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INACTIVATION OF ENZYMES IN BEET COSSETTES PRIOR TO DIFFUSION

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This invention relates to sugar beets and has among its objects the provision of processes for treating sugar beets whereby to facilitate the recovery of sugar-bearing juice from the beets. A particular object of the invention is the provision of processes for devitalizing the sugar beet tissue or inactivating the enzymes therein so that the subsequent extraction of sugar from the tissue can be carried out more effectively and efficiently. Particular advantages of the devitalization process of this invention are:

(*a*) The capacity of the diffusion apparatus is increased.

(*b*) The devitalization is accomplished without a dilution effect on the sugar in the beets.

(*c*) The amount of non-sugars extracted during diffusion is decreased.

(*d*) The amount of fermentation which takes place during diffusion is decreased.

(*e*) The diffusion juice contains a lower proportion of invert sugar, colloids, and colored materials than would normally be present.

Further objects and advantages of the invention will be obvious from the following description.

In the production of sugar from sugar beets, the beets are first washed then cut into strips known as cossettes. These cossettes are then subjected to diffusion, that is, they are contacted with warm water to cause the sugar in the tissue to diffuse into the water. The diffusion may be carried out batchwise or continuously. In the continuous process the cossettes are carried through a series of about 20 cells by the use of drag chains or other mechanical devices. At the same time water is passed through the cells in a direction countercurrent to the direction of cossette travel. The resulting liquor, known as raw juice, is then purified and subjected to evaporation and crystallization to obtain pure sugar.

The diffusion process is a key step in the entire production and its effectiveness depends upon many factors. For example, essentially all sugar in the beets must be extracted for the production to be economically sound. The extraction of sugar must be essentially complete yet the extraction of non-sugars must be kept at a minimum since increased amounts of non-sugars introduce complications in the juice purification steps necessitating use of more reagents, such as lime, carbon dioxide, filter aid, etc., and also increasing the amount of non-crystallizable sugar in the final molasses. Also the extraction of sugar from the beets must be accomplished with a minimum amount of water because the water must eventually be evaporated and the production will not be profitable unless the amount of water used is kept low so that the cost of evaporation will not be excessive. The diffusion process provides the raw material from which the crystalline sugar is eventually produced and every defect or disadvantage occurring during diffusion is passed along through the process and thus imposes a burden on subsequent operations.

In order for the diffusion to be effective it is necessary that the beet tissue be devitalized, that is, its viability must be destroyed. The raw beet tissue is in a living state at least insofar as respiration and similar vital processes are concerned. In this viable state if the cossettes are contacted with water, diffusion of sugar from the beet cells into the water occurs at such an extremely slow rate as to be negligible for practical purposes. Thus in the viable state, the energy of the cells counteracts the osmotic pressure tending to cause diffusion of sugar out of the cells. It has been found, in laboratory experiments, that the rate of diffusion of sugar out of viable beet tissue is about one-eighth the rate of sugar diffusion out of devitalized beet tissue.

In commercial practice this devitalization (or scalding, or denaturating, or blanching, as it may also be termed) is accomplished by initially subjecting the raw cossettes to heated juice. Thus in a continuous diffuser, the first four or five cells in the diffusion train are provided with heaters so controlled that the juice within these cells is maintained at about 85° C. The raw cossettes entering the system are at about air temperature (generally less than 20° C.) and they do not actually reach the temperature of the liquid surrounding them until they leave the fourth or fifth cell. A scalding and diffusion system of this kind while expedient to use in practice, possesses many disadvantages. In the first place the diffuser is not being used at its actual capacity for diffusion. Thus the first four or five cells are being used partly as heat exchangers to heat the cossettes sufficiently to devitalize them. Until the cossettes are brought up to the devitalization temperature, diffusion is slow so that the total amount of diffusion which occurs in these cells is less than the amount which would take place where the cells being used solely for diffusion and not partly for heat exchange and partly for diffusion. Another point is that by maintaining the juice in four or five cells at about 85° C., the juice is being unduly heated with the result that much colored material is developed by reaction of reducing sugars with nitrogen compounds present in the juice. These colored compounds add to the complexity of subsequently purifying the juice. Another point is that contacting the cossettes with juice at the relatively high temperature of 85° C. causes the extraction of substantial amounts of colloidal materials (pectin, arabans, proteins, etc.) which interfere with purification of the juice and crystallization of sugar. A further point is that considerable fermentation may take place. The raw cossettes contain a large microbial population and these microbes multiply at a rapid rate particularly in the first cell where the hot juice is cooled by the incoming cool cossettes. Conditions about the cossettes are favorable for microbial growth because of the warmth and the sugar and nitrogen nutrients present in the juice. Fermentation is a serious disadvantage since sugar is lost by being converted into lactic acid, acetic acid, carbon dioxide, or into polysaccharides such as dextrans. The latter, being of a glutinous, slimy nature, impede filtration and purification of the diffusion juice.

It might be pointed out that in this known system wherein the devitalization is effectuated by contacting the raw cossettes with heated sugar-containing juice, the degree of devitalization cannot be increased by raising the temperature of the juice which initially contacts the raw cossettes. If this were done, it would mean that the development of colored compounds (by interaction of re-

ducing sugars and nitrogen compounds) would be greatly accelerated and also sugar sucrose would be hydrolyzed to form invert sugar.

It has now been found that the disadvantages enumerated above can be minimized or even eliminated by a process which involves devitalizing the raw cossettes by contacting them with heated moist air (or other heated moist gas) prior to subjecting them to diffusion. Thus in accordance with this invention the raw cossettes directly as obtained from the slicers are contacted with heated moist air (or other gas) for a sufficient period of time to cause essentially complete devitalization or inactivation of the enzymes in the beet tissue. The so-treated cossettes are then without delay subjected to conventional diffusion employing temperatures only high enough for effective diffusion since heating to cause devitalization is now not necessary.

The gaseous medium for the devitalization is obtained, for example, by mixing steam with hot air or by mixing steam with air at ordinary temperatures and then heating the mixture. In any case the proportions of steam and air should be so adjusted that the gaseous mixture has a dry bulb temperature in the range from about 100 to about 120° C. and a wet bulb temperature in the range from about 70 to about 90° C. Instead of air, other gases may be used, for example, nitrogen, waste gases from furnaces, etc. The use of the temperatures in the above stated ranges produces several benefits. For example, by using a dry bulb temperature of about 100 to 120° C., the temperature gradient tending to heat the raw cossettes is of a high order and as a result the temperature of the cossettes is raised rapidly. A rapid rise in cossette temperature is desirable since it means that the devitalization can be completed in a few minutes. Rapid devitalization is not only desirable from an economic or efficiency standpoint but also is technologically desirable since it means that opportunity for undesirable reactions such as degradation of cellular materials, synthesis of colored compounds, etc. is minimized. Further, by using a wet bulb temperature of 70 to 90° C., it means that the cossette temperature cannot rise above this range. Thus the cossettes are wet and act in the same manner as the moist wick in a wet bulb thermometer. Thus no matter how long the contact of cossettes and heated gas is maintained, the temperature of the cossettes cannot rise above the wet bulb temperature of the gaseous medium. This limit on temperature rise is a very important benefit as it prevents overheating of the beet tissue. Over heating would lead to decomposition or degradation of cellular materials in the beet tissue, the decomposition products would be extracted from the beets in the subsequent diffusion step and would interfere with the purification process and the crystallization of sugar. The wet bulb temperature of the gaseous medium is therefore high enough to obtain essentially complete devitalization of the beet tissue without causing any deleterious effects. Also by using a moist gaseous-medium no water condenses on the beets with the result that no dilution of the beet juice in the beet cells occurs. Thus the gaseous medium has a low relative humidity as indicated by the large difference between the dry and wet bulb temperatures. When the gaseous medium is cooled by contact with the cool cossettes, the relative humidity of the medium increases but not to such an extent that the gas becomes saturated with moisture. The net result is that all of the moisture present in the incoming stream of moist heated gaseous medium and any moisture evaporated from the cossettes remains as vapor in the gas stream and there is no condensation of moisture.

Some of the advantages of the process of this invention are explained as follows:

(1) The capacity of the diffusion apparatus is increased because all the cells in the diffusion train are employed for actual diffusion; this is contrary to conventional practice wherein the first 4 or 5 cells serve mainly to heat the cossettes. Since the capacity of the diffusion apparatus is increased, more beets can be processed in the same size diffusion apparatus resulting in substantial operating economies.

(2) Since the cossettes are treated with moist air and the moisture remains in the vapor phase there is no condensation of moisture and hence the sugar in the beets is not diluted. This means that the process of the invention does not lead to increased evaporation costs.

(3) After the cossettes have been devitalized by contact with the heated moist gas, they are extracted (subjected to diffusion) with water at temperatures optimum for diffusion of sugar from the cells into the liquid surrounding the cossettes. Such temperatures may be for example from 50 to 70° C. Since the diffusion is conducted entirely at these relatively low temperatures (as contrasted with temperatures of around 85° C. in prior processes wherein the hot juice is used to scald the raw cossettes), the amount of non-sugars extracted from the cossettes is drastically reduced. In many cases the diffusion juice produced in accordance with this invention will contain ½ to ⅓ as much colloidal material as a conventional diffusion juice.

(4) Virtually no fermentation takes place because the cossettes are not contacted with sugar-containing juice until the microbial population of the cossettes has been essentially destroyed. In the process of this invention, the raw cossettes are directly subjected to contact with a moist heated gas. The microorganisms being on the outside of the cossettes are rapidly decimated by the hot gas. Then when the treated cossettes are subjected to diffusion and contacted with sugar-containing juice, few microbes are present to cause fermentation. This is in sharp contrast to conventional practice wherein the raw cossettes loaded with microbial flora are directly contacted with sugar-bearing juice; in such case conditions are ideal for fermentation to proceed at a rapid pace.

(5) The devitalization of the beet tissue by direct contact with the moist hot gas takes place so rapidly that little opportunity is afforded for the degradation of proteins, pectin, arabans, or for the hydrolysis of sucrose. This is in contrast to conventional practice wherein the juice in the first 4 or 5 cells has to be maintained at tissue-devitalizing temperatures. In the usual diffusion system the juice remains in each cell for 3 minutes so that a total heating time of 12 to 15 minutes is involved which is conducive to the development of undesirable products such as degradation compounds of pectin, arabans, protein, sucrose, etc. which interfere with subsequent purification of the juice or crystallization of sugar.

The devitalization in accordance with this invention can be accomplished in many different types of equipment. The aim is primarily to provide some means for obtaining maximum contact of a stream of hot gas with all the surfaces of a batch of cossettes being treated. Thus the cossettes may be placed on a mesh tray while a current of the gas is passed over or preferably through them. To insure good contact of gas and beets the tray or the cossettes themselves may be subjected to shaking, rotation or other form of movement to repeatedly expose different surfaces of the cossettes to the gas. To promote rapid heating of the cossettes, it is also preferred to employ a larger excess of hot gas over that theoretically required and to apply it to the cossettes at high velocity. The use of an excess of hot gas over that theoretically required to heat the beets to the proper temperature is advantageous not only to enhance the rate of heating but also to ensure that the temperature of exhaust gas does not fall below its condensation temperature. If this would happen, moisture would condense on the beets and dilution would occur.

A convenient system of equipment for carrying out the devitalization involves transporting the cossettes on an endless mesh belt through a zone where they are subjected to a current of the heated moist gas. The belt conveyor may be arranged to receive the cossettes directly

from the beet slicers and to deliver the treated beets to the first cell of the diffusion battery. Such a system is preferred as it is adapted to the continuous operation of the beet sugar line.

In contacting the raw cossettes with the moist hot gas, the time of contact is regulated to obtain essentially complete de-vitalization of the beet tissue, the treated cossettes then being removed from the zone of heating. The proper time of contact will vary depending on many factors such as the properties of the beets, the degree of contact obtained between the gas stream and cossettes, the initial temperature of the cossettes and temperature of the gas stream, etc. The proper time for any particular set of circumstances can be determined by conducting the process on a pilot batch of cossettes and withdrawing a sample of the cossettes from time to time and testing it for the presence of active enzymes. This may be done, for example, by cutting the cossette in half, placing a drop of 1% catechol solution on the cut surface and noting whether or not a brown color develops. If no brown color develops the cossette may be considered as devitalized as the enzyme systems have been inactivated. Other enzyme activity tests may be employed. Where the treatment is performed under such conditions that the stream of hot moist air makes good contact with most of the surface of the cossettes being treated, complete devitalization will be attained in a matter of at most a few minutes, usually about from 1 to 5 minutes. Instead of determining the optimum time for treatment by investigating the disappearance of enzyme activity, one may ascertain the internal temperature of the cossettes as by the use of a thermocouple or other temperature measuring device small enough for insertion into a cossette. When the cossettes reach a temperature of at least 70° C., the tissue is properly devitalized.

After the cossettes have reached the proper temperature to devitalize the tissue, it is preferred that the cossettes be immediately subjected to diffusion. By doing this the heating effect is abruptly stopped since the cossettes come into contact with the relatively cool diffusion juice.

The invention is further illustrated by the following example.

Twelve pounds of raw sugar beet cossettes were placed in a layer 1 inch deep on a mesh tray and a hot moist air stream (dry bulb temp., 120° C., wet bulb temp. 82° C.) was directed upwardly through the bed of cossettes. This heating was continued for one minute. It was found that the beet tissue was devitalized as indicated by the absence of enzyme activity in the tissue. Also the treated cossettes still weighed 12 lbs. indicating that there had occurred no uptake of water by the beets and therefore no dilution of their sugar content.

Devitalized beets were subjected to diffusion with water at about 70° C. The sugar-containing diffusion juice was found to contain approximately one-third as much colloidal material precipitable at pH 2 as a standard diffusion juice prepared in the usual way by directly subjecting the raw cossettes to diffusion using conventional scalding with hot diffusion juice. The sugar yields in both cases were the same.

Having thus described the invention, what is claimed is:

1. A process for obtaining sugar from sugar beets which comprises subjecting raw cut sugar beets to contact with a hot moist gas having a dry bulb temperature about from 100 to 120° C. and a wet bulb temperature about from 70 to 90° C. to inactivate the enzyme in the beet tissue, and directly subjecting the so-treated beets to diffusion at a temperature below that required to devitalize beet tissue whereby to obtain a diffusion juice having a reduced content of colloidal impurities.

2. The process of claim 1 wherein the diffusion is conducted at a temperature not higher than 70° C.

3. A process of obtaining a sugar-bearing diffusion juice having a reduced content of colloidal impurities as compared with a normal diffusion juice which comprises initially subjecting raw, freshly-prepared sugar beet cossettes to intimate contact with a current of heated moist air having a dry bulb temperature about from 100 to 120° C. and a wet bulb temperature about from 70 to 90° C. whereby to obtain devitalization of the beet tissue in a period of time not over about 5 minutes, immediately subjecting the so-treated beets to diffusion at a temperature of not over about 70° C. and separating the sugar-bearing juice of reduced colloidal content from residual beet pulp.

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