

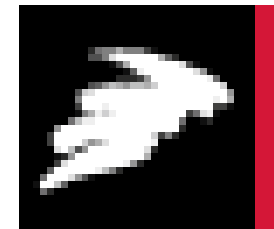
Added Value Biorefining

Value added products from wet-fractionation of residual biomass

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Bio-based materials group

- Intelligent utilisation of biobased resources
- Development of new, functional and sustainable building-materials for industry and society.
- Extraction of value-added components via fractionation and hydrolysis of biomass
 - Proteins
 - Waxes
 - Fibre
 - Polymers



Laboratorier og pilotanlæg



Pilot scale
2 - 100 kg



Pilot production scale
0,1 - 10 ton



Laboratory
0,01 – 2 kg

Process in full scale ??



Biobaserede restressource

- Fra bio til business!



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Laboratorie og pilot skala

Development of sustainable building-materials



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- Panels (MDF, OSB, PB)
- Binders, bioplastics and glues
- Insulation mats
- Bio-composites



Development of sustainable building-materials

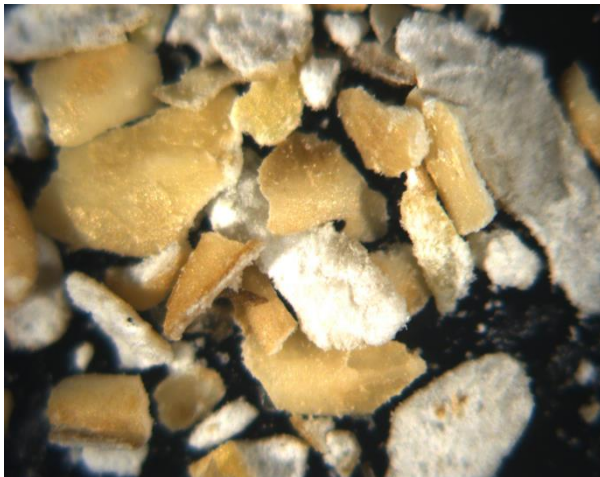
- Development of agri-raw materials as cellulose fibre feedstock for pulp molding / packaging





WET FRACTIONATION

- APPROACH TO ADDED VALUE BIOREFINING OF RESIDUALS

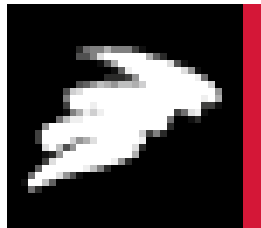


■ Process

- Mixing xx and Water
- Using selected enzymes
- Hydrolysis processing
- Slurry deactivation
- Physical separation
- Drying solids
- Concentration of liquid

■ Optional

- Extruding
- Super critical extraction
- Ultra filtration
- Enzymatic refining of aqueous slurries



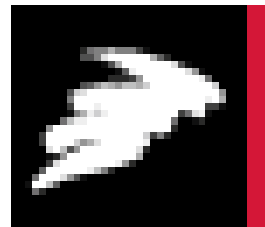
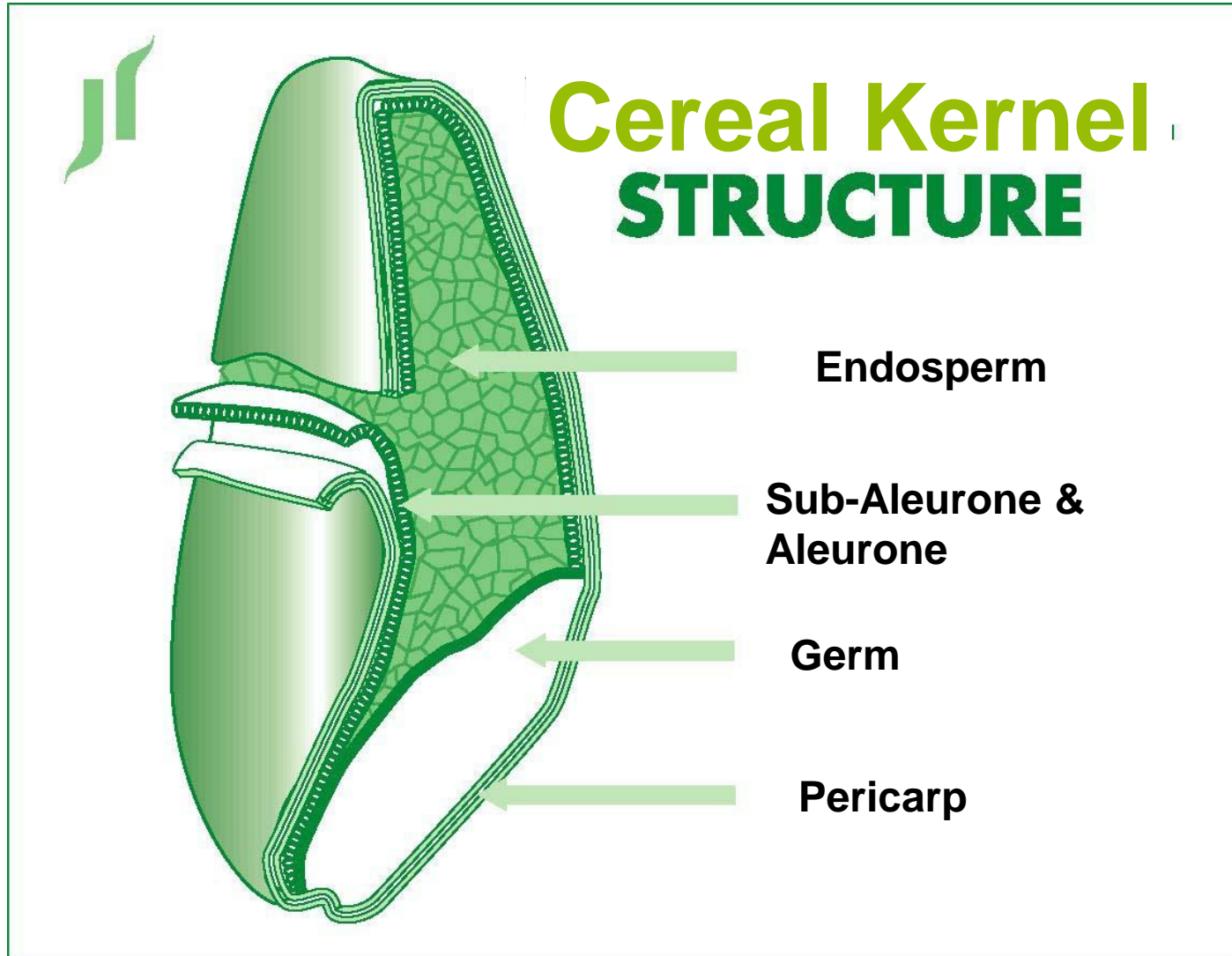
WET FRACTIONATION



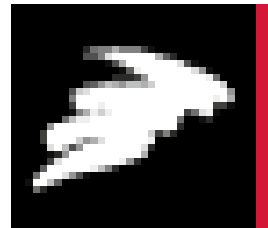
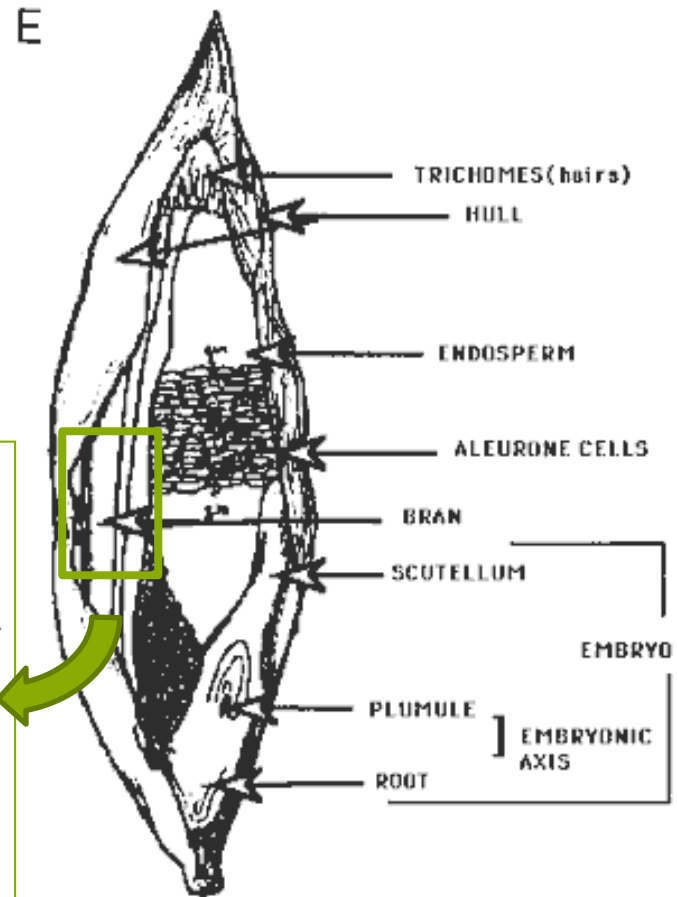
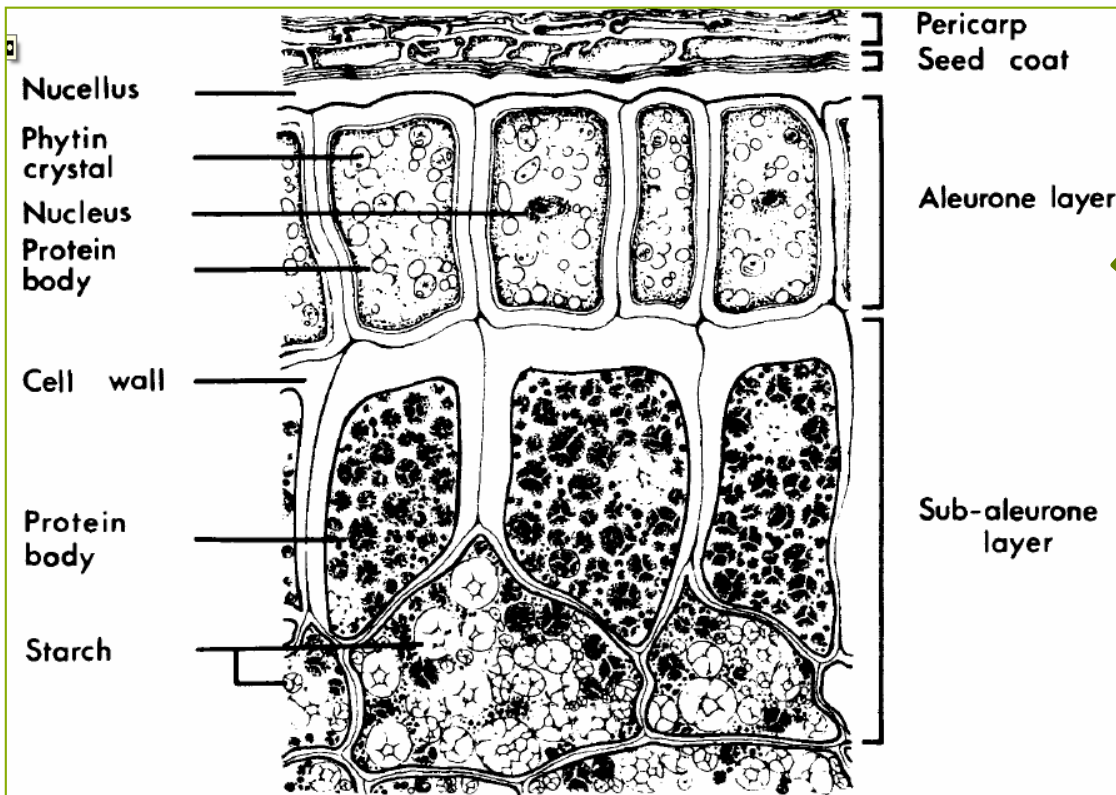
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Enzymes

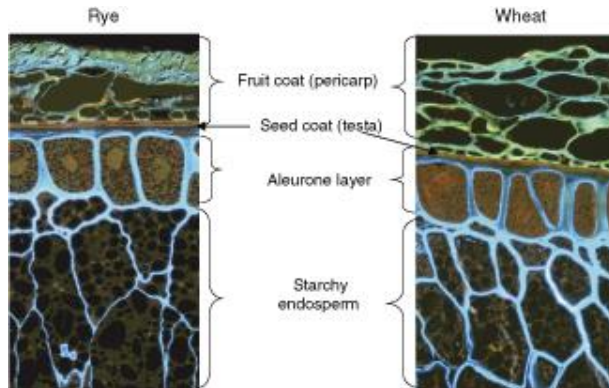
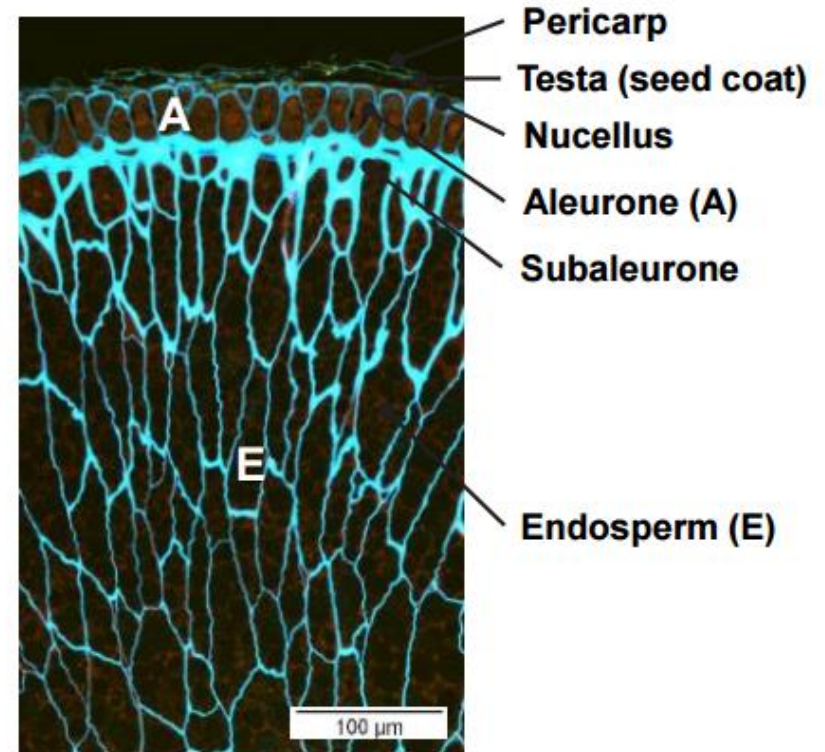
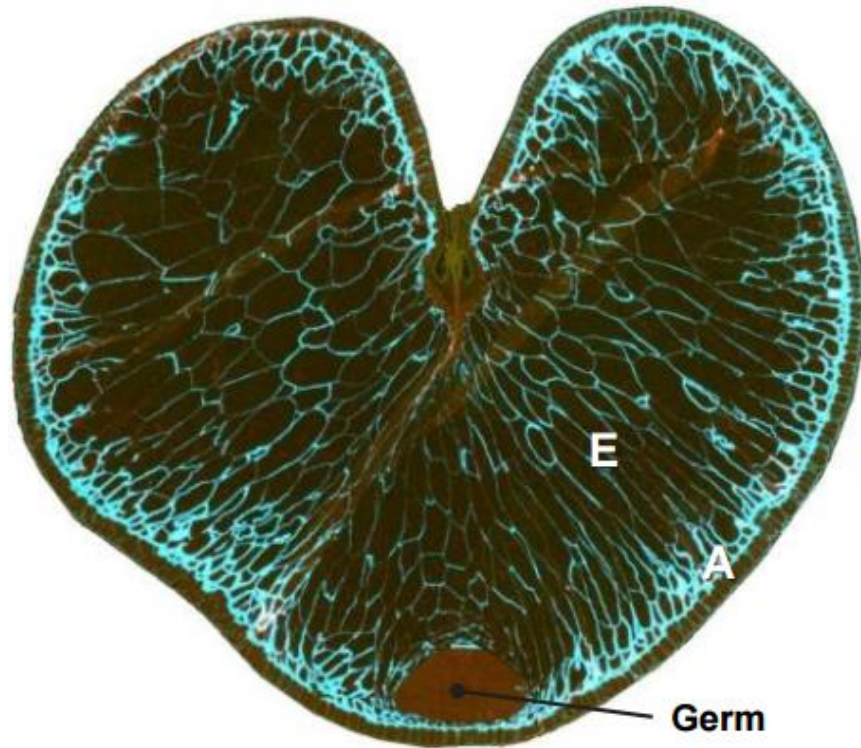
- **Polysaccharidases:**
 - Starch degrading (amylases, amyloglucosidases, beta amylase)
 - Hemicellulases (Xylanases, Mannases, Beta glucanases)
 - Cellulases (Cellulase, beta (1,4) glucanase, Cellubiase)
 - Pectinases and Pectic lyases
- **Proteases**
 - Several types: endo- and exo-proteases
- **Esterases, e.g. ferulic esterase**



■ ■ ■ (sub-) ALEURONE



Beta-glucan, cell wall material in cereals

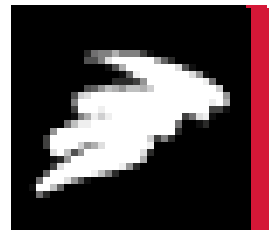


Microstructure of parts of intact grains of oats, rye and wheat. The sections have been stained with Acid Fuchsin and Calcofluor: protein appears red, cell walls rich in β -glucan appear light blue and lignified cell walls of the fruit coat appear yellowish-brown.



■ ■ ■ Oat bran – nutrient / bio-resource

- Soluble fibres (Beta Glucans) – high value
- Proteins (globulin rich) – medium-high value
- Oils: non-polar and polar lipids – medium-high value
- Insoluble fibre – food value
- Starch / maltodextrins / sugar – lower value

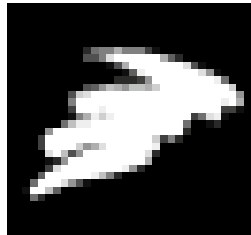


■ ■ ■ Classification according extraction behaviour

	brine	water	alcohol	residue
	globulins	albumins	prolamin	glutelin
In oats	majority	minor	minor	

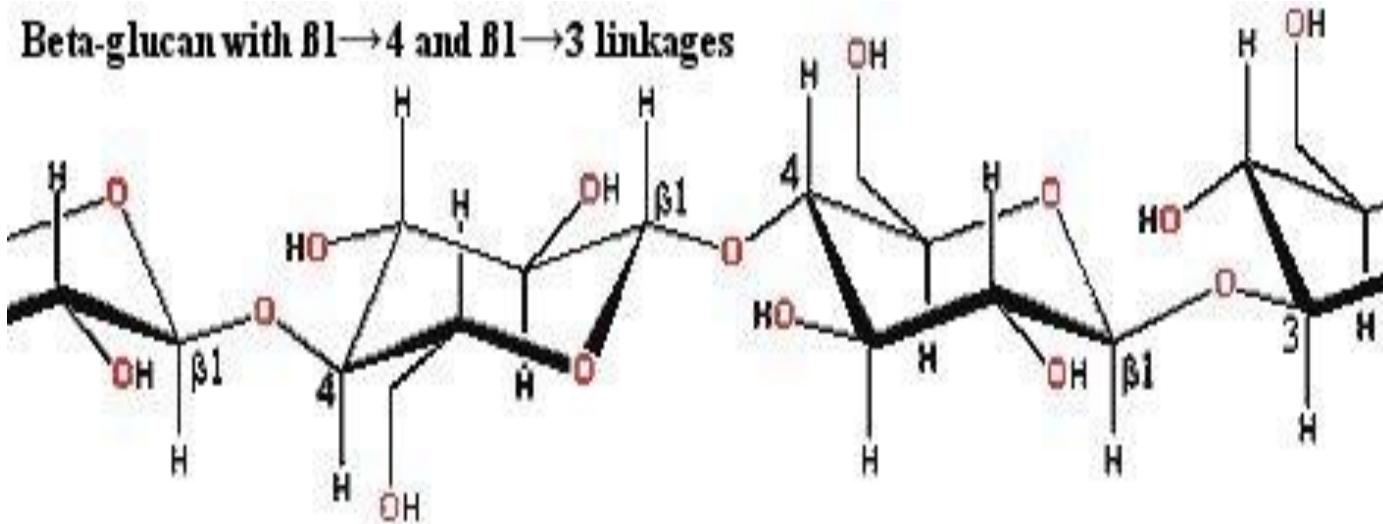
A. GLOBULINS

As mentioned earlier, oat is the only cereal in which the major proportion of the grain protein is soluble in salt and thus classified as globulin. Quantitative data published on the proportion of globulins vary widely (from 40–50% to 70–80%).^{24,25} The globulin fraction of oats (called avenalin) is a mixture of different polypeptides



■ ■ ■ BETA GLUCAN

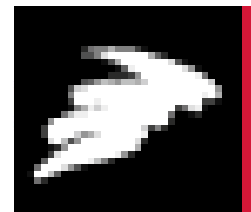
Beta-glucan with $\beta 1 \rightarrow 4$ and $\beta 1 \rightarrow 3$ linkages



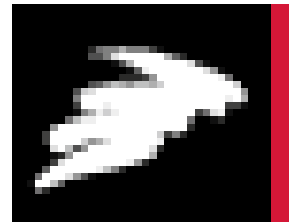
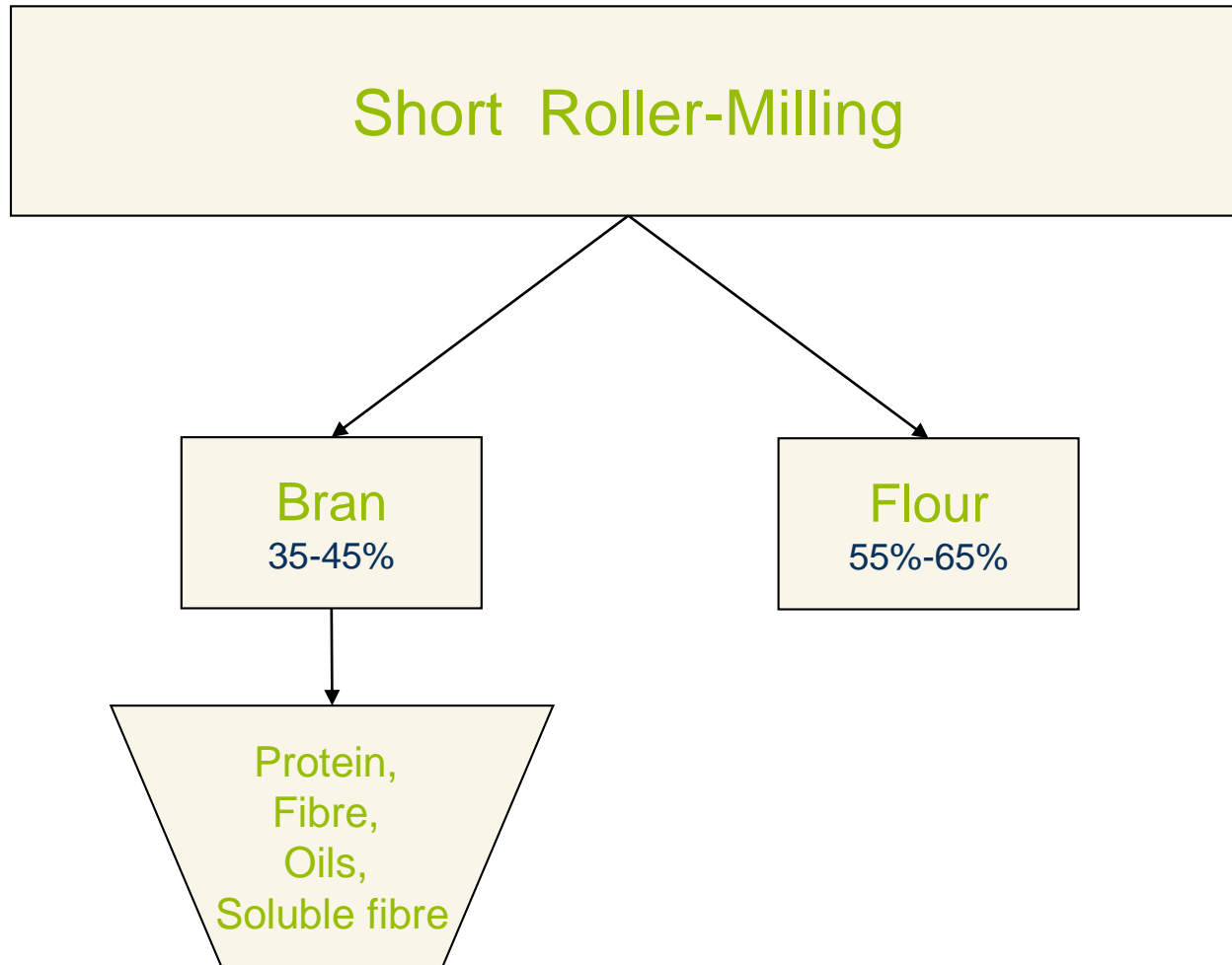
70% (1→4)-linked and 30% (1→3)-linked β -D-glucopyranosyl residues

organised in blocks of (1→4)-linkage sequences (cellotriosyl and cellotetraosyl cellulose-like segments)

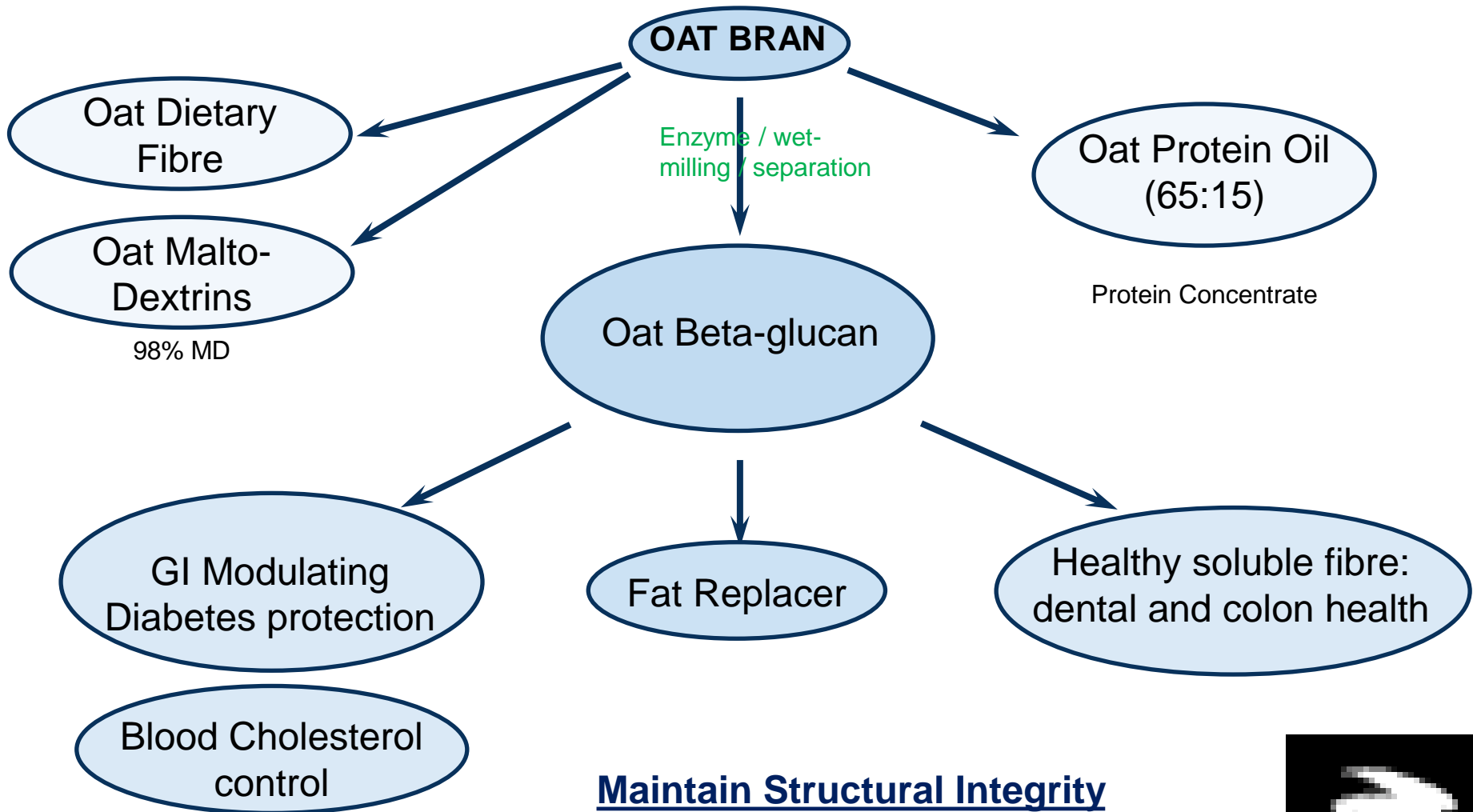
separated by single (1→3)-linkages.



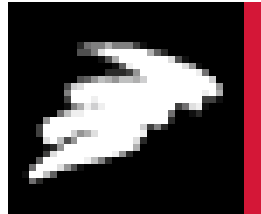
■ ■ ■ Oat Processing – non traditional.....



■ ■ ■ Oat Bran Fractionation

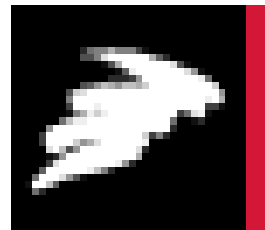


Maintain Structural Integrity
Separation Value



■ ■ ■ Bio-refining

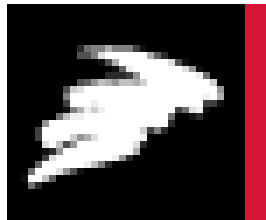
- Real example of "cascade bio-refining" ✓✓
- Results in at least 4 saleable product streams ✓✓
- Far higher value than feedstock (essentially waste) ✓✓
- Works for all cereal brans ✓✓



■ ■ ■ Beta Glucan: Properties

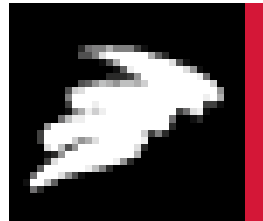
Properties of Beta Glucan

- The soluble fibre component of oat bran
- Remains undigested in the stomach and small intestine, with documented physiological function and impact:
 - Cholesterol Reduction
 - GI & Diabetes control
 - Prebiotic



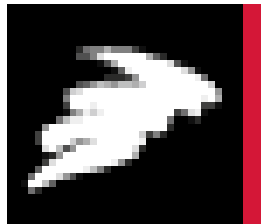
■ ■ ■ Beta Glucan rich fraction: Summary

- Natural fraction of oat grain
- Allows delivery of positive oat messages when added into foods and supplements
- Rich in beneficial oat beta glucan soluble fibre - 35%
- FDA and EFSA cholesterol claims
- Healthy, multi-functional, clean label ingredient
- White, taste neutral, water soluble powder



Mutifunctional hydrocolloid

- Mutifunctional Food and Cosmetic ingredient
- Emulsifying and stabilising properties
- Adds body and texture to food products and drinks
- White, soluble, taste neutral powder



■ ■ ■ Beta Glucan: Potential in Food Products

Example Application Areas

- Breakfast products
 - Spoonables, juices, smoothies
- Mayonnaise, dressings, dips
- Ready meals
- Butter spreads
- Processed meats
- Baked goods
- Dietary supplements
- Slimming products
- Personal Care / Cosmetics



■ ■ ■ Oat Beta Glucan in Personal Care

The substance has the following properties and benefits in personal care products:

Moisturizing

Soothing

Anti-irritant

Hydrating

Reduces inflammation and redness (erythema)

Anti-aging, reducing fine line and wrinkles

Naturally separated from the oat grain

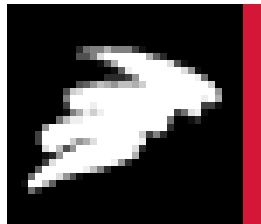
(1,3), (1,4) - β -D-Glucan

GMO-free

INCI: Beta Glucan or Beta Glucan (Oat)

Gluten-free

Hypoallergenic

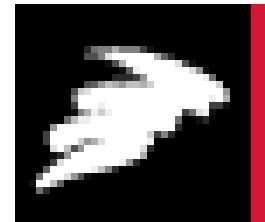


■ ■ ■ Current usage of oat beta glucan in skin care applications

- Facial, body and hand creams and lotions
- Face mask and Cleanser
- Pre and after-sun creams
- Wound dressings
- Bath cream & Shower cream
- Sanitary wipes
- Bandages for wound healing
- Insect-bite products
- Soothing products



Sales price into this sector: 5000 euro per dry kg
Market: 100-200 MT worldwide

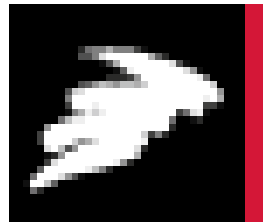


■ ■ ■ Economic Impact Example: Oats

10,000 MT oat bran frac plant (27,500 MT oat grain input)			
	Amount (ton)	Price (€/ton)	Amount (€)
Revenues			
Beta glucan rich	1.400	14.000	19.600.000
Maltodextrins	3.670	0	0
Oat protein rich	2.240	4.000	8.960.000
Fibre	2.710	800	2.168.000
Oat Flour (for extrusion etc)	10.000	300	3.000.000
Oat husk (energy source)	6.800	0	0
Total Revenues			33.728.000
Operating Costs			
Oat grain	27.500	250	6.875.000
Fractionation - processing + labour			4.100.000
Other Costs			750.000
Total Operating Costs			11.725.000
EBDITA			22.003.000

Investment: Around 8-10 mio euros based on N.European equipment costs
 All operating costs based on local labour and energy costs.

NB: Husk, which can be 25 + % can be burnt to fuel driers



Process in full scale ??



Wheat Straw:

- 2-4 mio ton in DK
- Infrastructure for collection in place
- Recycled fibre / paper price climbing
- Straw 500 Dkr per ton: 50 + % Cellulose fibre content.

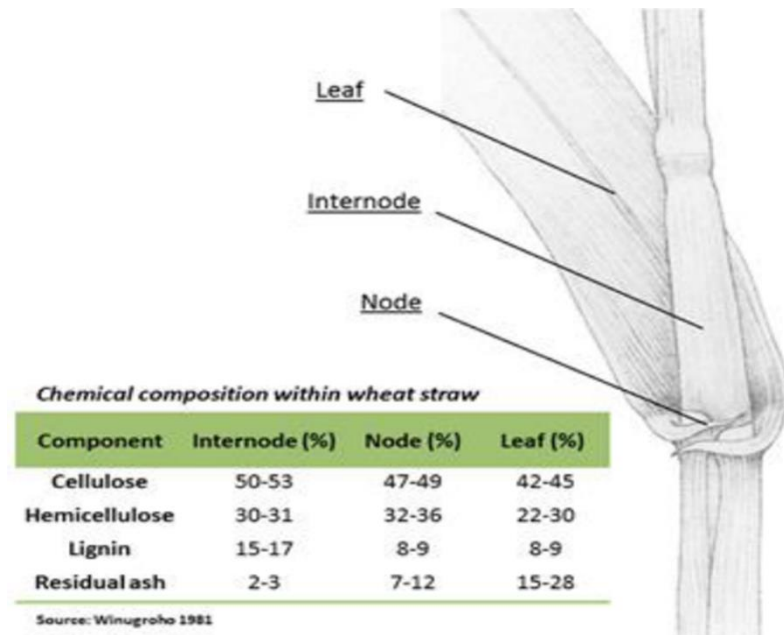
Wheat Straw:

Table 1. Ranges of chemical composition within the plant, wheat straw. (Winugroho 1981)

Component	Internode (%)	Sheath (%)	Blade (%)
Cellulose	50-53	47-49	42-45
Hemicellulose	30-31	32-36	22-30
Lignin	15-17	8-9	8-9
Residual ash	2-3	7-12	15-28

Annual Plant lignocellulosics (e.g. straws)

- Fibres can be major product or by-product
- Only potential to yield short fibres
- Pulping / refining also generates large amounts of fine particles as well as fibres



1 / 1 100%
A schematic drawing of a typical slender-stemmed straw internode is presented in Figure 4.3.

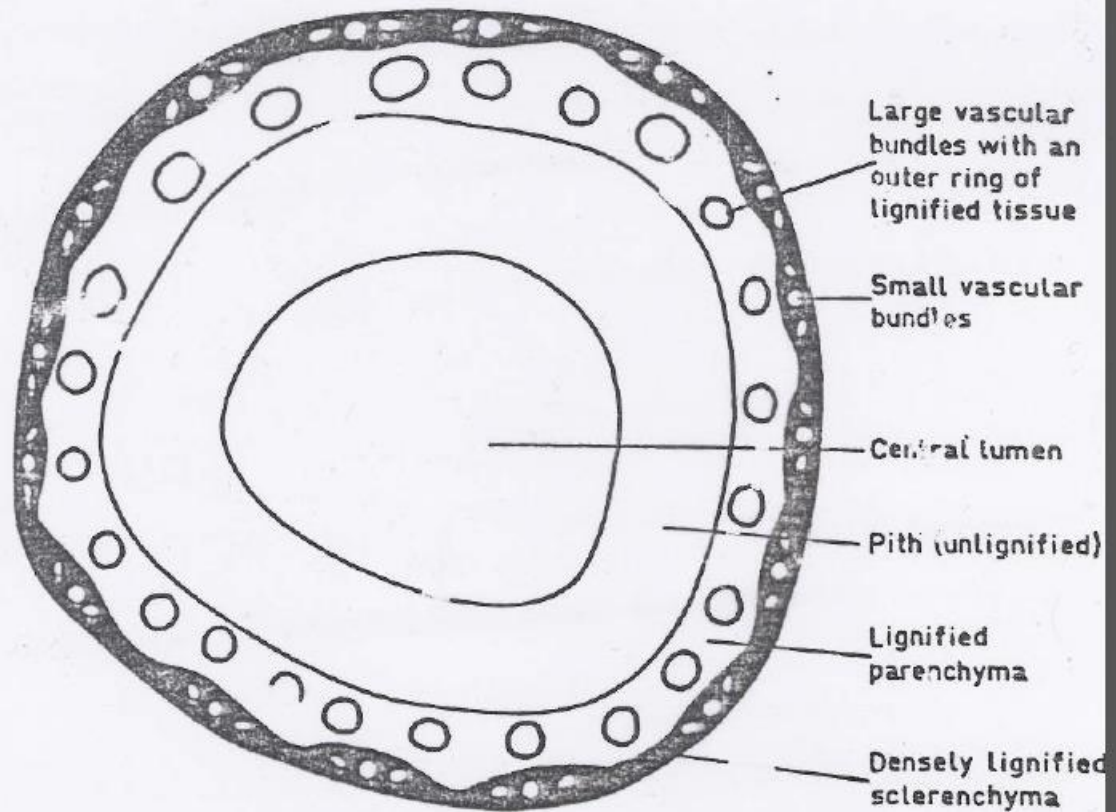
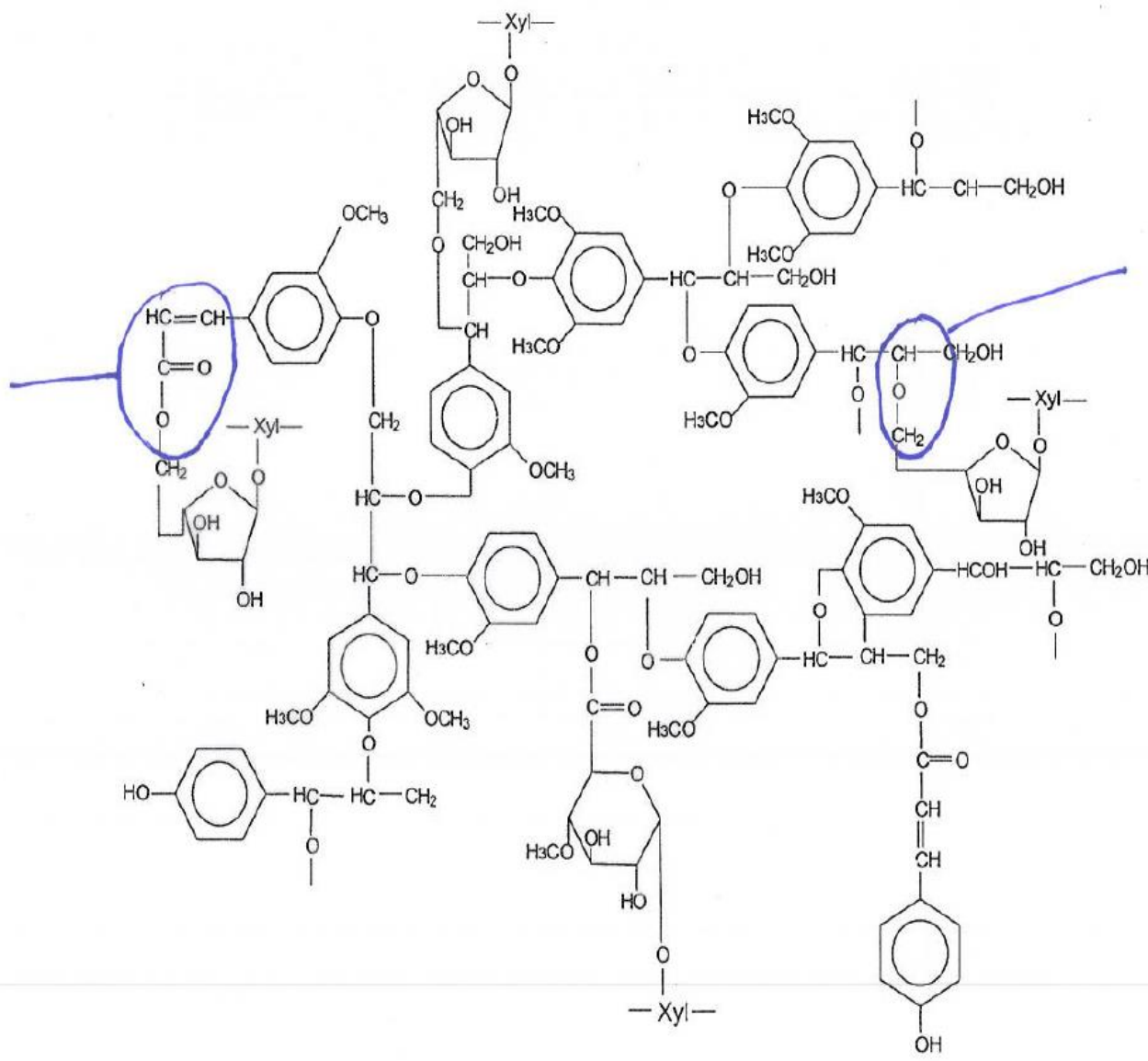


Figure 4.3. Schematic presentation of a transverse section of the internode of wheat straw.



ESTER
BOND.



ETHER BOND

Is there a business case ??



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10,000 DM ton wheat straw plant			
	Amount (ton)	Price (€/ton)	Amount (€)
Revenues			
Hemicellulose	2.000	2.000	4.000.000
Cellulose rich fibres	5.000	0	0
Lignin	1.000	1.000	1.000.000
oligomers	1.000	1.000	500.000
Total Revenues			5.500.000
Operating Costs			
Wheat straw	10.000	50	500.000
Fractionation - processing + labour			2.800.000
Other Costs			650.000
Total Operating Costs			3.950.000
EBDITA			1.550.000

Investment Around 5 - 6 mio euros based on N.European equipment costs
All operating costs based on local labour and energy costs.

Tørfraktionering



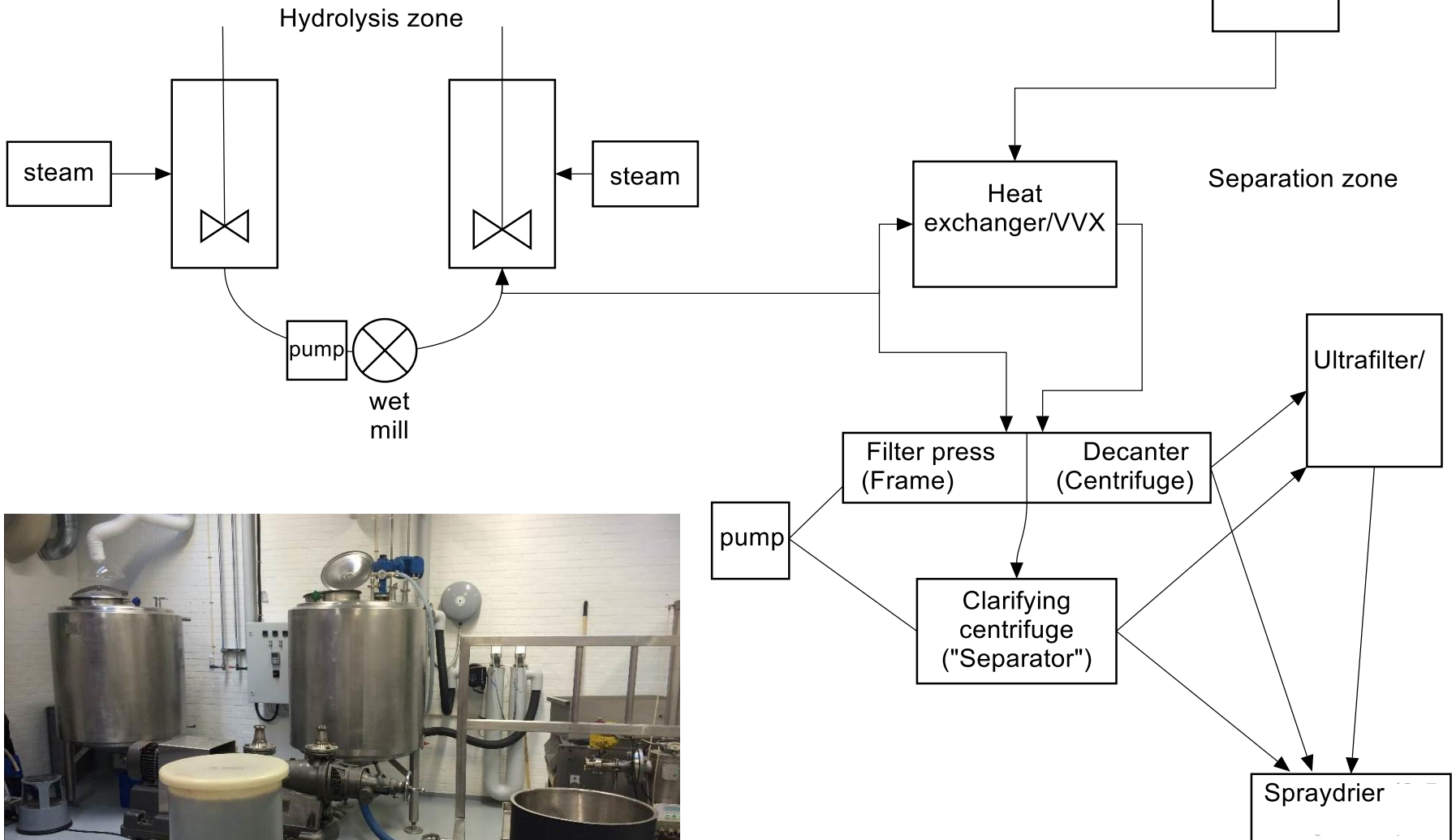
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- Hammermølle
- Skivemølle
- Sigtekanal
- Cirkulationskreds
- Varmepresse



Generisk pilotanlæg

- kaskadeudnyttelse af restressourcer



Wet Plant 1



Wet Plant 2



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RAPESEED PRESS-CAKE



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crude protein averaged at 36.1% and varied from 30.2% to 37.8% in dry matter. The content of crude fat varied in dry matter of expeller extracted rapeseed cake from 10.3% to 15.1% being 12.2% as an average. Minimum value of crude fibre content was 11.6% and maximum 16.8% in dry matter.

It was determined contrarily to the great variation in most of the nutrients that the content of metabolizable energy was relatively stable. The difference between minimum and maximum value was only 0.4 MJ/kg.

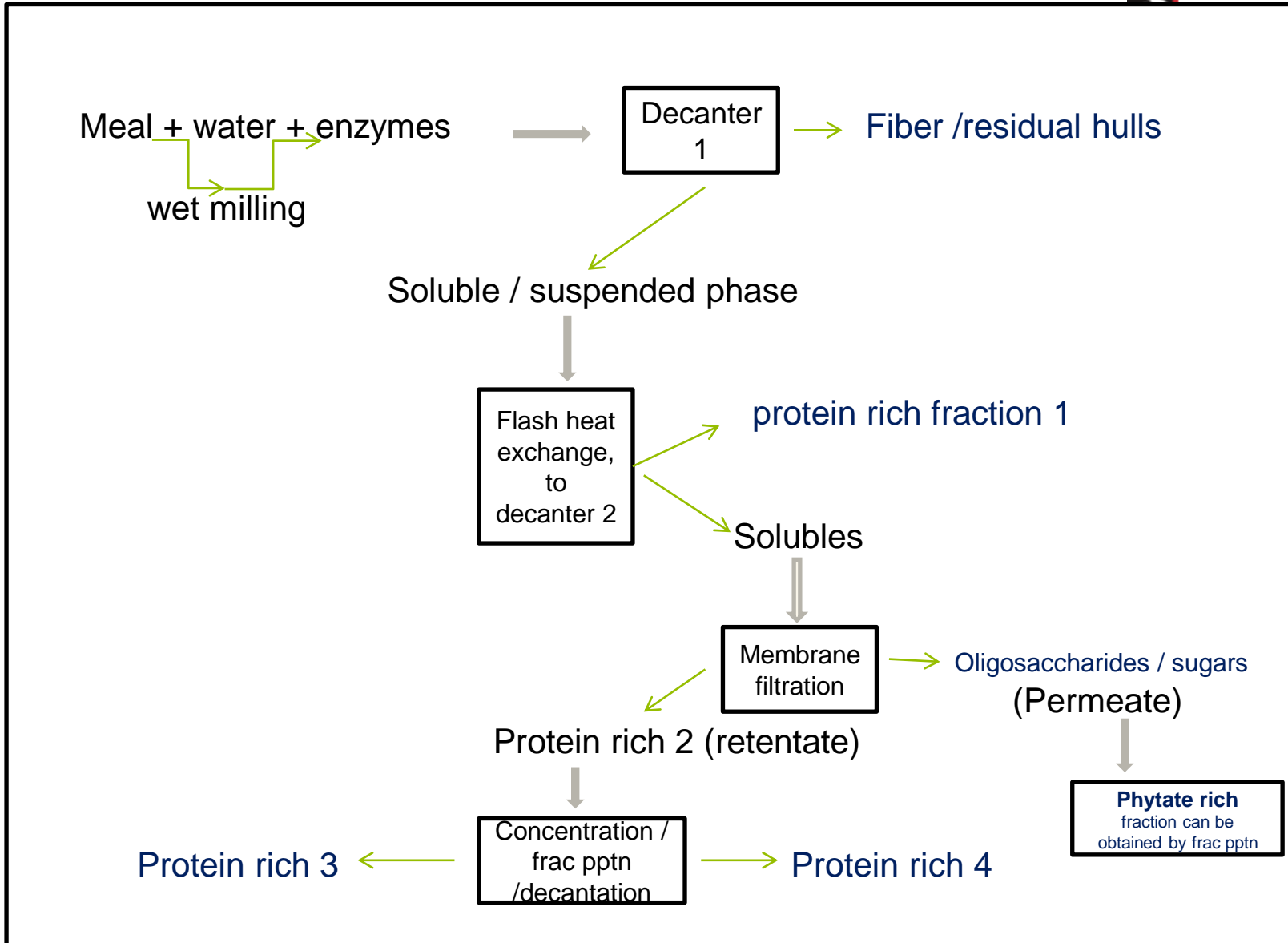
Table 2. Nutrient content and boundary values in dry matter of expeller extracted rapeseed cake (n=13)

Traits	Expeller extracted rapeseed cake			s
	mean	min	max	
Dry matter, %	95.3	89.6	98.2	2.6
Crude protein, %	36.1	30.2	37.8	2.2
Crude fat, %	12.2	10.3	15.1	1.5
Crude fibre, %	13.1	11.6	16.8	1.6
Crude ash, %	7.1	6.5	7.4	0.3
N-free extractives, %	32.2	30.6	34.2	1.2
Phosphorus, %	1.0	0.7	1.2	0.2
Calcium, %	0.7	0.7	0.9	0.1
Gross energy, MJ/kg	21.5	21.2	22.0	0.3
Metabolizable energy, MJ/kg	14.8	14.6	15.0	0.1

Leming and Lember, 2005.

Rapeseed press-cake typical sequence

ISK





RAPESEED PRESS-CAKE

Depending on the degree of processing used, we can achieve protein concentrates or isolates in different fractions.

Treatment of rapeseed press cake (from cold-pressing plant, typically around 35-40 % protein): wet fractionation processing previously run has yielded **4 different protein rich fractions**; protein contents ranging from 40 % (residuals) through 60%, 68% (ie two concentrates) and 90 + % (**isolate** achieved by ultrafiltration of separated liquor).



RAPESEED PRESS-CAKE

Up to 90% of the available protein was located in these fractions, with 74% of that within the 2 concentrates and the isolate. These should be pooled if maximal protein extraction from the meal is the driver. Some final steps can be omitted, depending on needs for maximal protein return vs fractionation of types.

In addition, a fibre (insoluble fiber) fraction and an oligosaccharide rich fraction were obtained.

Plus a small fraction (approx 2 -2.5% of the input dry matter) in which the **phytates** were concentrated at around 60% concentration, the remainder being basic peptides and mineral.

Rapeseed Residual processing



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Starting with hexane-treated, defatted meal, **yields are lower** due to reduced protein solubility and mobility (partial denaturation due to heat exposure).

In such case, at most 30-45% of available protein can be isolated as concentrates.

Potential rapeseed refinery: including cold pressing of seeds

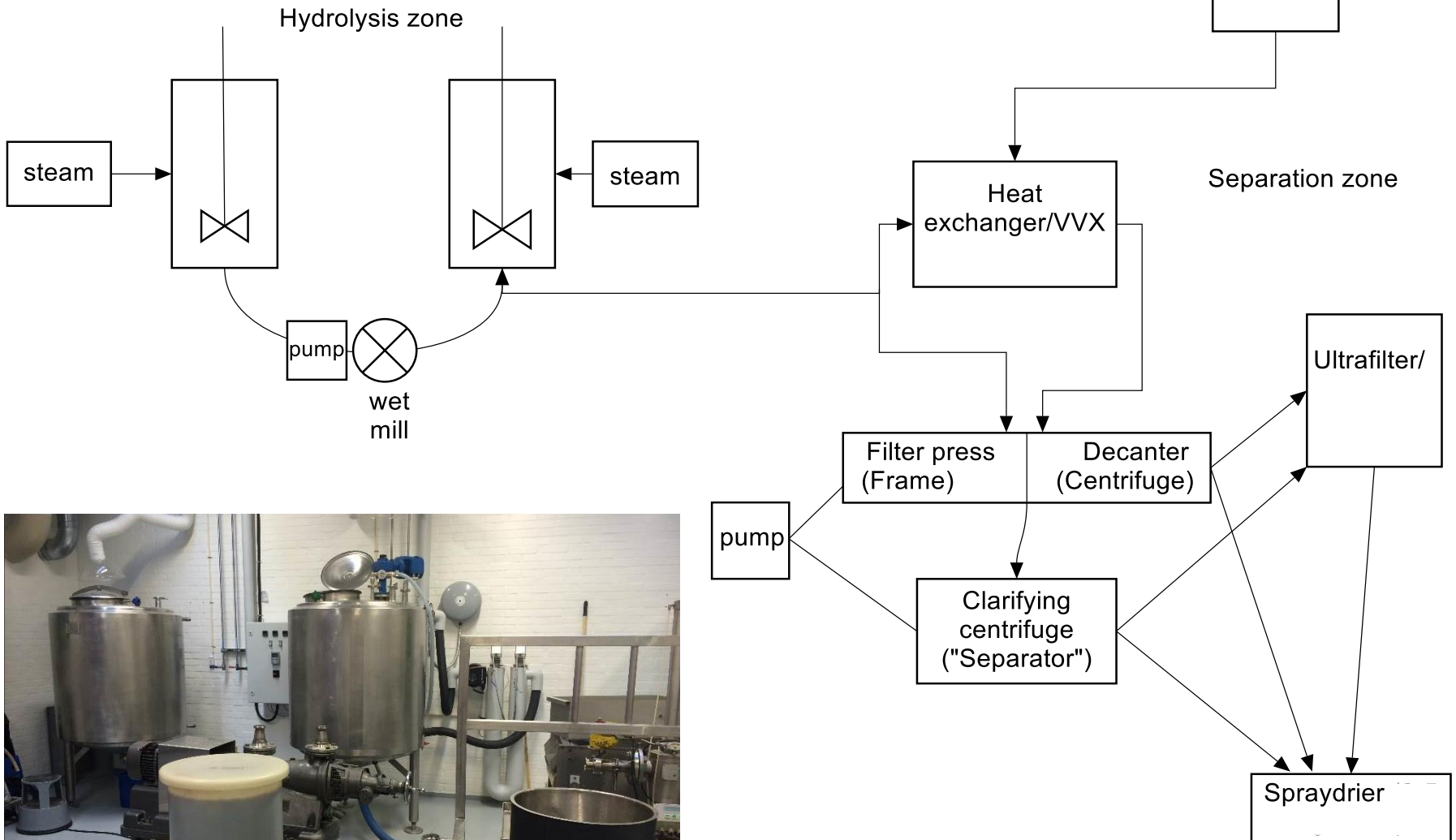


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10.000 tonne Rapeseed : scenario 2			
	Amount (ton)	Price (€/ton)	Amount (€)
Turnover			
Oil: cold-pressed	3200	2000	6400000
Protein Concentrate	1.700	2.000	3.400.000
Protein Isolate	350	8.000	2.800.000
Phytate	200	7.500	1.500.000
Sugars	1.650	250	412.500
Fibre	1.200	135	162.000
Total Turnover			14.674.500
Operating Costs			
Rapeseed	10.000	350	3.500.000
Chemicals, enzymes etc			200.000
Energy: gas + electricity			2.000.000
Lab + maintenance			50.000
Personnel Plant + admin)			500.000
Total Operating Costs			6.250.000
Net Income before deprec., interest and taxes:			8.424.500

Generisk pilotanlæg- Projekt "Subleem"

- kaskadeudnyttelse af restressourcer



Biobaserede restressource

- Fra bio til business!



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Laboratorie og pilot skala



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Thank you for staying Awake !!

