CONTINUOUS SEED PREPARATION

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ABSTRACT
This paper examines various aspects concerning continuous seed preparation including the criteria for a commercially acceptable system, results from experimental trials and some applications of continuous seed production which are currently in use. Batch preparation of seed for use in continuous pans is also briefly discussed. Continuous seed preparation is seen as potentiality adding substantial benefits to sugar crystallization schemes but, at present, it is not an established technology. Only a few examples have been found where sugar seed crystals are being produced continuously on a commercial basis. It is seen that several procedures have been tested, generally without success, and that these attempts have highlighted the important parameters which have to be addressed for successful implementation of a continuous seed preparation system.

INTRODUCTION
During the past 25 years continuous boiling technology has developed to the extent that it provides an appropriate alternative to batch boiling operations for most sugar crystallization duties. These include continuous boiling of all strike grades of massucuite in cane raw sugar factories. In the beet industry continuous boiling is employed in applications covering all strike massacuites including the boiling of white sugar massacuites of 95 purity. Some success has also been reported with refinery strike boilings. However, one area of the technology that is not yet sufficiently developed for commercial acceptance is that of continuous seed preparation.

At present the successful operation of continuous pans for strike massacuites relies almost universally on the provision of a batch produced seed massucuite of good quality. The development of procedures for continuous seed preparation has been given lesser attention in the past than other continuous boiling applications, mainly because it presents some quite difficult challenges. This paper examines various aspects concerning continuous seed preparation including the criteria for a commercially acceptable system, results from experimental trials and some applications of continuous seed production which are currently in use. Batch preparation of seed for use in continuous pans is also briefly discussed.
Continuous seed production is considered to encompass those processes in which crystal seed material is produced on a continuous flow basis, requiring that all inlet and outlet streams flow continuously. A continuous seed production system could be self-nucleating, could use a slurry of fine sucrose particles as the initiation source for crystals or possibly use a magma of crystals produced at the centrifugal station. The main distinction from a continuous pan producing strike masssucces is that the product crystals from the continuous seed production facility are still of small size and require substantial further growth before centrifuging.

**REQUIREMENTS FOR CONTINUOUS SEED PRODUCTION**

A continuous seed preparation method must be able to satisfy several criteria to be suitable for commercial application. In general these requirements apply whether the seed material is to be used as the feedstock for subsequent batch or continuous crystallization. These criteria include:

(a) The seed production facility must provide adequate flexibility in production rate to be able to accommodate disruptions to production. Intermediate buffer storage would be required even where the seed is being supplied to a continuous pan.

(b) The seed crystals should be of the appropriate mean size required for the subsequent crystallization duty. The mean size of the crystals produced is largely a function of the growth rate and residence time provided in the facility and can generally be achieved through suitable design and selection of process conditions.

(c) The crystal size distribution of the seed must have an acceptably narrow spread of sizes, i.e., have a small coefficient of variation (CV). This is particularly important if the seed is to be used as the footing for shipment sugar production. In practice the attainment of a narrow size distribution is very difficult to achieve in this application.

(d) It is important that there is good control on the number of crystals established for growth in the first stages of the seed preparation facility and that nucleation is avoided in the subsequent stages. This is essential for the production of seed at specification, particularly with regard to mean size and CV. For the same reasons, agglomeration must be avoided at all stages of growth.

(e) The seed production must have a high crystal content. This is desirable for several reasons including:...
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- Reduced volumetric capacity required for the intermediate storage,
- Reduced likelihood of nucleation occurring during storage or on establishment of boiling conditions in the subsequent crystallization step.

(f) Tight process control of the supersaturation of the mother syrup must be provided. In the first stages of the continuous seed preparation facility the crystal surface area is low and the likelihood of nucleation or dissolution occurring through variations in supersaturation is high.

BATCH PRODUCED SEED FOR CONTINUOUS STRIKE PANS

Presently almost all continuous strike pans use batch produced crystals as the seed supply. This is primarily because batch operations provide the same residence time for all seed crystals and easier supervision of the critical crystal initiation step. Consequently batch seed preparation provides a means to more easily produce seed crystals of appropriate specification on a consistent basis.

In most cases the seed is produced in batch evaporative pans, either from a slurry material or by washing a magma of crystals obtained from the centrifugal station. Computer control has been employed in many Australian factories to undertake the seed production step (Wallace9). Generally the seed quality is quite acceptable.

In Europe, commonly the seed for all three grades of strike massecuites is prepared from slurry in batch evaporative pans, often employing sophisticated control procedures and automated slurry addition. Some of the aids employed include transmitting TV-pan microscopes.

During the past decade the development of seed crystals directly in evaporative pans has lost favour in sections of the European industry owing to the assessment that it provides inadequate reproducibility for tight commercial practice (Austmeyer and Schliephake; Austmeyer1). This is attributed to variations in the supersaturation in different regions of the pan resulting in variable crystal numbers (due to both nucleation and dissolution) and a high probability of agglomeration of the slurry particles. Consequently several different schemes, based mainly on batch cooling crystallization of slurry particles, have been adopted. One such scheme has been described by Schliephake and Ekelhof. The main advantages claimed for these procedures are the production of a higher quality seed exhibiting a lower proportion of agglomerates and a narrower crystal size distribution.

ADVANTAGES OF CONTINUOUS SEED PREPARATION METHODS

The main advantages to be gained from implementation of continuous seed
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preparation procedures are improvements in steam economy for the factory and reduced supervision. The benefits in steam economy are greatest where the
continuous seed pan consumes large quantities of high purity syrup as the feed material and consequently has a high evaporation requirement. In these circumstances continuous seed production allows for improved factory steam economy through the provision of a steadier demand for heating vapor/steam and the greater use of bleed vapor from the evaporator station.

When operated in conjunction with a continuous strike pan, continuous seed preparation has the potential to provide other benefits. These include a reduction in capital investment through the use of smaller plant items for seed preparation and reduced intermediate storage capacity for the seed massecuite. For example, when batch pans are used to prepare seed massecuite for a continuous strike pan the volume of the batch pan is normally selected on a conservatively estimated cycle time and the buffer storage capacity is typically 1.5 times the volume of the batch seed massecuite at 'drop'. Improvements in sugar recovery and sugar quality may also result (by virtue of reduced sucrose degradation) owing to reductions in the time that seed massecuites are held at elevated temperatures in storage of batch produced seed.

possible methods for continuous seed production

There are several methods which may be suitable for continuous seed preparation and some of these are discussed. In some instances the results of experimental trials are presented.

1. Direct production in a continuous pan

It is not considered feasible to inject a slurry of ground crystal directly into a continuous pan owing to difficulties with satisfying many of the criteria. In particular, problems with the control of crystal numbers and the attainment of a narrow size distribution would be experienced.

2. Secondary nucleation in a continuous vessel

Randolph and Ziebold7 explored the feasibility of utilizing secondary nucleation in a sucrose/water/ethanol system to produce a continuous supply of seed. These nuclei were grown in a supersaturated syrup to a size of 0.05 mm to improve their survival rate on feeding into a continuous pan. The size spread of the crystals produced in this system was too broad (CV on a mass basis, CVm = 0.45) for commercial application.

CXXII
3. Use of self nucleated, cooled, undiluted A molasses

Trials were conducted by SRI in the early 1970s using different sources of seed material as feedstock to a prototype continuous low grade pan (Broadfoot et al.3). One series of trials was conducted using undiluted A molasses (72 purity) which was stored for approximately eight hours while being cooled by a sparge of air. During this holding time profuse quantities of seed crystals formed with mean size 0.055 mm and $CV_n = 0.48$ (i.e. $CV$ on a number basis). This seed material was then metered to the first cell of the continuous pan which comprised six cells.

As a result of the large increase in crystal size in Cell 1, resulting from the long residence time, the spread of crystal sizes widened substantially. On average over three trials the crystals in Cell 1 had a mean size of 0.125 mm and a $CV_n = 0.6$. Subsequent growth in Cells 2 to 6 of the pan failed to improve sufficiently the $CV$ of the crystals to yield a satisfactory size distribution in the product C massecuite.

An additional problem encountered with this seeding method was that the material was far too variable in crystal number density to be suitable for a commercial proposition. Also a large proportion of the seed crystals dissolved on entering Cell 1, so that frequent inspections of the crystal content of this cell were necessary.

In these trials the seed was in fact produced in batches but the results of the exercise demonstrate the difficulties that exist in using a seed produced in this manner, either in continuous or batch equipment.

4. Seed preparation by continuous cooling crystallization

A prototype cooling crystallizer of 2.6 m$^3$ capacity comprising 22 stirred compartments was evaluated at North Eton Mill (Broadfoot and Hutchinson4) for the continuous production of seed massecuite of specification suitable for supply to a continuous low grade pan. Figure 1 shows a plan view of the arrangement of the cooling seed crystallizer.

Slurry of ground crystals (mean size 0.010 mm and $CV_n = 0.5$) was metered continuously into a supersaturated A molasses (70 purity) being fed at a controlled rate to the first compartment. The A molasses was cooled from an initial temperature of 70°C to a final temperature of 48°C. The cooling profile through the unit was selected to maintain the supersaturation driving force while avoiding secondary nucleation.

The seed massecuite produced by the unit had a crystal content of only 10 to 12% on massecuite. The mean size of the crystals was 0.08 mm and the $CV_n =$
FIGURE I. Plan view of the seed crystallizer showing the cooling water flow and baffle arrangement.
The spread of sizes was much broader than expected from this number of compartments and this was attributed to some deficiencies in the flow arrangement through the crystallizer.

Laboratory boiling tests showed that the seed material was quite suitable for supply as feedstock to the first compartment of a continuous low grade pan. The proposed arrangement for the continuous seed preparation facility as part of a continuous low grade pan station is shown in Figure 2.

Overall the trials indicated that the technique had considerable potential and should provide a consistent supply of seed material. However no further evaluations were conducted. The main difficulty that was left unresolved with the technique was whether seed of sufficiently high crystal content could be produced by cooling crystallization, particularly when using 70 purity molasses. This is the highest purity feed liquor which is suitable for use for low purity (recovery) crystallization. Overall it was considered that an evaporative crystallization procedure would offer greater potential and be more economical.

5. Use of C sugar as seed to a continuous high grade pan

During the evaluation program on the SRI continuous high grade pan at Maryborough Factory (Broadfoot et al.) a trial was conducted in which a magma seed, comprising C sugar supplied from the C centrifugal stage, was supplied directly to the first cell of the pan. At the time the C sugar had experienced substantial breakage during centrifuging (due mainly to significant crystal elongation) and the magma was of very broad distribution. The first cell (and later two cells) was operated at an undersaturated condition to provide judicious dissolution. However the crystal feed to the first growth cell in the pan was still very broad, with some crystals being close to zero size. Ultimately the massecuite produced from the pan using this seed supply was not of acceptable quality.

The exercise provided a clear indication that this technique could succeed only if the magma comprised few broken crystals or if there was a definite size differential between the main seed crystals and the fragments which would facilitate the dissolution of the finer size fraction.

CURRENT APPLICATIONS OF CONTINUOUS SEED PREPARATION METHODS

There are no continuous seed production facilities operating at present in Australian factories and to the authors' knowledge no procedures have received wide acceptance in any sugar industry. Through the literature and correspondence the authors are aware of a couple of commercial applications but have no performance data on which to judge their success. These applications include:
FIGURE 2. Equipment layout and control instrumentation for a continuous low grade pan station incorporating a continuous seeding crystallizer.
At Illovo Factory, South Africa, a massecuite is produced in a continuous flow system of pans using B magma as the seed to the first compartment (Robillard). The B magma is produced in continuous centrifugals which are fitted with large diameter casings. The extent of crystal breakage in the B magma is sufficiently small that no further dissolution, such as operating at undersaturated conditions in the first cell of the continuous pan, is required. The magma is put directly to growth in the continuous pan.

For this application the B sugar typically has a mean size of 0.3 mm and the product A sugar is of mean size 0.75 mm.

The system at Illovo Mill does not involve any specific seed preparation facility but the seed is supplied continuously from the B centrifugal station into the continuous A pan and in this regard is novel.

2. Fletcher Smith Seaford Continuous Vacuum Pan

Two pans of the Fletcher Smith Seaford design are installed at Zuckerfabrik Raffinerie Aarberg in Switzerland for the continuous production of B and C seed (Randall). Each produces the seed material for a continuous strike pan. These seed pans are of horizontal design with vertically mounted plate heating elements placed across the axis of the vessel. Stirrer paddles are fixed to twin horizontal stirrer shafts and these provide a full sweep of the cross-section of the pan. The pan is divided into a number of compartments. Performance data provided by Randall indicate that for a pan comprising five compartments the CV of the seed produced is 0.36. No information is given on the source of the initiating crystals in the seed pan itself or on the crystal content of the seed product.

CONCLUSIONS

Continuous seed preparation provides substantial benefits to usual sugar crystallization schemes but, at present, it is not an established technology. Only a couple of examples are known where sugar seed crystals are being produced continuously on a commercial basis. Several procedures have been tested, generally without success, and these attempts have highlighted the important parameters which have to be addressed for successful implementation of a continuous seed preparation system.

REFERENCES


LA PREPARATION EN CONTINUE DE L'ENSEMENCEMENT

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RESUME

Ce papier examine plusieurs aspects concernant la préparation, en continu, des grains d’ensemencement. On étudie les critères pour un système commercial, on donne les résultats d’expériences et finalement on présente quelques applications du système. La préparation en discontinu, pour des cultures continues, est aussi discutée brièvement. La préparation en continu de l’ensemencement devrait être avantageuse pour la cristallisation. Elle n’est toutefois pas une technologie bien établie et on a trouvé peu d’ exemples de son application commerciale. Plusieurs précédents ont été essayés, sans succès. Les essais ont souligné la nécessité d’étudier tous les facteurs qui ont un effet sur l’application de la préparation de l’ensemencement continu.

CXXVIII
Este escrito examina varios aspectos relacionados con la preparación continua de la semilla, incluyendo el criterio de un sistema aceptado para su uso comercial basados en resultados experimentales y algunas de las aplicaciones de la producción de la preparación continua de la semilla que están actualmente en uso. La preparación de semilla por cargas para su uso entachos de operación continua es también brevemente discutida. Se visualiza que la preparación continua de la semilla va a tener resultados substancialmente beneficiosos para la cristalización del azúcar, pero hasta el presente no se ha establecido como tecnología. Solamente unas pocas muestras se han encontrado donde cristales de semillas de azúcar han sido producidos continuamente en bases comerciales. Se ha visto que ciertos procedimientos han sido probados, generalmente sin éxito alguno, pero que estos esfuerzos han traido a la luz importantes parámetros, los cuales han sido dirigidos para implementar el uso exitoso del sistema de preparación continua de la semilla.

PREPARACIÓN CONTINUA DE LA SEMILLA

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RESUMEN

CXXIX