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Production of xylitol by catalytic hydrogenation of xylose

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Xylose can be converted to xylitol, a high valued natural sweetener used in the food industry by catalytic hydrogenation. Traditionally, nickel catalysts are employed in the production of xylitol on industrial scale. Xylitol, a natural sweetener, has got additional advantages over common sugar 'sucrose'. Firstly, xylitol has no insulin requirement, making it suitable for usage by diabetics. Secondly, it is very good for patient suffering from dental problems, viz., dental carries, tooth decay and falling of teeth. It is non cariogenic and nontoxic.
Xylose is reduce to xylitol by catalytic hydrogenation in a pressure reactor. Parameters like temperature, pressure, initial concentration of xylose, agitation rate, catalyst loading and pH for the process need to be optimized. Finally under the optimized conditions the process is carried out to produce maximum amount of the product i.e. xylitol. Normally this reaction process is carried out under pressure at elevated temperature.
Keyword: Corn cobs, xylitol, catalytic hydrogenation.

1. Introduction

The need for eco-efficient processes has motivated extensive researches aiming to convert industrial and agricultural wastes into valued products [10, 11]. Xylose occur in the form of the polymeric pentosans (xylan) which are the binding material of the fibres of cellulose in plants. Xylose is obtained by hydrolysis of pentosans from wood, straw, bran, oat hulls, sugar cane bagasse, cotton seed hulls, coconut shells, corn cobs etc. Later xylose can be converted into xylitol, a product sweeter than sucrose. Over the last decades, the sweeteners demand for natural (particularly xylitol) has increased in the world market [15]. Besides its anti-cariogenic properties, xylitol has lower insulin requirements and higher sweetening capacity than sucrose being especially suitable for usage by diabetics. Xylitol can also used in pharmaceutical, cosmetic, and synthetic resin industries [21, 12, 14].

The Corn cobs contains about 38-40% Xylan, a xylose polymer made up of D-xylose Units, which can be converted to xylose (about 22-24%) by hydrolysis and then to xylitol (about 20%) by hydrogenation. (Table 1)

Table 1: percentage of Xylose in agricultural wastes

S. No.	Xylose (%)	Agricultural wastes
1	10.8	Wheat Bran
2	10.2	Rice husk
3	13.6	Cotton seed hulls
4	23.2	Corn Cobs
5	18.6	Sugar cane Bagasse

2. Optimization of Parameters for hydrogenation

The Xylose reduced to Xylitol under high pressure of Hydrogen and at high temperature in the presence of a metal catalyst [7]. Firstly Xylose was produced by the acid hydrolysis of corn cobs. Then Xylose was reduced to Xylitol by catalytic hydrogenation in a Pressure reactor. Normally this reaction process is carried out under pressure at elevated temperatures. In a sequence, the various parameters, viz. temperature, pressure, time, xylose concentration, agitation rate, catalyst loading & hydrogen ion concentration for the process to be optimized. The optimization of one was done by keeping other parameters fixed arbitrarily. Finally, under the optimized conditions, the process was carried out to produce maximum amount of the product that is xylitol.

2.1 Optimization of temperature

Hydrogenation process was carried out at temperatures 110, 120, 130, 140, 150 °C in Pressure reactor. As the reaction temperature was increased upto 140 °C., the conversion of xylose to xylitol increased to the maximum. Further increase in temperature upto 150 °C. Did not influence the yield of xylitol. Therefore it is quite evident that the optimum temperature for the reaction is 140 °C at which the conversion of xylose to xylitol has been found to be the maximum. Raising the temperature more than 150 °C may lead to cleavage of carbon chain (like hexose into ethylene glycol and glycerol [23].

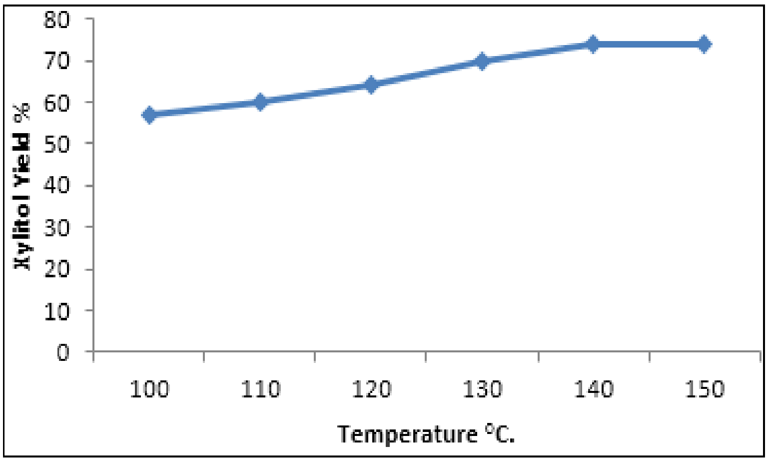

Fig 1: Xylose conversion into xylitol along batch time. Hydrogenation of xylose at P=120 psig., Cx=5%, Vx=500 ml, pH=7.4, r=420 rpm, CNi=3%.

2.2 Optimization of Pressures

Hydrogenation process was carried out at the pressures 100, 200, 300, 400, 500 & 600 Psig in Pressure reactor. Xylitol production increased by increasing pressure upto 400 Psig. Further increase in pressure of the reaction upto 600 Psig did not influence the production of xylitol.

In this reaction small amount of xylose got converted into xylonic acid by oxidation of xylose due to air left in the head apace of the reactor.

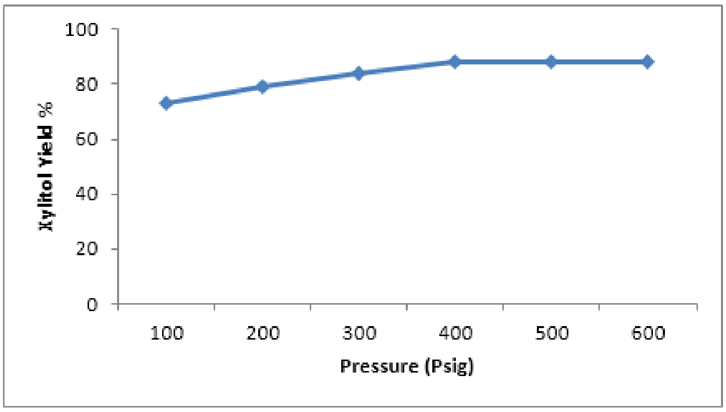

Fig 2: Xylose conversion into xylitol along batch time. Hydrogenation of xylose at T=140 °C., Cx=5%, Vx=500 ml, pH=7.4, r=420 rpm, CNi=3%.

2.3 Optimization of initial concentration of xylose solution

Hydrogenation process was carried out at 4, 5, 6, 7.5, 8.5, 9, 10 percent initial concentration of xylose in the reaction medium. Xylitol production increased by increasing the initial concentration of xylose upto 5% and decreased gradually and reached to zero percent at 9 and 10 percent initial concentration of xylose. The results are quite surprising that increasing concentration of reactant, it itself inhibit the product formation. This phenomenon is quite common in biological reactions. In the reaction when an enzyme, like amylase in hydrolysis of starch into glucose, is used as catalyst, higher concentration of starch reduces the product formation. This is because starch molecules block the active sites of the enzymes and reaction does not occur. The same is the reason for diminishing product (xylitol) formation on increasing the concentration of reactant (xylose). The reaction completely stops because higher concentration of xylose itself does not allow other molecules of xylose to come in contact with hydrogen gas on the surface of nickel catalyst.

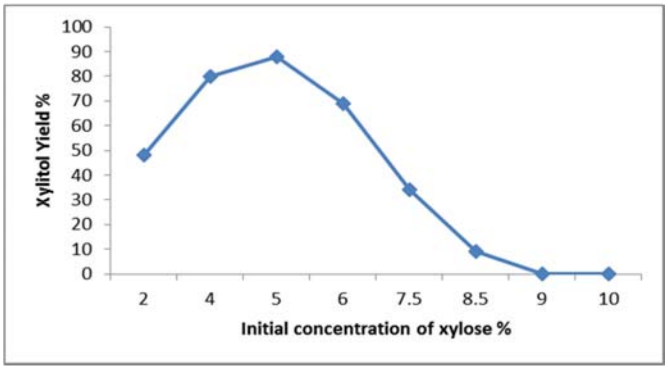

Fig 3: Xylose conversion into xylitol along batch time. Hydrogenation of xylose at T=140 °C., P=400 psig., Vx=500 ml, pH=7.4, r=420 rpm, CNi=3%.

2.4 Optimization of concentration of catalyst

Hydrogenation process was carried out with 1, 2, 3, 4, & 5 percent Raney-nickel catalyst based on xylose by weight, which was initially taken. As the percentage of catalyst increased to 3 percent (of xylose by weight), the conversion of xylose to xylitol reached to the maximum. Further increase of catalyst upto 5 percent, did not influence the production of xylitol. Therefore it is quite evident that the optimum concentration of catalyst for the reaction is 3 percent at which the conversion of xylose to xylitol has been found to be the maximum.

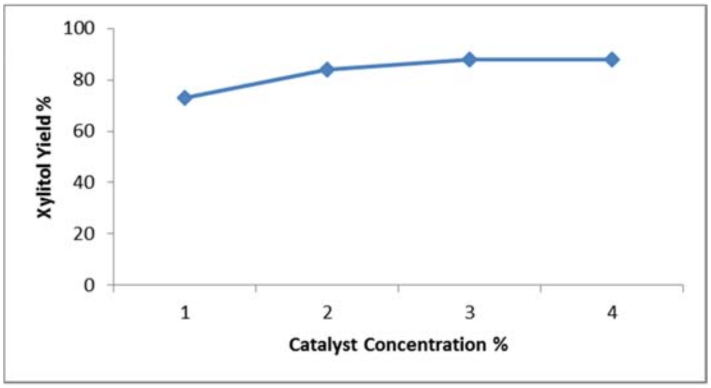

Fig 4: Xylose conversion into xylitol along batch time. Hydrogenation of xylose at T=140 °C., P=400 psig., Cx=5%, Vx=500 ml, pH=7.4, r=420 rpm.

2.5 Optimization of agitation rate

Hydrogenation process was carried out at agitation rates of 192, 279, 322, 420 & 492 rpm. Xylitol production increased by increasing agitation rates. As the agitation rate increased upto 279 rpm the conversion of xylose to xylitol increased to the maximum

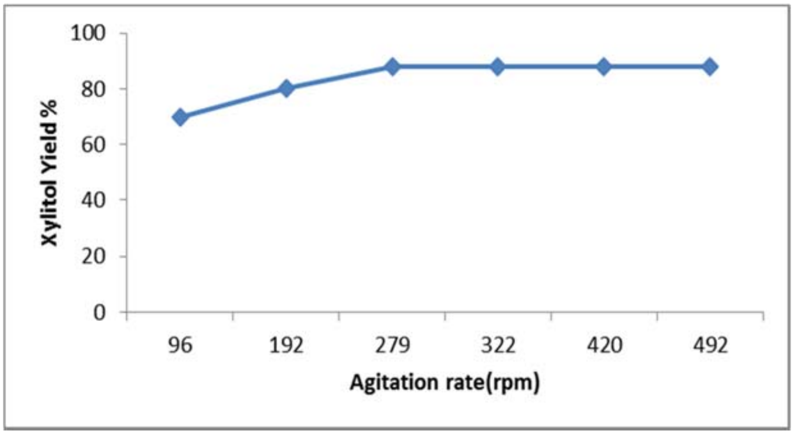

Fig 5: Xylose conversion into xylitol along batch time. Hydrogenation of xylose at T=140 °C., P=400 psig., Cx=5%, Vx=500 ml, pH=7.4, CNi=3%.

2.6 Optimization of pH

Hydrogenation process was carried out at pH 7.5 and 8.5. Xylitol production increased by increasing pH to the alkaline range and reached to the maximum at pH 7.5 & 8.5 respectively.

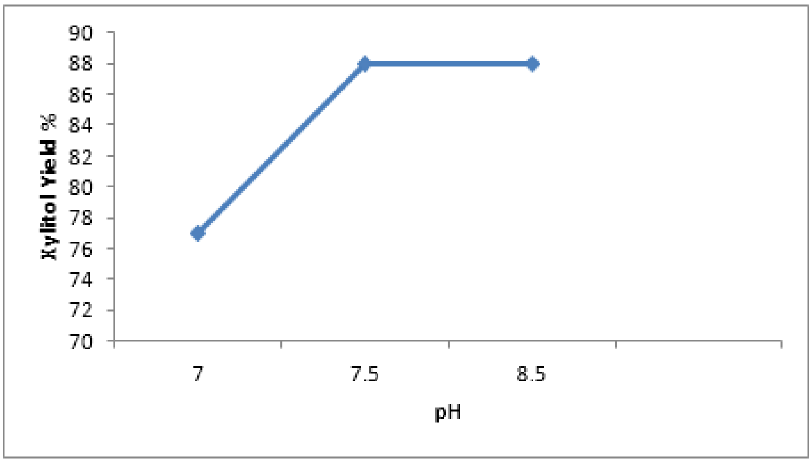

Fig 6: Xylose conversion into xylitol along batch time. Hydrogenation of xylose at T=140 °C., Cx=5%, Vx=500 ml, P=400 psig., r=420 rpm, CNi=3%

3. Conclusion

Therefore, it is concluded that the maximum yield of xylitol has been obtained when the reaction was carried out under optimized parameters as mentioned below:-

1.	Temperature	: 140 °C.
2.	Pressure	: 400 psig.
3.	Initial concentration of xylose	: 5%
4.	pH	: 7.5
5.	Agitation rate	: 420 rpm
6.	Raney-Nickel catalyst	: 3% of xylose by weight

In this process, some fraction of xylose (less than 2%) was oxidized to xylonic acid along with the production of xylitol due to air left in the head space of the reactor. It is possible to produce xylitol (yield over 20% on dry basis), a sweetener from corn cobs which is an agricultural waste.
On the basis of above mentioned results, about 88% of xylose can be converted in to xylitol by catalytic hydrogenation at optimized conditions. It is realistic to expect only a relatively small future for replacement of sugar by xylitol. Xylitol's special characteristics, particularly its dental and metabolic aspects, justify its greater use

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