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(54) **Title:** PROCESS FOR THE CONVERSION OF SACCHARIDE-CONTAINING FEEDSTOCK

(57) **Abstract:** The invention provides a process for the catalytic conversion of a saccharide-containing feedstock in a reactor, wherein saccharide-containing feedstock is provided to the reactor as a feed stream through a feed pipe and is contacted with a catalyst system in the reactor, wherein the saccharide-containing feedstock in the feed pipe is maintained at a temperature below the degradation temperature of the saccharide contained therein and a section of the wall of the reactor at the point where the feed pipe enters the reactor is cooled to a temperature below the temperature of the bulk of the reactor and the reactor contents.

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PROCESS FOR THE CONVERSION OF SACCHARIDE-CONTAINING  
FEEDSTOCK

Field of the Invention

The present invention relates to a process for the catalytic conversion of a saccharide-containing feedstock.

Background of the Invention

5 In recent years increasing efforts have been focussed on reducing the reliance on fossil fuels as a primary resource for the provision of fuels and commodity chemicals. Carbohydrates and related 'biomass' are seen as key renewable resources in the efforts to provide new  
10 fuels and alternative routes to desirable chemicals.

In particular, certain carbohydrates can be reacted with hydrogen in the presence of a catalyst system to generate polyols and sugar alcohols. An example of such a process is described in Angew. Chemie. Int. Ed. 2012,  
15 51, 3249 and US 2011/0313212 and may be used to provide ethylene glycol and 1,2-propylene glycol, which are valuable materials with a multitude of commercial applications, e.g. as heat transfer media, antifreeze, and precursors to polymers, such as PET. Ethylene and  
20 1,2-propylene glycols are traditionally made on an industrial scale by hydrolysis of the corresponding alkylene oxides, which are the oxidation products of ethylene and propylene, produced from fossil fuels.

A major problem encountered in the catalytic  
25 conversion of saccharides by known methods is the degradation of the saccharides in reactor feed pipes at high temperatures. Such degradation can lead to fouling and blocking of the pipes. One way to limit this problem

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is to supply the feed in the pipes at a lower temperature than the degradation temperature of the saccharides. The feed is, therefore, also at a lower temperature than the material in the reactor. However, degradation, fouling and blocking will still occur at the point where the feed pipes enter the reactor, due to the inevitable increase in temperature at this point.

Fouling and blocking of the feed pipes lead to reactor shut-downs for cleaning and/or replacement of the feed pipes and connections. This translates to higher running costs and reduced productivity. It would, therefore, be highly desirable to provide a method to reduce saccharide degradation in reactor feed pipes.

#### Summary of the Invention

Accordingly, the present invention provides a process for the catalytic conversion of a saccharide-containing feedstock in a reactor, wherein saccharide-containing feedstock is provided to the reactor as a feed stream through a feed pipe and is contacted with a catalyst system in the reactor, wherein the saccharide-containing feedstock in the feed pipe is maintained at a temperature below the degradation temperature of the saccharide contained therein and a section of the wall of the reactor at the point where the feed pipe enters the reactor is cooled to a temperature below the temperature of the bulk of the reactor and the reactor contents.

#### Brief Description of the Drawings

Figure 1 is a schematic diagram showing an aspect of an exemplary, but non-limiting, embodiment of the process described herein.

#### Detailed Description of the Invention

The present inventors have surprisingly found that saccharide degradation at the point of entry to a reactor

can be significantly decreased by maintaining the temperature of the saccharide-containing feedstock in the feed pipe below the degradation temperature of the saccharide contained therein and also cooling a section  
5 of the wall of the reactor at the point where the feed pipe enters the reactor.

The process requires a saccharide-containing feedstock. Said feedstock suitably comprises at least 1wt% saccharide in a solvent. Preferably the saccharide-  
10 containing feedstock comprises at least 2wt%, more preferably at least 5wt%, even more preferably at least 10wt%, most preferably at least 20wt% saccharide in a solvent. Suitably, the saccharide-containing feedstock contains no more than 50wt%, preferably no more than  
15 40wt% saccharide in a solvent.

One or more further feed streams comprising solvent may also be added to the reactor together with the saccharide-containing feedstock, either through the same feed pipe or at a separate point in the reactor.

20 It is envisaged that the composition and amount of the saccharide-containing feedstock, the contents of the reactor and the amount of any further feed stream added to the reactor will be coordinated such that the concentration of saccharide in the solvent in the reactor  
25 while the reaction is proceeding is at least 0.01wt% saccharide in solvent. Preferably the concentration of saccharide in solvent in the reactor is at least 0.02wt%. Most preferably the concentration of saccharide in solvent in the reactor is at least 0.25wt%. It is  
30 envisaged that the composition and amount of the saccharide-containing feedstock, the contents of the reactor and the amount of any further feed stream added to the reactor will be coordinated such that the

concentration of saccharide in the solvent in the reactor while the reaction is proceeding is at most 5wt% saccharide in solvent. Preferably the concentration of saccharide in solvent in the reactor is at most 2wt%.

5 Most preferably the concentration of saccharide in solvent in the reactor is at most 1.5wt%

The saccharide-containing feedstock comprises at least one saccharide selected from the group consisting of monosaccharides, disaccharides, oligosaccharides and polysaccharides. Examples of polysaccharides include 10 cellulose, hemicelluloses, starch, glycogen, chitin and mixtures thereof. If the saccharide-containing feedstock comprises oligosaccharides or polysaccharides, it is preferable that it is subjected to pre-treatment before 15 being fed to the reactor in a form that can be converted to glycols when contacted with hydrogen in the reactor in the presence of a suitable catalyst system. Suitable pre-treatment methods are known in the art and one or more may be selected from the group including, but not 20 limited to, sizing, drying, grinding, hot water treatment, steam treatment, hydrolysis, pyrolysis, thermal treatment, chemical treatment, biological treatment.

Preferably, the saccharide-containing feedstock that 25 is fed to the reactor, after pre-treatment if necessary, comprises one or more saccharide selected from the group consisting of glucose, sucrose and starch. Said saccharide is suitably present as a solution, a suspension or a slurry in the solvent.

30 The solvent may be water, a C<sub>1</sub> to C<sub>6</sub> alcohol, or mixtures thereof. Preferably, the solvent is water. As well as the solvent provided in the saccharide-containing feedstock there may also be further solvent already

present in the reactor and/or added to the saccharide-containing feedstock as set out above. Said solvent is also suitably water, a C<sub>1</sub> to C<sub>6</sub> alcohol, or mixtures thereof. Preferably, all solvents are the same. More preferably, all solvents comprise water. Most preferably, all solvents are water.

Any reactor type suitable for a semi-batch or continuous process, requiring a saccharide starting material to be added as a feed stream through a feed pipe, may be used in the process of the invention. Preferably, the process of the invention is carried out as a continuous flow process, wherein a reaction product is continuously removed from the reactor.

In this embodiment, any reactor type or combination of reactors suitable for a continuous flow process in which reaction product is continuously removed from the reactor may be used for the process of the present invention. For example, suitable reactor systems include ebullated catalyst bed reactor systems, immobilized catalyst reactor systems having catalyst channels, augured reactor systems, fluidized bed reactor systems, mechanically mixed reactor systems and slurry reactor systems, also known as a three phase bubble column reactor systems, and combinations thereof.

The temperature in the reactor is suitably at least 130°C, preferably at least 150°C, more preferably at least 170 °C, most preferably at least 190°C. The temperature in the reactor is suitably at most 300°C, preferably at most 280°C, more preferably at most 270°C, even more preferably at most 250°C. Preferably, the temperature in the reactor is above the degradation temperature of the one or more saccharides in the saccharide feedstock. Preferably, the reactor is heated

to a temperature within these limits before addition of any starting material and is maintained at such a temperature until all reaction is complete.

To reduce degradation of the saccharide-containing feedstock, the temperature of the saccharide-containing feedstock in the feed pipe is suitably maintained below the degradation temperature of the saccharide contained therein. As used herein, the term degradation temperature relates to the temperature at which 1% of the saccharide present is degraded within an hour and will vary depending on the saccharides present. Preferably, the temperature of the saccharide-containing feedstock in the feed pipe is suitably maintained at least 10°C, more preferably at least 20°C, even more preferably at least 50°C, below the degradation temperature of the saccharide contained therein.

In one embodiment of the invention, it is preferred that a further source of heat is provided to the reactor, in order to maintain the temperature within the reactor. Said extra source of heat may be provided by providing extra heat to the reactor contents, for example by providing heat to a recycle stream. Alternatively, part of the solvent provided to the reactor may be provided as a separate stream to the saccharide-containing feedstock and at a higher temperature. This separate stream, which contains essentially no saccharide may then preferably be supplied to the reactor at a temperature such that the mixed temperature of the separate stream when combined with the saccharide-containing feedstock is within 10°C of the temperature of the reactor.

In the process of the present invention, a section of the wall of the reactor at the point where the feed pipe enters the reactor is cooled to a temperature below

the temperature of the bulk of the reactor and its contents. Preferably, said section of wall of the reactor is cooled to a temperature below the degradation temperature of the saccharide in the saccharide-  
5 containing feedstock. Preferably, the temperature of the section of wall of the reactor is suitably maintained at least 10°C, more preferably at least 20°C, even more preferably at least 50°C below the degradation  
10 temperature of the saccharide in the saccharide containing feedstock.

The section of the reactor wall that is cooled is preferably of the smallest size possible to prevent degradation of the saccharide and build up of deposits. Typically, in the process of the present invention, rapid  
15 mixing and/or reaction will occur that will inherently reduce saccharide concentration and, thus, degradation, once the feedstock has entered the reactor. Suitably no more than 10% of the surface area will need to be cooled. Preferably, no more than 5%, more preferably no more than  
20 2%, even more preferably no more than 1%, most preferably no more than 0.5% of the reactor wall will need to be cooled.

It will be clear to the skilled person that a balance should be maintained between increased  
25 efficiencies achieved by preventing saccharide degradation and maintaining the bulk of the reactor and its contents at the required reaction temperature without excessive application of heat.

The section of the wall of the reactor at the point  
30 where the feed pipe enters the reactor may be cooled by any suitable means known in the art. Preferably, the cooling is achieved using a cooling liquid, by air cooling, or by using the heat to evaporate water in order

to provide low pressure steam. In one embodiment, the cooling may be integrated with the process such that the cooling is achieved using heat exchange with another stream in the process which requires heating.

5           The pressure in the reactor must be above the vapour pressure of the solvent at the reaction temperature and is suitable at least 1 MPa, preferably at least 2 MPa, more preferably at least 3 MPa. The pressure in the reactor is suitably at most 16 MPa, preferably at most 12  
10           MPa, more preferably at most 10 MPa, even more preferably at most 8 MPa, most preferably at most 6 MPa. Preferably, the reactor is pressurised to a pressure within these limits by addition of hydrogen before addition of any saccharide-containing feedstock. The  
15           pressure of hydrogen is maintained by addition of hydrogen as a separate feed stream throughout the process.

          Preferably, the process of the present invention takes place in the presence of hydrogen. Preferably, the  
20           process of the present reaction takes place in the absence of air or oxygen. In order to achieve this, it is preferable that the atmosphere in the reactor be evacuated and replaced with hydrogen repeatedly, after loading of any initial reactor contents, before the  
25           reaction starts.

          In one embodiment of the invention, the catalytic conversion of a saccharide-containing feedstock in a reactor comprises the conversion of one or more saccharides in the presence of hydrogen and a catalyst  
30           system to ethylene glycol and 1,2-propylene glycol. In this embodiment of the invention, the catalyst system used preferably comprises at least two active catalytic components comprising, as a first active catalyst

component, one or more materials selected from transition metals from groups 8, 9 or 10 or compounds thereof, with catalytic hydrogenation capabilities; and, as a second active catalyst component, one or more materials selected from tungsten, molybdenum and compounds and complexes thereof.

Preferably, the first active catalyst component consists of one or more of the group selected from iron, cobalt, nickel, ruthenium, rhodium, palladium, iridium and platinum. This component may be present in the elemental form or as a compound. It is also suitable that this component is present in chemical combination with one or more other ingredients in the catalyst system. It is required that the first active catalyst component has catalytic hydrogenation capabilities and it is capable of catalysing the hydrogenation of material present in the reactor.

Preferably, the second active catalyst component comprises of one or more compound, complex or elemental material comprising tungsten, molybdenum, vanadium, niobium, chromium, titanium or zirconium. More preferably the second active catalyst component comprises one or more material selected from the list consisting of tungstic acid, molybedic acid, ammonium tungstate, ammonium metatungstate, ammonium paratungstate, tungstate compounds comprising at least one Group I or II element, metatungstate compounds comprising at least one Group I or II element, paratungstate compounds comprising at least one Group I or II element, heteropoly compounds of tungsten, heteropoly compounds of molybdenum, tungsten oxides, molybdenum oxides, vanadium oxides, metavanadates, chromium oxides, chromium sulfate, titanium ethoxide, zirconium acetate, zirconium

carbonate, zirconium hydroxide, niobium oxides, niobium ethoxide, and combinations thereof. The metal component is in a form other than a carbide, nitride, or phosphide. Preferably, the second active catalyst component

5 comprises one or more compound, complex or elemental material selected from those containing tungsten or molybdenum.

The catalyst components may be heterogeneous or homogeneous with respect to the solvent or solvents

10 present in the reactor during the process of the present invention. The catalyst components may be preloaded into the reactor or, if they are in liquid form or present as a solution or slurry in a solvent, they may be fed into the reactor as required in a continuous or discontinuous

15 manner during the process of the present invention.

Preferably, at least one of the active catalyst components is supported on a solid support. In this embodiment, any other active catalyst component may be present in either heterogeneous or homogeneous form.

20 Said any other active catalyst component may also be supported on a solid support. In one embodiment, the first active catalyst component is supported on one solid support and the second active catalyst component is supported on a second solid support which may comprise

25 the same or different material. In another embodiment, both active catalyst components are supported on one solid support.

The solid supports may be in the form of a powder or in the form of regular or irregular shapes such as

30 spheres, extrudates, pills, pellets, tablets, monolithic structures. Alternatively, the solid supports may be present as surface coatings, for examples on the surfaces of tubes or heat exchangers. Suitable solid support

materials are those known to the skilled person and include, but are not limited to aluminas, silicas, zirconium oxide, magnesium oxide, zinc oxide, titanium oxide, carbon, activated carbon, zeolites, clays, silica alumina and mixtures thereof.

5

Suitably, the weight ratio of the first active catalyst component to the second active catalyst component is in the range of from 0.02:1 to 3000:1, preferably in the range of from 0.1:1 to 100:1, on the basis of the weight of metal present in each component.

10

The weight ratio of the first active catalyst component (based on the amount of metal in said component) to sugar is suitably in the range of from 1:100 to 1:10000. The weight ratio of the second active catalyst component (based on the amount of metal in said component) to sugar is suitably in the range of from 1:10 to 1:1000.

15

An effluent stream comprising ethylene glycol and 1,2-propylene glycol is continuously removed from the reactor. Said effluent stream may also contain water, hydrogen, unreacted saccharide, intermediates, by-products and catalyst materials. Said catalyst materials may be the result of decomposition of the catalyst system in the reactor or may be catalyst material present as part of an at least partially homogeneous catalyst system. Such catalyst materials will need to be separated from the effluent stream and optionally recycled to the reactor or a reactor feed stream.

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The remaining effluent stream will then require separation and purification of the desired products. Unreacted saccharides and intermediates may be separated and recycled to the saccharide-containing feedstock. Hydrogen and water may also be separated and recycled to

30

reactor feed streams.

Embodiments of the present invention will now be described by way of example only and with reference to the accompanying non-limiting figures.

5           The flow of saccharide-containing feedstock 102 is provided to a reactor through a feed pipe 101. Said feed pipe 101 enters the reactor through the reactor wall 103. A section 104 of the reactor wall is cooled by means of a heat exchanger 106. Cooling fluid 105 enters the heat  
10           exchanger 106 and is subsequently removed as heated fluid 107.

C L A I M S

1. A process for the catalytic conversion of a saccharide-containing feedstock in a reactor, wherein saccharide-containing feedstock is provided to the reactor as a feed stream through a feed pipe and is  
5 contacted with a catalyst system in the reactor, wherein the saccharide-containing feedstock in the feed pipe is maintained at a temperature below the degradation temperature of the saccharide contained therein and a section of the wall of the reactor at the point where the  
10 feed pipe enters the reactor is cooled to a temperature below the temperature of the bulk of the reactor and the reactor contents.
2. A process according to claim 1, wherein the section of the wall of the reactor at the point where the feed  
15 pipe enters the reactor is cooled using a cooling liquid, by air cooling, or by using the heat to evaporate water in order to provide low pressure steam.
3. A process according to claim 1 or claim 2, wherein the section of the wall of the reactor at the point where  
20 the feed pipe enters the reactor is cooled by heat exchange with another stream in the process.
4. A process according to any one of claims 1 to 3, wherein the saccharide-containing feedstock in the feed  
25 pipe is maintained at a temperature at least 10°C below the degradation temperature of the saccharide contained therein.
5. A process according to any one of claims 1 to 4, wherein the saccharide containing feedstock is also contacted with hydrogen in the reactor.

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6. A process according to any one of claims 1 to 5,  
wherein the catalytic conversion of a saccharide-  
containing feedstock comprises the conversion of said  
feedstock into ethylene glycol and 1,2-propylene glycol  
5 in the presence of a catalyst system.

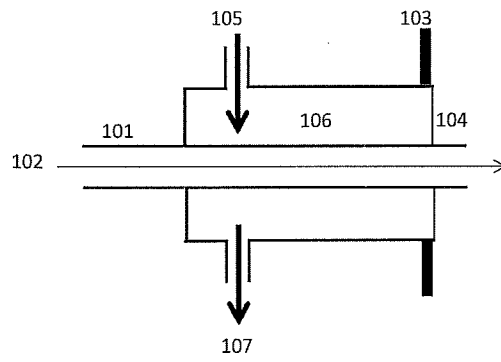
7. A process according to claim 6, wherein the catalyst  
system comprises at least two active catalytic components  
comprising, as a first active catalyst component, one or  
more materials selected from transition metals from  
10 groups 8, 9 or 10 or compounds thereof, with catalytic  
hydrogenation capabilities; and, as a second active  
catalyst component, one or more materials selected from  
tungsten, molybdenum and compounds and complexes thereof.

8. A process according to any one of claims 1 to 7,  
15 wherein the solvent comprises water.

9. A process according to any one of claims 1 to 8,  
wherein the saccharide-containing feedstock comprises one  
or more of glucose, sucrose and starch.

10. A process according to any one of claims 1 to 9,  
20 wherein the temperature in the reactor is in the range of  
from 150 to 250°C and the pressure in the reactor is in  
the range of from 1 to 16 MPa.

Figure 1



**INTERNATIONAL SEARCH REPORT**

International application No  
PCT/EP2014/068350

A. CLASSIFICATION OF SUBJECT MATTER  
INV. C07C29/00 C07C31/20  
ADD.  
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED  
Minimum documentation searched (classification system followed by classification symbols)  
C07C  
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)  
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2011/313212 A1 (T.N. KALNES, ET AL.) 22 December 2011 (2011-12-22) cited in the application	1,4-8,10
A	paragraphs [0007], [0015], [0018], [0032]; claim 1	2,3,9
X	----- WO 2013/015955 A2 (UOP) 31 January 2013 (2013-01-31)	1,4-6, 8-10
A	paragraphs [0008], [0014] - [0017], [0021]; claims 1, 4 -----	2,3,7

Further documents are listed in the continuation of Box C.  See patent family annex.

\* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"E" earlier application or patent but published on or after the international filing date	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O" document referring to an oral disclosure, use, exhibition or other means	"&" document member of the same patent family
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search <b>24 October 2014</b>	Date of mailing of the international search report <b>03/11/2014</b>
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Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer <b>English, Russell</b>
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**INTERNATIONAL SEARCH REPORT**

Information on patent family members

International application No

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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