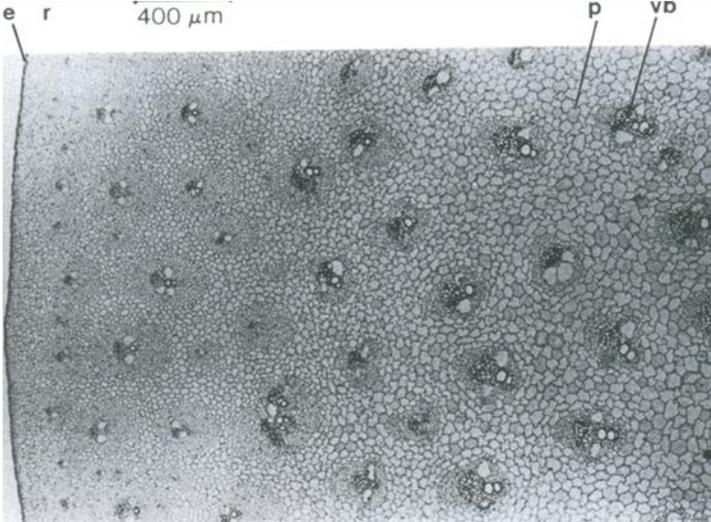


Biorefinarias associadas ao setor sucro energético de cana e etanol de milho

Cana



Milho



Tradicionalmente ficava no campo

Pense >> Como gerar monossacarídeos a partir dos polissacarídeos do bagaço de cana?

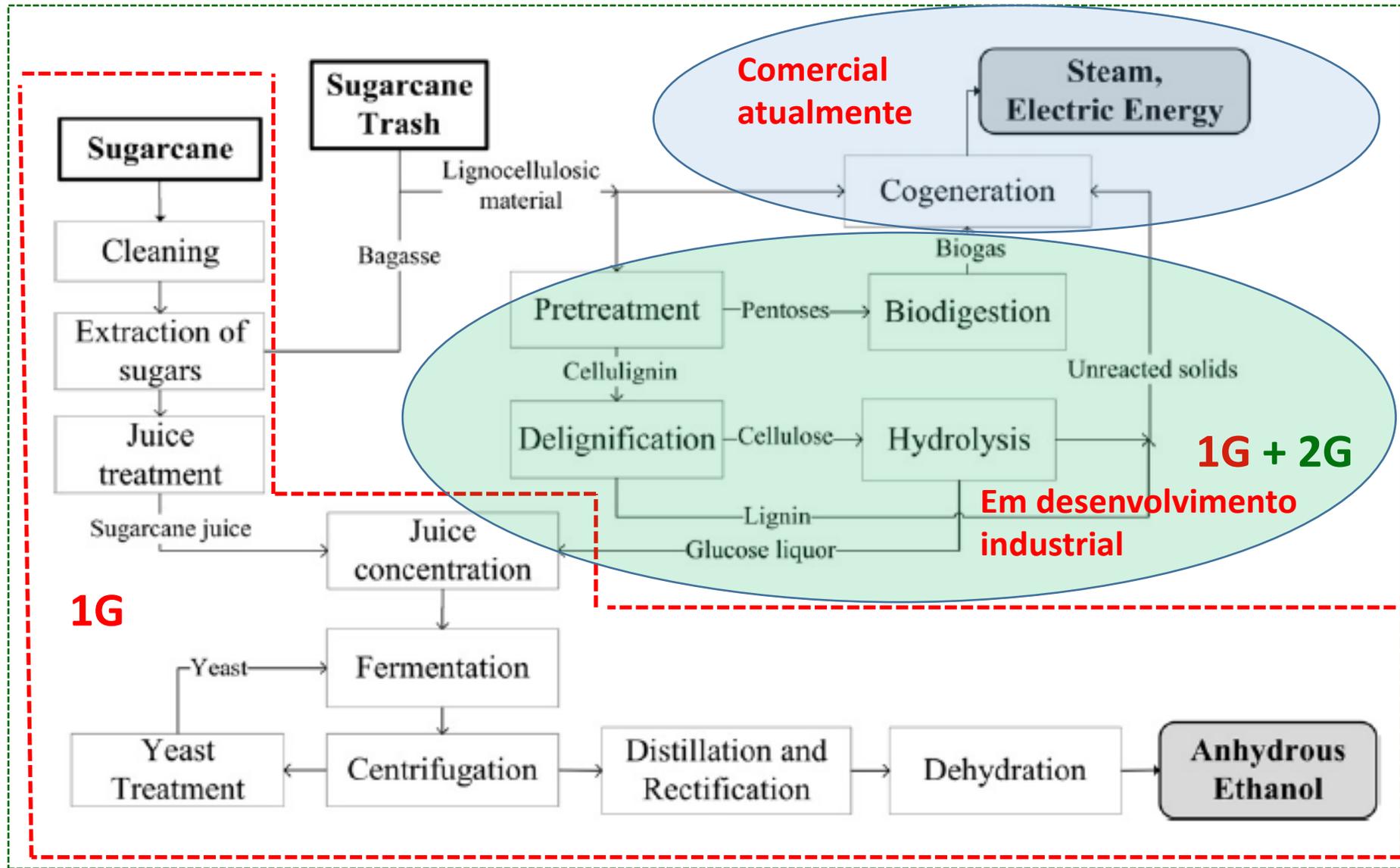
Hidrólise ácida?? Quais os problemas??

Hidrólise enzimática ?? Quais os problemas??

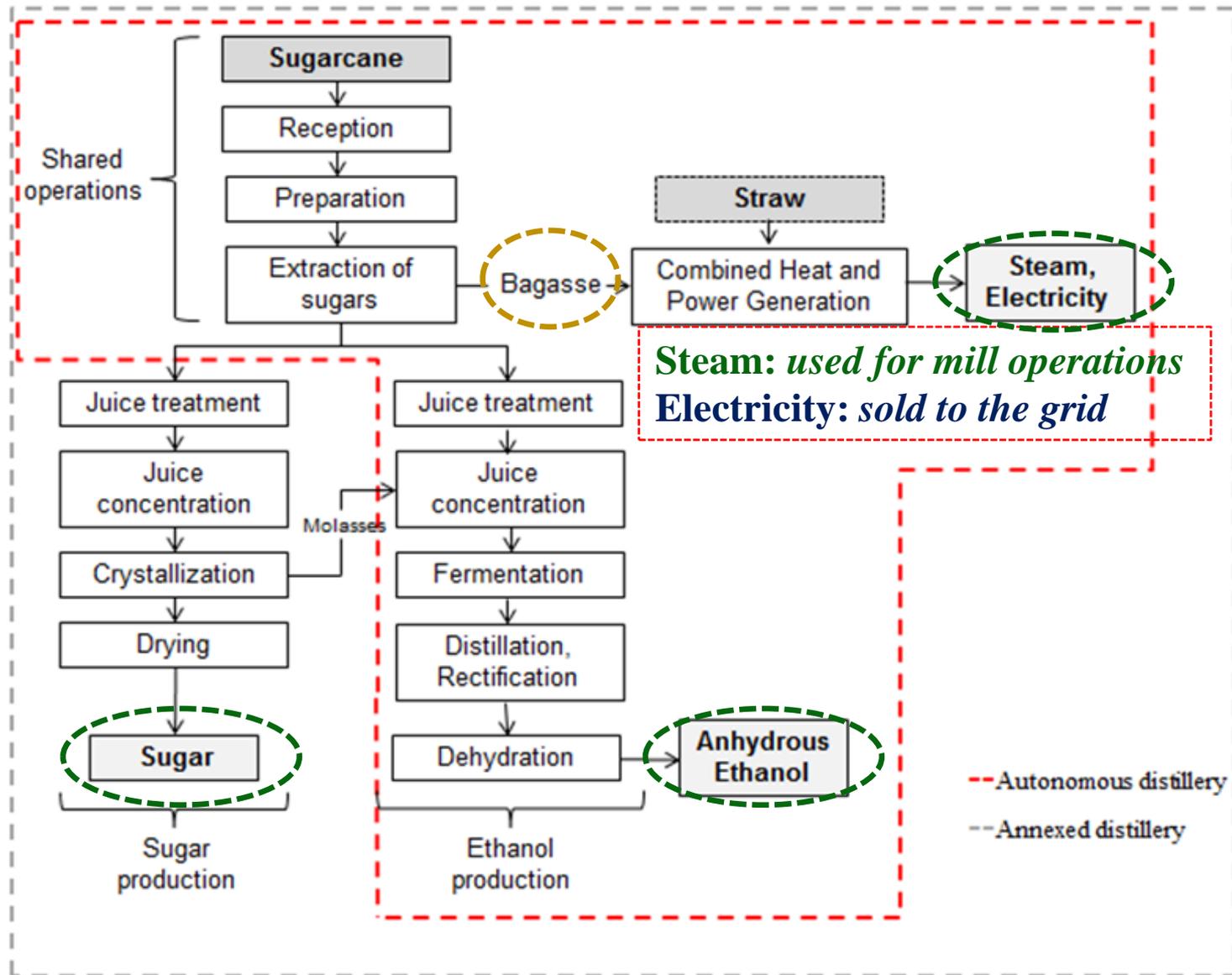
Deslignificação ajudaria?? Polpação kraft???

Quanto custa???

Integração de um processo de produção de etanol desde sacarose (1G) e de celulose e demais polissacarídeos (2G)



Traditional 1G-sugarcane biorefinery



1G-production standards according to the sugarcane cultivar

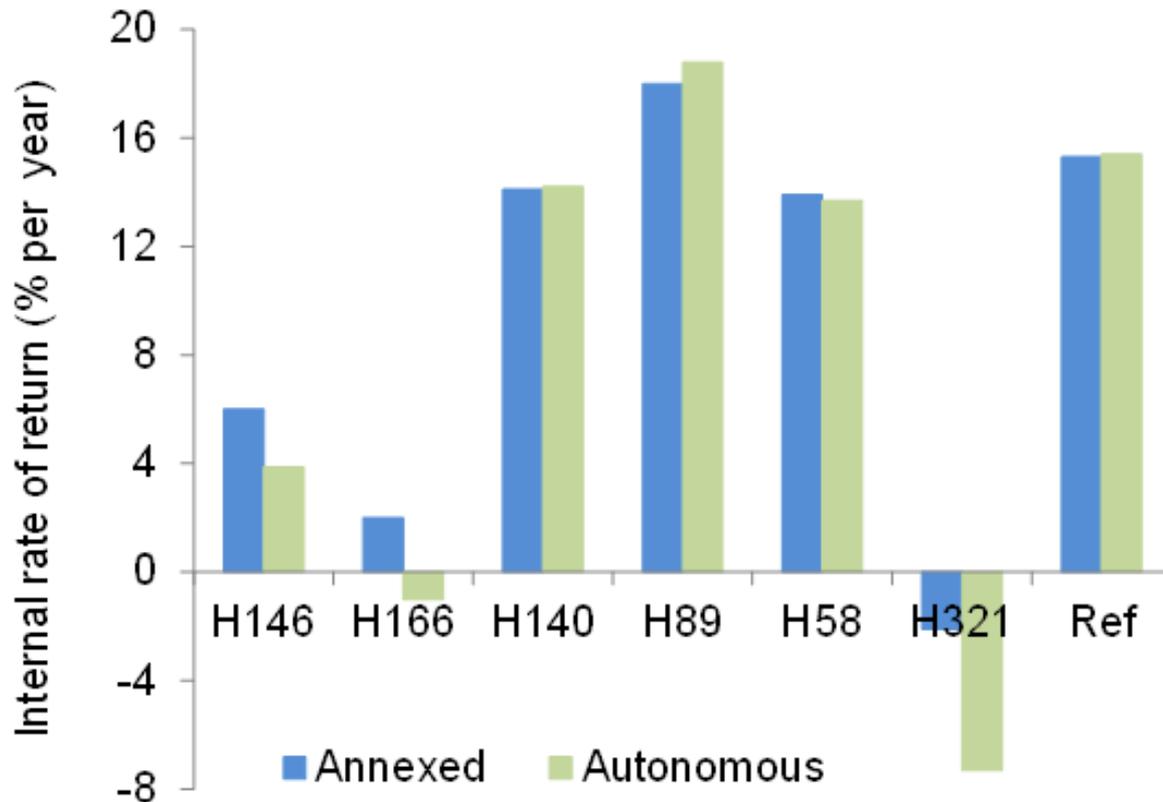
Simulation results for ethanol, sugar and electricity production for **annexed** and **autonomous distilleries**

	Sugarcane sample	Anhydrous ethanol		Sugar		Surplus electricity	
		L/TC ^a	L/ha	kg/TC ^a	kg/ha	kWh/TC	MWh/ha
Annexed distillery	H146	55.8	2662	53.5	2816	129	6.8
	H166	52.7	2662	50.4	2546	163	8.2
	H140	46.8	4121	44.6	3927	247	21.7
	H89	52.4	5303	51.7	5235	243	24.6
	H58	49.8	4235	47.5	4038	200	17.0
	H321	45.7	2485	43.2	2350	166	9.1
	Reference	53.0	4508	50.8	4318	189	16.1
Autonomous distillery	H146	88.7	4669	-	-	132	7.0
	H166	83.7	4230	-	-	166	8.4
	H140	74.0	6545	-	-	249	21.9
	H89	85.5	8656	-	-	244	24.7
	H58	78.9	6703	-	-	200	17.0
	H321	72.2	3931	-	-	166	9.0
	Reference	84.3	7167	-	-	193	16.4

(a) TC means ton of sugarcane stalks as harvested in the field (wet basis)

Internal rate of return for **traditional 1G-processing**

Sugarcane		
Sugar	Ethanol	Electricity



Using sugarcane bagasse for “new products”

1G-2G integration is the natural choice

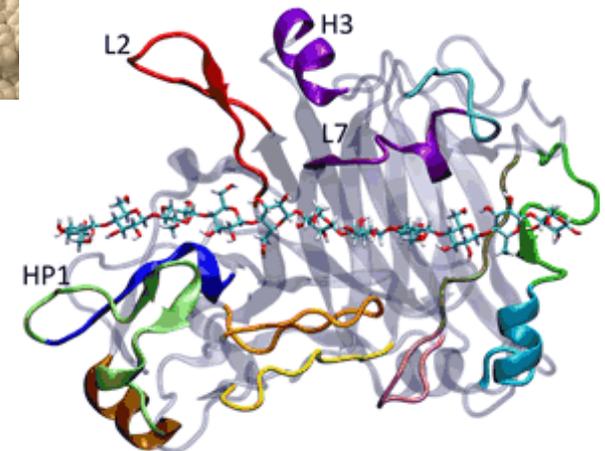
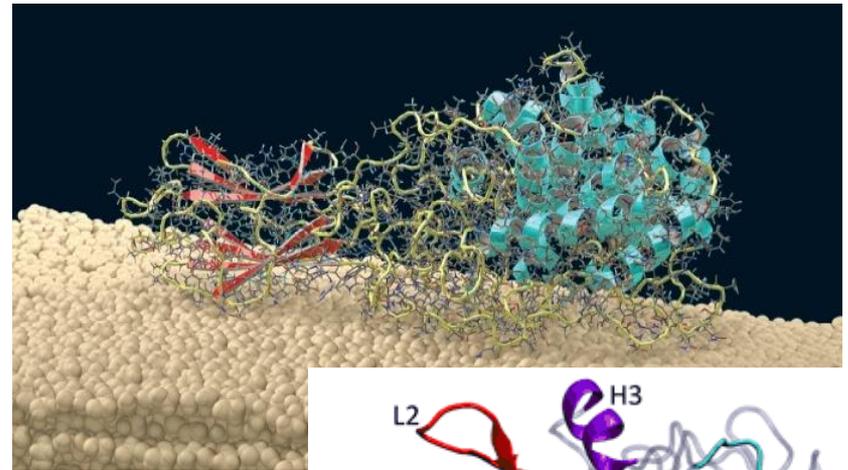
Biomass
polysaccharides

monosaccharides

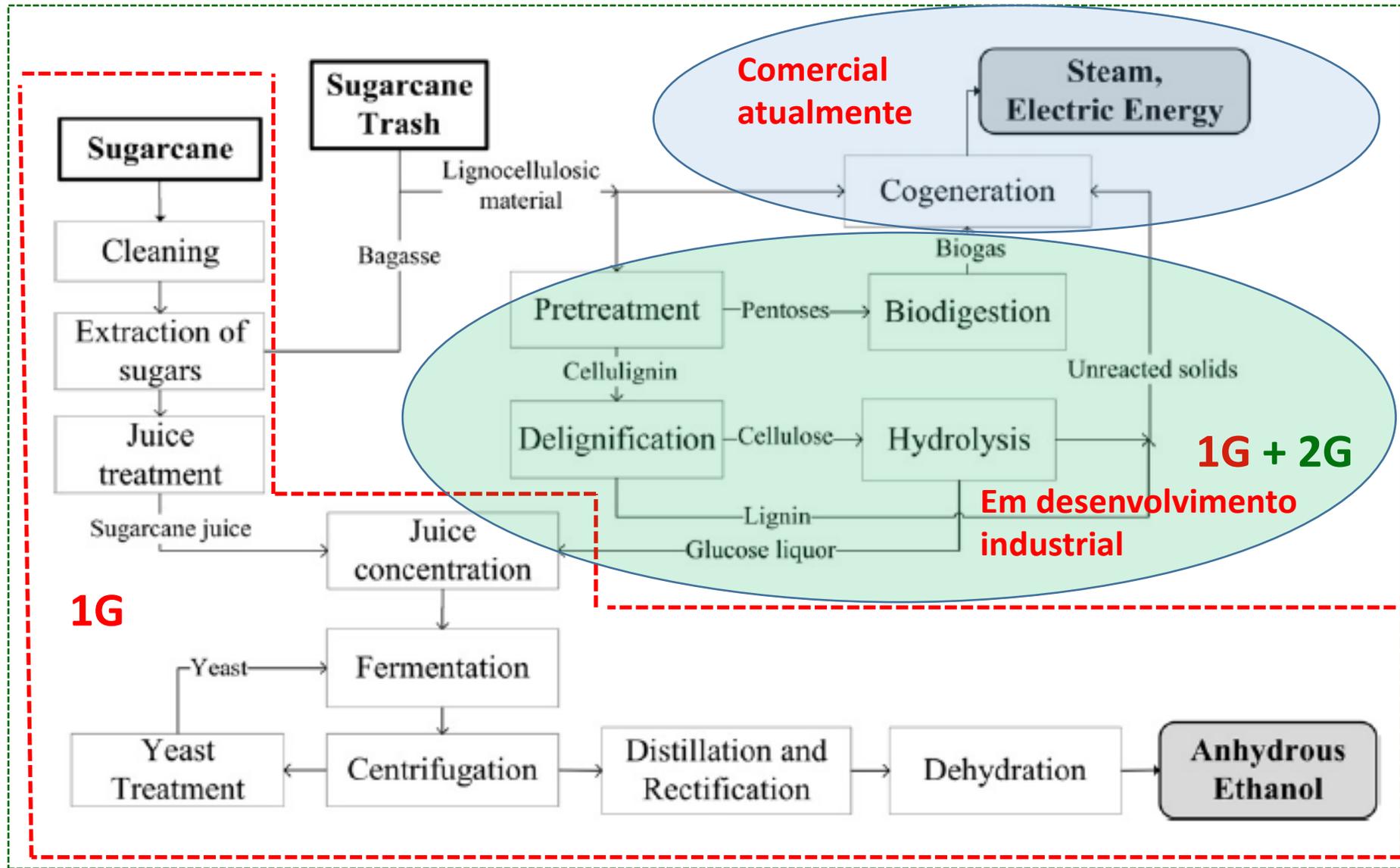
2G-ethanol

However, lignin and hemicellulose involve cellulose causing recalcitrance

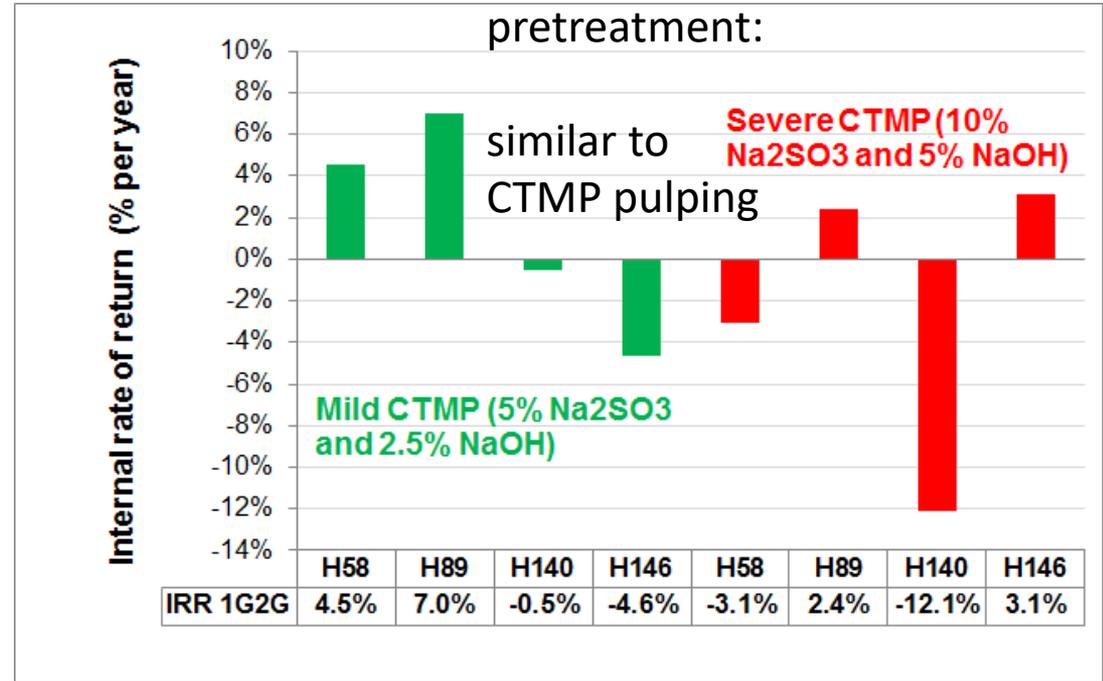
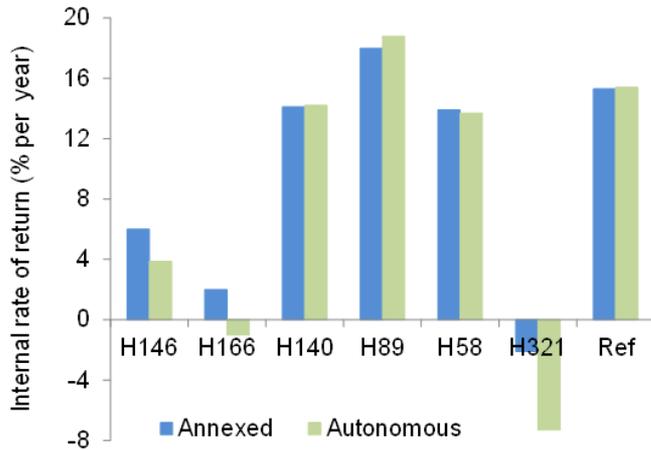
➔ Pretreatment is required



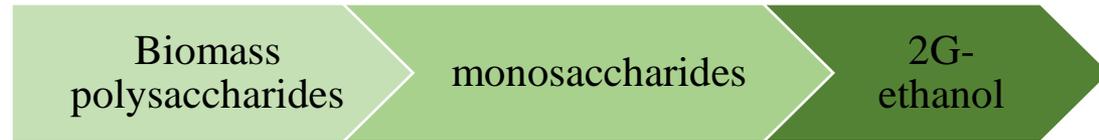
Integração de um processo de produção de etanol desde sacarose (1G) e de celulose e demais polissacarídeos (2G)



Internal rate of return for 1G-2G integrated sugar and ethanol production *(avoiding exciting electricity)*

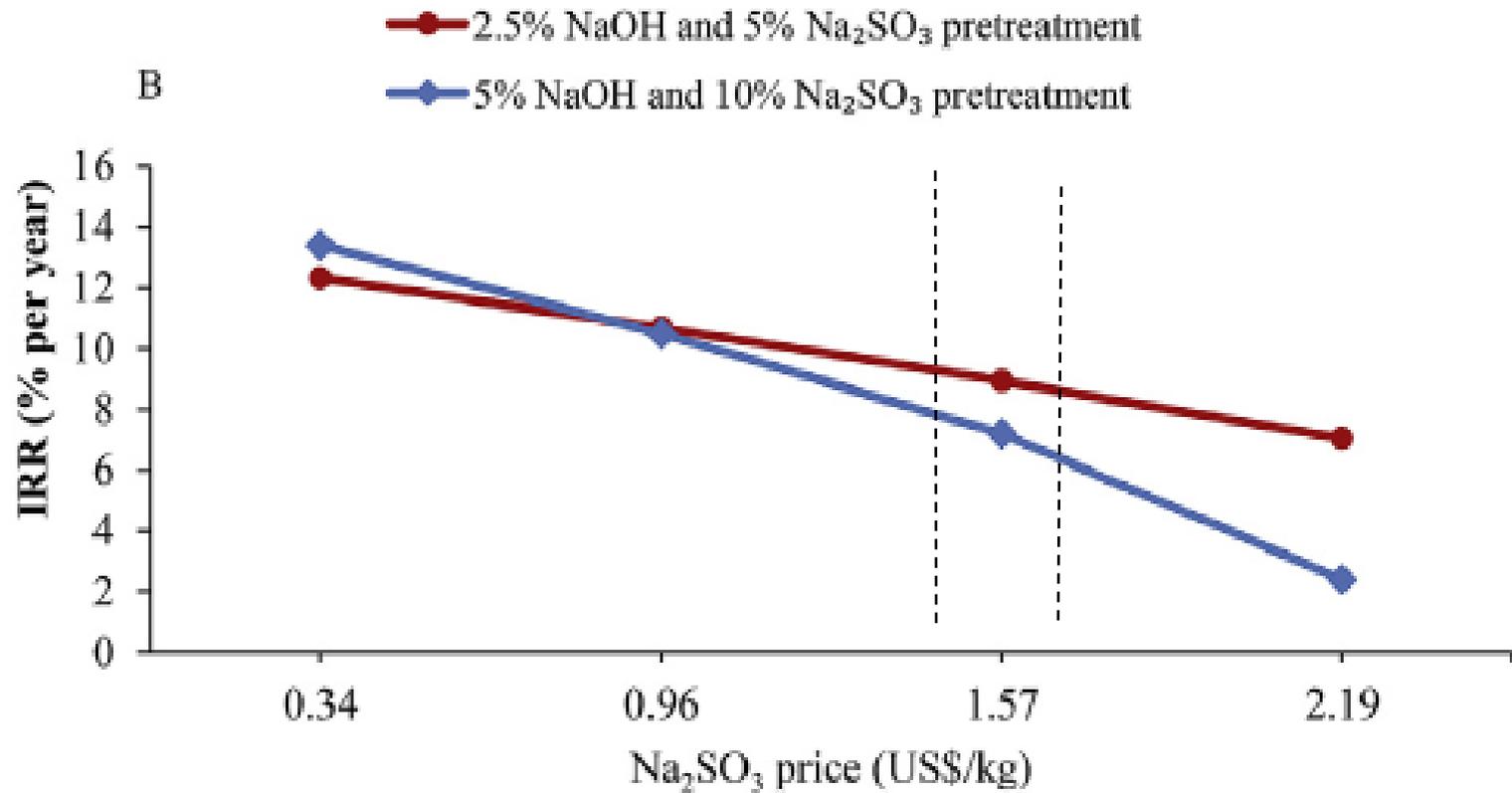


Integrated 1G-2G (for sugar and ethanol production)



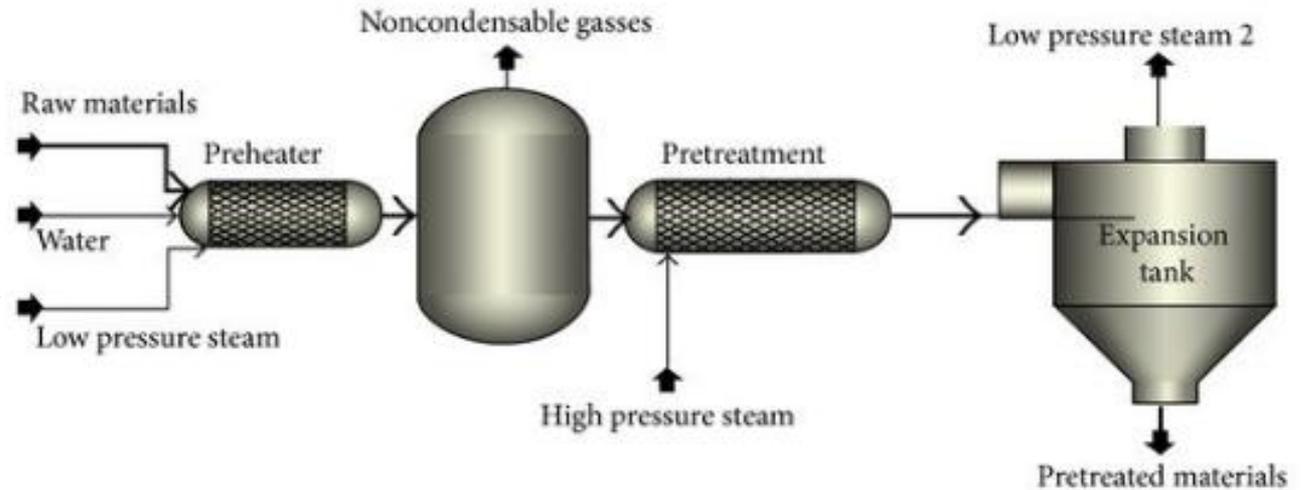
Integrated 1G-2G

(for sugar and ethanol production): Technology is dependent on the pretreatment cost (CTMP pretreatment)



Pré-tratamento em meio ácido, autohidrólise, ou explosão a vapor

- O objetivo básico nesses sistemas é **remover a hemicelulose seletivamente** a partir de um processo de hidrólise “branda”. O licor gerado contém os monômeros ou oligômeros oriundos da hemicelulose. O resíduo sólido, contendo celulose e lignina, pode ser fracionado por deslignificação alcalina.

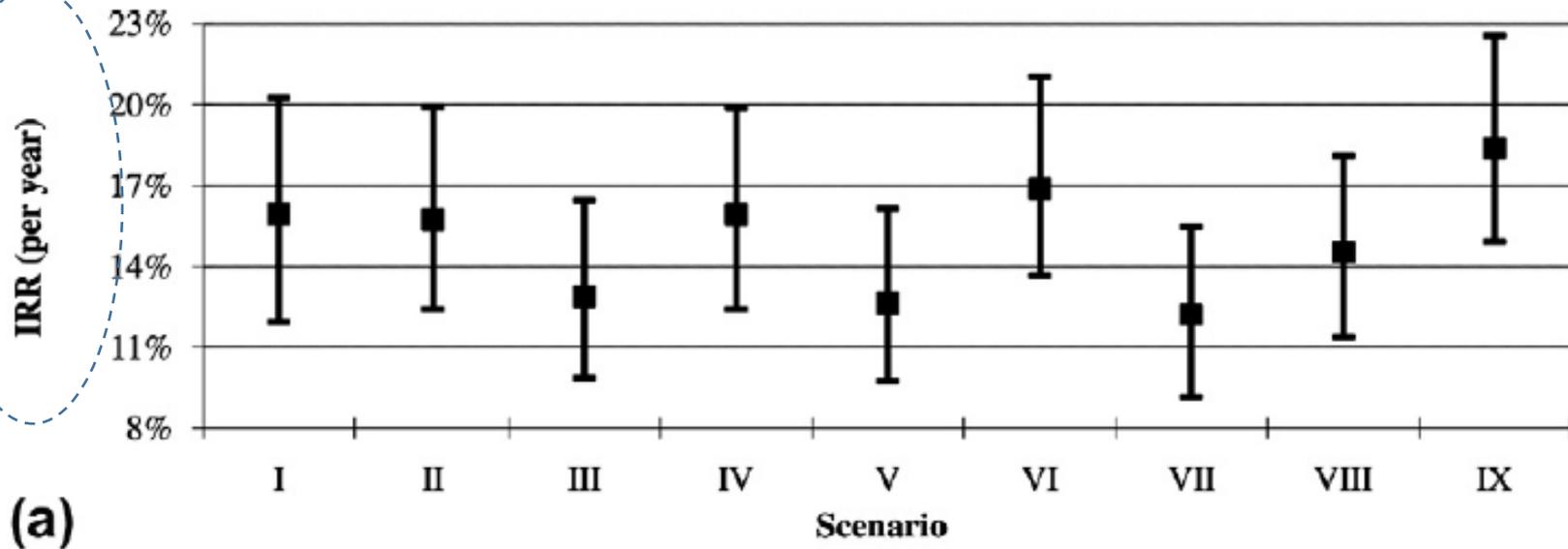


Fração aquosa: Rica em açúcares C5, provenientes da hemicelulose

Fração sólida: Praticamente toda a celulose e lignina, porém com digestibilidade à enzimas aumentada

Integrated 1G-2G

(for sugar and ethanol production): Technology is dependent on the pretreatment cost (Steam explosion pretreatment)



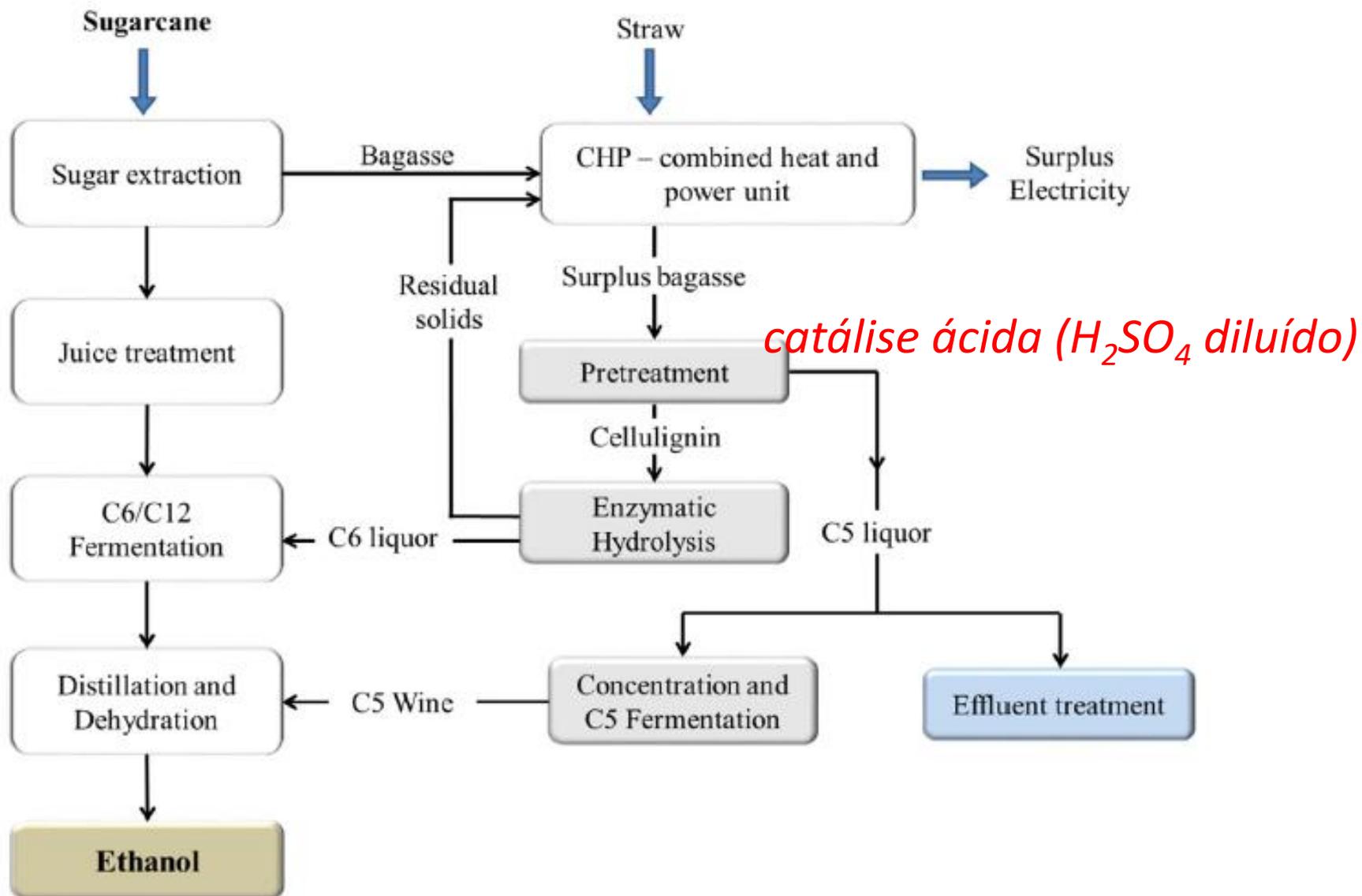


Table 2

Conditions considered for each evaluated scenario.

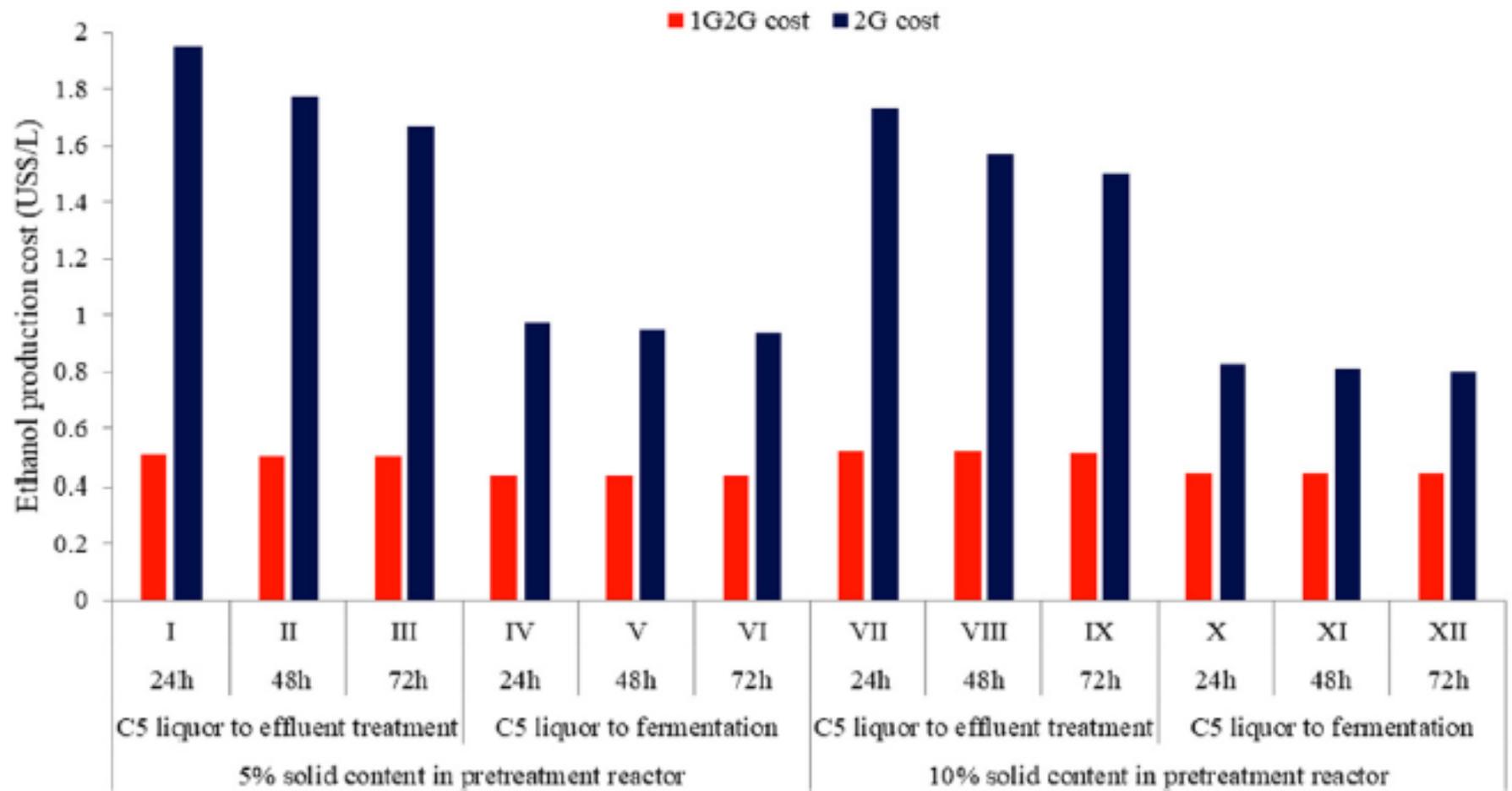
Scenario	Conditions		
	Solids content in the pretreatment reactor	Enzymatic hydrolysis incubation time	C5 Liquor destination
I	5%	24 h	Effluent treatment
II		48 h	
III		72 h	
IV	5%	24 h	Fermentation
V		48 h	
VI		72 h	
VII	10%	24 h	Effluent treatment
VIII		48 h	
IX		72 h	
X	10%	24 h	Fermentation
XI		48 h	
XII		72 h	

Table 5
Mass and energy balance for each simulated scenario.

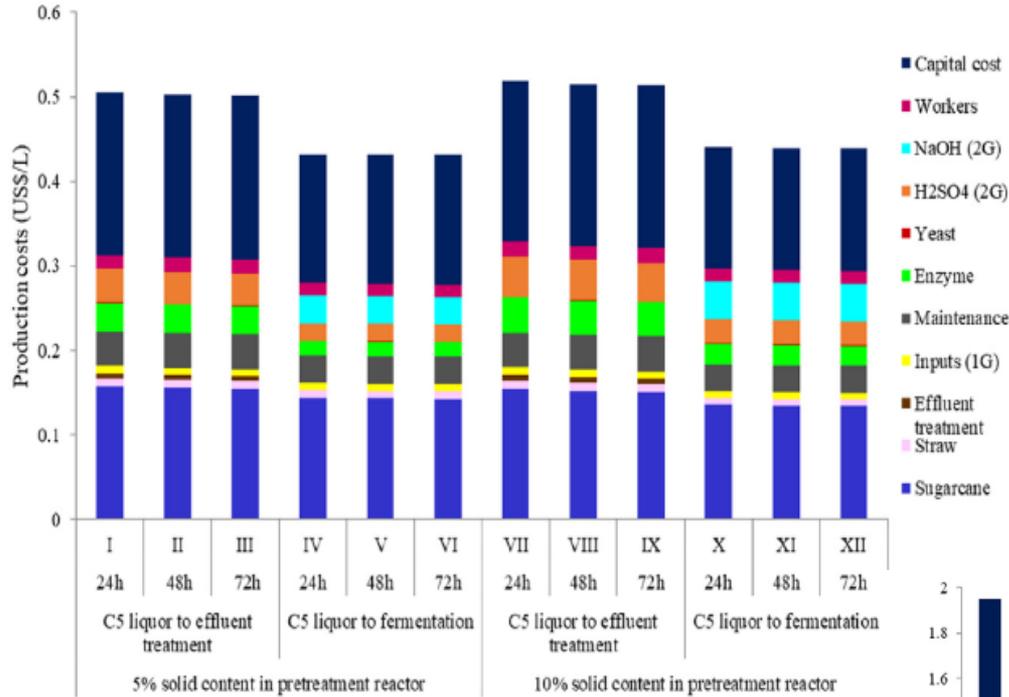
Scenarios	Conditions			Fraction of burnt bagasse (%)	Steam (kg/TC ^a)	Anhydrous Ethanol (L/TC ^a)	Anhydrous Ethanol (L/ha ^b)	Surplus electricity (kWh/TC ^a)	Surplus electricity (kWh/ha ^b)
	Solids content in the pretreatment reactor	Enzymatic hydrolysis incubation time	C5 Liquor destination						
I	5%	24 h	effluent	33.0	830.1	97.0	9816.4	100.3	10150.4
II		48 h	treatment	33.6	822.5	98.4	9958.1	99.1	10028.9
III		72 h		34.1	818.3	99.3	10049.2	98.4	9958.1
IV	5%	24 h	fermentation	62.0	953.6	103.6	10484.3	130.2	13176.2
V		48 h		62.2	949.6	104.3	10555.2	129.5	13105.4
VI		72 h		62.6	946.9	104.7	10595.7	129.1	13064.9
VII	10%	24 h	effluent treatment	15.1	754.4	100.1	10130.2	89.1	9016.9
VIII		48 h		16.5	748.2	101.8	10302.1	88.2	8925.8
IX		72 h		17.5	744.5	102.8	10403.4	87.6	8865.1
X	10%	24 h	fermentation	42.9	872.8	112.7	11405.3	115.2	11658.2
XI		48 h		43.8	868.1	113.6	11496.3	114.5	11587.4
XII		72 h		43.8	862.9	114.5	11587.4	113.6	11496.3

^a TC = Metric tons of sugarcane stalks.

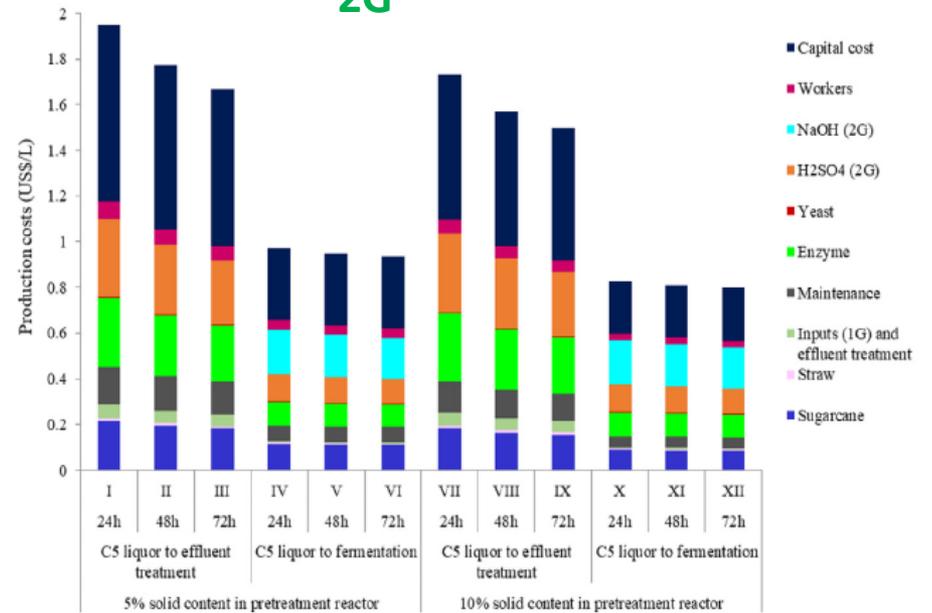
^b ha = hectare.



1G2G integradas



2G



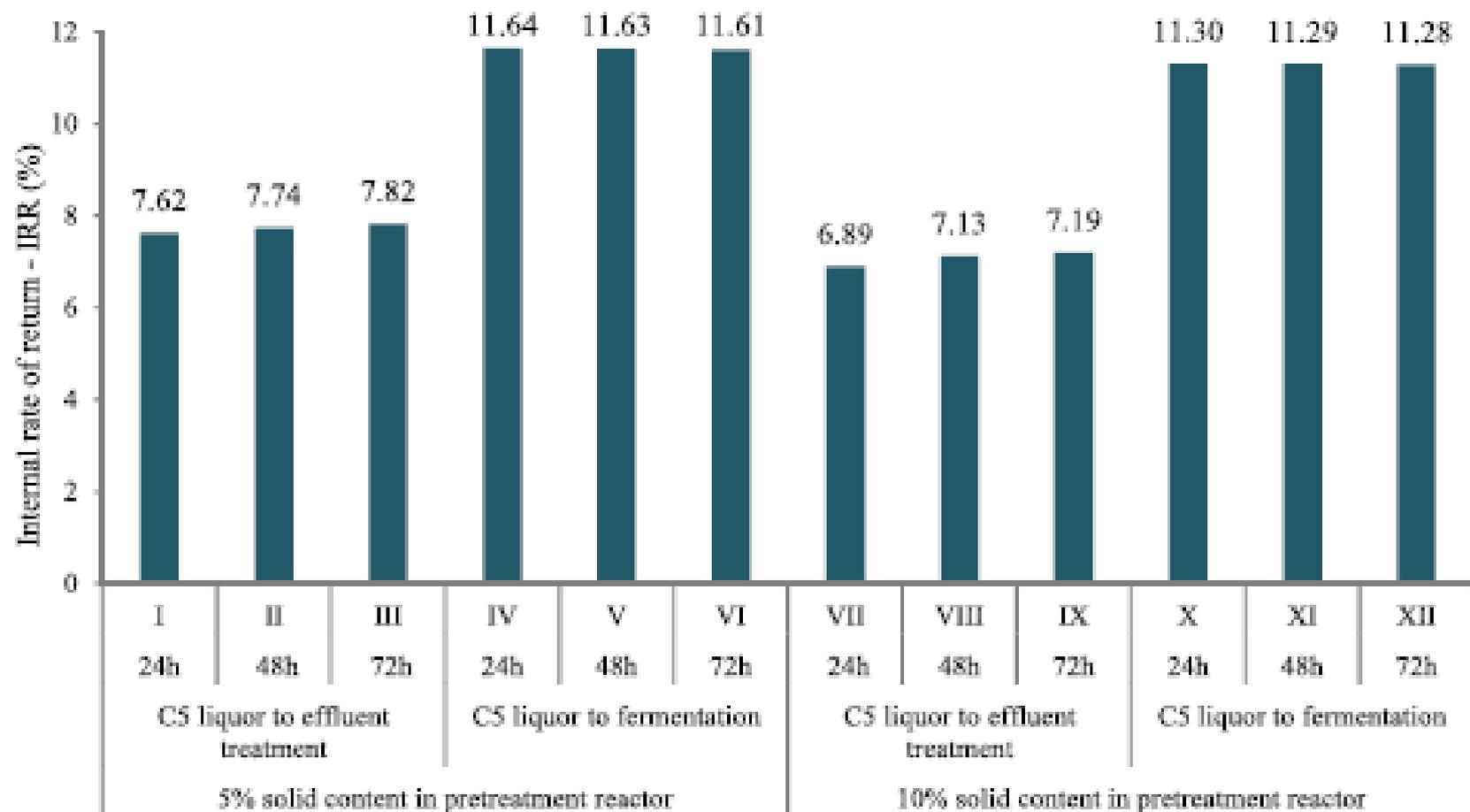
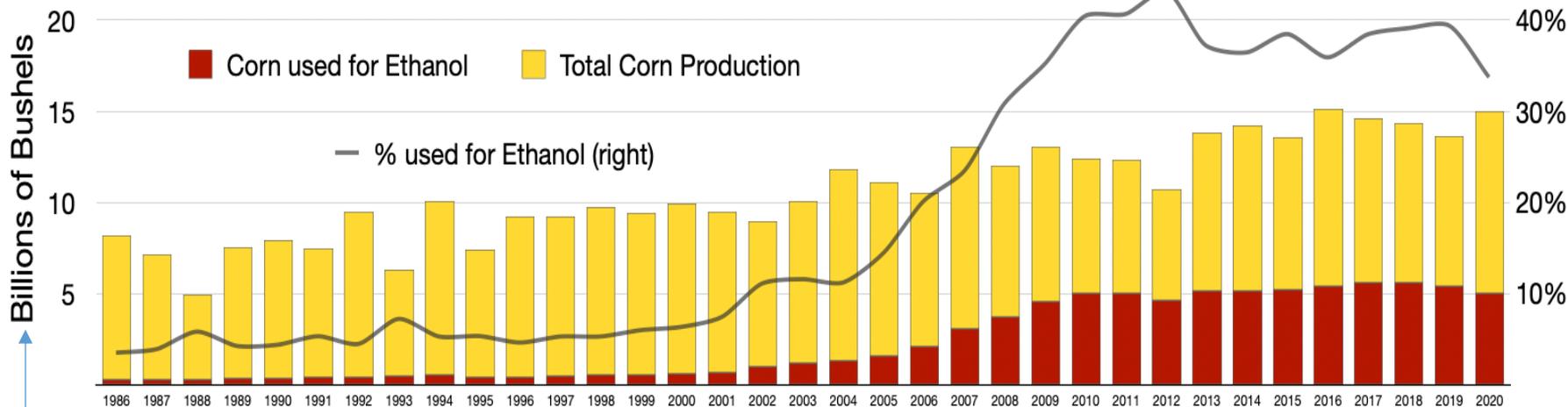


Fig. 4. Internal rate of return (IRR) for each 1G2G integrated scenario. 24, 48, and 72 h are the incubation times of enzymatic hydrolysis.

Etanol do milho (1Gmilho)

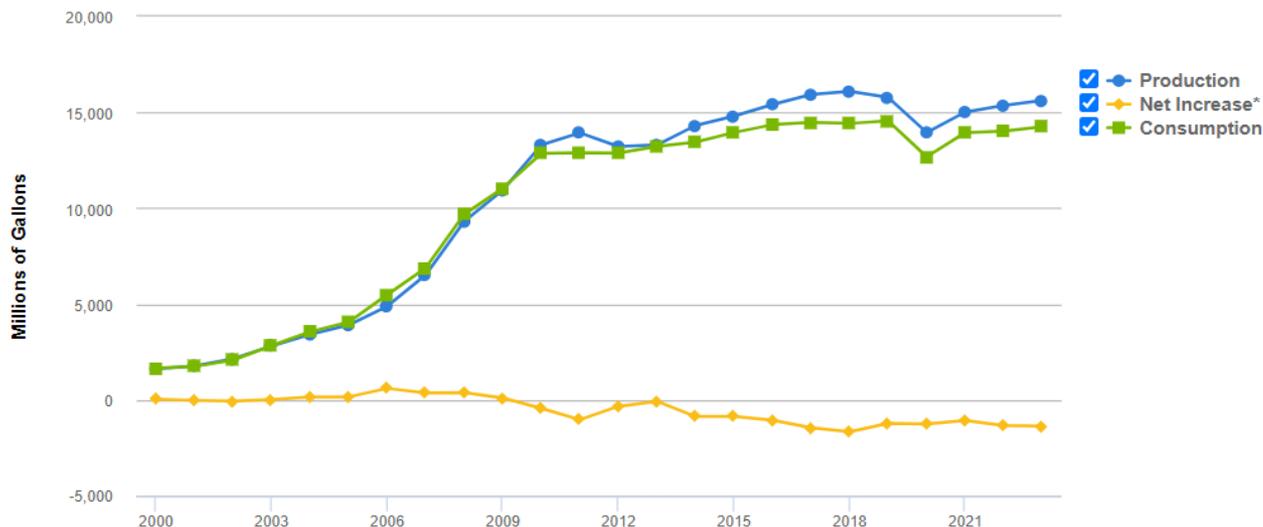
U.S. Corn Production and Portion Used for Fuel Ethanol



x 35.2 = Litros

U.S. Production, Consumption, and Trade of Ethanol

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Last updated: April 2024
Printed on: June 6

Source: U.S. Energy Information Administration (EIA) [Monthly Energy Review](#), Table 10.3

Notes: *Net increase through imports and stock change

Diagrama de processo >> moagem a seco é o mais disseminado

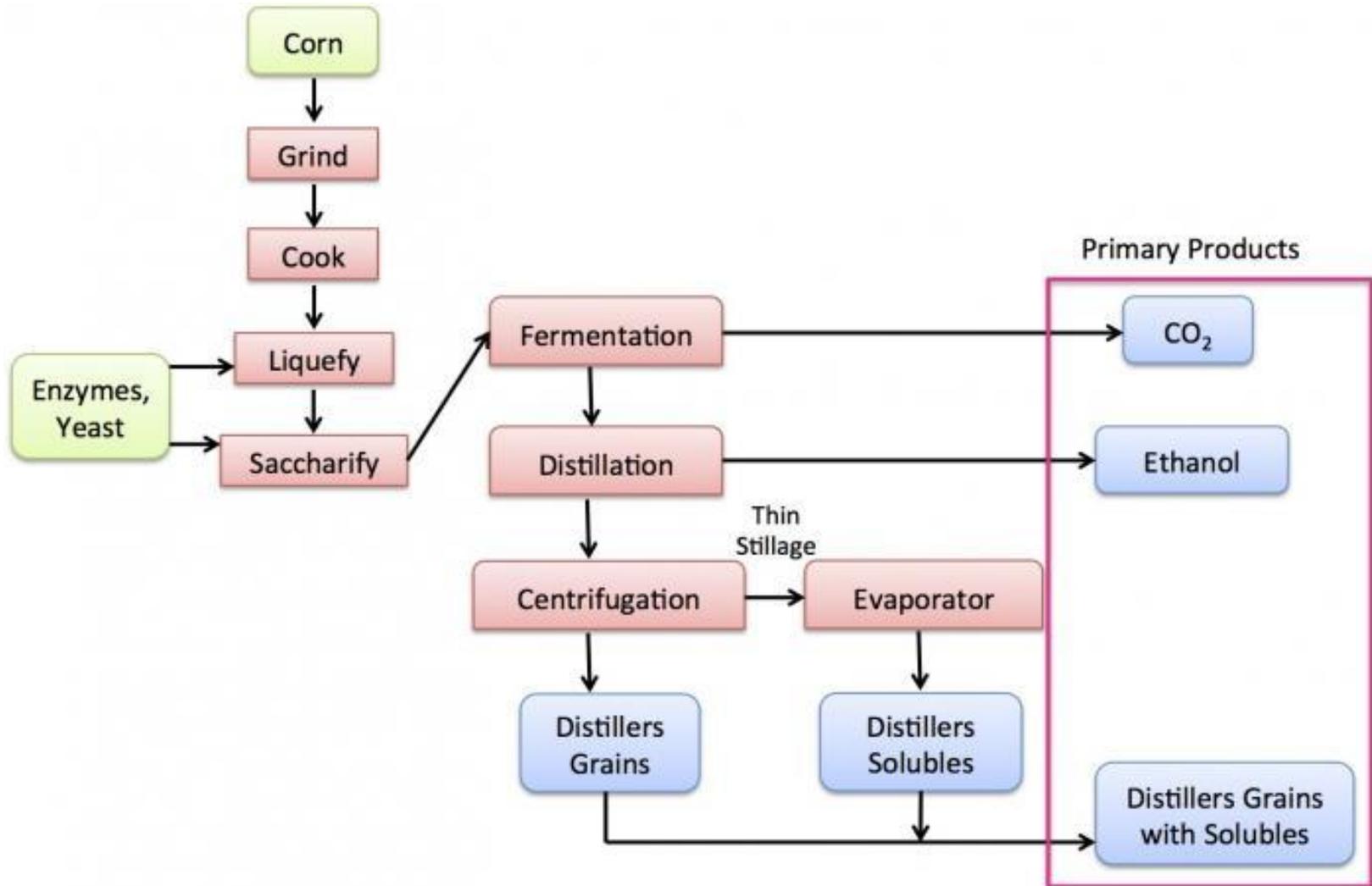
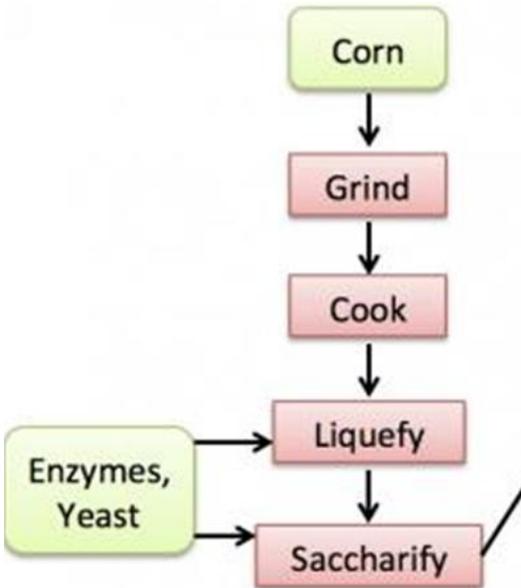


Table 1. *Composition of Corn*

Component	Percent (average) Dry Matter
Carbohydrates (total)	84.1%
<i>Starch</i>	<i>72.0%</i>
<i>Fiber (NDF)</i>	<i>9.5%</i>
<i>Simple Sugars</i>	<i>2.6%</i>
Protein	9.5%
Oil	4.3%
Minerals	1.4%
Other	0.7%

Requer hidrólise do amido até glicose por via enzimática

Different enzymes used in starch depolymerization. (Credit: MF Chaplin and C. Bucke, *Enzyme Technology*, Cambridge University Press, 1990)



Enzyme	Source	Action
α-Amylase	<i>Bacillus amyloliquefaciens</i>	Only α-1,4-oligosaccharide links are cleaved to give α-dextrins and predominantly maltose (G2), G3, G6, and G7 oligosaccharides
	<i>B. licheniformis</i>	Only α-1,4-oligosaccharide links are cleaved to give α-dextrins and predominantly maltose, G3, G4, and G5 oligosaccharides
	<i>Aspergillus oryzae</i> , <i>A. niger</i>	Only α-1,4 oligosaccharide links are cleaved to give α-dextrins and predominantly maltose and G3 oligosaccharides
Saccharifying α-amylase	<i>B. subtilis (amylosacchariticus)</i>	Only α-1,4-oligosaccharide links are cleaved to give α-dextrins with maltose, G3, G4 and up to 50% (w/w) glucose
β-Amylase	Malted barley	Only α-1,4-links are cleaved, from non-reducing ends, to give limit dextrins and b-maltose
Glucoamylase	<i>A. niger</i>	α-1,4 and α-1,6-links are cleaved, from the nonreducing ends, to give β-glucose
Pullulanase	<i>B. acidopullulyticus</i>	Only α-1,6-links are cleaved to give straight-chain maltodextrins

Biorefinarias - Rotas bioquímicas para uso de biomassa lignocelulósica (*processos atuais em escala industrial*)

