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Beet Quality

Decrease of beet quality during storage in clamp and field

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On-farm storage of sugarbeet during more than two months is needed at longer campaigns. In this period losses of sugar and quality have to be minimized, and beet have to be protected against frost damage. The effect of covering strategies (incidental coverage at low temperatures and permanent covering with special sheets) on sugar losses and beet quality were investigated using the "paired net" method. Similar storage losses were found with different covering strategies. Sugar content after storage was higher using polypropylene fleece (Toptex) coverings compared to occasionally covering the clamp during frost. This was mainly due to drying of the beet. An experiment during campaign 2007/2008 compared the changes in yield and quality of beet remaining in field and after different storage periods. It was shown that during November yield and quality improved in the field, while they reduced during storage. In the period from December up to the middle of February the reduction in sugar content was lower during storage than in the field. This was partly due to drying of the beet in the clamp. Invert sugar content increased only in the clamp and not in the field, while raffinose increased in the clamp as well as in the field. Best yield and quality for delivery mid-February was obtained with the beet harvest end of November.

Influence of long term storage on processing characteristics of sugar beets

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The storage of sugarbeet in field clamps over periods longer than six weeks can become of a higher importance in the future. In the last years experiments have been undertaken to determine the influence of covering the clamps and of storage time on the sugarbeet quality. The sugarbeet quality was determined by the analysis done normally at the beet reception and by processing the sugarbeet under laboratory conditions. Samples were processed from cossettes to thick juice. The colour and the purity of thick juice allow to estimate the effort which is necessary to crystallize white sugar matching the specifications and to estimate the molasses loss. The conditions in the beet clamp were documented by data loggers. The changes in technological quality were determined by processing experiments. For the storage periods longer than 50 days a detoriation of the sugar beet quality was observed. The degree of detoriation depends very much on the weather conditions during the storage period. The molasses losses estimated on the basis of thick juice purities obtained by the processing experiments were much higher than the molasses losses estimated by the so called Braunschweig formula for the evaluation of the technological value of sugarbeet.

Processing deteriorated beets

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Since 2004 in the Netherlands 3 sugar factories have been closed. Only 2 factories of beet capacities in the order of 20,000 t daily slice rate remained. Despite a quota reduction the campaigns will still last until mid-January. The risk of having to process frost-damaged beets has therefore increased. During the 1998 campaign the use of Dextranase proved to be very effective, but costly. Following British Sugar both Suiker Unie sugar factories are now equipped with PCC reactors to prevent 2nd carbonatation filtration blockage. Instead of batchwise, however they operate on a continuous base. Principles and measurements will be presented.

Biotech in sugarbeet and sugarcane: Current status

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In 2007 the total biotech crop area in the world reached 114.3 million hectares. This occurred in 23 countries comprised of 12 developing countries and 11 industrial countries. The top 12 countries are the USA, Argentina, Brazil, Canada, India, China, Paraguay, South Africa, Uruguay, Philippines, Australia and Spain.
The North American beet sugar industry entered the world of biotechnology in 2006 with a commercial demonstration in Idaho and followed that with a commercial demonstration in Michigan in 2007. This paper will discuss the events which led up to these demonstrations and results of these two demonstrations. In 2008 the North American beet sugar industry launched biotechnology on a large scale. This will also be discussed.
The world cane sugar industry has had experimental varieties of biotech sugarcane in Brazil, Australia, South Africa, Colombia, Argentina, U.S. and possibly Indonesia. Within the U.S. cane sugar industry there are experimental varieties of biotech sugarcane grown in various regions examining the importance of a number of traits including herbicide, insect and disease resistance, as well as other traits. In an attempt to investigate commercialization, the industry is now conducting an analysis of the cost/benefit ratio along with other issues involved with biotechnology. This paper also discusses the attempts by sugar industries to move sugarcane biotechnology forward.

Energy

Development of energy costs

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The ECG (Energy Consulting Group) is a consulting company, that deals with the purchasing of energy and consults its customers in this subject. This company has a good survey on the European energy market, it knows the trends in the past and the dependences on different influences on the market and has an idea of the trends in the near future.

Energy optimization by improving water treatment

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With respect to water consumption, sugar factories are special because of their positive water balance: they "make water". The intake of water for the primary process is negligible. The Dutch sugar factories purge the water content of the beet after purification direct to local surface waters, and they meet the high standards set by the regional water authorities. The surface water quality must comply with the European Water Framework Directive. Besides water quality, the energy aspects of the water treatment is already an important factor for several years. Aerobic water purification, the last purification step before purging to surface water, is a high energy consuming process. Improved aeration and process management has decreased the energy input, measured in MJ per kg of removed COD. This value should be between 1 and 2, and recent data give values for optimally operating reactors at approximately 1.2. More important are the anaerobic reactors, well known in Dutch sugar factories during the last 30 years. Nowadays, these reactors are not only in focus for water purification, but more as an energy producing tool as so called methane reactors. The overall energy situation is favorable; the production of methane exceeds the electrical energy input of the aerobic reactors. In general, the aerobic purification consumes 2.4 MJ per tonne of beet while the methane yield of the anaerobic reactors is equivalent to 28 MJ per tonne of beet. Aerobic and anaerobic systems must be in balance. The goal is to add easy degradable COD to the aerobic reactors only for nitrate removal and to avoid oxidation of these components by oxygen. So the aerobic reactors have to run close to its performance limit, while effluent standards have to be met. The anaerobic reactors operate at a maximum removal rate of 30 kg COD (d.s.) per m^3 per day, with a steady increase in the first days. This sustainable operation needs good management in the form of daily technical and technological supervision, quality control and data acquisition.

Separation of water through gas hydrate

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Gas hydrate is normally recognized as troublemaker in the oil and gas industry. On the other hand, gas hydrate has some interesting possibilities for use in connection with separation of water. Danisco Sugar have investigated the possibility to use gas hydrates for concentration of sugar juice. The goal of the project was to formulate an alternative separation concept to replace the traditional water evaporation process in the sugar production. During the work with the process development, Danisco Sugar I&T had contact to a with a range of knowledge centers and universities working with gas hydrate: DTU (Denmark), SINTEF (Norway), NTNU (Norway), IFE (Norway), The Heriot-Watt Univercity (Scotland) and Delft University (Holland). Presentation will illustrate the formation of gas-hydrate from sugar solutions, the conclusions from the study and discuss the pro's and con's for taking this technology to industrial scale.

Optimized standard of sugar manufacturing

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Caused by the difficulty to compare factories with different technological states the idea of an optimized standard of sugar manufacturing (OSSUM) was born by the ESST working group on energy. Aim is to determine the energy demand of an idealized factory to get a benchmark that could be used by everyone in the sugar industry and to find out how far a particular factory is away from the optimized ideal and whether an energy saving investment pays back. This standard process does not include thick juice storage and there is no dissolution of white sugar. So the question of the share of refined sugar (EU1 quality) must not be taken in consideration. Also the kind of fuel used and the efficiency number of the boilers will not be subject of this treatise, because these parameters do not influence the state of optimization of the process of sugar manufacture including the heat transfer scheme of the factory. The standard factory is supplied by beets with a certain sugar content and has a certain amount of sugar losses during the process. It will be shown how the specific energy demand depends on content of sugar of the beets and the loss of sugar in the factory.

Energy demand for the processing of thick juice in European sugar factories

W. Klosterhalfen, T. Boch Andersen, M. Bruhns, T. Frankenfeld, F. Lorenz, C. Mayhew, G. Sittel, F. Windhagauer, A. Wittenberg

In Europe several million tonnes of sugar are produced from stored thick juice. The storage of the intermediate product thick juice has the advantage that the equipment for crystallization can be smaller in comparison with factories without thick juice storage. The disadvantage is that the specific energy consumption for the process steps from thick juice to white sugar is lower when the thick juice is processed during beet campaign. The aim of this study of the ESST working group on energy is to collect empirical data on specific energy consumption for thick juice processing. An overview of the specific energy consumption in western European sugar factories will be given and the consumption will be discussed in relation to thick juice purity and colour, to the duration of the thick juice campaign and to the quality of the white sugar produced.

Reconsidering vapour compression for sugar crystallization

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Vapour compressors are heat pumps used for evaporation processes. They can either be driven mechanically or by high pressure steam. The oldest installation of a vapour compressor in a sugar factory is still working in Aarberg, Switzerland. In the 1980's several sugar factories in France installed vapour compressors for recompression of crystallization vapours. A literature survey of these installations will be given. Operation parameters of vapour compressors will be explained and the possibilities of integrating these apparatus into sugar factories, especially in case of a thick juice campaign, will be discussed. A special attention will be given to a so called vapour fans which have a lower pressure ratio performance than compressors but might be more economical.

Sustainability

The development of sustainability standards in the sugar industry

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The production of bioethanol and biodiesel and the prospect of its importation into the EU have lead to various initiatives to ensure that only biofuels which are produced in a sustainable way are acceptable. Standards which are set to define the important sustainability issues are in various stages of development. The processes involved are of interest to the sugar industry, as both sugarcane and sugarbeet have enormous potential as feedstocks for bioethanol. The Better Sugarcane Initiative is underway to define standards for the sustainable production of both sugar and bioethanol from sugarcane. This paper attempts to discuss the major issues surrounding sustainable production of sugar and ethanol, outlining the processes involved in setting and maintaining sustainability standards. This is discussed in particular to the development of the Better Sugarcane Initiative and looks forward to the implications for all stakeholders.

European bioethanol from cereals and sugarbeet from an ecological viewpoint

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Recent investigations have shown that bioethanol from grain and sugar beet contributes far more to greenhouse gas reduction than assumed in previous studies. Greenhouse gas balances, analogously to eco-balances, must encompass the entire life cycle of a product. In the case of biofuels, this includes, among other things, taking into account the direct and indirect effects (e.g. land utilization effects) of by-product production as well as the effects of the utilization phase (motor efficiency). Because biofuel production fundamentally involves the utilization of land, which is available only to a limited extent, the evaluation of the various biofuel routes must proceed – against the background of the discussion of food versus fuel – on the basis of their respective absolute greenhouse gas reduction per area unit employed (land use efficiency). Area balances show that bioethanol from grain and sugarbeet has the great advantage over other investigated bioenergy routes of achieving very high greenhouse gas reductions per area unit required. Compared with other biofuels and the same total area employed, these greenhouse gas savings are obtained without constraining food production. Taking this into account, bioethanol from grain and sugar beet has advantages built into the system also over second-generation biofuels, such as wood-based from short-cycle plantations. The use of bioethanol in the form of low blends (e.g. blends of gasoline and bioethanol in a 90:10 ratio = E10) leads to higher motor efficiency which to a considerable degree compensates for the lower calorific value of bioethanol compared with gasoline. In contrast to bioethanol from grain and sugarbeet alternative power concepts, such as electric or hydrogen vehicles, only make a contribution worth mentioning to climate protection if the energy supply comes from nuclear or renewable sources, such as wind. This theoretical analysis does not take into account that the storage problems involved have not yet been technically satisfactorily resolved and that vehicle operation over longer distances is not yet possible. To be avoided, however, is supplying the electricity or hydrogen from agricultural biomass, as this means a very inefficient use of limited land resources.

Sustainable sugarbeet production: Current challenges and future prospects

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In order to assess sustainability, criteria have to be established to measure eco-efficiency for cultivation of sugarbeet as raw material for sugar, feedstock and bioenergy. In this context, eco-efficiency involves economical as well as ecological parameters in a well-balanced approach. The ecological evaluation of sugarbeet production has to include parameters which are easy to evaluate, resilient and robust concerning interpretation and external influences and which are scientifically proofed. For cultivation of sugarbeet the energy input, pesticide use, nitrogen fertilizer rate and dirt tare are under research to quote the ecological aspects of sustainability. The economic evaluation is mostly influenced by yield and quality. Technical progress of about 1,5% p.a. and further scientific approach are a prerequisite to improve the productivity of the crop. As a consequence of the reform of the EU sugar regime, sugarbeet cultivation concentrates more on better farms which will further improve productivity. However, costs of cultivation are increasing concurrently. As a target, costs of 100 € t^{-1} of sugar for producing sugar in the field is a realistic midterm demand. Scientific milestones such as the cultivation of winter beet will further help to increase or even stabilize the productivity of the entire supply chain "beet sugar". Thereby, the eco-efficiency as the relation between input and harvested sugar yield will continuously increase by reducing inputs or increasing yield or it will increase exponentially by improvement of both. Thus, the societies demand for sustainable development of beet cultivation can be followed.

Bioethanol: sugar beet, sugar cane or second generation?

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Bioethanol 'first generation', made from sugar or starch is supposed to be produced with a low energy and greenhouse gas efficiency, with sugarcane as an exception. Bioethanol 'second generation', made from cellulose, is supposed to be produced with a high efficiency and, moreover, is often presumed not to compete with food production. Thorough analysis, however, shows a much less rigid picture. Energy efficiency of biofuel production is usually defined as the ratio between net energy yield and gross energy yield, and as such it depends largely on the energy use during growth, transport and processing of the biomass. Most energy used for bioethanol production is needed for fermentation and distillation. This energy is mostly fossil energy in sugarbeet processing, where pulp is sold as animal feed but bioenergy in sugarcane and ligno-cellulose processing. However, when pulp and eventually beet leaves are used as processing energy, bioethanol processing from sugar beet can reach an energy efficiency comparable with sugarcane and ligno-cellulosic biomass. The same holds for greenhouse gas efficiency. Using co-products as an energy source could also provide an energy efficient sugar production from beets, comparable with sugarcane. Competition with food production is mostly considered as a competition for edible feedstock. This is a too narrow view that might hold for co-products like straw, but not for ligno-cellulosic crops like Miscanthus which need agricultural land as well as food crops do.

Sustainable sugar beet production – resource efficiency and yield potential

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An important element of a sustainable crop production is the efficient use of natural resources such as land, light, and water. First of all the potential and the availability of resources have to be identified. For agricultural production, arable land is the major resource.

However, its availability is limited as, at least in Europe, all the arable area is already under cultivation whereas the demand for food, feed, and bioenergy will increase due to the increasing population. Therefore, there is an urgent need to enhance land use efficiency which can be achieved by cultivating the crops with the highest biomass production, by increasing the yield of crops, and by increasing production intensity up to a certain optimum. Sugarbeet has a higher biomass production than most other crops in Europe, and moreover, a higher net energy gain. Sugarbeet yield can be improved further by increasing the light use efficiency as another important resource. Yield formation is limited by light interception which is the factor driving dry matter production of plants. In winterbeet the time of leaf formation is optimized with respect to radiation intensity. By this measure large yield increases are expected. Sufficient water availability is one of the major constraints to crop production. Sugarbeet uses water more efficiently than other crops to produce biomass. Future concepts for efficient resource use have to consider sugarbeet production as sugarbeet can be used for multipurpose. Optimum production intensity, however, depends on the target product and can differ for root yield, sugar yield and total biomass. Sugarbeet production can certainly contribute to balancing highly productive land use and environmentally sound intensity.

The sustainability of beet sugar production in comparison with other sugar crops

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The *sustainability* term is defined, analyzed and discussed in the frame of the particular industry. The beet sugar production is compared under the criterion of sustainability with other sugar crops, aiming to produce sugars and other carbohydrates to be used as feedstock either for food or for biofuel production, e.g., bioethanol. These alternative crops include sugarcane, sweet sorghum, cereal grains (wheat, corn), Jerusalem artichoke, etc. The comparison of these crops will cover both qualitative and quantitative factors, and will take into consideration the energy consumption and the CO_2 emissions for their cultivation, as well as transport and processing of raw material. The environmental impact, which is basic for the assessment of sustainability will be also examined. The beet sugar sustainability is also examined under the criterion of energy self-sufficiency, according to scenarios where in the case of sugarbeet the steam-dried pulp is used as fuel, and in the case of sugarcane processing, where the bagasse is used as fuel. The presently high prices of fuel-oil enhance such considerations. The sugarbeet cultivation using the crop rotation principle has some advantages with respect to sustainability compared to sugarcane (and sweet sorghum) cultivation in the form of plantations. The past and future of the beet sugar production in international level compared to that of cane sugar is examined in the context of the sustainability assessment results.

Technology

Alternative products from sugarbeets

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For over 200 years sugarbeets have been used in Europe mainly as raw material for white sugar production. Recently, European sugar industry undergoes sugar market regime reform, which assumes considerable reduction of beet sugar production in Europe. This will result in Europe becoming an importer of cane sugar. Such situation will cause a considerable reduction of sugarbeet area in Europe, which, in turn, will be unfavorable for the fertility of soil because sugarbeet plays an important role in crop rotation. Thus, it seems to be a problem of vital importance to find possibilities of using sugarbeets for products other than sugar. Such a solution will be profitable from the economical as well as social point of view. The above assumptions became a basis for the authors of the present paper to find alternative products which might be obtained from sugarbeets. The authors suggest a complex use of sugarbeets as raw material for various products in one factory. The paper presents the concept of no-waste production of bioethanol and feedstuff from sugarbeets. Raw juice and concentrated raw juice are the most profitable raw materials for the industrial production of bioethanol. Raw juice can be used for instant processing, while concentrated raw juice can be stored and processed after diluting. To lower the costs, production of bioethanol should be accompanied by production utilizing the remaining waste. Thus, an alternative use of vinasse may be the production of feeding yeast. Sugarbeet pulp remaining after raw juice extraction may be used for biogas production. In order to increase the economic results of the factory the following products may be additionally obtained: L-lysine, biopolymers, oligosaccharides or nutrition fiber products. A fully comprehensive approach to the problems of sugar beet treated as raw material for practically no-waste production of several valuable substances by means of bioconversion should ensure all year round production of a factory and in this way promise to give new possibilities for the development and profitability of sugar industry.

Electrodialysis of molasses for enhanced sugar yield

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The idea through electrodialysis to remove salts from molasses to increase sugar yield is not new, but few long terms industrial tests have been reported. Danisco Sugar I&T can report the learnings and results from over 2000 hour operation of a continous, 4 loop electrodialysis plant treating approx. 100 kg/h molasses. A lot of experience in operation and optimiuation was gained. Results as well as overall evaluation of process and economics will be discussed. The possibility to use electrodialysis as a pretreatment to boost a chromatographic separation plant operating on molasses was tested and seems as a viable option. The current delevelopment of electrodialysis technology to improve the process key performance will be described and possible future enhancement discussed.

Optimal dosage of alkalising agent in the juice purification

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In Austrian Agrana factories it has been necessary in the last years to apply alkalising agents in the juice purification in order to lower the calcium concentration in the thin juice. Initially, the calcium content after the 2nd carbonatation was determined in the laboratory and used as a command variable to operate the addition of NaOH or Na_2CO_3. Due to the low frequency of analyses it was not possible to obtain consistent values for thin juice hardness. The automation of a simple method (*Clark* method) significantly changed the situation for the better. By means of the Lime Salts Analyser (LISA) the frequency of analyses was markedly increased. The incorporation into the process control system finally led to an automation of the alkalisation. Experiences with LISA in the factories have been consistently positive. However, irregularities occurred in phases of changing juice quality due to the time lag between NaOH dosage (measurement) and recording of Ca content in the thin juice (effect). An optimal dosage of alkalising agents is only achievable by eliminating this lag time. This can be achieved by the recording of the effective alkalinity (difference between alkalinity and total hardness) in the filtrate of the 1st carbonatation. The total hardness can be determined after the principle of LISA, due to the high calcium content the common method LISA (20 °dH) needed a pre-dilution to extend the measurement range to 200 °dH (LISA+). At the beginning, juice alkalinity was determined in the factory laboratory and manually transferred into the process control system. The effective alkalinity is calculated from the difference of juice alkalinity and juice hardness. Taking into account the hourly juice amount the requirement of alkalising medium is calculated. The method was further improved by the determination of the effective alkalinity by automated recording of the effective alkalinity of the juice. Similar to the hardness determination the alkalinity is determined by acidic titration and the result is made available for the process control system. After two years of application of the method for an optimized dosage of alkalising agents into the juice purification, highly consistent calcium contents were obtained in the thin juice. Furthermore, it was possible to maintain low pH-variations in the thick juice. This was achieved despite fluctuating beet quality and broadly scattered effective alkalinity values in the filtrate after the 1st carbonatation.

Affinity based separation technologies and their role in the current and future sugar industry

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Recent changes in the economic conditions of sugar industry require innovative approaches to the development of new technologies and their effective integration into existing infrastructure. The principles of affinity based technologies – industrial chromatography, adsorption and ion exchange will be reviewed. In the past relatively large volumes of separation media have been used in various sugar applications, such as softening, decolorization, and chromatography. Development of compact equipment utilizing relatively short beds of separation media resulted in significant reduction of capital requirements and opened up some opportunities previously not considered feasible. Structure of capital and operating cost will be analyzed using an example of a molasses desugarization project. Although resin based separation media are not anticipated to play role in the first generation biorefineries, they may become more important in separation of value-added components from multicomponent biomass mixtures. Possible directions for development of the affinity based technologies targeting minimization of the capital investment will be outlined.

The benefits and constraints of a DDS three stage sugar house with separate discharge of dried second product

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Investigation of the benefits and constraints by changing the sugarhouse at Danisco Sugar Nykøbing from producing refined sugar from dissolved second product to producing dried second product sugar using the DDS-scheme with three step sugarhouse has begun in 2007. The reasons for this change were partly saving energy and partly producing customer desired products. The preliminary findings in 2007 from energy test show reduced energy consumption in the range of 10–15% and that customer desired product could be produced. The theoretical potential is depending on multiple factors but needs "all other equal" consideration. It was also found that an increased focus on the colour and purity balance in the sugarhouse is necessary to succeed. These findings will be investigated further in 2008 to verify the results from 2007 and if possible find the settings for optimal running of the sugarhouse for reducing the energy consumption and still be able to make sugar with the desired specification without dissolving second product sugar and without unnecessary sugar in molasses.

Practical experience of juice decalcification using a weak acid cation exchange resin plant incorporating fractal fluid distribution

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With the prospect of operating longer campaign periods and increasing fuel costs it has become increasingly important to keep juice evaporator heat exchange surfaces clean for as long as possible. Close attention to operating procedures and the use of antiscalant agents can reduce the tendency for scale to deposit on heat exchange surfaces up to a point, but further protection is achieved by reducing the soluble calcium (lime salts) in juice to a very low level using ion exchange resins. Following successful trials using a pilot size weak acid cation exchange resin plant incorporating a fractal distribution system during 2006/07 campaign, it was decided to install a full size plant at British Sugar's Bury St Edmunds factory in the summer of 2007. Equipment cost, size of installation, ease of operation and options for the use of spent regenerant were all important factors considered when deciding to opt for this type of system rather than other systems traditionally used in the sugar industry. This paper describes the initial plant design and commissioning together with the operational experiences (throughput, reliability and performance) since the start of 2007/08 campaign.

A new process for the production of "Seed crystals"– Process development and field report from the factories

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Seed crystals are used to start the crystallization process. The size of the sugar crystal at the end of the crystallization process is controlled by the amount of seed crystals at the seeding point of the crystallization process. A new process was developed to make seed crystals based only on sugar components. That means the suspension of seed crystals contains no alcohol and other dispersing agents like glycerine. Therefore the introduction into the crystallization process causes no problems in respect of additives. The seed crystals consist of complete crystals. There are no broken crystals which are seen in seed crystals prepared by milling. Compare to the broken crystals the crystal size distribution is very uniform. This is also true for the product sugar made of the new seed crystals.The specific number of seed crystals in one gram crystal mass is comparable to the common slurry preparation by wet-milling a sugar/isopropanol suspension in a ball mill. The production is done in a central location and distributed to the sugar factory in 1 m^3 plastic container. The sedimentation of the crystals in the container during several months is very low. The handling in the sugar factory is very easy. For example the seed crystals can be pumped through a ring tube to the evaporating crystallizers where they are needed. In this way the seeding in the crystallization process can be automated by computer. No further manual operation are necessary.

Posters

Application possibilities and properties of carbonatation lime

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The review ponders on feasible carbonatation lime applications – both in and out of the sugar factory. Carbonation lime as a raw material for this use can be in many forms – precipitate in filtration cake, water suspension, and dried or carbonized carbonation lime. The presented composition of carbonatation lime comes from literature data and latest knowledge. When using contemporary low lime additions the percentage of $CaCO_3$ + $MgCO_3$ is only about 43 %. The large part of the paper is devoted physical properties of carbonatation lime as particle size, specific area, specific heat capacity, specific enthalpy, equilibrium water content, refractive index of particles, and viscosity of water suspensions.

Water vapor sorption isotherms of cane sugars

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Water vapor sorption isotherms are non-linear functions describing the relationships between the water content of a product and water activity in constant temperature and constant pressure. The determination and proper interpretation of isotherms is particularly important and it plays a significant role in planning and optimization of such processes as: drying, cooling, conditioning and storage. The shape of sugar sorption isotherms is well known, however, a particular mathematical model depends on sugar quality (invert content, ash content, color, crystal size distribution). Cane sugars assortment is much richer than of beet sugar. It comprises not only white sugar but also a wide range of brown sugars of different organoleptic features and quality. The aim of the paper is to determine water vapor sorption isotherms of different types of cane sugar in comparison with beet sugar. Different samples of white beet and cane sugar and brown cane sugar were the material for the analysis. The sorption isotherms were determined in temperature 5 °C and 25 °C for water activity from 0.33 to 0.87. In the analyzed sugars the following parameters were also determined: color, conductivity ash, content of K, Na, Ca, Mg and content of dextran. Significant differences in water sorption were found between different types of cane sugar and beet sugar.

On- and off-line computer models to improve process control

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Over the last ten years, Suiker Unie developed several computer applications to improve process operation. On-line OMS programs (Operations Management Systems) are used to produce performance data of the process e.g. *k* values and energy losses. Other applications are to assist the process operators by controlling more complex processes like the combination of batch and continuous installations in the sugar house. These can be advisory or fully automated control systems in the top of the automation pyramid. These systems are running on a PC system, working with process data from the AspenTech IP-21 database. This database collects the data from the process computers. The software in which the applications are written is Matlab-Simulink, a software package for mathematical calculations and dynamical system simulation. An off-line example is a technological computer model of the sugar factory which calculates quantity and quality figures of all product flows in the factory as a function of the input values like: amount of processed beet with a certain sugar and nonsugars content and the operational parameters. With these, a detailed picture of – for instance – the energy consumption is generated. For all factory subsystems the available technological knowledge can be implemented with desired detail into installation models. With the technological output of the model, the costs and benefits are calculated in an economical shell around the process model. The model is capable of generating an economical picture of the campaign with varying parameters over the whole production period. The model is frequently used to evaluate different production concepts, change of process parameters, investment projects and energy studies. Because of the positive experiences with OMS, Suiker Unie is now looking for further vertical data integration. By connecting an ERP-system (level 4) to OMS it is also possible to incorporate more remote and batch processes (e.g. sieving operations and production of sugar specialties) into model and *vice versa.*

Minimizing energy consumption of thin juice evaporation through pre-concentration by membrane technology

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Energy cost is the second major operating cost in sugar production. The amount of water to be removed by evaporation in a beet factory is about 95%. Typically, 75% of beet is water and about 20% water is added during the production processes. Evaporating this 95% water consumes enormous amount of energy due to high latent heat of water (2270 kJ/kg). In the present work six different reverse osmosis and nanofiltration membranes from various membrane manufacturers have been investigated for use before multiple effect evaporators to pre-concentrate thin juice. A comparison of energy consumption of multiple-effect-evaporation (5-effects) without and with membrane technology will be presented. The results show about 50% reduction in the thermal duty of evaporation step if the thin juice is pre-concentrated from initial feed concentration of 15% to 25% with reverse osmosis/nanofiltration membranes. Further investigation for higher pre-concentration is in progress.

Research for a sustainable European sugar sector

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As a result of EU sugar market reform started in 2005, the sugar output of regions of less favourable beet growing conditions has been reduced causing changes in the EU sugar sector as illustrated in the table below.

Season	Sugar production quota, mn t	Beet growing area 1000 ha	No. of sugar factories
2005/06	17,4 + 5,6*	2100	192
2006/07	17,2 + 1,4*	1700	161
2007/08	16,7 + 1,4*	1600	143
2008/09**	below 15,0	?	113

* EU market + export; ** estimated

To facilitate the sustainability of EU sugar sector at changed market conditions, new ideas on production technology, engineering & management and value-chain organization are needed for the restructuring of the European sugar industry. In an attempt to meet the challenge, a Specific Support Action titled "Towards Sustainable Sugar Industry in Europe – TOSSIE" was running in the period 2006–2008 under the FOOD priority of the 6th Framework Programme of the EU. TOSSIE was a joint effort of a consortium composed of eight European partners: four industrial companies and four higher educational institutions including Warsaw University of Technology as the coordinating organization. The work-programme consisted in identifying and discussing the current state and directions of restructuring of the European sugar industry from the point of view of its chances for sustainable development. In 2007, industrialists and researchers took part in three thematic workshops devoted to state of the art and optimization of beet sugar technology, engineering and management tools for the optimization of sugar factories, and value chain optimization in the sugar sector. 50 presentations from these workshops are available for downloading in project website www.tossie.pw.plock.pl. On the basis of workshop results, the members of project team worked out discussion paper "Research Needs of the European Sugar Sector". It includes summaries of 33 priority research topics and the analysis of their compatibility with the strategic research areas defined by the relevant European Technology Platforms: Food for Life, Sustainable Chemistry, Biofuels, Plants for the Future. The paper was presented at TOSSIE Stakeholder Meeting held in Brussels on 4 April 2008 and is now posted, together with seven presentations from that meeting, in a separate website intended as a workplace of the Virtual Working Group of sugar-sector experts – www.tossie-experts.pw.plock.pl. Interested parties are welcome to register in this website and join the exchange of information that may lead to organizing research projects devoted to the needs of EU sugar sector.

Formation of high molecular melanoidin fractions in cane sugar during processing

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Native cane sugars from various origins show differences in colour as well as in the amount of high molecular mass components detectable by SEC-HPLC. Heat treatment of native cane sugar samples result in an increase of colour and proportion of higher molecular mass compounds with heating time. A correlation between colour fractions and the amount of α-dicarbonyl compounds formed as intermediates of sugar degradation reactions can be made.

Colour formation in sucrose solutions – the correlation between specific α-dicarbonyl compounds and the molecular size of melanoidins

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The Maillard reaction of carbohydrates and amino acids is the chemical basis for flavour and colour formation in many processed foods. Pathway and kinetic of the Maillard browning are influenced by constitution, concentration and stereochemistry of reaction partners and by reaction conditions like temperature, pH value or presence of oxygen. Dicarbonyl compounds like 3-deoxyosone and D-glucosone as well as short chain dicarbonyls like methylglyoxal are key compounds of the Maillard browning in highly concentrated sucrose solutions. The formation of α-dicarbonyl compounds was shown to be mainly influenced by the temperature, whereas their conversion to melanoidins is clearly favoured under alkaline conditions. These dicarbonyls are very reactive which explains their importance throughout the browning reaction. The α-dicarbonyls are starting materials for polymerization reactions which lead to formation of carbohydrate based melanoidins. The dicarbonyls alone and together with amino compounds can form the skeleton of brown coloured final products. In dependence of the dicarbonyl compound different possible chemical structure of melanoidins will be discussed. The analysis by size exclusion chromatography (SEC-HPLC) revealed that those coloured compounds differ in their molecular size, and are directly associated to reactions with specific α-dicarbonyl compounds. So the SEC analysis showed that the melanoidins, which were formed by methylglyoxal had a higher molecular size than those formed by 3-deoxyosone and/or D-glucosone.

Determination of the sugar content and the dry matter content of thick juices and run-off syrups from beet sugar production – A collaborative study initiated by the German National Committee of ICUMSA

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Background and reasons for the study: The sugar content and the dry matter content of thick juices and run-off syrups in the course of beet sugar production have always been important parameters in process control. In the last years these syrups have become important sales products, being mainly used in industrial fermentation processes. This new situation resulted in a need for a thorough determination of the precision of the methods used for determination of sugar content (by polarimetry) and dry matter content (by refractometry) of these products. The knowledge of the resulting precision data, the repeatability and the reproducibility of the analytical results, will enable buyers and sellers as well as authorities or customs to handle the trade of these products to everybody's satisfaction. For the refractometric dry matter content, it seemed sufficient, to prove the applicability of the existing ICUMSA Method GS4/3-13 (2007) to these types of products, and to determine the required precision data, in order to give this method Official status for this application. For the polarimetric determination of the sugar content, the study should also include comparative measurements to enable the selection of some suitable clarifying agent, preferably avoiding the maintenance of the traditional clarification with wet lead acetate. Following these considerations, an international collaborative study was organised according to the guidelines of ICUMSA/IUPAC.

Organization of the collaborative study: Four samples of syrups (two thick juices, one raw sugar run-off syrup and one white sugar run-off syrup) were distributed as blind duplicates to the 34 participating international laboratories. Participants were asked to determine the refractometric dry substance content of all eight samples, as well as the polarimetric sugar content using 6 different clarification methods, that were wet lead acetate, Carrez solutions, two different aluminium salts, furthermore without any clarification of the thick juice samples at a visible wavelength and for all eight samples at a NIR wavelength. Results of measurement after Carrez clarification and accordingly lead acetate clarification were published on presented to the 26th Session of ICUMSA session, the additional studies will be published separately.

Results and discussion: The arithmetic means of measurements achieved by lead acetate clarification method and Carrez clarification method respectively reveal no differences at a significance of 1 %, which is established and recommended to support a reliable decision. Polarisation measurement with Carrez clarification showed best precision (equal or in some cases even better than with lead acetate clarification). Additionally Carrez clarified solutions had good filtration properties, are not critical concerning health aspects and the filtrate, which – besides the sample components – only contains the excess of zinc salts, does not cause environmental risks.

Measurements for one of the thick juices and both run-off syrups were performed at homogeneous precision, whereas the uncertainty in measurement is significantly reduced by applying Carrez clarification to the second thick juice. Carrez clarification method provides results for the second thick juice substrate at significantly enhanced precision.

Considering the different clarification methods, which will be published completely in a separate paper, some ambiguities were observed, which will be studied further. There seem to be hints that polarization with different clarification methods and without clarification respectively give different results, although these results could not yet be proved to be statistically significant.

Based on a comparison of the precision data, the method for polarization measurement applying Carrez clarification (modification of the raw sugar polarization method GS1/2/3/9-1 (2007)) was given official status for beet sugar juices during the 26th Session of ICUMSA session and will be published in the ICUMSA Methods Book as Method GS8-2 (2009).

Colour formation in technical sucrose solutions – Kinetics aspects of sucrose degradation

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Production of colour-less white sugar with very high quality belongs to most important manufacturing issues of every sugar factory. The improvement of the quality itself is possible only by a reduction of colorants concentration in the final product. The suppression or at least the reduction of the colour index in technical sugar solutions is possible only by technological measures, based on detailed knowledge of reaction kinetics during colorants formation. This contribution is focused on the understanding, modelling and prediction of colour formation in technical sucrose solutions.

New colorants are formed mostly in evaporation and crystallization and influence not only technological performance of chemical engineering units, but also the economics of any factory and consequently also sugar prices. Therefore, this paper summarize basic information about chemical transformations during thermal degradation of sucrose (Maillard reaction) from technical sugar solutions.

Formation of colorants in technical and model sucrose solutions was studied, resulting in a novel kinetic approach of *Maillard* reaction. During thermal degradation of sugar a new aspects of the non-enzymatic browning reaction was found. Two temperature depending pathways of colour formation were found, whereas both reaction mechanisms are based on the formation of α-dicarbonyl compounds, the key intermediates of colour formation. Discussing a temperature dependence of colour formation, a change on Maillard reaction mechanism takes place at 100.4 °C. Above this temperature colour formation is strongly accelerated. Activation energy of the non-enzymatic browning energy for temperatures $\vartheta < 100.4$ °C amounts to 77 kJ/mol. In this temperature range D-glucosone is the most important α-dicarbonyl compound for the studied reaction system. Above 100.4 °C, the activation energy is equal to 112 kJ/mol and 3-deoxyosone is the dominant colour formation intermediate.

The results bridge the gap between the termination step of Maillard reaction – i.e. of colour formation (represented by its activation energy) and intermediates formation (reaction kinetics). In particular, a change of colour formation depending on temperature was confirmed by specific formation of two α-dicarbonyl compounds, responsible for Maillard reaction in technical sugar solutions.

In Figure 1, an imaginative reaction pathway of sucrose degradation is given extended by calculated values of activation energies for studied chemical reactions.

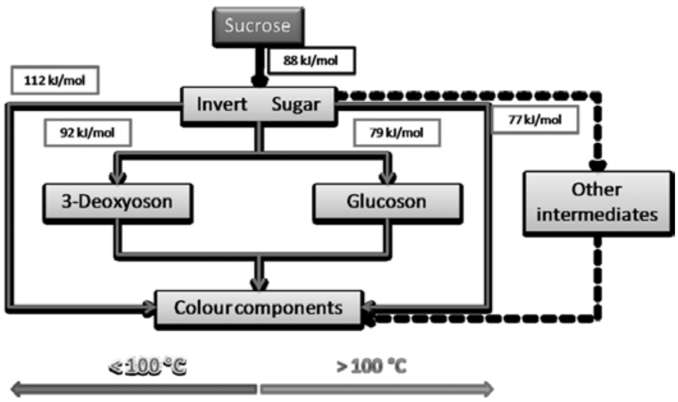

Fig. 1: Reaction pathway of colour formation in technical sucrose solution (thick juice). In figure are listed calculated activation energies and temperature range of the chemical reactions.