Scoping study on hemicellulose valorisation

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Scoping study on hemicellulose valorisation

- RVO, on behalf of Biobased Circular Business Platform (BCBP), has requested WFBR to make an offer for a desk study on "lignocellulosic valorisation strategies, focus on hemicellulose" (phase I)
- WFBR has replied it is only capable of performing a part of phase I before the end of August and has made a projectplan according to this:
- An overview of the composition in terms of hemicellulose and C5 sugars will be made for various types of biomass
- A product tree for products based upon xylose/arabinose (see www.biobased.eu/market study for glucose), including estimated TRL levels, order of magnitude of prices and production of commercial products

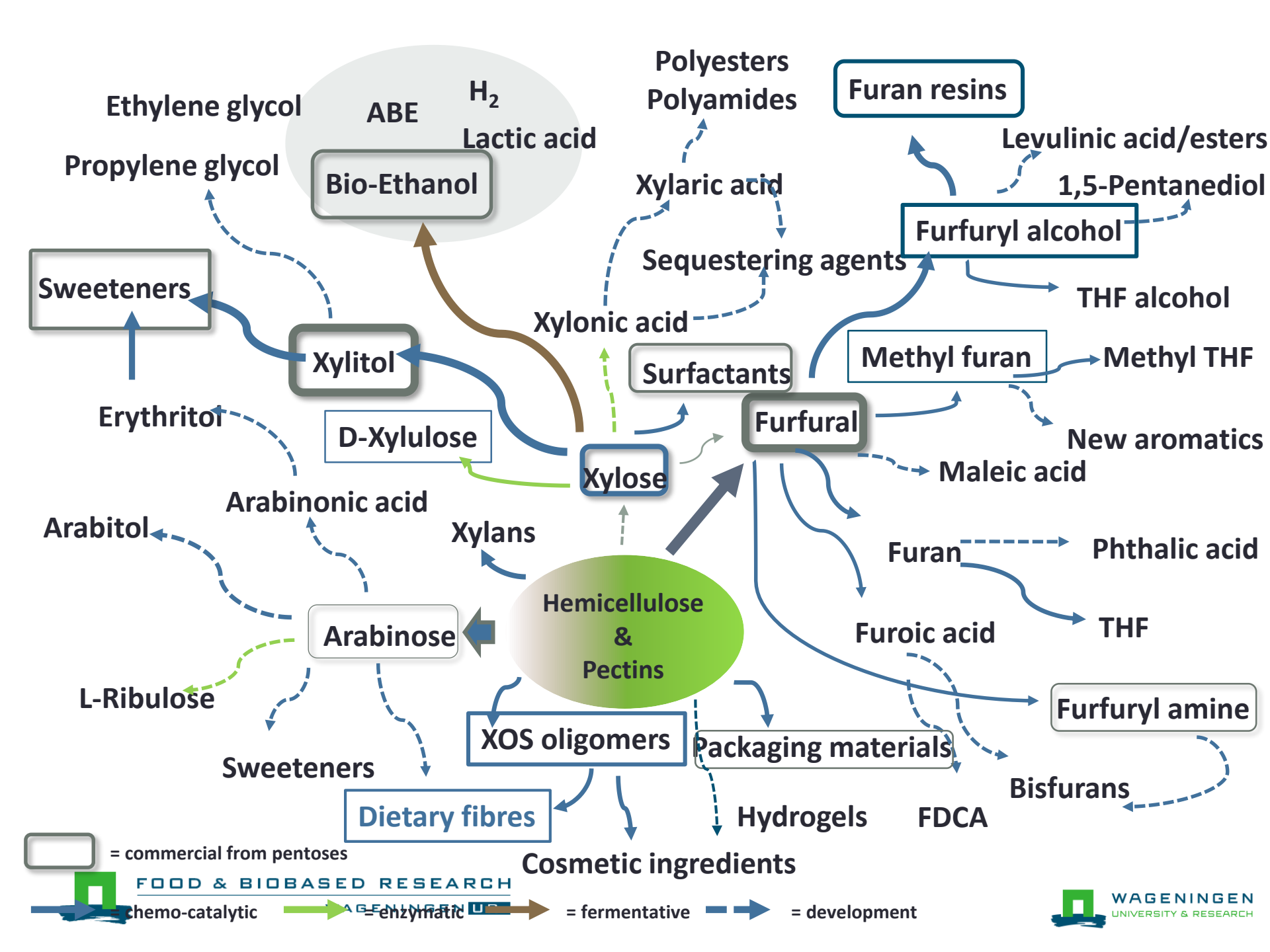
Disambiguation of sources

Engels	NL	Hout	Soort (vb)
Spruce	Fijnspar	Vuren	Picea Abies
Fir	Zilverspar	Dennen	Abies Balsamea
Pine	Den	Grenen	Pinus Silvestris
Poplar	Populier	Populier	Populus Alba
Beech	Beuk	Beuken	Fagus Sylvatica

Composition of various feedstocks

%	Arabinose C5	Xylose C5	Mannose C6	Galactose C6	Hemicellulose	Ref
Spruce	0.7	4.7	9.9	1.8	16.7	Eigen metingen FBR
	1.2	*5.6*	*13.6*	*2.8*		*Fengel & Wegener*
Fir	0.9	4.1	10.0	1.5	16.5	Eigen metingen FBR
	1.1	*5.2*	*10.0*	*1.0*		*Fengel & Wegener*
Pine	1.7	5	11.9	1.4	20	Eigen metingen FBR
	1.5	*7.6*	*12.4*	*1.9*		*Fengel & Wegener*
Poplar	0	11.7	2.3	0.4	14.5	Eigen metingen FBR
	0.9	*21.2*	*3.5*	*1.1*		*Fengel & Wegener, (populus tremuloides, amerikaanse ratelpopulier)*
Beech					21-28	Phyllis database ECN
	0.7	*19*	*19.0*	*1.4*		*Fengel & Wegener*
Eucalyptus	0.5	14	1.0	1.1	17	Eigen metingen FBR
Wastewood A	No unambiguous definition, no unambiguous composition					
Miscanthus	1.3	18.1	0.1	0.4	19.9	Eigen metingen FBR
Sugar beet pulp	14.5	0.8	0.8	4	20	Eigen metingen FBR
Birch wood (Betula genus)	0.5-1	18-25	1.8-.3.2	0.7-1.0		

Wood—chemistry, ultrastructure, reactions, by D. Fengel and G. Wegener, Walter de Gruyter, Berlin and New York, 1984, 613 pp. DOI: 10.1002/pol.1985.130231112


Ethylene glycol
ABE
H_2
Lactic acid
Polyesters
Polyamides
Furan resins
Levulinic acid/esters
Propylene glycol
Bio-Ethanol
Xylaric acid
1,5-Pentanediol
Furfuryl alcohol
Sweeteners
Sequestering agents
THF alcohol
Xylonic acid
Xylitol
Surfactants
Methyl furan
Methyl THF
Erythritol
D-Xylulose
Furfural
New aromatics
Xylose
Maleic acid
Arabinonic acid
Arabitol
Xylans
Furan
Phthalic acid
Hemicellulose
&
Pectins
THF
Furoic acid
Arabinose
L-Ribulose
Furfuryl amine
XOS oligomers
Packaging materials
Sweeteners
Bisfurans
Dietary fibres
Hydrogels
FDCA
Cosmetic ingredients
= commercial from pentoses
= chemo-catalytic
= enzymatic
= fermentative
= development
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Some general observations

- Largest commercial application of xylose based products are currently xylitol and furfural (derivatives)
- Furfural derivatives are currently produced without intermediate isolation of (purified) xylose
- Danisco/Dupont xylitol production is based on Birch wood; why birch wood not included as a feedstock in BCBP study? Danisco xylitol produced from sidestream paper /pulp production in “wood based integrated concept”
- Fermentation of C5 sugars in most cases leads to same products as fermentation of C6 sugars
- Xylitol and xylonic are unique for C5 sugar fermentation, but can also be derived via chemo-catalytic or biocatalytic processes
- Fermentation of C5 sugars often proceeds slower than C6 sugars
- Chemo-catalytic conversion offers most perspectives for unique structures (those which are difficult to obtain from C6 sugars)

Commercial xylose derived products

Product	Tonnage/turnover	Price Indication(US $ kg)*	Suppliers
Xylose		1-3	
Xylitol	750 million US $ turnover (ca 60 Kton production in US, about 300 kton globally)	2-3	Danisco (DuPont), Futaste Pharmaceutical, Yucheng Lujian and Hangzhou Shouxing
XOS	88 million US $ turnover		Chinese suppliers
Xylose based surfactants	Several thousands tonnes		ARD, Soliance
Arabinose		20-50	
Bio-ethanol from C5			
Furfural	450 million US $ turnover in 2013; CAGR of 11-13% (e.g. TFC/Pennakem)	0.9-1.2	TFC, Pennakem , Chinese suppliers
Furfurylalcohol		1.4-1.6	TFC
Furan resins		0.9-1.8	TFC
Methylfuran	No public data on turnover/ tonnages found; marketing studies available	2.5-3	Pennakem, Chinese suppliers
Methyl-THF			
Furan#			
Tetrahydrofuran		1.2-1.5#	
Furfurylamine	Product at low tonnages <100 tonnes/year	6-8	Pennakem
Furoic acid	Product at low tonnages <100 tonnes/year		Pennakem

- * source; www.alibaba.com
- # Current Tetrahydrofuran production THF from fossil sources

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Development stage non-commercial xylose derived products

Product	Estimated Development level (TRL)
Xylonic acid	4-5
Xylaric acid	4-5
Xylulose (intermediate in fermentation xylose and furfural production)	Ref. to market reports* suggest commercial production but situation unclear
New aromatics (e.g. methylphthalic acid)	3-4
Arabinonic acid	3-4
Arabitol	3-4
A,B,E, lactic acid from xylose	5-6
XOS based cosmetic ingredients	
Maleic acid (from furfural)*	2-3

*Maleic acid is currently produced from fossil feedstocks

Xylo-oligosaccharides

- Advocated as dietary fiber/prebiotic.
- Dietary fibre /prebiotic is component that is not digested by humans, but by good bacteria in the human gut; has (perceived) health benefits
- Many classes of oligosaccharides are being classified as prebiotic including inulin, FOS (fructo- oligosaccharides, GOS (galacto-oligosaccharides and XOS). Inulin, FOS and GOS and XOS are being commercialised. Optimal DP of oligosaccharides for functioning as prebiotic is in range DP 2-6
- Literature describes various procedures for isolation of XOS from predominantly agricultural side streams, e.g. wheat bran, citrus pulp, brewer's spent grain, corn hobs, but also e.g. Eucalyptus wood
- Global dietary fibers market valued at USD 3.3 billion in 2015 (www.grandviewresearch.com/industry-analysis/dietary-fibers-market)

Xylo-oligosaccharides

- Global xylo-oligosaccharides market about 88 M USD in 2015
  (www.marketpublishers.com/report/chemicals_petrochemicals/global-oligosaccharides)
- Application segments:
  - Medical and health products
  - Food and drinks
  - Feed
  - Others
- Key players; e.g. Longlive, Kangwei, Yuhua, ShunTian
- Many marketing studies on oligosaccharides for sale at about 4000 €

Additional remarks

- Price of isolated, crude xylose should be in range 300-400 €/ tonne to make the furfural based product tree profitable
- Important question is to what extent xylose needs to be purified for subsequent conversion
- In case prices of xylitol lower to the range of sorbitol (glucose reduction product, sorbitol is currently at 0.9-1.2 US $/kg*), xylitol can compete with sorbitol for market applications such as cosmetics and personal care, chemicals;
- Global sorbitol market is projected to reach 1,6 billion US $ turnover in 2022 and 2.34 million tonnes in 2020 (www.hexaresearch.com/research-report/sorbitol- market)
- Cosmetic and personal care segment; provides US $ 500 million of sorbitol turnover and chemicals segment 400 million US $.

*www.alibaba.com

Concluding remarks

Follow up research (phase 2; focus on xylose) research necessary to address:

- What is the optimal starting material; hemicellulose, mixture C5/C6 sugars, (more) purified xylose? What can we learn in this respect form current xylose based commercial products?
- Which applications become competitive at which market prices of xylose ?
- How does this (prices) relate to purity of xylose containing streams that can be obtained?
- What are the available technologies to purify xylose or to obtain xylose rich streams?
- Do other breakthrough technologies need to developed?
- What is overall the best lignocellulosic stream to obtain xylose?
- How to optimally combine xylose (derivatives) production with other major product e.g. 2nd generation bioethanol or cellulose fibers?

Thank you

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