Juice Storage - Alternative or Supplement?

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Whether in beets or in juice, what we really wish to store is sucrose. The ultimate objective, regardless of method of storage, is to recover, as nearly as possible, the same amount of salable sucrose with storage as we might have recovered by processing fresh beets at all times. We assume, of course, constant and effective process conditions in all instances.

Direct comparison of juice vs beet storage is complicated by the fact that the beets must be processed in either case. Thus, juice storage cannot completely be an alternative to beet storage. In those growing areas where, with present technology, beets cannot be stored for more than a few days, utilization of juice storage automatically becomes supplementary. In northern areas, where beets must be dug quickly and stored in quantity, juice storage can be both alternate and supplement. Economic considerations for the specific local conditions and aims will determine whether juice storage is desirable.

Holly Sugar Corporation must be given credit for pioneering juice storage at their Carlton, California plant. It was first used in 1960 after several years of experimental work had established the feasibility of storage and set the range of conditions required. Their's was the circumstance in which beet storage was not an alternative because of high ambient and soil temperatures during the processing season. Juice storage not only proved eminently successful in providing expanded production, but also demonstrated the practicality of the scheme to the rest of the world. A good many organizations in this country and abroad now employ juice storage on a routine basis.

The general term "juice storage" is used herein to represent any of the possible forms of concentrated, partially processed juice that may be stored for later final processing and sugar recovery. While "evaporator thick juice" (juice after carbonation and evaporation) and "standard liquor" (evaporator thick plus remelt sugar) are the forms generally employed, other concentrated juices, such as diffusion juice have at one time or another been considered.

Since the principal aim is to save or preserve sucrose, loss or degradation must be prevented. The two potential causes of degradation in stored juice are: (1) microbial and (2) chemical.

Microbial

By far the more feared of the two is microbial, since as you know from experience with beet degradation from this cause, once well started destruction can be quite rapid and the loss high.

Of the parameters or properties of storage that may affect the keeping qualities of juice three stand out in first order importance. They are concentration, pH, and temperature. Probably the most important is concentration. High concentration creates high osmotic pressure which can literally dehydrate and kill certain microorganisms. The optimum juice concentration would be exactly at the saturation point so that the highest possible concentration (and osmotic pressure) will be existent. Higher concentration merely causes crystallization which can become a problem when the juice is processed, and lower concentration will not give the best osmotic pressure protection. However, since both purity and temperature affect the saturation concentration, exact control at saturation is impractical. A compromise range is established for each location depending upon purity and temperature conditions. Usually a target spread of 1 1/2 - 2% is desired within the overall range of 67 -72% solids.

pH above 8.0 has been shown to inhibit microorganism growth and this is generally agreed to be the minimum that should be used. The optimum, however, is not so well agreed upon. Some feel a range of 8.4 - 8.8 is near optimum, while others believe that 9.0 or higher is to be preferred. The former minimizes color build up during storage, but the latter offers more certain inhibition to fermentation.

The third parameter of first order importance is temperature. Most feel that juice should be put to storage at a temperature no higher than 30 C. Both from the microbial and chemical loss standpoints, juice should be at as low a temperature as possible, with the practical limitations of economical cooling capacity, pumping ability, etc., being the controlling criteria. Ambient temperatures encountered during the storage period need also to be considered.

If juice is put in storage at a temperature much higher than ambient there is danger of vapor condensation on the tank walls. Condensate may dilute the juice at the surface and provide potential locus for microbial attach. Control of air humidity within storage tanks so that the dew point is never reached at the tank walls will prevent condensation. The use of a layer of oil atop the juice is a common practice. The oil provides a vapor barrier which helps in condensation control. Other measures for condensation control may include circulation of filtered dry air, and tank design that presents a minimum of exposed surface to the atmosphere, when the tank is full. Air circulation also helps keep surface temps down in summer. Use of an oil layer is felt by some to be of a questionable value, because of the possibility of a layer of condensate (and thus dilute juice) being trapped under the oil layer.

Further preventive measures against microbial attack may include the use of sterilants such as formaldehyde. Its use is common in Europe. Fogging of biocide into the airspace atop the juice is also practiced and considered important. Careful filtration is believed by many to be necessary insurance against both entrance of yeast and mold spores and entrance of extraneous solids that might assist in harboring the growth of organisms. SO_2 added to the juice can serve as both a deterrent to microbial activity and a protection against color formation.

Chemical

Relatively little is known of the chemical reactions and potential reactions that take place in stored juice. It is known that at high temperature and alkalinity sucrose may be degraded. However, at what we might call the medium to mold alkalinity and relatively low temperatures of juice storage information is scarce. We would strongly suspect that reactions, however slowly, are occurring.

Although, to my knowledge, no tanks of stored juice have yet been lost, instances have been encountered wherein significant changes have taken place in pH, invert sugar content, color, and purity. Generally, however, the juice returned from storage to process will be little changed in either composition or processing characteristics. The consensus is that juice, under the proper conditions, can readily be stored for 6 months or longer. It is felt that 9 or 10 months storage can be satisfactory, allowing essentially year round operation. It is also felt that more basic information is needed on reactions and reaction kinetics of components in stored juice.

Advantages of Juice Storage

Increased utilization of a given facility with the attendant advantages of increased production, lower overhead, better equipment utilization and a more stable and better qualified work force will be common to either beet or juice storage. But even in favorable storage areas the present limitation seems to be 4-5 months for beet storage at best. Further, however, it must be remembered that beets processed for juice storage must also be sliced within the same time limitation.

There are several additional advantages to juice storage:

1. Considerably less storage area (and volume) is required. While approximately 6 pounds of sucrose (16% beet) per cubic foot will be stored in the beet pile, about 50 lbs/cu. ft. may be stored as juice--an 8.1 ratio.

2. There is no respiration loss in stored juice, while the usual values quoted for respiration in beets of 0.3 - 0.5 lb per ton of beets per day means that some 10 - 15% of the original sugar is lost in 100 days (plus the fact that at least part of the loss will remain in the beet as non-sugars which will result in further loss to molasses).

3. Greater flexibility in plant operation. The beet and sugar end portions of the plant are less interdependent. If trouble occurs on the beet end, the sugar end can remain at optimum capacity by bringing back stored juice. If trouble occurs on the sugar end, the beet end can remain at full capacity with diversion of concentrated juice to storage.

4. Sugar end operation can be more efficient. Because of the ability to control the amount of juice to the sugar end, purity and crystallization conditions can be kept more constant, the result being

more consistent quality of product and more effective exhaustion of molasses.

5. Storage of sugar in juice form is cheaper than storage in granulated form. In some ways it is also safer.

6. Increase flexibility and efficiency in packaging, warehousing, and marketing are possible, since juice storage provides production over an extended time period.

Both beet and juice storage provide for extension of the time of operation of a plant and the advantages attendant thereto. Although the storage of beets cannot claim the number of advantages relative to juice storage that the converse indicates, one very important advantage does exist: the capital cost required per unit of sucrose stored is far less under those conditions where the two storage methods are directly competitive. On the other hand, when juice storage is supplementary, a capital cost advantage exists, because only the beet end is used. Capital outlay for sugar end equipment is unnecessary.

There are disadvantages to juice storage. Because of double handling, added labor cost, and decreased thermal efficiency, sugar produced during a juice campaign is more costly than that made during the beet campaign. Maintenance costs on sugar end equipment is greater, and maintenance is required on storage equipment. Further, there is always the risk of loss of sucrose in the stored juice due either to improper storage conditions or to reactions and conditions not yet completely known or understood.

At this point I would like to make a pitch for industry sponsored study of the reactions and reaction kinetics of stored juice. As important as juice storage has become, it would behoove us to know more about what does and can happen to both the sugars and nonsugars in stored juice. The value of juice in storage today is considerable and the investment should be protected. I suggest that the B.S.D.F. seriously consider undertaking this project. Perhaps this is the time to try to get back the assistance of the U.S.D.A. labs at Albany.

Economics

Needless to say, economics is the controlling factor in the usage of juice storage. Capital costs are high, being estimated presently at 2.5 - 4 million dollars per thousand tons of beet slice equivalent. The amount will, of course, vary with the particular equipment situation and requirement for the given plant. Of course, no sugar end equipment has been included in this cost, this being the advantage from the capital expenditure viewpoint over total point expansion.

As previously indicated, extra labor, power, steam and maintenance cost must be charged against juice storage.

On the plus side, all of the operational advantages must be considered and their economic impact determined. This is not always

easy. For instance, exactly how much per bag of sugar produced is the worth of a more stable and better qualified work force, or the operating flexibility provide? Other factors, such as storage cost compared with granulated sugar, overhead, respiration loss, etc., are more easily assigned a value. It is interesting to note that at .3 - .5 lbs respiration loss per ton per day, the savings per year is about 10% of the capital cost, so respiration savings alone cannot justify juice storage.

Only a detailed evaluation of each specific case will determine the favorability of the economics. The extent to which juice storage is presently practiced indicates that it is well worth looking into.

Summary

While juice storage under certain specific conditions can be considered alternative to or competitive with beet storage it will be used most advantageously as supplementary. Sucrose losses during juice storage should be relatively small, if the proper conditions of storage are maintained, the most important parameters being concentration, pH and temperature. Because of potentially rapid degradation and loss due to microbial attack all possible precautions must be taken to avoid same. At present, loss due to chemical degradation is thought to be minor, though little is known of this area and more work is indicated. There are a number of operating advantages attributable to juice storage, all of which can have important economic implications. While savings of respiration losses can contribute significantly to juice storage economics, other considerations must be included before justification is possible. In any case provision must be made to store and process those beets from which the juice stored will have come.