Aalto University
School of Chemical
Engineering

CHEM-E1150
BIOMASS PRETREATMENT AND FRACTIONATION
Theme 1: Kraft pulping, Module 1
Raw Materials, Mechanical pretreatment

Herbert Sixta, 2019

Outline Theme 1

Module 1: Raw materials and mechanical pretreatment

Module 2: Prehydrolysis

Module 3: Kraft cooking

Module 4. Screening, washing, bleaching and drying

Module 5: Pulp properties and uses

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Module 1

1. Why pretreatment?
2. Lignocellulosic raw materials
3. Wood chipping

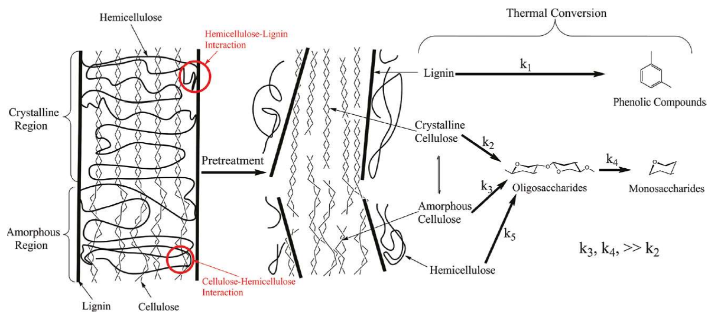
Pretreatment vs Fractionation?

- **Pretreatment** focuses on the creation to **access** carbohydrates
- **Fractionation** focuses on the **separation** of lignocellulosic components

Why pretreatment?

- **Hydrophobic lignin** forms a physical barrier
- **Recalcitrance of cellulose** owing to its crystalline structure
- **Hemicelluloses** form **sheets around fibrils**
- Low surface area and small capillaries inaccessible to enzymes

Schematics of Pretreatment



- Prerequisite for **chemical** or **enzymatic** treatments of biomass.
- **Size reduction prior to** thermochemical processes

Zhang, Xiaolei et al. Energy&Fuels, **2011**, 25, 4786-4795

Pretreatment Requirements

- High recovery of all carbohydrates
- High cellulose digestibility in subsequent enzymatic hydrolysis
- No or little sugar and lignin degradation products
- High sugar concentration in solution
- Low energy demand
- Low capital and operational costs

Galbe and Zacchi, Adv. Biochem Eng/Biotechnol (2007), 108, 41-65

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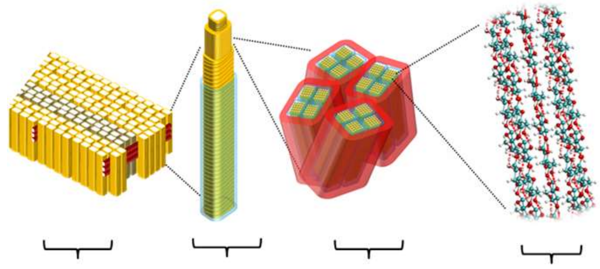
Hierarchical Structure of Lignocellulose



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Lasse Tolonen: PhD thesis 2016

Recalcitrance of lignocellulose

- Hydrophobic lignin forms a physical barrier
- **Recalcitrance of cellulose** owing to its crystalline structure
- **Hemicelluloses** form sheets around fibrils
- Low surface area and small capillaries inaccessible to enzymes:
  - Cellulase diameter ~5.1 nm (Arantes and Saddler, Biotechnol. Biofuels, 2011, 4:3, 1-16)
  - Lamellar space between spruce microfibrils aggregates: ~10 nm (Fahlen and Salmen, Holzforschung, 2005, 59, 589-597)

Adriaan van Heiningen, lecture notes autumn 2009

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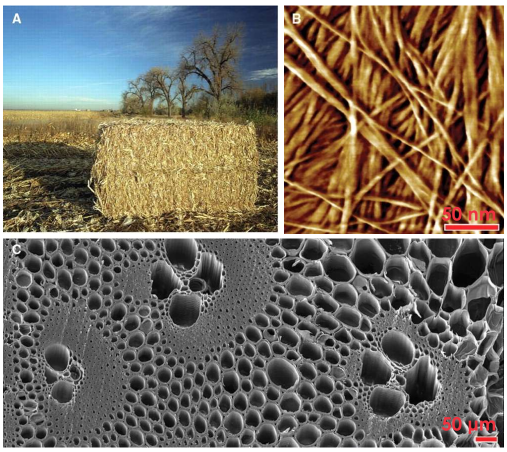
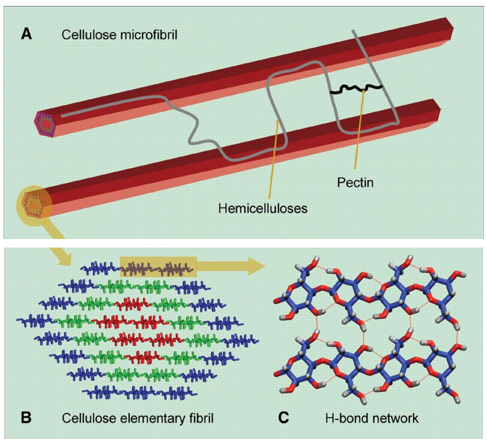
Plant cell wall

Fiber level



Molecular level



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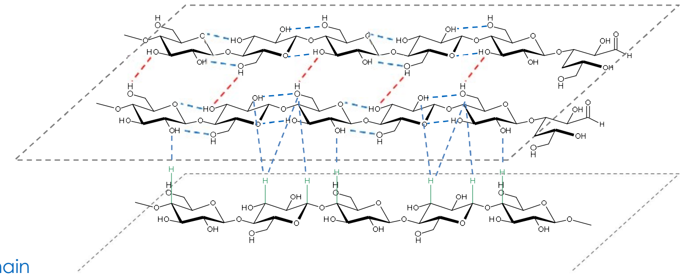
Science, 2007: Vol. 315, Issue 5813, pp. 804-807. DOI: 10.1126/science.1137016

Supramolecular structure of Cellulose



O3-H-O5 intrachain
O2-H-O6 intrachain
O6-H-O3 interchain

intersheet H-bond

- aliphatic H atoms occupy the axial,
- all OH groups the equatorial position.
- Each glucose unit can interact with 14 other nearby residues.

H. Sixta, M. Hummel, EPNOE, 2011

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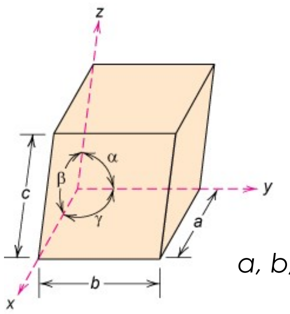
Crystal Systems

Unit cell: smallest repetitive volume which contains the complete lattice pattern of a crystal.



7 crystal systems

14 crystal lattices

a, *b*, and *c* are the lattice constants

Fig. 3.4, *Callister & Rethwisch 8e.*

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Crystallographic Planes

- **Miller Indices:** Reciprocals of the (three) axial intercepts for a plane, cleared of fractions & common multiples. All parallel planes have same Miller indices.

- **Algorithm**
  1. Read off intercepts of plane with axes in terms of *a*, *b*, *c*
  2. Take reciprocals of intercepts
  3. Reduce to smallest integer values
  4. Enclose in parentheses, no commas i.e. (*hkl*)

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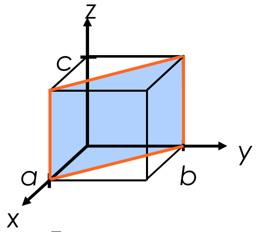
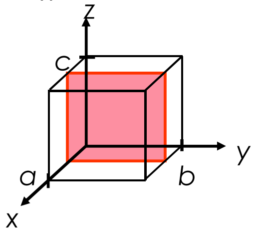
Crystallographic Planes

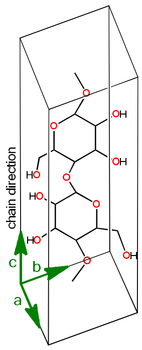
example		*a*	*b*	*c*
1.	Intercepts	1	1	∞
2.	Reciprocals	1/1	1/1	1/∞
		1	1	0
3.	Reduction	1	1	0
4.	Miller Indices	(110)		



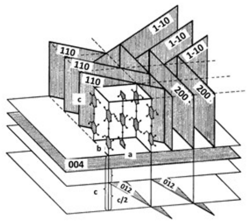
example		*a*	*b*	*c*
1.	Intercepts	1/2	∞	∞
2.	Reciprocals	1/½	1/∞	1/∞
		2	0	0
3.	Reduction	2	0	0
4.	Miller Indices	(200)		



Unit Cell - Coordinate System



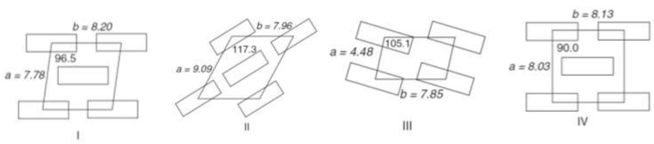
- **Simplest repeating unit in a crystal**, charcterized by
- Vectors: a, b and c form the edges of a parallelepiped
- Angles: a (b/c), β (a/c), **ɣ (a/b)**
- **Convention:**
  c cellulose chain axis;
  b forms the plane with c;
  a forms the distance between the sheets
- **Monoclinic: a≠b≠c, a=β=90° ≠ɣ**
- **Triclinic: a≠b≠c, a≠β≠ɣ**



Temming Linters (1973), p 161 revised
Cellulose (2013), 20: 20703-2718. DOI 10.1007/s10570-013-0071-8

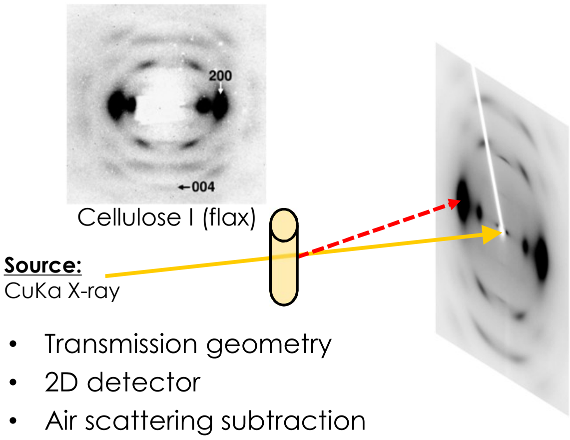
Cellulose polymorphs

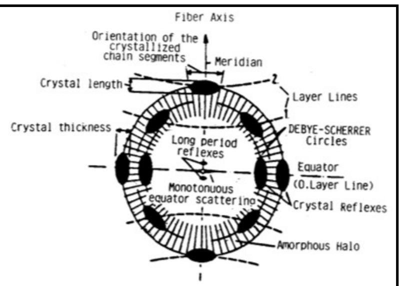
Poly-morph	Space group	Chains / unit cell	Chain direction	a [Å]	b [Å]	c [Å]	a [°]	β [°]	ɣ [°]
Ia	triclinic, P1	1	parallel	6.72	5.96	10.40	118.1	114.8	80.4
Iβ	**Monoclinic, 2P1**	**2**	**parallel**	**7.78**	**8.20**	**10.38**	**90.0**	**90.0**	**96.5**
II	**Monoclinic, 2P1**	**2**	**antiparallel**	**8.10**	**9.08**	**10.36**	**90.0**	**90.0**	**117.3**
III_I	Monoclinic, 2P1	1	parallel	4.48	7.85	10.31	90.0	90.0	105.1
IV_I	Triclinic, P1	2	parallel	8.03	8.13	10.4	90.0	90.0	90.0

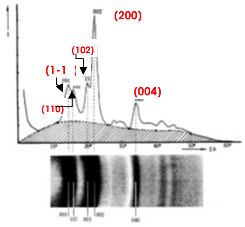


Seong H. Kim et al. *Korean J.Chem.Eng*. (2013), 30(12), 2127-2141
Nishiyama, Y., et al., J. Am. Chem. Soc., 2003. **125** p. 14300-14306.
Nishiyama, Y., P. Langan, and H. Chanzy, J. Am. Chem. Soc., 2002. **124** p. 9074-9082.
Kobayashi, K., et al., Carbohydr. Polym., 2011. **86** (p. 975-981
Bellesia, G., et al., J. Phys. Chem. B, 2012. **116** p. 8031-8037

Wide angle X-ray diffraction (WAXS)





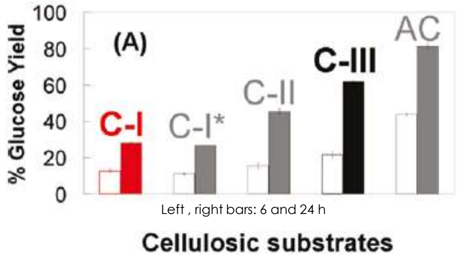


- Transmission geometry
- 2D detector
- Air scattering subtraction

Sawada Daisuke

Cotton linters, Temming, p160

Effect of supramolecular structure on enzymatic hydrolysis?



AC > C-III > C-II > C-I

C-I native cellulose Iβ
C-II mercerized cellulose
C-III liquid ammonia treated
AC treated in concentrated phosphoric acid: amorphous cellulose

Chundawat, Shishir P. S. et al. *JACS*, **2011**, 133, 11163–11174

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Module 1

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3. Wood chipping

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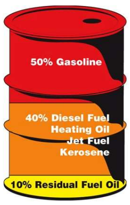
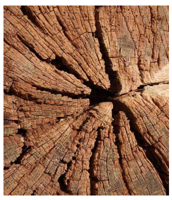
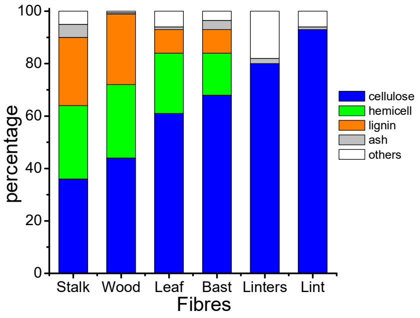
Elemental Composition of Feedstock

	Crude oil	Oil / Fat	Lignocellulose
C	85-90%	76 %	50 %
H	10-14%	13 %	6 %
O	0-1,5%	11 %	43 %



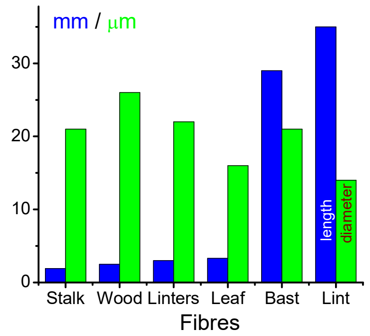


Lignocellulosic Substrates



Stalk fibers: cereal straw, bamboo, sugar cane bagasse
Bast fibres: flax, hemp, jute, kenaf
Leaf fibres: abaca, sisal
Seed and fruit fibres: cotton lint, cotton linters
Wood fibres: soft-, hardwood

Lignocellulosic Substrates



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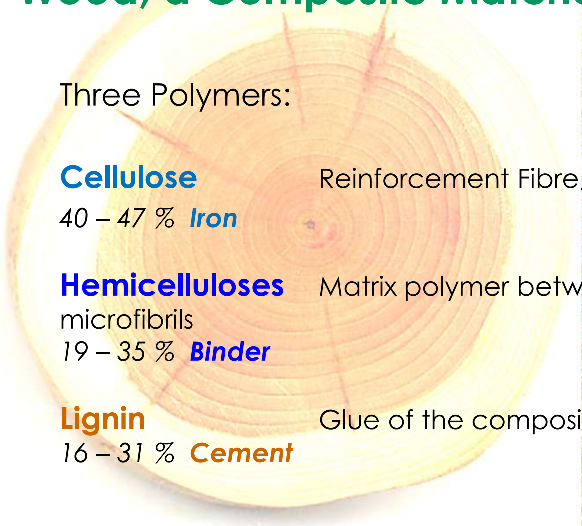
Wood, a Composite Material



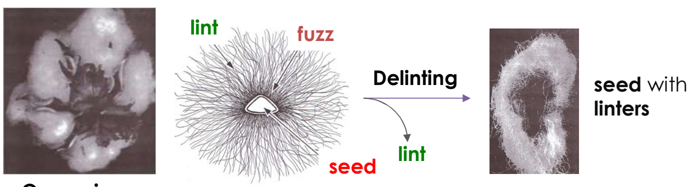
Three Polymers:

Cellulose — Reinforcement Fibre, Microfibrils
40 – 47 % ***Iron***

Hemicelluloses — Matrix polymer between microfibrils
19 – 35 % ***Binder***

Lignin — Glue of the composite
16 – 31 % ***Cement***

Cotton Linters (seed fibers)



Open, ripe cotton ball
*Gossypium**

Cotton hair with lint and fuzz

seed with **fuzz**

Temming Linters, 1973

Bast fibers

Flax

Hemp

Jute

Temming Linters, 1973

Stalk fibers

Bamboo fibers

Leaf Fibers

Sisal

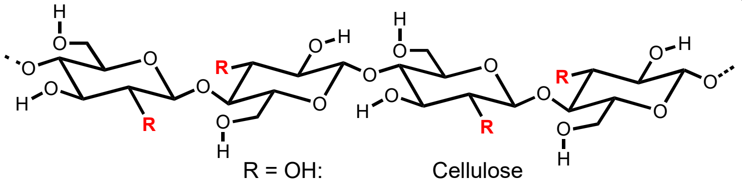
Abaca

Other polysaccharides

- Chitin / Chitosan
- Starch
- Pullulan
- Xanthan
- Dextrins, cyclodextrins
- Alginate

Chitin, Chitosan

- Derived from shells of prawns and crabs
- **Chemistry:**
  - white to light-red solid powder, insoluble in water, soluble in organic acid



R = OH: Cellulose
R = $NHCOCH_3$: Chitin
R = NH_2: Chitosan

http://www.ensymm.com/pdf/pharmaceutical/ensymm_chitosan_production_abstract.pdf

Products derived of Chitosan

- **Products:**
  - Cosmetic products: shampoos, moisturizer for the skin
  - Additives to textile, pharmaceutical ingredients,
  - Antibacterial, anti-fungal and anti-viral: wound dressing
  - Food additive: dietary cookies, potato chips
- **Price:**
  - 20 – 1000 US$/kg

http://www.ensymm.com/pdf/pharmaceutical/ensymm_chitosan_production_abstract.pdf

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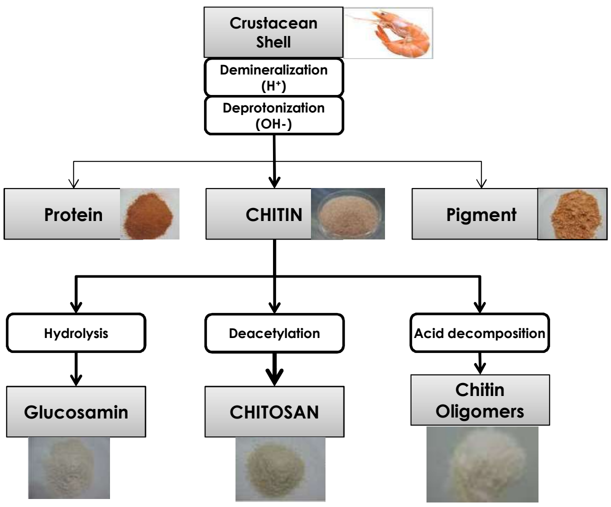
Chitin, Chitosan Production



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Starch

– In cereal grains, potatoes, legumes (beans): amylose (linear) and amylopectin (banched).

– **1812**: First starch sugar plant in Weimar, Germany

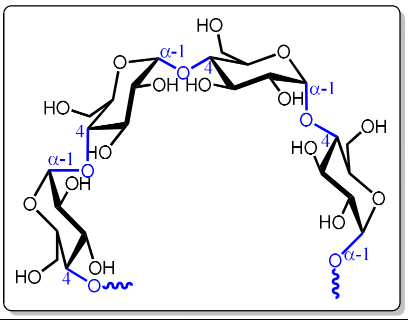
– **1835**: **J.J. Berzelius**, Sweden, introduced enzymatic hydrolysis of starch into sugar and introduced the term „catalysis".

– Consumption in Europe (2007):
– 5.6 Mio t for food;
– 3.7 Mio t for non-food (**pape**r),
– 1.9 Mio t for fuel ethanol.

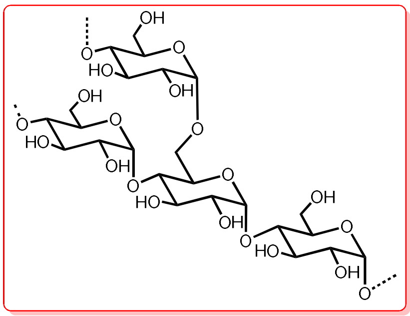
Starch

Endproduct of photosynthesis in plant; available in wheat, rice, corn and potato.

Amyloses (20-30%) : helical polymer made of a-D-glucose units, bound to each other through a(1→4) glycosidic bonds



Amylopectin (70-80%): branching with a(1→6) every 24 to 30 units; linear segments as double helix



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Thermoplastic starch (TPS)

- Native starch is not thermoplastic
- The H-bond interaction between starch molecules have to be reduced to melt-process native starch.
- TPS formed through the de-structuring of native starch granules by heating at relatively high temperatures, in high shear conditions, and with limited amounts of water→individual chains move freely.

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Thermoplastic starch (TPS)

- **High amount of amylose preferred**, however
- Problem of retrogradation, a natural crystallization over time, leading to increased brittleness. Tendency of macro-molecules to form H-bonds during the expulsion of water.
- Can be avoided by the addition of plasticizer (water, glycerol,..)

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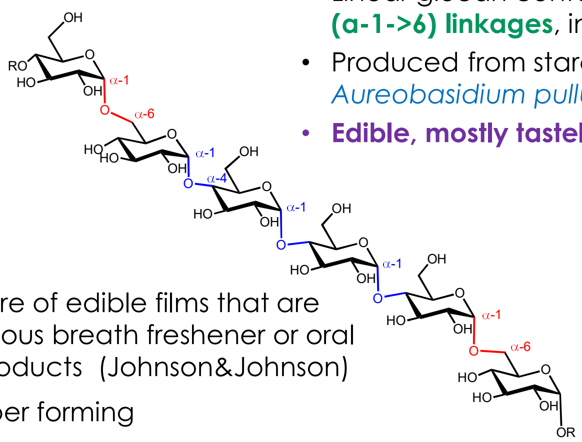
Pullulan

- Linear glucan containing **α-(1->4)** and **(α-1->6) linkages**, in 2:1 ratio
- Produced from starch by the fungus *Aureobasidium pullulans.*
- **Edible, mostly tasteless polymer**.



- Manufacture of edible films that are used in various breath freshener or oral hygiene products (Johnson&Johnson)
- Film and fiber forming

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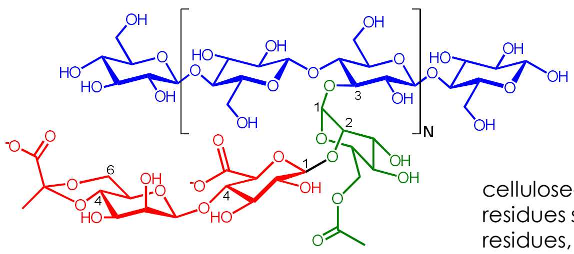
Xanthan

– Microbial desiccation-resistant polymer, **>30,000 tons per year** by aerobic submerged fermentation from *Xanthomonas campestris* (E415)

– **In food** (gluten-free baking, emulsifier, ice cream), drilling mud; concrete additive



cellulose-like backbone of (1,4)-linked β-D-Glcp residues substituted at O-3 of alternate glucose residues, with a trisaccharide side chain:

α-(1→3)-glycosidic: β-D-mannopyranosyl-(1→4)-β-D-glucuronopyranosyl-(1→2)-6-O-acetyl-α-D-manno-pyranosyl- side chain

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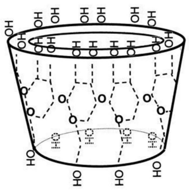
Cyclodextrine

Cyclic Oligosaccharides

Available from starch using cyclodextrin glucotransferase (CGTases), amylolytic enzymes produced by *Bacillus macerans*

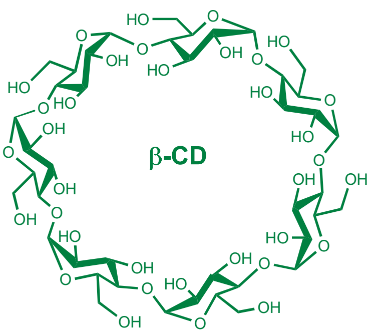
The most common and commercially available cyclodextrins consist of **six**, **seven** and eight glucose units, **α**-, **β**- und **γ**-cyclodextrines.

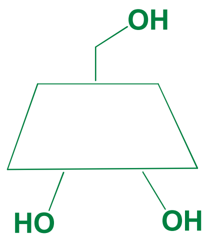


Cyclodextrine

Conical molecules, with well defined cavities, **hydrophilic exteriors**, and more **hydrophobic interiors.**

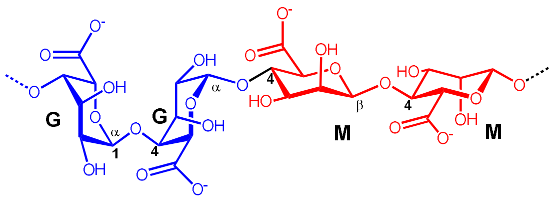
Hydrophobic compounds entrapped in the cavities→**drug delivery system**





Alginate

- Alginic acid is a linear copolymer with blocks of (1-4)-linked **β-D-mannuronate (M)** and its C-5 epimer **a-L-guluronate (G)** residues.



- In cell walls of brown algae (**seaweed**).
- Binding of water → viscous gum. In extracted form it absorbs water quickly up to 200–300 times its weight. Thickening drinks and food

Module 1

1. **Why pretreatment?**
2. **Lignocellulosic raw materials**
3. **Wood chipping**

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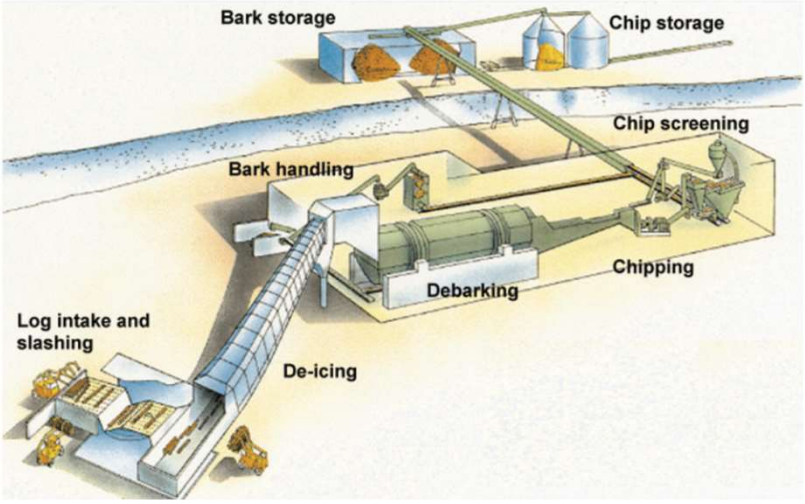
School of Chemical Engineering

Chip Preparation

1. **Wood yard**
2. Wood intake
3. Debarking
4. Chipping
5. Chip screening
6. Chip storage

Wood yard



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Wood handling

Metso, 2003

Log Storage

PhD Thesis, A. Promberger, 2004

Fungal Infestation

(1) Heart Rot: Infestation along the Roots

5 cm distance

100 cm distance

(2) Heart Rot: Formation during Storage

Deterioration zones along the rays

PhD Thesis, A. Promberger, 2004

Dominating Fungi

(1) *Schizophyllum commune*

(2) *Chondrostereum pupureum*

PhD Thesis, A. Promberger, 2004

Objective, Experimental

Storage of Beech Logs

FRESH

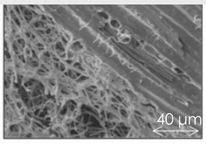
WET - 15 months

Wet, submersed in water

Dry in air

DRY- 15 months

FUNGI

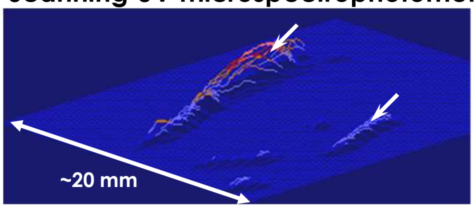


Infected with fungi

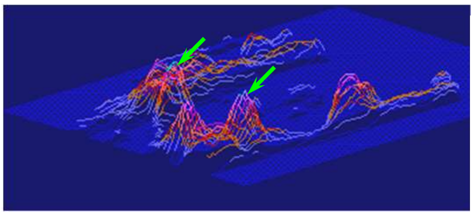
PhD Thesis, A. Promberger, 2004

Topochemical Characterization of Unbleached Sulfite Pulp

Scanning UV microspectrophotometry at λ_{278nm}



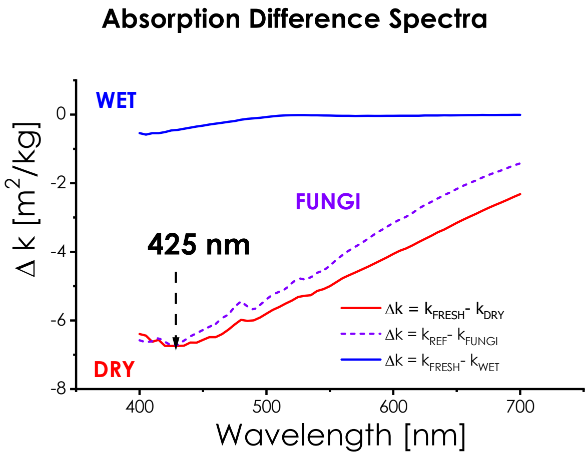
WET
Fragments of a Middle Lamella.



DRY
Polyphenolic compounds, attached to the cell wall and deposited in the lumina of parenchyma cells.

PhD Thesis, A. Promberger, 2004

Chromophores in Unbleached Pulps



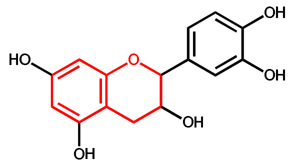
A. Promberger, PhD Thesis, 2004

Chromophores in Unbleached Pulps

Pulps from **DRY** and **INFECTED** confirm the presence of strongly absorbing chromophores.

Minimum at 425 nm and pronounced tailing towards longer wavelengths indicates occurence of highly conjugated compounds **(*e.g.* polyphenolic structures*).**

WET almost comparable to **FRESH**



Catechin

A. Promberger, PhD Thesis, 2004

Chip Preparation

1. Wood yard
2. **Wood intake**
3. Debarking
4. Chipping
5. Chip screening
6. Chip storage

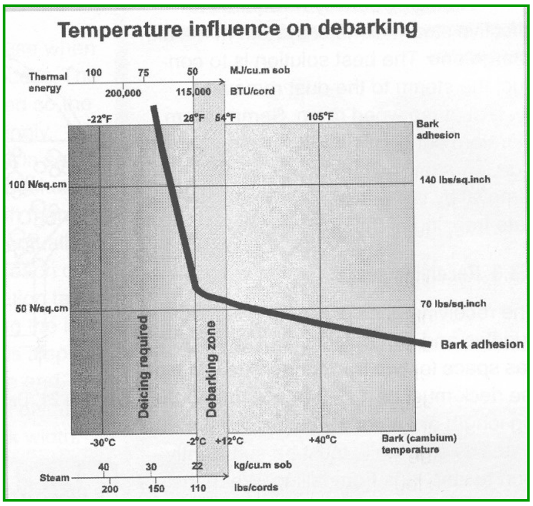
Wood Intake

- Logs are transported from the forest by truck, train, ship,..
- The length of the logs varies between 3 - 5 m
- Part of wood supply maybe saw mill chips
- Logs are stored in the woodyard, or, in certain cases also in the forest.

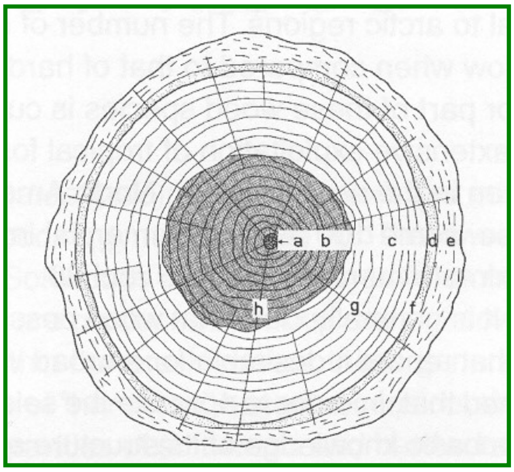
De-icing

- Necessary to ensure debarking
- Sufficient to de-ice the surface
- Usually de-icing with hot water:
  - **50 – 100 MJ/m^3 softwood**
  - **80 – 140 MJ/m^3 birch**

De-icing



Cross section of wood stem



a) Pith
b) Heart wood
c) Sap wood
d) Inner Bark (Phloem)
e) Outer Bark
f) Cambium
g) Secundary rays
h) Primary rays

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Chip Preparation

1. Wood yard
2. Wood intake
3. **Debarking**
4. Chipping
5. Chip screening
6. Chip storage

Debarking

- Efficient removal of bark since its **fiber yield is only 20%**
- **Shear forces** primarily act on the **radial layers** of the **cambial cells**.
- Depending on the species, moisture content, age, location, temperature, etc. the **bond strength** of the bark ~ **20 and 500 N/cm^2**.
- Production of **chips with uniform dimensions** regarding length, width and thickness.

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Debarking efficiency

Bark thickness, bark structure affect the ease of debarking.

However, not the species, but the season has the most prominent influence on debarking efficiency.

Adhesion N/cm2	**Debarking Efficiency**	**Wood Species**
30	very easy	**Southern Pine, maple**
50	easy	hemlock, spruce, beech
90	difficult	elm, birch
130	very difficult	poplar
>200	almost impossible	**Hickory, limewood**

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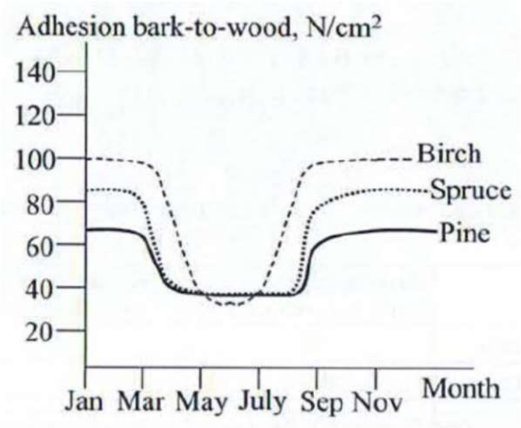
Effect of Cutting Season on Debarking



E. Brännvall, *Pulping Chemistry and technology*, Vol 2, p. 16

Factors affecting debarking degree

- Wood species and density
- Wood temperature
- Log length and diameter
- Drum filling degree
- Drum rotation speed
- Drum diameter and length

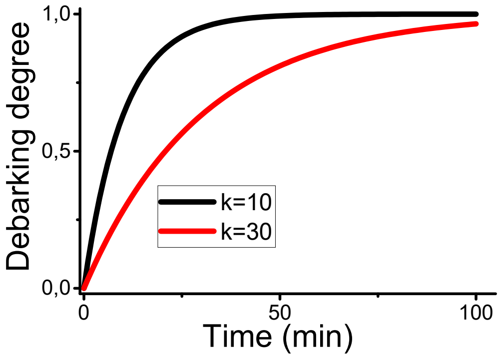
Debarking Methods

- **Drum Debarker**
- Rotary or Cradle Debarker
- Ring Debarker

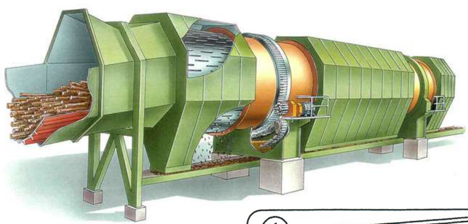
Drum Debarking Parameters

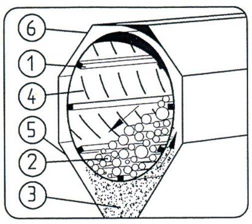
- Rotation speed almost linearly affects its efficiency.
- 4 – 7 rpm at 5.5 m of diameter
- Degree of barking proportional to $(1 - Exp(-t/k))$ with
  t = retention time, k =f(rpm, filling degree, etc.)
- **Wood loss linearly dependent on retention time and influenced by rotation speed.**

Drum Debarking Parameters



Rotary Parallel Drum Barker





1. Log lifters
2. Logs
3. Bark, sand, stones
4. Bark slots
5. Bark chutes
6. Hood

Parallel drum for long logs:

D = 3 - 4.5 m, L = 40 – 60 m

Tumble drum for short logs:

D = 4 - 6 m, L = 20 - 40 m;

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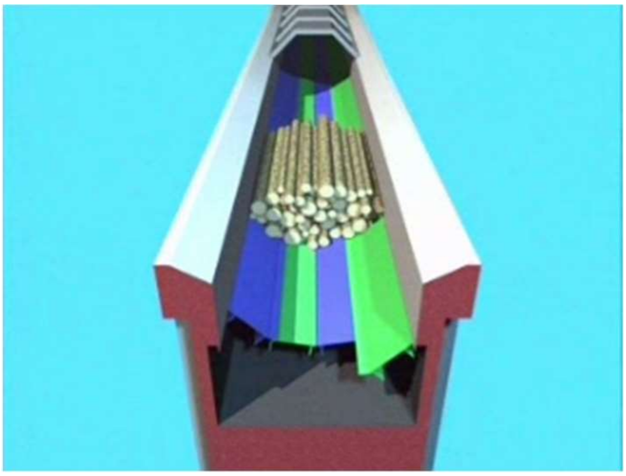
Gentle Log Feed



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Rotary Parallel Drum Barker

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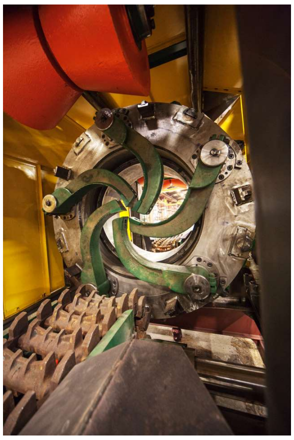
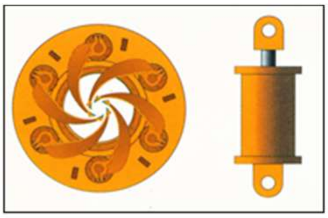
Rotary Debarker

- Assembly containing pair-wise openings in the bottom.
- Debarking plates are fixed on the surface of the rotors.
- Spinning plates hit the logs and bark removal occurs by breaking the fiber bonds at the cambium layer.

Ring Debarker

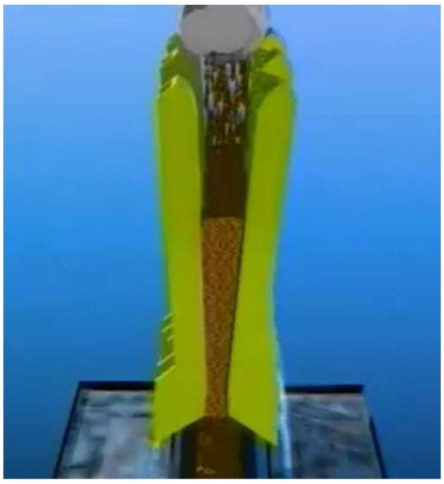




Variable pressure air seal debarking ring (Ø 31…183 cm)

- Single stem process
- Counter rotating ring for stringy bark
- Cannot accept logs < 1.8 m
- Higher wood loss than rotary

Bark Handling



- Long contact between water and bark impairs water removal
- Pressing improves water removal
- Uniform pressure over the whole area of the bark layer

Utilization of Bark

Proportion of bark between 10 and 20 % (vol). Important energy source.

Species	volume fraction of bark, %
Pine	11.8
Spruce	12.8
Birch	14.1

Utilization of Bark

High Heating Value, HHV:

- 12.2 MJ/kg at 40% moisture content
- 8.1 MJ/kg at 60% moisture content
- 6.1 MJ/kg at 70% moisture content

$$HV_{wet} = HV_{dry} \cdot (1 - m_{water}) - H_{25} \cdot m_{water}$$

HV	heating value in MJ/kg fuel
m_{water}	mass of water in kg water/kg biomass
H_{25}	evaporation heat for water at 25°C = 2.44 MJ/kg water

Bark is pressed and burnt in a fluidized bed incinerator.

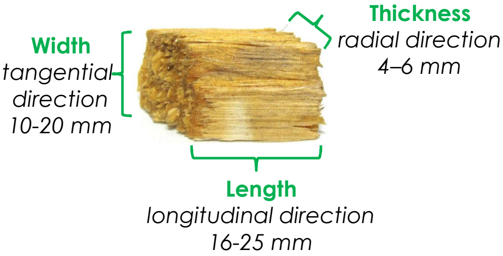
Chip Preparation

1. Wood yard
2. Wood intake
3. Debarking
4. **Chipping**
5. Chip screening
6. Chip storage

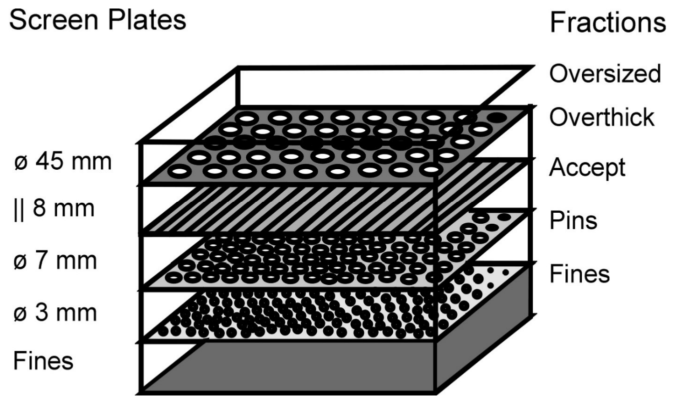
Size Reduction Energy

	GJ/t
• **Wood chipping**	**0.1**
• Chips to saw dust by hammer mill	1.0
• Stone grinding	5.0
• Disc refining	7.0
• Wood to ethanol (0.24 t/t w)	7.2

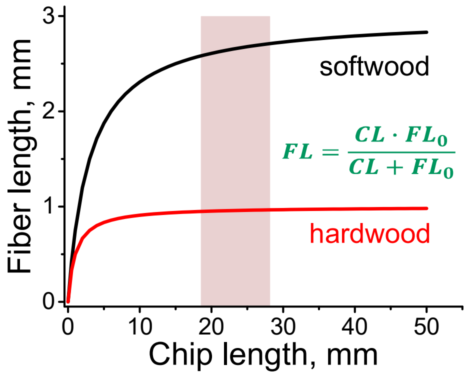
(Target) Chip dimensions



Measurement of Chip Size Distribution



Chip length vs Fiber length

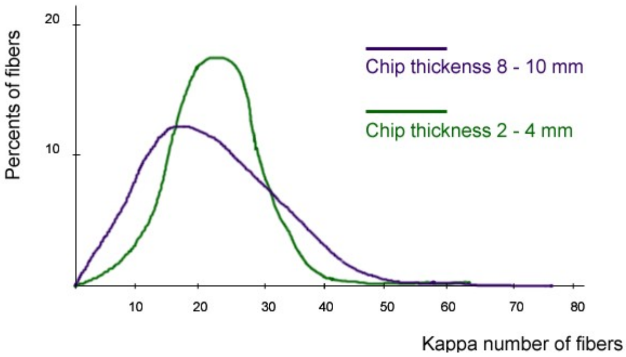


Numbers of 3.5 mm long fibres in the longitudinal direction of a 25 mm long chip are ~ 25/3.5 = ~7.

Number of fibres in the radial direction of a 3 mm thick chip would be ~ 3.0/0.03 = ~ 100.

Effect of chip thickness on delignification

Kappa number (=lignin content) for both pulps is 20 (3%)



CHIP DENSITY

$$\rho_{dc} = \frac{m_C}{V_C}$$

$$\rho_{dc} = \rho_S(1 - \varepsilon_i)$$

$$V_V = \frac{1}{\rho_{dc}} - \frac{1}{\rho_S}$$

$\rho_S = 1.53\ kg \cdot L^{-1}$
ρ_i ... *internal chip*
ε_i ... *void volume fraction*

Wood densities

Wood species	Dry density, ρ_{dc}, kg/L	Void volume, V_V, L/kg
Aspen	0,37	2,05
Spruce	0,43	1,67
Pine	0,47	1,47
Beech	0,68	0,82

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EXAMPLE

$\rho_{dc} = 0.40\ kg \cdot L^{-1}$

$\varepsilon_i = 1 - \frac{\rho_{dc}}{1.53} = 1 - \frac{0.40}{1.53} = 0.74$

Total void volume:

$V_V = \frac{1}{0.40} - \frac{1}{1.53} = 1.85\ L \cdot kg^{-1}$

Volume of air inside chip at MC_w=50%:

$MC_w = 50\% = \frac{m_{wc} - m_{dc}}{m_{wc}} = \frac{2-1}{2} = 0.5$

$V_V = 1.85 - 1.00 = 0.85\ L \cdot kg^{-1}$

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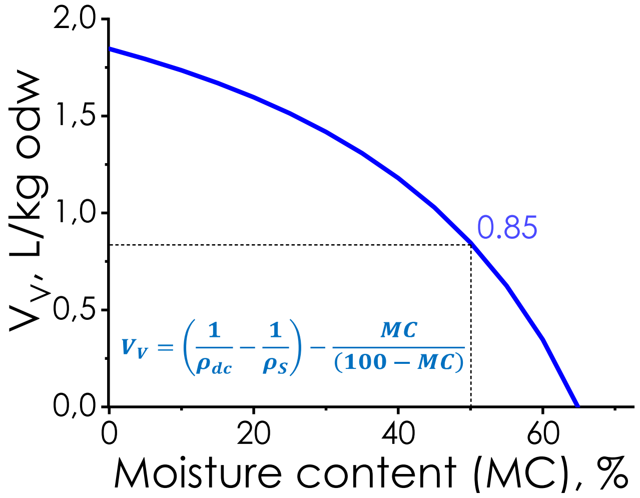

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PENETRATION : $P_0 = \frac{V_{i,H_2O}}{V_V}$

Aspen chip:

$$\rho_{dc} = 0.37 kg \cdot L^{-1}$$

$$DS = \frac{m_{dc}}{m_{wc}} = 0.55$$

$$m_{wc} = \frac{1}{0.55} = 1.82\ kg \cdot kg^{-1} DS$$

$$m_{moisture} = 1.82 - 1.00 = 0.82\ kg \cdot kg^{-1} DS$$

$$V_V = \frac{1}{\rho_{dc}} - \frac{1}{\rho_S} = \frac{1}{0.37} - \frac{1}{1.53} = 2.05\ L \cdot kg^{-1} DS$$

$$P_0 = \frac{0.82}{2.05} \cdot 100 = 40\%$$

Physical Properties of Chips

Comparison of chip dimensions and the spherical **e**quivalent **d**iameter (=diameter of a sphere of the same volume as a chip particle):

L	W	T	ED
	mm		mm
25	15	5	15,3
25	15	10	19,3
35	20	10	23,7

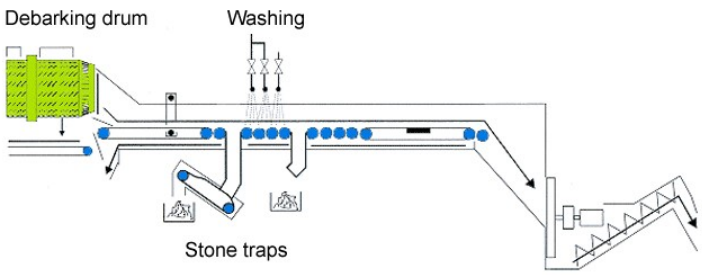
$$ED = \left(\frac{6 \cdot L \cdot W \cdot T}{\pi}\right)^{\frac{1}{3}}$$

Chip Production

Transport To Chipper

- Alignment of the logs
- Removal of stones and other particulate impurities
- Removal of loose bark
- Log washing
- Sorting too short and to long logs
- Metal detection and removal

Chipper Infeed Line



Chippers

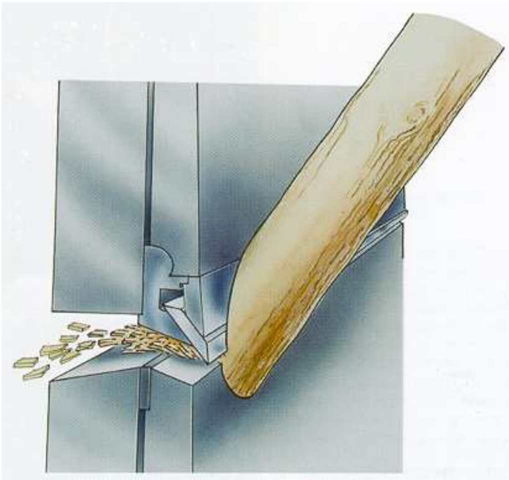
- **Disc Chipper**
- Drum Chipper

Disk Chipper

- Most frequently used in pulp mills.
- Several straight knives (6 - 16) are mounted on a heavy, rigid disc in radial arrangement.
- Disc revolves in either a vertical or in a slanted plane.
- Generated chips pass through slots in the disc and may be discharged from the top, bottom or sides of the disc housing.

Disk Chipper

- Supply of logs via an **infeed spout** at an **angle** between the face of the disc and the spout axis of about **30 - 40°**.
- When the knife edge cuts the wood, the fibres are more or less compressed in a longitudinal direction.



Chippers

- Diameter of the disc 3.4 m
- Number of knives 10 – 14
- Capacity 450 m^3/h (av)
- Velocity 3.8 m/s
- Moment of inertia 23 000 kg*m^2
- Total weight 33.5 t
- Twin-motor drive 2*1000 kW

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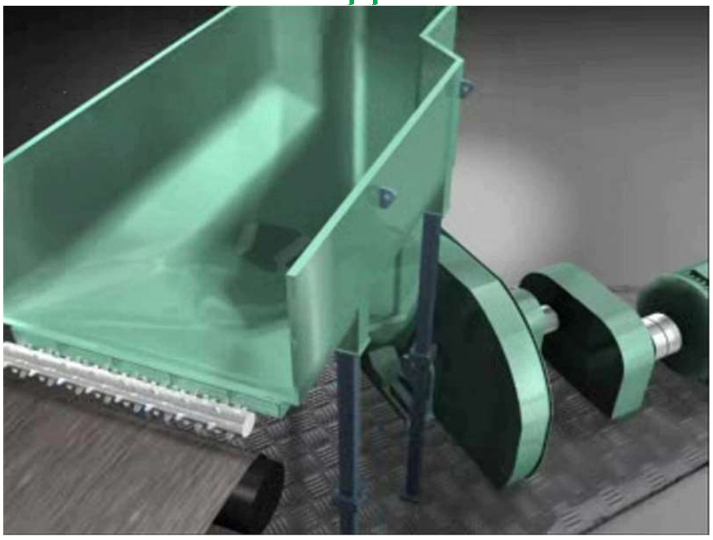
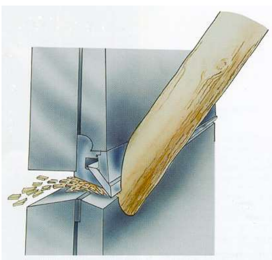
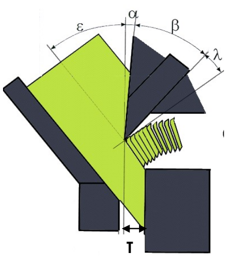
Chipper



Disk Chipper





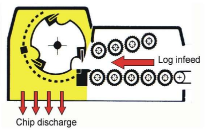
- Generated chips pass through slots in the disc
- $L = \frac{T}{sin\varepsilon}$
- With increasing **ε**, chip length, **L**, decreases. ε-angle is typically 32-38°
- Chip thickness decreases with increasing **λ**.

L	chip length
T	distance chipper/disc/knife
ε	infeed angle (30 - 40°)
α	pull-in angle = clearance angle (1-7°)
β	sharpness or knife angle (30 - 40°)
λ	complementary angle = 90°-(α+β+ε)

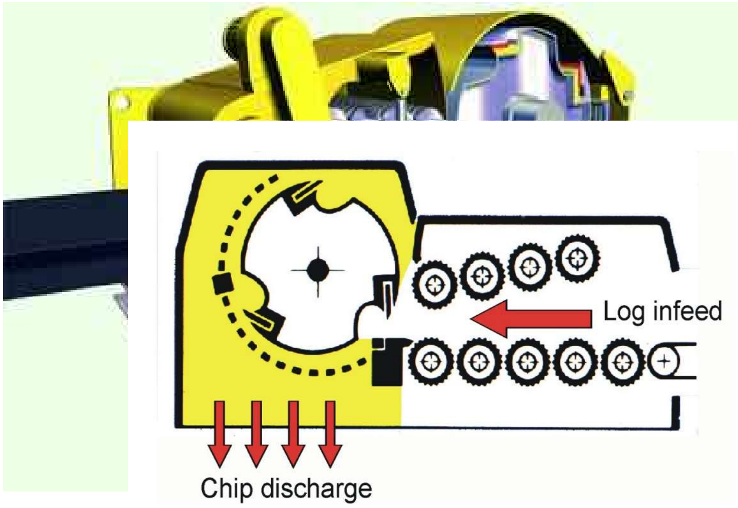
Chippers

- Disc Chipper
- **Drum Chipper**

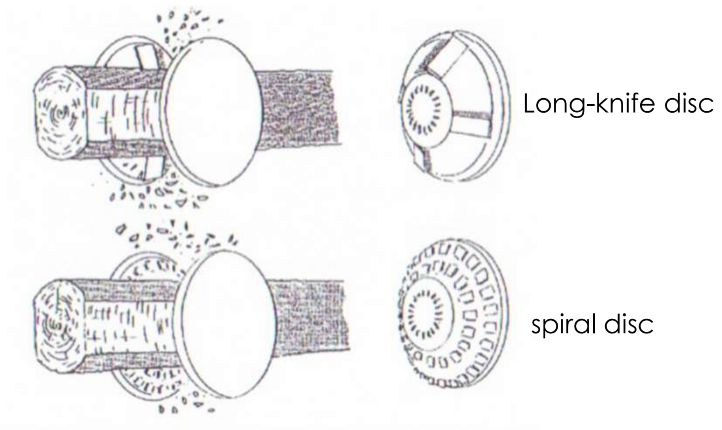
Drum Chipper



- Preferred in sawmills (wood residues, etc.)
- Wood is **cut between the knife edge** and **an anvil** which is fixed at the bottom end of the infeed spout.
- Cut chips are caught in pockets, while larger pieces are further broken down by specially designed bridges.



Chips from Sawmills



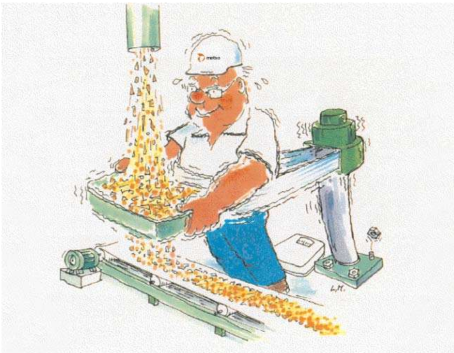
Chips from Sawmills

- About 30% of the wood chips in Nordic countries derive from saw mills.
- In sawmills chipping is achieved while timber is reduced to blocks →**Reducers**.
- **Chip length is controlled by the log feed speed** and the **rotation speed** of the **reducer**.

Chip Preparation

1. Wood yard
2. Wood intake
3. Debarking
4. Chipping
5. **Chip screening**
6. Chip storage

Chip Screening



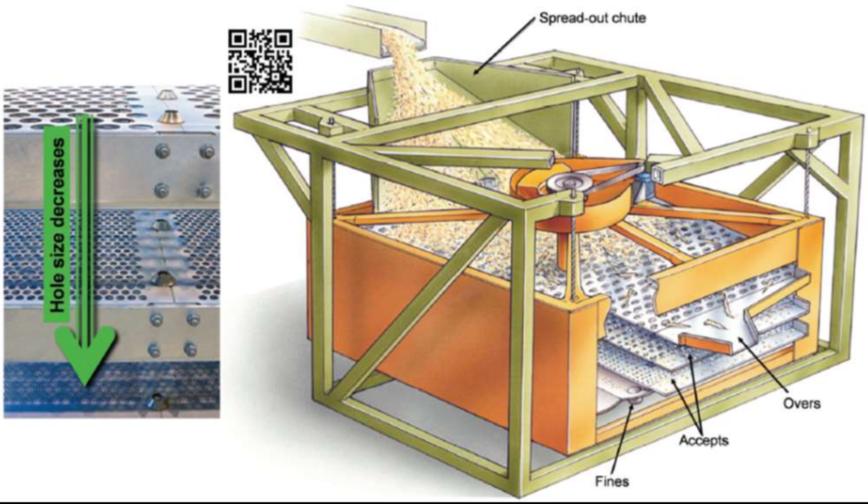
Chip Screening

Removal of oversize, overthicks, pins and fines:
Gyratory screening

Perforated plates placed one above the other.

Chips are spread out on top plate and a vibrating motion shakes the chips.

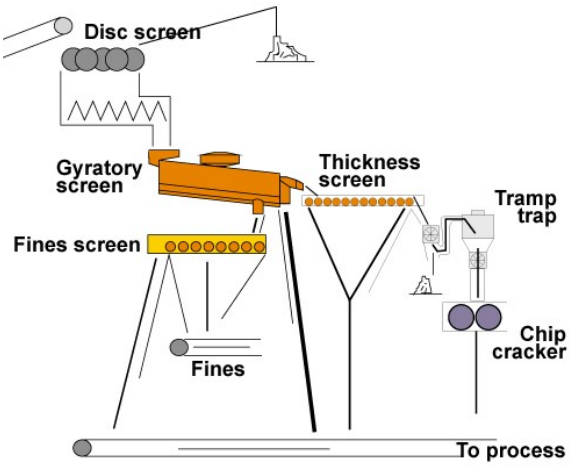
Chip Screening (EasyScreen)



Disc Screens

- **Rotating shafts with discs mounted on them**.
- The spacing between the shafts are the slots through which thin chips thin enough can escape.
- Used for removing overthick chips.

Disc Screens



Roll Screens

Pre-adjusted **space between adjoining rolls**.

Fines and acceptable chips pass these gaps at

- different travelling distances and are
- discharged from below the roll carpet by a conveyor

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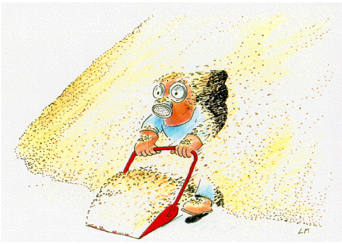
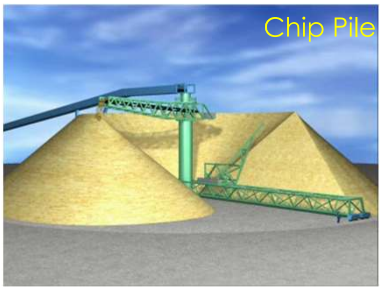
Roll Screens

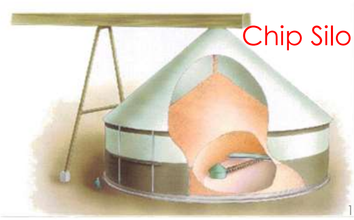
Chip Preparation

1. Wood yard
2. Wood intake
3. Debarking
4. Chipping
5. Chip screening
6. **Chip storage**

Chip storage







Continuous supply of high-quality chips.

Chip storage time ≤ **3 d**

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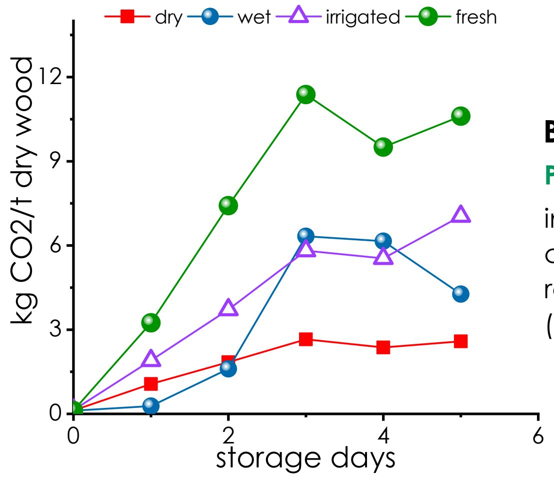
Chip Storage

- Continuous supply of high-quality chips.
- **Chip storage time should not exceed 3 days:**
  - because of economic reason and
  - because of quality reason: hardwood chips are easily affected by **bacteria** and **fungi**.

Chip Storage

- First-in first-out principle.
- Two forms of chip storage:
  - **PILES**
  - **SILOS**

CO_2 formation upon Chip Storage



A. Promberger, PhD Thesis, 2004

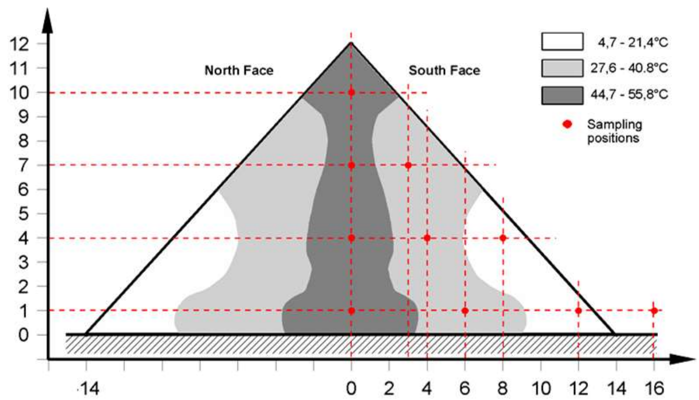
Beech wood 30°C

Parenchyma cells

in fresh cut chips are still alive and consume oxygen to oxidize the residual reserve polysaccharides (*e.g.* starch).

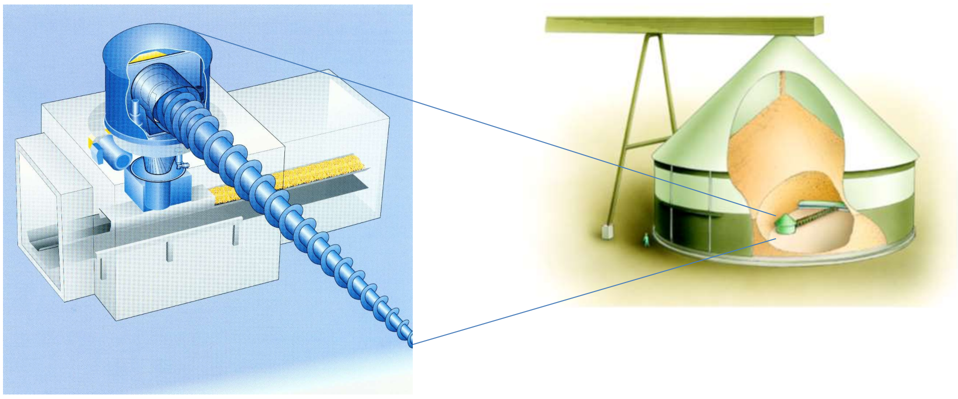
Effect of Chip Storage

- At ~ 40°C, autoxidation and hydrolysis of carbohydrates starts.
- **Wood substance losses during chip storage are at least 1 % per month**
- Losses are significantly higher with hardwood than for softwood chips. The same applies to sapwood.



(according to Wolfhaardt, Rabie 2003)

Screw Reclaimer



Slewing screw reclaimer - CenterScrewTM (Andritz 1999)

Wood Yard Losses