes and cossettes that were weighed and then frozen before extraction (unlike the experiments reported in Table 1, where cossettes were cut from frozen-thawed beets).

#### Sugar Extraction Rates

A comparison of the extraction curves for cossettes cut from fresh and from FT sugar beets (Figure 6) reveals

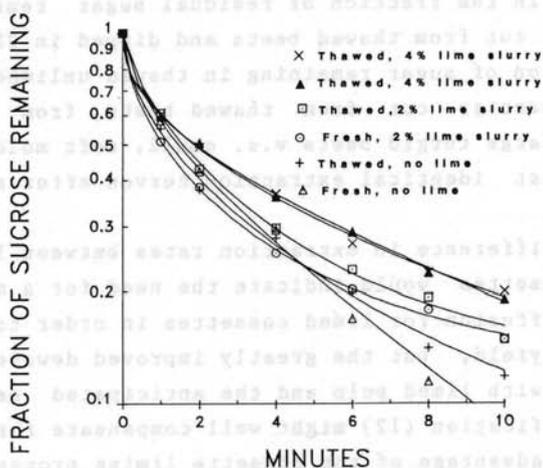


Figure 6. Fraction of sugar remaining in cossettes cut from both fresh and frozen-thawed beets and limed with either 2% or 4% lime slurries. (The top two curves represent results with both good quality and moldy beets.)

25.6% more residual sugar remaining in the pulp of FT cossettes after 10 minutes of extraction. The reduced rate of extraction was due, at least in part, to the loss in turgidity of the frozen-thawed beet tissue, resulting in greater compaction of the cossettes in the extraction baskets and a reduced flow of water through the cossette bed. Previous laboratory experiments using both 18 mm diameter by 1.6 mm thick discs and 3 mm diameter by 6 mm cylinders

of beet tissue show that the diffusion rate of sucrose in FT tissue is higher than in fresh tissue (1,9). However, cossette extraction in the baskets used in our experiments probably gives results closer to what might be expected in most factory diffusers, where cossette compaction can be more important to the overall extraction rate than the rate of diffusion of sucrose within the tissue (11). The fraction of sugar remaining in cossettes dipped in the 4% slurry was 34% higher than those from the 2% slurry treatment. There was also a 57% increase in the fraction of sugar remaining in the pulp of fresh cossettes limed with a 2% slurry over that of fresh unlimed cossettes and a 26% increase in the fraction of residual sugar remaining in cossettes cut from thawed beets and dipped in 2% TJS over the fraction of sugar remaining in thawed unlimed cossettes. Cossettes cut from thawed beets from different batches (large turgid beets v.s. small, soft moldy beets) gave almost identical extraction curves after a 4% TJS treatment.

The difference in extraction rates between limed and fresh cossettes would indicate the need for a more prolonged diffusion for limed cossettes in order to achieve the same yield, but the greatly improved dewatering obtainable with limed pulp and the anticipated savings in juice purification (12) might well compensate for this apparent disadvantage of the cossette liming process.

#### SUMMARY

This examination of the effect of the addition of  $\text{Ca}(\text{OH})_2$  by different methods and at various concentrations, reaction times and temperatures to cossettes cut from frozen-thawed (FT) beets on the selected parameters of shear strength, pressed pulp solids, pulp yield and sugar extraction rate reveals the following:

1. Shear strength prior to extraction was generally improved over control (unlimed) cossettes cut from FT beets, and the improvement was greater than in similar experiments with fresh beets.
2. The shear strength improvement, however, did not sur-

vive the extraction process as well as similarly treated fresh cossettes.

3. Pressed pulp total solids contents of extracted limed (FT) cossettes were almost as high as with limed fresh cossettes in the lower pressure Succulometer experiments, and were equal to, or perhaps higher than, the total solids content of press pulp from limed fresh cossettes in the 520 psi Carver press experiments.

This would indicate that shear strength is not a good indicator of dewatering characteristics.

4. Pressed pulp total solids contents were not improved much by extending the thin juice-lime slurry (TJS) reaction time beyond 10 minutes.

5. The amount of dry solids retained in the pulp from limed cossettes cut from thawed beets was always greater than that retained in the pulp of unlimed cossettes cut from thawed beets. The increase however was not as great as that obtained from similar experiments with fresh beets.

6. Sugar extraction rates were reduced considerably in compacted cossettes cut from thawed beets over similarly treated cossettes cut from fresh beets; slurry lime treatment further reduced the extraction rate, the slowest extraction occurring with the 4% TJS treatment. These results would indicate the need for a prolonged diffusion in any extraction processing of thawed beets.

For most of the parameters examined, a 2% TJS treatment at 21-22°C gave better results than a similar 4% TJS treatment. Only the shear strength of unextracted cossettes from the 4% TJS treatment was higher than that from the 2% TJS treatment.

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Reference to a company and/or product named by the Department is only for purposes of information and does not imply approval or recommendation of the product to the exclusion of others which may also be suitable.

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#### INTRODUCTION

Sugarbeet is a deep-rooting crop which accumulates large quantities of soil nutrients. For instance, each metric ton of harvested storage roots usually removes between 1.5 to 1.8 kg of K<sup>+</sup>; the quantity of K<sup>+</sup> in tops, including crowns, is approximately one and one-half to two times the total quantity in roots (13). In addition, sugarbeet is a heterophilic species (10) that can accumulate large quantities of Na<sup>+</sup> and 115 other members of the Chenopodiaceae, Cl<sup>-</sup> (11). Sugarbeet tops may also accumulate large quantities of N (7).

Tops of sugarbeets, grown under typical conditions in the Red River Valley of Minnesota, North Dakota and Manitoba, are normally returned to the soil as a green manure crop; part of the crown is usually included with the tops in this region. Consequently, inclusion of sugarbeets in a cropping system may result in changes or redistribution of chemical constituents such as NO<sub>3</sub><sup>-</sup>, Cl<sup>-</sup>, K<sup>+</sup> and Na<sup>+</sup> in the soil profile. The purpose of this study was to determine changes in these constituents within certain Red River Valley fields, high in soil NO<sub>3</sub><sup>-</sup>, as a result of the growth of sugarbeets.

#### MATERIALS AND METHODS

Five fields, each of approximately 40 ha located in Grand County, North Dakota, were planted to sugarbeets in the spring of 1983. After re-planting, while the ground was still frozen, 15 soil cores per field to a depth of

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