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VDZ VEREIN DEUTSCHER ZUCKERTECHNIKER

Abstract of papers

Microbiology and Co-products

New microbiological challenges for the sugar industry (*W. Antheunis, C. Bergwall, M. van den Bliek, M. Goddard, M. Jacobs, M. Klingeberg, M. Oakley-Heemels, M. Omann*; ICUMSA Microbiologist Workgroup)

The sugar production process can be regarded as a process that significantly reduces the microbiological contamination via various steps such as juice purification and evaporation. Spore forming bacteria are one main microbial contaminant in sugar products. The level of spore forming bacteria in sugar can be considered low in a direct comparison to many other agricultural food raw materials. The general perception of sugar products are that they are low risk food raw materials. A new challenge for the sugar industry is spore forming thermophilic and acidophilic bacteria (abbreviated TAB) exemplified with the species belonging to the *Alicyclobacillus* genus. The bacteria are characterised as extremly temperature resistant in the range of 20 and 70°C in combination with an exceptional pH tolerance down to around 2.0. *Alicyclobacillus* species produce heat resistant spores that may survive a normal beverage pasteurization. TAB are considered to be one critical microbiological parameter for beverage applications. The contribution will focus on background information on the relevance of TAB, method development within the ICUMSA Microbiologist Workgroup, assessment of the significance of TAB in sugar, results on contamination tracing work in the sugar process ending up with potential technical solutions to reduce the negative impact of TAB in sugar products.

Microbiology in the sugar industries (*M.S. Wright*; USDA-ARS-SRRC, USA)

Sugars from sugarcane, sweet sorghum and sugar beet juice are susceptible to growth of microbes that are present in the field and factory. Microbial contamination can cause loss of both quality and quantity of fermentable sugars through consumption and production of byproducts such as exopolysaccharides. Some microbes find the conditions of juice more conducive to growth and will out-compete other populations. Microbial populations are also affected by temperature, rainfall, soil type, plant variety/cultivar, and pH value. Microbes on the plant and in the soil are introduced to juice during processing, and will consume sugars during transport and storage. The timeframe between harvest and final processing is thereby limited. Efforts to develop effective technologies to minimize microbial contamination are challenging because of the broad range of microbial types that can potentially contaminate sugar crops. Populations of microbes that prefer microenvironments, such as high temperature and high osmotic pressure, further exacerbate attempts to control microbes during sugar processing. Microorganisms found in juice also impact the potential to develop value-added uses for bagasse and other byproducts, including soil amendments, fuel, and animal feed. Challenges specific to microbial contamination of each sugar crop will be discussed, as well as the potential for targeted control.

Nitrite: Review of existing and new physiological data in ruminants (*G. Kozianowski*, Südzucker AG, Germany; *M. Focant, Y. Larondelle*, Université Catholique de Louvain, Belgium; *K. Maier*, Verein der Zuckerindustrie, Germany)

"Products and by-products from sugar beet and sugarcane" are exempted from maximum limits for nitrite (Directive 2002/32/EC), The Standing Committee on Plants, Animals, Food and Feed (SCoPAFF) is now discussing the abolition of nitrite maximum limit to replace it with a Commission Recommendation on nitrite and nitrate.

The EU sugar producers, represented by CEFS, have contributed to the availability of reliable data on the nitrite contents in feed materials they produce, and have through ESST investigated the potential process factors that may influence nitrite formation. From that work it can meanwhile be concluded that the levels of nitrite in feed materials from sugar plant processing is unpredictable and variable and that prevention of nitrite formation is hardly feasible at a the full scale factory process.

Supplementary to the technological and analytical programme of CEFS and ESST regarding nitrite in feed materials of the sugar industy, members of the German Sugar Association (Verein der Zuckerindustrie – VdZ) reviewed the physiological-toxicological data base on nitrite in ruminants included in the EFSA Opinion of 2009 (EFSA-Q-2005-287). The established toxicological endpoint of nitrite is oxidized hemoglobin (methemoglobin) that leads to a lack in oxygen supply.

The review of the EFSA Opinion revealed that the NOAEL of 3.3 mg/(kg nitrite · kg bw · d) in ruminants was derived by EFSA from a nitrate administration (990 mg nitrate/kg bw – likely via drainage) to cattle. In this study, no adverse effects were reported (*Bradley* et al., 1940). The *Bradley* study does not mention nitrite and EFSA imputed a nitrite dose of 99 mg/kg bw, assumed that nitrite would be 10 times more toxic, and applied an uncertainty factor of 3.

Physiological data other than from acute intoxications were not available to support a limit of nitrite in feed materials in ruminants. On the contrary, based on investigations by *Kemp* et al. (1977), it could have been assumed that an intake of 1 g nitrate/kg bw might have been converted into as much as

200 mg nitrite/kg bw by the endogenous ruminant flora without obvious effects in said study by *Bradley*.
Because of this lack of data on the one hand and implausibility of adverse effects of moderate levels of nitrite in feeds for ruminants, the German VdZ commissioned an acute study in cannulated cows. In this study, cows received 7.5 mg nitrite/(kg bw · day) over a period of 7 days. After dosage, an expected transient increase of nitrite in ruminal fluid was observed that disappeared 1.5 h after dosage. No relevant increase in methemoglobin was observed.
From this study, it can be concluded, that repeated feeding of 7.5 mg nitrite/kg bw did not result in adverse effects. The dosage corresponded to 5.5 g nitrite intake per day. Such a level would cover a nitrite content of 500 mg/kg molasses on top of an otherwise 10 mg nitrite/kg compound feed. The data are supportive that nitrite is a normal metabolite in ruminants that should not be regulated as contaminant in feed for ruminants.
The contribution will cover key points from the literature review as well as new experimental data that were generated by Larondelle and colleagues at the Université Catholique de Louvain, Belgium.

New approaches for the determination of dextran in the sugar production process (*K. Abraham*, SternEnzym, Germany; *E. Flöter*, Technical University of Berlin, Germany)
This work is concerned with the determination of dextran whose presence can cause several adverse effects during the sugar production process. The extent of these effects caused by the presence of dextran does not only depend on the concentration, but also on the molecular weight of this glucose-based polymer.
The detailed determination and characterization of this polysaccharide in sucrose solutions still represents a great challenge. The enzymatic hydrolysis of dextran is a promising and often used method to minimize the dextran-related processing problems. The appropriate and cost-efficient dosage of dextran-degrading enzymes requires the most precise knowledge of the existing dextran levels and fractions. The relatively low levels and the wide range of the molecular mass of dextran in raw juices however make an accurate determination and characterization and hence targeted mitigation difficult. Existing methods such as the haze and *Roberts'* copper method suffer from lack of precision, selectivity and are often time consuming and laborious. Consequently new concepts and approaches for the determination of dextran were investigated to improve the situation. A new method for the determination of dextran based on polarisation was investigated and compared to the most common haze method and its modifications. The prototype of the new method appears to be superior with respect to trueness and precision, the inclusion of all dextran fractions, and the potential to deliver more detailed information of the specifics of the dextran contamination at hand.
Due to the lack of accurate analytical tools the influence of specific dextran fractions and decomposition products resulting from enzymatic hydrolysis on the sugar manufacturing processes is not understood in great detail.
To this end studies to better understand the impact of dextran and enzymatically decomposed dextran on the different process steps were performed. This covers effects on the sucrose crystallization as well as on the juice purification process The significant effects known on the different processing steps are reconfirmed but now in more detail related to the characteristics of specific dextran fractions present. The improved understanding and analytical method should allow to better target future mitigation approaches of dextran contaminations occurring in sugar processing.

Steam drying compared to drum drying increases early phase in vitro rumen fermentability of sugar beet pulp (*M.O. Nielsen, H.H. Hansen,* University of Copenhagen, Denmark; *K. Larsen, A.S. Jensen*, EnerDry, Denmark)
Background: Beet pulp can be dried to produce a valuable feed for dairy cows. There are different methods for drying: Indirect fired rotation drums or steam drying under pressure. Steam drying reduced the large energy consumption usually required for drum drying by almost 100% and as there is no outlet to the atmosphere, there is no air pollution; but steam drying plants are more costly to establish.
When considering establishment of new plants, it is therefore important to also consider the impact of drying method on total dry matter yield of pulp and its nutritional value for high yielding dairy cows, which has so far not been investigated thoroughly. In-vitro gas production is an established method to determine degradability of ruminant feeds, particularly for feeds such as sugar beet pulp, where the major part of digestion occurs in the forestomachs.
Objective: To assess how steam versus drum drying affects fermentability of sugar beet pulp in the forestomachs of cattle.
Materials and methods: Sugar beet pulp was collected on the same dates from two different sugar factories located in the same region. The samples were collected before and after drying in the associated steam or drum dryer. Dry matter (DM) content in fresh and dried pulp was determined by freeze drying, and appr 0.500 g freeze dried material subsequently incubated over 48 h with 90 mL of a buffered rumen fluid media. The rumen fluid was collected and mixed from 2 different cows fed at maintenance level. The incubation was conducted at 39.5 °C using the AnkomRT in vitro gas production system (Ankom Technology, Macedon, NY, USA), and gas released during fermentation was continuously recorded throughout the incubation period. After termination of the incubation, DM remaining in the fluid was collected by filtering (25 µm pore size) to calculate the total amount of degraded DM. The produced gas and residual DM was corrected for gas and DM from samples in which no sugar beet pulp had been added.
Results: Fresh sugar beet pulp from the two factories had similar chemical composition and overall fermentation traits. Sugar beet pulp produced by steam drying increased the rate of fermentation (gas production) during first 12 h of incubation compared to the raw pulp, while drum drying tended to decrease it. Thus, sugar beet pulp dried by steam drying had a more rapid rate of fermentation (degradability) during the first 6 hours of incubation (appr. 40% higher) and reached a higher total degradability after 48 h of incubation (appr. 15%) compared to drum dried sugar beet pulp.

Discussion: Steam drying produced sugar beet pulp with greater rumen fermentability (degradability). This may be ascribed to more rapid fermentation of easily degradable chemical fractions during the early stages of fermentation, whereas slower degradable fractions are less affected by drying method. This results in higher feeding value for high-yielding dairy cows, where the mean retention time in the rumen for small, easily digestible feed particles is expected to be below 20 h.

Ignition and burning behavior of products and co-products of the sugar beet production – an evaluation of selected products in their storage formats from a fire protection viewpoint (*A.G. Degenhardt, B. Faulhammer, H.-G. Burow*; Pfeifer & Langen GmbH & Co. KG, Germany)

The ignition and the burning behavior of sugar, speciality sugars and molassed beet pellets depend on their chemical and physical properties and on their way of storage. Apart from the grain size, significant differences can be expected between sucrose and cellulose dominated matrices, foil and paper packaging as well as bulk and pallet storage. Up to now, literature has only considered production processes with a focus on explosion behavior. The evaluation of products during storage outside of campaign periods has been insufficient. By means of examples of selected product samples, situations are simulated which characterise the ignition and burning behavior of the products in connection with their packaging and storage materials. Based on the obtained results, recommendations are drafted for the storage of products and co-products of the beet sugar production from a fire protection management viewpoint.

Environment

Reduce odor and NH_3 emission: condensation of the carbonatation vapors (*N. Antens, J. Struijs, F. Caljouw, L. Rietsema*; Suiker Unie, The Netherlands)

The vapors from the first and second carbonatation contain a significant amount of odor components, NH_3 and waste heat, which is normally directly released to the environment. Due to sustainability motivations, obligations regarding odor nuisance and future stricter regulations regarding NH_3 emission limits, Suiker Unie planned to take measures. During the 2015 beet campaign, pilot scale plant trials have been performed to investigate the efficiency of direct and/or indirect condensation of the carbonatation vapors.

Based on this experimental work it was concluded that obtaining an odor and NH_3 removal efficiency above 90% is possible using direct condensation (gas scrubber). A final concept of design was selected, which also includes heat recovery. A two-stage gas scrubbing concept was designed: in the first stage main goal is condensing the vapors and use the heat of condensation to heat up limed juice, while the actual scrubbing (at lower temperature) takes place in the second scrubber. Cold condensate is used as scrubbing media, as the NH_3 and odor components should be treated in the water purification. This two-stage gas scrubbing concept has been built at the Vierverlaten factory and was started up in the 2016 beet campaign. Actual odor and NH_3 measurements were part of the commissioning phase to validate the experimental work of 2015.

An economical and effective upgrading of a current anaerobic effluent treatment system based on a granular sludge bed reactor implemented in an existing asset (*R.M. Schoth*, Nordzucker AG, Denmark; *Ch. Pipper, J. Jeppesen*, Nordic Sugar, Denmark)

The capacity of the COD degradation in Nykøbing's old WWTP facilities was limited. Thus the wastewater treatment continued for many weeks after the end of the sugar campaign. This resulted in a net energy consumption for wastewater treatment outside the campaign.

In 2014 a new type of an anaerobe Internal-Circulation reactor, special designed for low calcified waste water, was tested in a pilot scale plant in Nykøbing F (DK). Encouraged by the positive results of this test, a full scale design (1800 m^3) was ordered to build into an existing tank before the 2015 campaign.

The full scale installation from the Dutch supplier PAQUES, is designed to treat a hydraulic flow of 400 m^3/h and 55 t COD load (91% degradation). The new system is able to replace the existing waste water plant and extend the COD load capacity by approximately 25 t COD per day. The installation work started in spring 2015 and was ready to start before the campaign start in October 2015. The investment could be realized at a significantly lower budget than needed for a "traditional" waste water plant with comparable design parameters.

The new plant shows an excellent COD degradation performance during the last two campaigns. Due to the high volumetric and organic COD load rates of the ICX reactor, the new system in Nykøbing increases the use of biogas for a full campaign by 7300 MWh/campaign.

Alternatives for the utilization of electricity in the context decreasing power prices and regulated CHP shut down in the sugar industry (*Ch. Schweizer*; bse Engineering, Germany)

The sugar factories with a CHP-plants are faced with new challenges in the future:

1 Decreasing power revenues by feeding the grid out of the CHP out of an oversupply of power by renewable power plants.
2 Due to the delayed grid expansion the grid operators will be instructed to shut down more and more commercial CHP plants in the future in order to increase the share of renewable energies in the system. The Bundesnetzagentur defines currently up to 30% of the area that allow grid operators to shut down CHP plants that are connected to the grid.

This measure represents a critical intervention in the continuous plant operation of a sugar factory.

The installation of a power sink unit at the sugar factory will prevent these risks. The power sink unit generates an additional commercial product for the market, which stabilizes the revenues. Secondly, the utilization of CO_2 with the power sink is able to increases the value of the produced electricity.

The first part of the presentation gives an overview of the new normative framework from EEG 2017, KWKG and EnWG and technically compares the resulting requirements for implementation by different power sink technologies like Power-to-Hydrogen, -Methane, -Methanol and Fischer-Tropsch-Synthesis.
The second part of the presentation deals with the technical and economic aspects of the use of power and carbon dioxide (from the lime kiln) for the production of electrical methanol (E-Methanol) as an additional valuable product. The normative classification of E-Methanol and the value forming factors as advanced fuel are presented.
Methanol expands the product portfolio as a co-product and has a large sales market. The various applications and their potential in different sectors are described.
Another focus is the presentation of an integration concept for plant interconnection of the existing sugar factory, lime kiln (as CO_2 source) and the methanol plant to maximise the synergies.
The current status of different research and development projects are presented which integrate the existing value chains (food/feed, power, heat, fuel) to the existing industry, thus improving the environmental, social and economic benefits.

Co-products and Environment

Beet pulp in material applications (*J. Seemann, T. Johannes Koch*; Pfeifer & Langen GmbH & Co. KG, Germany)
Sugar beet pulp is dominantly used as animal feed or biomass for biogas plants. Since the industrial production of beet pulp allows supply of a uniform raw material, sugar industry is looking for alternative uses of beet pulp.
As functional fiber or filler in composite materials different natural fibers (e.g. sugarcane bagasse or wood) are already known. The natural fibers currently used are mainly characterized by their high lignin content compared to beet pulp. The effects of pectin in material applications are currently deeply investigated. Well known examples of natural fiber composites are deckings, made of WPC (wood-plastic composites)
First research trials on various methods for conditioning of beet pulp show different pathways for the use of beet pulp as a fiber in material applications. Major challenges in using natural fibers for those applications are residual moisture content and high processing temperatures during the compounding. In order to keep the burden on beet pulp fiber as low as possible, gentle fiber processing methods were used in the trials. First experiments showed the general feasibility of use in extrusion and injection molding. A decking and a business card holder are the first sample products made of beet pulp. The processing of different plastics and processing methods were performed successfully. Long-term tests on samples for indoor or outdoor applications, e.g. decking are currently performed.

Approach to better beet washing. Part II (*D. Nouws, A. Wittenberg, J. Struijs*; Suiker Unie, The Netherlands)
At the ESST Conference in Warsaw in 2013 Suiker Unie presented an approach to better beet washing. The experiments done since 2009 gave new insights in mechanical washing of sugar beets from clay-type soil. The washing experiments showed it was impossible to reach the desired washing result by using only mechanical washing. It was concluded that additional jet washing is required to reach the desired washing result. The remaining soil should be removed by an effective high pressure jet-washer. Understanding about the relevant design parameters and the optimal configuration of a jet-washer was derived from theoretical studies and pilot experiments. The wet surface area, washing time, tare removal and sugar losses were determined. The chance that the beet groove is hit by a jet depends on the configuration of the jet-washer. The impact of the water onto the clay covered beet material is determined by water pressure, nozzle type and configuration. An additional benefit of using a jet-washer instead of a secondary mechanical washer is the short contact time with wash water, which results in a lower sugar elution. The sugar elution by beet washing not only hurts the sugar yield, but also has a major impact on the water treatment and methane production. By analyzing the sugar elution per equipment the approach to better beet washing has been completed. In 2017 both Suiker Unie factories in the Netherlands will run with new beet washing facilities. This study was used for these projects.

Modification and expansion of sugar production plant from a legal point of view (*A. Versteyl, J. Pötzl*; Andrea Versteyl Rechtsanwälte, Germany; *M. Sauer*; Suiker Unie, Germany)
The expansion of a sugar production plant requires an adaptation of the existing permissions according to immission law. For this reason, the legal support and control of the expansion project are significant factors for its success. They presuppose the early and permanent coordination and cooperation with the project management, planners, evaluators and experts.
In preparation of the expansion, it may become necessary to secure the existing status/adaptation to the technical status of the location and to identify possible emission sources in an emission register. This register und the consolidation described are of particular importance in the sugar industry with its variety of immission types and continual change to existing plant. Evaluators are also of central importance in this respect.
An early involvement of the public plays an important role in terms of procedural law. Currently it is being given an enormous boost by the discussion about privileged agricultural building activities in the exterior area. It is also important for the sugar industry because it often operates very old locations, now situated next to residential areas. In addition to that, the projects are mostly expansion measures rather than the installation of new plants.
Finally, special attention needs to be paid to the preservation of the status of surface waters (so-called deterioration ban according to the Water Framework Directive) and of bodies of

groundwater as well as the designation of protected areas. In order to implement these targets, intensive evaluation activities by experts (groundwater monitoring, elaboration of logistics concepts, dragnet inspections in the field of the preservation of clean air) will also be required.

General Sugar Technology

Studies on the storage stability of white beet sugar depending on its quality (*Ph. Bruhns, L.W. Kroh,* Technical University of Berlin, Germany; *Timo Koch*; Pfeifer & Langen GmbH & Co. KG, Germany)
Storage stability is an important element of sugar quality. Due to color formation during storage the sugar color can exceed the quality criteria for white sugar. It is not possible to predict the color formation tendency of a white sugar charge. Also the source and the mechanism of color formation are unknown.
Color formation is caused by several factors, which can be divided into the external influences such as humidity and temperature during storage and the internal causes such as contents of ash, polyphenols, nonsucrose-saccharides and amino nitrogen. Experiments under accelerated storage conditions have shown an influence of the temperature and the humidity on the color development. But the internal color sources are more important. This can be seen in the strong color formation tendency of the syrup layer in the surface film of white sugar crystals.
In the study investigations on the color distribution in sugar crystals were carried and the nonsugar compounds in the surface film were analyzed. The purpose of this study was to detect reactive monosaccharides and amino acids and to show correlations between the changes in contents of nonsugar compounds and color formation. Caramelization and *Maillard* reaction are possible color forming reactions. The saccharides were analyzed with a HPAEC-PAD, the amino acids were enriched with a solid-phase extraction and quantified with a GC-MS. 14 amino acids could be quantified in white sugar. The decrease in the amino acid and monosaccharide content during storage indicates that the *Maillard* reaction is responsible for color formation.

Exopolysaccharides in sugar manufacturing (*A. Antczak-Chrobot, M. Wojtczak*; Lodz University of Technology, Poland)
Deteriorated beet are an important topical problem in sugar processing. Deterioration of beet is mainly a result of storage of thawed beet. The most harmful result of deterioration of beet is the appearance of exopolysaccharides (EPSs), which are difficult to remove during the process.
The division of polysaccharides known from literature and the major polysaccharides causing technological problems at beet processing are presented.
The fact that exopolysaccharides consists of a family of molecules of different molecular masses and different branching structures makes it difficult to develop a specific analytical technique. The many analytical methods cited in the literature can be divided into "factory methods" that allow to determine the content of dextran in sugar beet and sugar juices and "specific advance analytical techniques" which are used to identify dextran and other exopolysaccharides and determine their chemical composition and structure.
A review of polysaccharide analysis used in routine analysis in sugar products is presented and a wide variety of modern analytical techniques of polymer analysis and identification is shown and an overview of the methods.

Linear pan growth control: a dual brix approach (*Ch. Mayhew, C. Parker, R. Howe, C. Haynes, Ch. Rhoten*; British Sugar, United Kingdom)
The fine control of the mother liquor saturation is key to efficient crystal production. Over many years the industry has developed several methods to approximate the mother liquor conditions across the total cycle of the batch pan. Both total massecuite rds and mother liquor rds have been used individually to control the degree of supersaturation indirectly, but neither method can accurately guarantee control of crystal growth in isolation. It is the interaction between both these rds measurements that can be used to portray the bigger picture of how the crystal is growing. This study, over the 2016/17 beet campaign at the Wissington sugar factory, will report on the investigation into how combining the output from a microwave meter and a refractometer can be used effectively to improve crystal growth within a batch pan.

Intensification of biobased chemicals manufacturing (*A.B. de Haan*; Delft University of Technology, The Netherlands)
In spite of the recently decreased oil price, the anticipated limitations in fossil fuel availability will continue to drive the transition to a future biobased economy. In this economy renewable resources will replace fossil resources to meet the demands of future generations. This transition to a biobased economy meets tremendous societal, logistic and technological challenges.
After growing and harvesting biobased resources, they must be separated into their constituents (fibers, sugars, proteins, lignin, etc.) to facilitate further valorisation by processing into biobased products such as feed, fuels and chemicals. In the applied processing schemes biobased raw materials typically undergo the opposite direction in molecular structure development compared to fossil based chemicals. Oxygen is being removed instead of added, making the products generally less instead of more polar. Furthermore most biobased raw materials, intermediates and products are more sensitive to the applied process conditions (temperature, pH value, solvents, etc) and also most characteristic biobased feedstock conversions concern equilibrium reactions. Extraction based technologies offer tremendous potential for the intensification of biobased product manufacturing processes. Important advantages of extraction compared to other separation technologies are the ability to process non-volatile components, operate at mild conditions, deal with complex mixtures including salts and solids and operate at high volumetric productivities.
This presentation will provide an overview on how extraction based technologies can intensify biobased product manufacturing processes along the four main intensification directions:

materials, conditions, equipment and hybrid systems. For each direction the developments will be discussed and illustrated with several characteristic examples that illustrate how economic viability as well as sustainability can be improved. Special attention will be given to the application of ionic liquids as new materials in the recovery of biobased chemicals (organic acids, diols, alcohols) from aqueous product streams such as fermentation broths and chemical reaction media. It will be shown that these unique designer solvents have the capability to outperform current solvent systems by orders of magnitude and thereby significantly reduce energy consumption compared to classical evaporation/distillation process schemes. The integration of extraction with (bio)chemical conversions is an excellent example of hybrid systems that enable process intensification for biobased chemicals. Lactate ester production will serve as an example to illustrate the governing process design parameters, rate based modeling and design approach, achievable performance improvement and future challenges.

Factory trial Dorr versus BMA65 (*St. Royce, D. Simkiss, Ch. Rhoten, M. Blowers, R. Howe*; British Sugar, United Kingdom)
British Sugar uses Dorr carbonatation as a method for beet raw juice purification. This purification technique has remained unchanged in British Sugar for many years whilst others have reviewed and installed classical purification processes. The classical purification process incorporates a 'hot liming stage' that results in juices of lower colour and increased thermostability however the downside is a loss of 'physical properties' namely settlement and filtration. British Sugar intend to carry out a trial that incorporates a 'hot liming' process using the BMA65 purification principles at their Bury St Edmunds factory during the 2016/17 Campaign with the objective to directly compare the two purification methods. The paper discusses the results and observations made during the trial.

The right approach how to design the conditioning system of a sugar silo (*N. Rösch*; Riedel Filtertechnik GmbH, Germany)
The incorrect design of a conditioning system of a sugar silo could lead to incredible consequences. In these days sugar silos are designed for up to 80,000 t and the roadmap how to design the conditioning system is always a customized approach.
The main target is to ensure the product quality of the sugar for the ongoing process as well as for the transport next to security aspects. The right treatment of the air, low air velocities, the air distribution within the silo are the main goals to achieve a good flow ability and the specified residual humidity of the sugar.
It will be explained which points needs to be considered and which worth case scenarios assumptions are the basics for the right design of the conditioning system because it is nothing that you can purchase off-the-shelf.

Isolation and identification of exopolysaccharides formed during degradation of frost damaged beet (*A. Antczak-Chrobot, N. Głowacka, A. Janiszewska, M. Wojtczak*; Lodz University of Technology, Poland)
Since sugar market regime results in longer campaigns, the problem of processing deteriorated beet is still an important topical problem. Deterioration of beets is mainly a result of storage of defrosted beets.
Frost damaged beet are very susceptible to microbiological infections which lead to several changes in the chemical composition of the beet. These changes concern mainly the hydrolysis of sucrose by microorganisms and the production of various metabolites. All this leads finally to the lowering of the technological value of the beet. The most harmful result of deterioration of beet is the appearance of exopolysaccharides (EPSs). EPSs is one of the most significant impurities negatively influencing sugar production mainly by slowing the filtration after carbonatation.
The aim of study is to develop methods of exo-polymers analysis and knowledge of the chemical composition and structure of EPSs formed during degradation of sugar beet. In the presentation the conditions of the beet's degradation and EPSs extraction and purification will be presented. Isolated EPSs were hydrolyzed by acid and various enzymes. In the presentation the results of the exopolisaccharides identification which were obtained by means of different methods such as anion exchange chromatography (HPAEC), sec chromatography (SEC), differential scanning calorimetry (DSC) and nuclear magnetic resonance (NMR) are shown.

Improved image analysis system for technical sugar crystal suspensions at Suiker Unie (*R. Daniels, D. Nouws, A. Wittenberg*; Suiker Unie, The Netherlands)
Since 2003 Suiker Unie used an off-line image analysis system to measure the size distribution of crystals in industrial massecuites. The practical range of the system was limited to suspensions with a mean particle size from 50 to 500 µm. Analyzing final A-product with a size of approximately 600 µm was not possible. This system was technically outdated and the opportunity was taken to extend the measuring range to include A-product with an updated system. The original light-microscope and automated XY-stage were extended with new components: an XY-stage controller, a high resolution camera and customized image analysis software. Combined hardware and software configuration now allow measurements in the crystal size range of 10 µm to 2000 µm. After image acquisition the individual images are merged into a large mosaic image which is then analyzed. The problem of edge-cut crystals is herewith avoided, providing a bigger size range and more accurate results with the same optical constellation. Detected crystals are particle sized and classified into four categories: fines, single crystals, and simple and complex conglomerates. Sample preparation procedure was modified to avoid false grain formation especially in suspensions of low purity. Samples are now directly fixated in sucrose-fructose solution. The updated system and procedure show less variance in mean aperture (MA) and coefficient of variation (CV) compared to the formerly used. Both seed crystals and the final A-product can now be analyzed, thus covering the complete sugar crystallization process.

Poster Session

1. Optimizing the work of continuous centrifugals by monitoring the sugar colour inline (*T. Holcomb*, The Amalgamated Sugar Company, USA; *T. Diringer*, Neltec, Denmark)
Colour transportation within the sugar end of a sugar factory has a major influence on sugar quality.
The colour components are not only transported downstream from the A product pans towards the molasses, they are also transported upstream by returning the run off of the batch centrifugals and also by returning dissolved B sugar and C sugar.
If both products B and C sugar are dissolved and returned to the standard liquor the colour of these sugar crystals will contribute significantly to the quality of the standard liquor.
In the Nampa sugar factory the work of the continuous centrifugals has been monitored and optimized by installing a Neltec inline colour measurement, to indicate the sugar colour inside continuous centrifugals. The influence of various parameters such as centrifugal load, water addition and steam addition on the sugar colour inside the continuous centrifugals has been tested.
This article gives a summary of the results achieved during these tests.

2. Investigation of hop alpha acids for the use in the sugar factory (*C.K. Kohout, R.R. Reiner, C.A.S. Shelswell, F. Emerstorfer*, Agrana Research & Innovation Center GmbH, Austria; *J.M. Grech*, BetaTec Hop Products Ltd, UK; *J. Forte*, BetaTec Hop Products Inc., USA)
Microorganisms (MOs) can enter the process of sugar production through different ways and can lead to economically significant sugar losses and other problems. Hop acids, especially hop beta acids are already used in the sugar industry since 1994. Due to their similar antimicrobial activity, the upcoming question is if alpha acids can be used in the sugar industry as well. Therefore three different hop products based on alpha acids provided from BetaTec were tested to evaluate their effect on the microbiological flora in the extraction area. In the next step their effect on the sensory integrity of white sugar and the content in white sugar after laboratory crystallization were determined.
All three tested products show an effect against microorganisms in raw juice with a difference in the required active concentration and the length of effectiveness. The content of all three hop products in laboratory produced crystalline white sugar was lower than the sensory relevant content. This content could not be determined significantly in a 10 % sugar solution.
These laboratory scale results give a promising forecast for the application of hop alpha acids in the beet sugar industry.

3. Pilot scale 2-step fermentation of hydrogen and methane from sugar rich substrates (*S. Martinek, W. Schnitzhofer*, Austrian Centre of Industrial Biotechnology GmbH, Austria; *F. Emerstorfer, C.A.S. Shelswell*, Agrana Research & Innovation Center GmbH, Austria)
Changes in the agricultural regulatory framework together with increasing competition from the large sugar producing countries in the world make it inevitable for European sugar producers to maximize sugar yield and minimize energy input. One possibility to achieve increased sugar yield is the application of chromatographic desugarization of molasses. In this process, a by-product called raffinate is produced. It is subsequently concentrated to give desugarized molasses. Raffinate contains sugars, which cannot be utilized at the moment, but could be suitable as substrate for a two-step fermentation process for biohydrogen and biomethane production in order to substitute fossil fuels. The separated fermentation digestate may further be concentrated and used as a fertilizer.
To test the suitability of raffinate for hydrogen and biogas production, a 2-step fermentation plant in pilot-scale is currently tested at Tulln sugar factory. In the first step, hydrogen is produced via a hyperthermophilic process in a specially designed bioreactor. Besides hydrogen and CO_2 a significant amount of organic acids are produced in this fermentation. For complete energy recovery the effluent of the hydrogen fermentation is further processed to biomethane in a second step using a stirring tank reactor. As an additional step, a liquid-solid separation of the digestate should take place in order to evaluate the suitability of the liquid fraction as a fertilizer.

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4. Changes in technological quality of frost damaged sugar beet during storage (*A. Antczak-Chrobot, P. Mikoś, A. Papiewska, I. Błaszczyk, M. Wojtczak*; Lodz University of Technology, Poland)
In the last years most of sugar factories in EU complete the process of sugar production in January or even in February. At the end of the campaign sugar beet have to be stored even up to 90 days. During the storage defrosting of beet is the most harmful effect. Frost damaged beet deteriorate rapidly and they cause many problems during processing.
The aim of this study was to determine the effect of storage duration and temperature on changes in the chemical composition of sugar beet. The beet were frozen and after thawing stored under controlled temperature. Sampling was done every day, during 10 days after the thawing. In the collected samples the following parameters were analyzed: dry matter, dextran, glucose, fructose, sucrose, raffinose, mannitol, organic acids and inorganic ions.
During the storage of beets, thawing is the most harmful effect because beets are very susceptible to microbiological infections. At the same time in frost-damaged beet the growth of microorganisms was analyzed (total number of bacteria and the slime forming bacteria).

5. Considerations about flow phenomena at the boundary layer of boiling massecuite and vapor (*M. Bruhns*; Germany)
Heat is transferred to massecuites in order create supersaturation by water evaporation. The separation of water

from massecuites takes place at the boundary layer between massecuite and vapor. The driving force of this process is the superheating of the massecuite, which has to overcome the resistance of the surface tension of the sugar solution. A part of the water fraction in the mother liquor changes the phase when heat is transferred from the massecuite into the vapor bubbles. At the usual pressure of the boiling process the ratio of the density of massecuite to the density of vapor is in the order of magnitude of 10,000.
The two phase flow of boiling liquids has been investigated with the purpose of the layout of steam generators in power stations. Under these conditions the density ratio of the phases are in the order of magnitude of 50 to 5. The literature describes different flow patterns of bubble flow, transition flow and slug flow for different ratios of the velocity of the single phase. Instabilities and disequilibria are characteristic for this change of phase. In this paper the engineering approach of two phase flow in steam generator will be applied to the conditions of boiling (in the sense of vapor formation) of massecuites.

6. Study of sugar beet thin juice purification by use of ions exchange resins (*E.-S. Soliman*, Technical University of Berlin, Germany/Assiut University, Egypt; *Th. Frankenfeld*, Schweizer Zucker AG, Switzerland; *E. Jarrige, E. Flöter*, Technical University of Berlin, Germany)
In this contribution, the evaluation of the application of different ion exchanger configurations to thin juice is reported. Thin juices, sourced from different factories were exposed to beds of different configurations of cation and/or anion-exchange resins. Some of the juices supplied had already been subject to ion exchange processes at factory scale. Different process parameters and varying resin combinations were studied. All experiments were performed at least in duplicate. Since experiments were carried out in small scale laboratory columns initial studies verified that no variation of the results was introduced by the relatively small sampling size of resin particles. Experimental procedures covered both, the use of fresh resin and with more emphasis the application of regenerated resin. The different juices were characterized in detail prior and after IEX-treatment. Points of attention were in particular juice color and turbidity. The later because the application of anion-exchangers could benefit the resistance against turbidity for thick juices during storage. Next to the direct effect of the IEX-treatment on juice color it was also evaluated in how far the different treatments influenced the potential of the juices to develop additional color during subsequent extended exposure to elevated temperatures.
The experimental work indicated that the experiments at laboratory scale were reproducible. Furthermore, the regeneration at this scale appeared not to induce significant additional variations between identical treatments. The results of the systematic study indicate that the combination of cation exchangers followed by an anion exchanger treatment is the most functional treatment. Analysis of the treated juices revealed that the IEX-treatment has, not surprisingly, a profound effect on the juice quality. This benefit also propagated into the difference in color development of the treated juices on subsequent temperature exposure. The treated thin juices did generate much less color during challenge tests. In how far these results at laboratory scale will be pursued any further is subject to the evaluation of the benefits found versus the additional processing and investment costs involved.

7. RHEWUM high performance screens in the sugar industry (*M. Gerards*; RHEWUM, Germany)
Even though sugar refining processes are well known for a very long time, the process design itself is still challenging. This poster presentation will focus on challenges and solutions for the screening of different types of sugar.
Screening processes are very often challenging due to the different types of sugars that have to be produced. As there are no worldwide standards concerning the particle size distribution of sugar products, machines for screening sugar have to be very flexible to adapt to every situation and producers demands. Furthermore, the quality specification for sugar is growing constantly, which often results in revamps of sugar plants in order to raise the capacity and quality. Thus new machines, which will replace older units, should have higher capacities at the same footprint. Additionally product qualities have to be kept constantly at a high level.
RHEWUM screening machines and feeders have been used for more than 60 years in the sugar industry and are constantly enhanced to meet these requirements. Especially for the challenging screening of fine and sticky sugars RHEWUM machines have gained an outstanding reputation for reliable and safe production.
In order to give an overview about modern screening technologies for sugar, the equipment portfolio is introduced and two case studies about recently delivered production plants are outlined.

8. Separation of carbohydrates by HPLC on zeolites (*C. Buttersack, M. Wecks, J. Hofmann*, University of Leipzig, Germany; *M. Hehn*, VDS optilab Chromatographie Technik GmbH, Germany)
The general use of zeolites for high pressure liquid phase separation (HPLC) has already been reported occasionally [1] and the separation of carbohydrates was investigated within two theses at the former sugar institute in Braunschweig [2, 3].
Here, further results on that topic will be presented. Usual commercial packing materials for HPLC have particle sizes around 4 µm. Zeolite particles consist of intergrown nanocrystals of that size and are therefore principally of interest. The exact pore geometry of only some Ångström should provide a strong size exclusion and the interaction of the solutes within the pores should depend on the nature of the counterions and the Si content.
A prerequisite for the use of zeolites is their mechanical stability within the columns up to pressures of 50 MPa. Some industrial zeolites were found to fail. The pressure stability correlates with the stability of the particle size during the application of ultrasound. FAU type zeolites in the Na+, K+, and Ca++-form resist against the high pressure and are also chemically stable in hot water. With pure water as eluent dif-

ferent retention times are found for monosaccharides, with earlier retention for deoxysugars and methyl glycosides. All disaccharides were shown to be excluded from the pores. However, when progressively replacing a part of water by methanol, the retention increases and the disaccharides come mostly later than the monosaccharides. The saccharides are separated from each other. Non-reducing saccharides are resolved into pyranose, furanose, α- and β-forms. Their interaction with the micropores of the zeolites is influenced by the limited solubility in the mixed aqueous phase and by interactions depending on the molecular conformation inside the micropores. At high methanol concentration the sugars were strongly adsorbed.

To minimize the pressure drop along the column, current and future research concentrates on the synthesis of rigid zeolite particles with spherical geometry. The method is based on the transformation of industrially available spherical materials (glass or silica) into materials with zeolite structure elements. Further improvement of the chemical stability is provided by covering the zeolite surface with silanes.

Zeolites have been tested as filling materials for process chromatography of fructose-glucose separation on the industrial scale during 1980 to 1990. That material consisted of particles around 1 mm held together with a binder material which did not withstand the long-term stress. The understanding of the stability of zeolite materials in the HPLC will help to improve the material for process chromatography.

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9. Improvement of acid catalysts for the industrial hydrolysis of sucrose (*C. Buttersack, M. Wecks, J. Hofmann*, University of Leipzig, Germany; *H. Appl*, Dr. Felgenträger & Co. Öko-chem. Pharma GmbH, Germany)

The hydrolysis of sucrose in a fixed bed of sulfonic acid resins is a well established process in the food industry.

Here, we present a study for screening a wide range of sulfonic acid ion-exchange resins as catalyst with special focus on the side products which are difructose dianhydrides (DFAs), 5-hydroxymethylfurfural (HMF), and color. The formation of DFA was found to be a second order reaction towards fructose. Its concentration can be measured after metabolizing sucrose, glucose and fructose to ethanol by yeast. The different DFA isomers were detected by gas chromatography of the silylated sugar mixtures. The amount of DFA formed per invert sugar (90% conversion) amounts to around 5000 ppm at 60 °C and 40% sugar content while the content of HMF was <200 ppm under these conditions.

All different acid resins exhibit a maximum of activity per bed volume at about 50% sugar content. That behaviour is attributed to the fact that on the one hand milled resins (< 60 µm) cause a linear increase of the activity with the sugar concentration up to 75% and on the other hand the diffusion limitation in beads of usual size (about 0.8 mm) also increase with the sugar content. High activity and good selectivity towards the formation of HMF was realized with the resins S2328 (Lanxess), FPC12 (Dow), and C124 (Purolite).

As the selectivity generally declines with increasing temperatures, the temperature during the industrial process is limited to 40 °C although 80 °C would be more favorable with respect to the main reaction rate and the viscosity. Also the sugar concentration which is usually below 50% may be increased to save the energy for evaporation after hydrolysis.

New resins were therefore synthesized which are expected to show a good selectivity also at high temperature and high sugar content. Promising results have been obtained up to now.

10. Effect of quality and origin of technical sucrose solutions on colorant inclusion into sucrose crystals (*K. Schlumbach, M. Scharfe, E. Flöter*; Technical University of Berlin, Germany)

Due to European market liberalization in 2017 co-processing of beet and cane is more taken into account to enhance the operating time of the sugar factories. For the application of this process the influence of raw material quality on final sugar color needs to be known. Manufactures need to derive the allowable amounts of added raw cane sugar and characteristic process parameter. Therefore this work established the effect of different quality within single sources, beet or cane, which is typically known over the duration of a campaign as well as from blends of both raw materials. The data gathered are interpreted considering quality variations of the raw materials to provide a better understanding of the functional mechanism of color inclusion into sucrose crystals.

The results allow a differentiation between the contributions made by different inclusion mechanisms on final sugar color. It is found throughout all experiments that co-crystallization is the dominant color inclusion mechanism. Furthermore it is shown that the earlier formulated framework allows to predict all color values of co-processed sugar based on data of the single source juices, beet and cane. The results suggest that significantly higher levels of co-processed raw cane sugar as currently recommended can be used.

11. A simple theoretical approach of modeling color inclusion into sucrose crystals (*K. Schlumbach, E. Flöter*; Technical University of Berlin, Germany)

The predominant target of industrial sugar production is the separation of solute from non-sucrose compounds such as colorants, polysaccharides, proteins and ash components which is mainly achieved by crystallization. Color inclusion is preliminary affected by raw material and process parameters. For practical reasons the amount of color inclusion into the final sugar is indicated by the color transfer factor which is expressed as percentage of the feed syrup color value. Although this method gives a good approximation of the final sugar color value it neglects the increasing concentration of the impurities in the mother liquor. This means that later in the process included mother liquor contains higher concentrations of impurities. Furthermore the crystal surface is increasing during crystal growth which provides a greater area for impurity inclusions onwards the process. The presented model considers the different influences of color incorpora-

tion regarding varying feed syrup color, color transfer factor and end crystal size.

12. Microwave transmission technology for online and in-situ measurement of beet pulp dry substance content for improved control of water addition processes and delivery compliance (*M. Monninger, R. El Korch,* Berthold Technologies, Germany; *A. Brechbühl, A. Gerber*, Schweizer Zucker AG, Switzerland)

In the 2016 campaign, the Aarberg sugar factory of Schweizer Zucker AG successfully installed and operated a microwave based moisture measurement system at the discharge line of the pressed beet pulp aiming for improved availability and reliability of dry substance value allowing a more precise adjustment of water content within contract specifications. For optimum performance, calibration and verification of the measurement results an automated sampling system has been introduced. The measurement results are presented and compared to laboratory analysis. The improvements achieved on pressed pulp processing in comparison to current methods as well as the sampling setup and the suitability of microwave transmission technology for this measurement task in general are discussed.

13. CSI two-stage HPA process technology for IER and GAC replacement in sugar refineries (*E.M. Sarir, B.R. Pabon, K. Saovapun, G.A. Omar, L. Jaramillo*; Carbo Solutions International, USA)

There are three main absorption methods of color removal processes in sugar refineries: Powder Activated Carbon (PAC), Granular Activated Carbon (GAC) and Ion Exchanges Resins (IER). In the past two decades, GAC and IER process becomes more popular for largest refineries despite its high capital investment, high operational cost and environmental impact. GAC is regenerated in a hot kiln where the color is burnt off from the carbon and IER is regenerated chemically, which gives rise to large quantities of unpleasant liquid effluents.

CSI two-stage HPA Technology uses especially Engineered High Performance Adsorbents to provide significant color removal, with very low capital investment, lower operational cost, high flexibility and minimal environmental impact.

CSI's Engineered High Performance Adsorbents are similar to Powder Activated Carbon but exhibit higher capacity to remove more impurities, with unique surface area and specially designed pore structure and filterability properties to allow more efficient adsorption in sugar solutions. CSI's patented range of HPA have integrated specific chemical functional groups to its surface thus enhancing the capacity to remove other impurities that traditional activated carbons have difficulties to remove. Factory and laboratory tests conducted in Thailand, Philippines, Indonesia, England, Dubai, Brazil and Guatemala, show that it is possible to achieve higher purification for refinery liquor than those obtained with GAC and IER technologies with lower operational cost.

This technical paper demonstrates how CSI's Patented HPA process aids have been designed to enhance or replace IER and GAC for both carbonatation and phosphatation refineries of different sizes.

14. Lime kilns: Retrofit technologies and their advantages in the sugar industry (*N. Engelhardt, O. Arndt*; Eberhardt GmbH, Germany)

Eberhardt GmbH, located in Germany, has a 155 year long experience in design and construction of lime kiln, milk of lime plants and surrounding equipment technologies. The company is globally active in lime, PCC, soda ash and – of course – in the sugar industry.

On the occasion of the ESST 2017 conference Eberhardt presents following topics:

- Inventions and improvements of retrofitting vertical mixed feed kilns focusing on a wide bandwidth of limestone fractions with a maximized planarity of the filling level by rotating or static distribution systems. Including the theoretical evaluations on wall effects in the working shaft to obtain higher efficiencies.
- Mechanical design and operational capabilities of hydraulic driven discharge equipment with its volumetric material movement. Review of the advantages in production and process in shaft kilns.
- Optimization of the exhaust gas CO_2 concentration in vertical lime kilns regarding to the demands of the sugar industry. How to obtain 40% of carbon dioxide gas content in mixed feed kilns.
- Increasing the production and health safety of skip hoist systems by retrofitting an integrated state of the art control system to existing hoisting machines with different options like automated brake tests and conversion to frequency converter drives.