Maximizing Oil Recovery From Corn Fermentation By-products

Tong Wang
Associate Professor
Food Science and Human Nutrition
Iowa State University

National ethanol production -

- 7.2 billion gal fuel grade in 2007
- 82% by dry-grind fermentation
- If 70% oil can be recovered, 440 million gal oil would be available for biodiesel production

Composition of corn and fermentation by-products

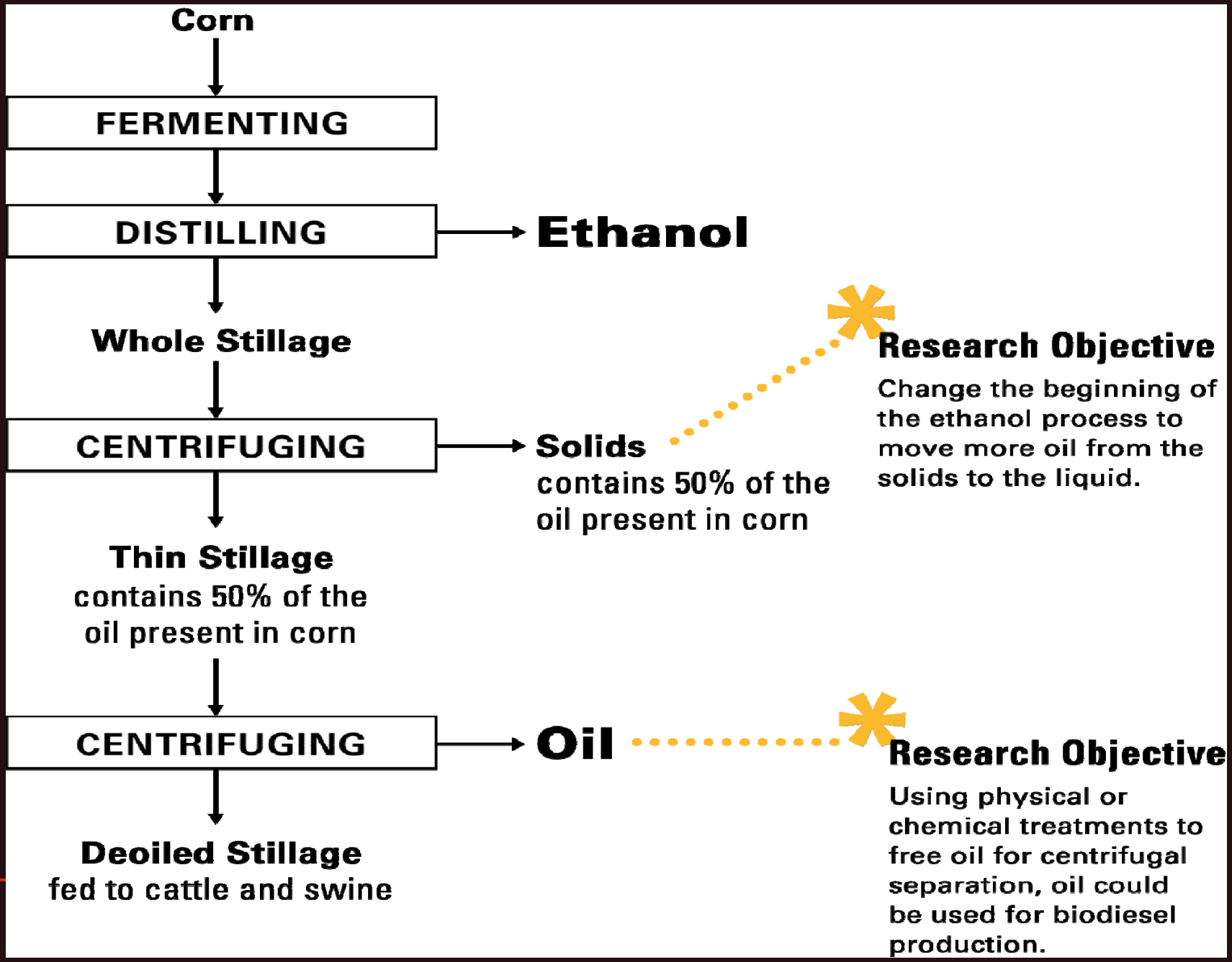
Typical products	Oil, %	Protein, %	Carbohydrate + others, %
Corn	4	10	86
DDGS	13	31	56
Thick stillage or syrup	20	14	66

General approaches to extract oil

- Solvent extraction from DDGS (Janes et al, 2008 patent; Singh and Cheryan, 1998)
- Solvent extraction from liquid (UNL)
- Centrifugation of liquid after treatment (Winsness et al, 2007 patent)

Our approaches to maximize oil extraction

- Upstream processing for oil release
- Downstream treatment to free the oil

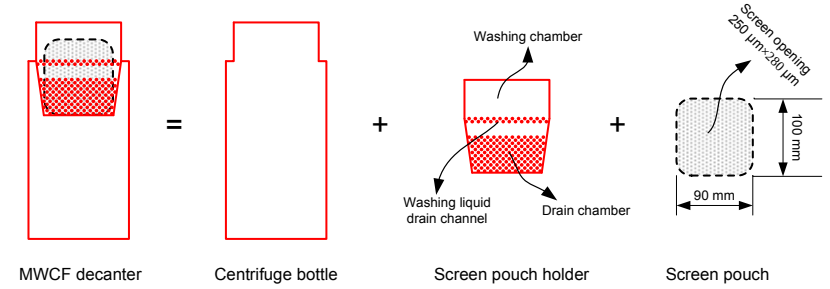

Corn
FERMENTING
DISTILLING
Ethanol
Whole Stillage
CENTRIFUGING
Solids
contains 50% of the
oil present in corn
Research Objective
Change the beginning of the ethanol process to move more oil from the solids to the liquid.
Thin Stillage
contains 50% of the
oil present in corn
CENTRIFUGING
Oil
Research Objective
Using physical or chemical treatments to free oil for centrifugal separation, oil could be used for biodiesel production.
Deoiled Stillage
fed to cattle and swine

Effect of corn grinding method on oil partition to liquid phase

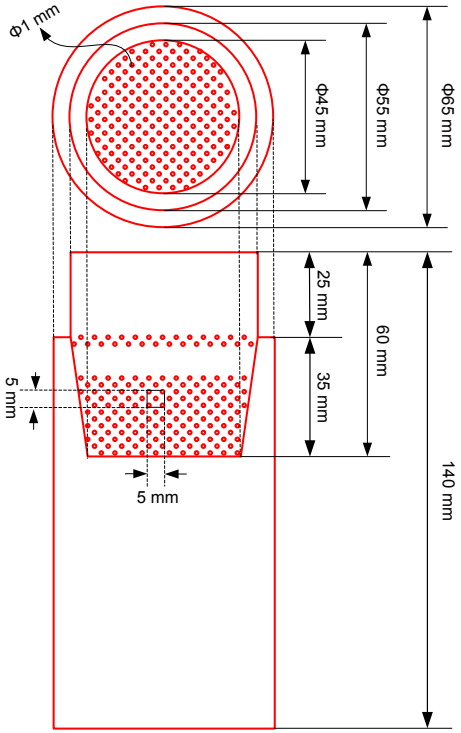
- Grinding to fine particle sizes
- Extrusion to destroy cellular structure
- Stillage separation by an unique MWCF process
- Oil extraction and quantification
  - Free oil (FO) = Centrifugable oil
  - Trapped oil (TO) = Hexane-extractable oil
  - Bound oil (BO) = Non-hexane-extractable oil

Establishing a Multiple-Wash-Centrifuge-Filtration Device

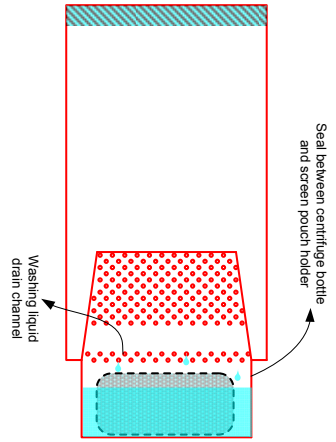
- Centrifugation and decanting work differently
- Lab simulation of industry process



A: assembly



B: construction

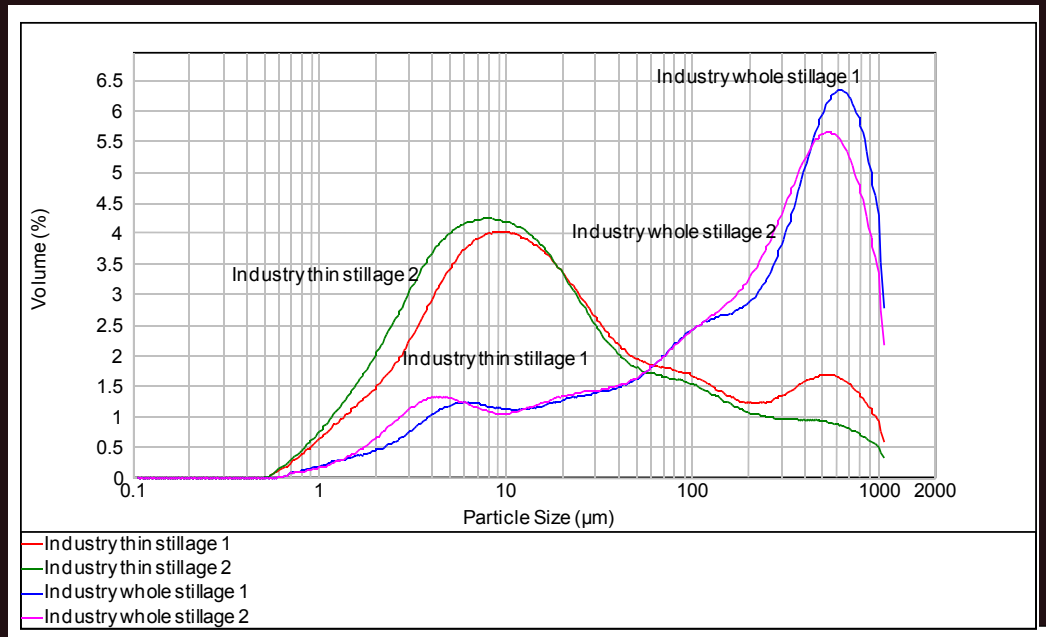


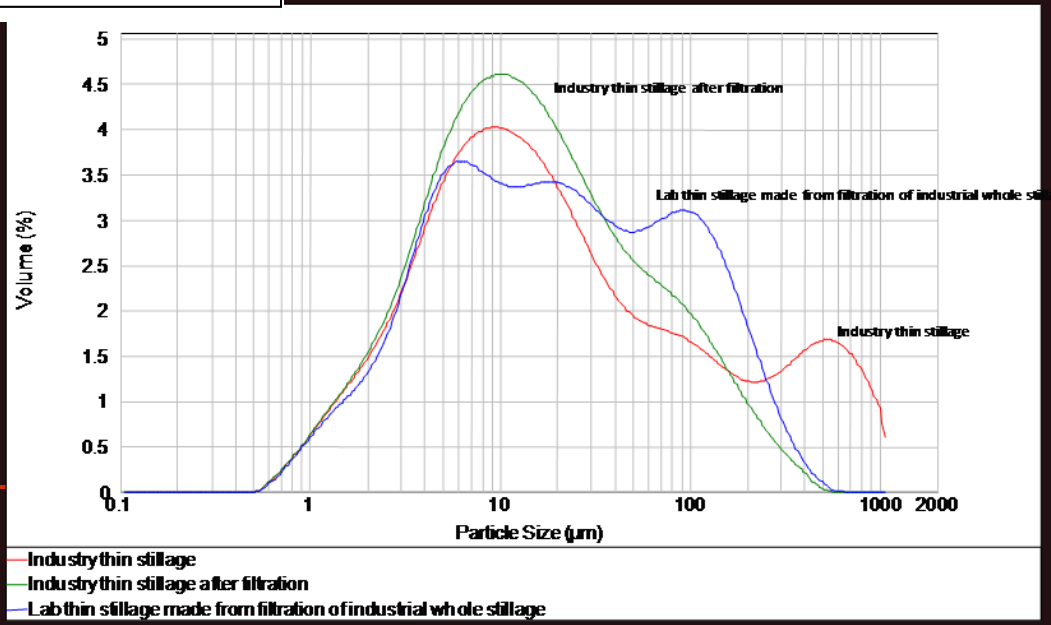
C: orientation during washing

Thin stillage composition by different treatment

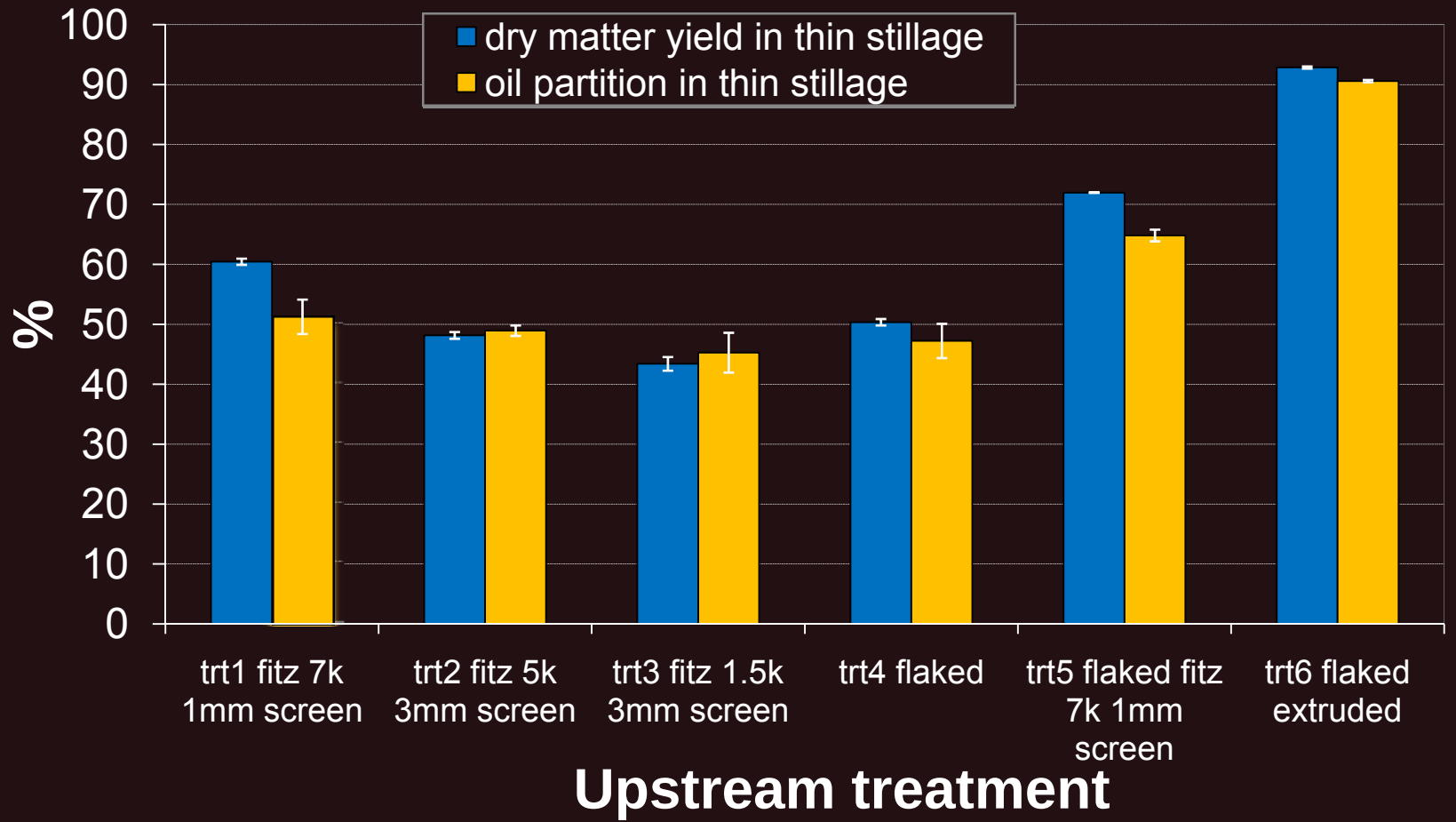
	Solids, %	Wet matter yield, %	Dry matter yield, %
Industrial decanting	7.19[a]	80.62[a]	45.27[a]
Lab centrifugation	5.08[b]	59.31[b]	23.17[b]
Lab 4MWCF	7.31[a]	83.26[a]	48.35[a]
$LSD_{0.05}$	0.79	3.27	7.12

Particle size distribution of stillages

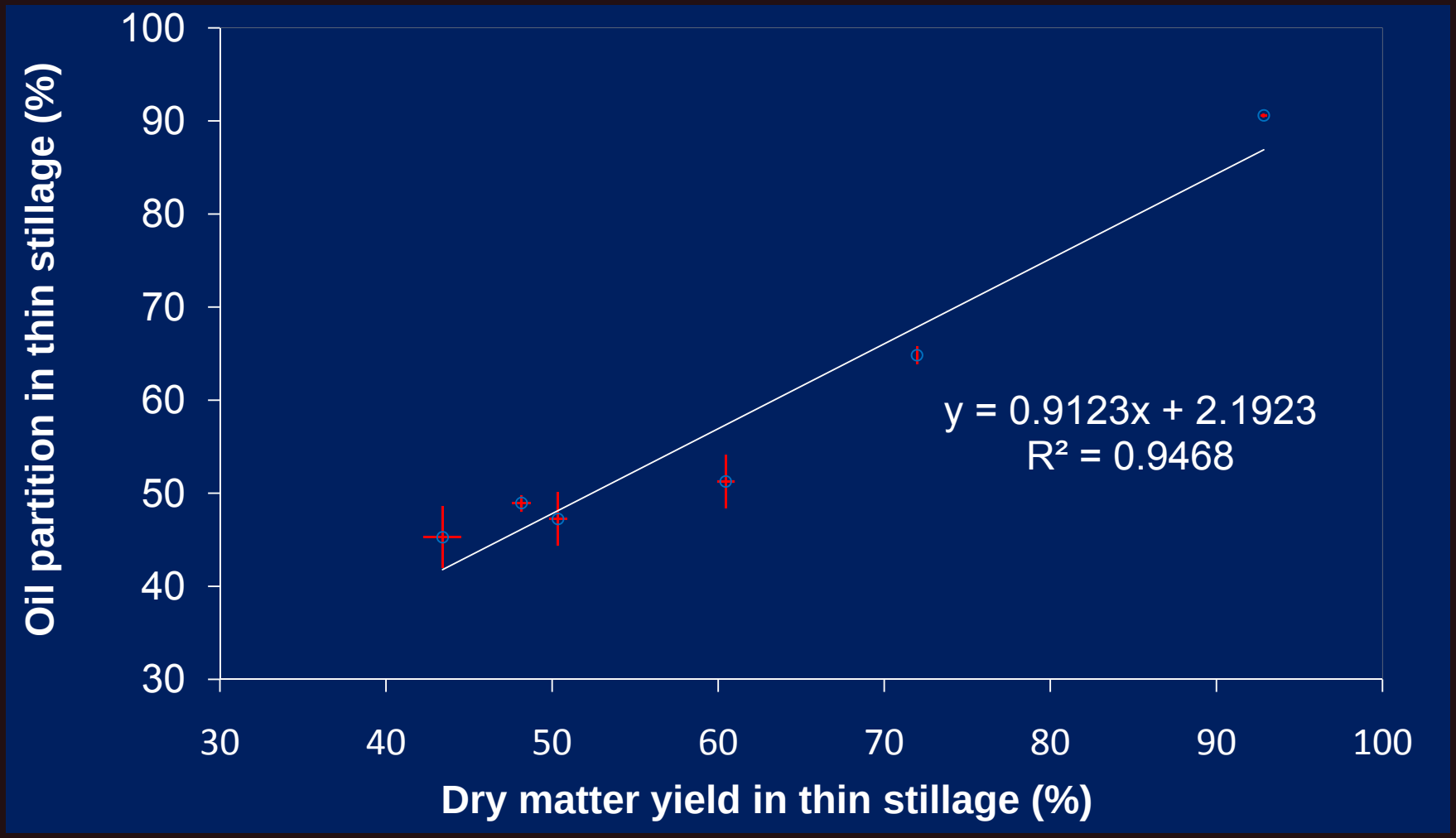




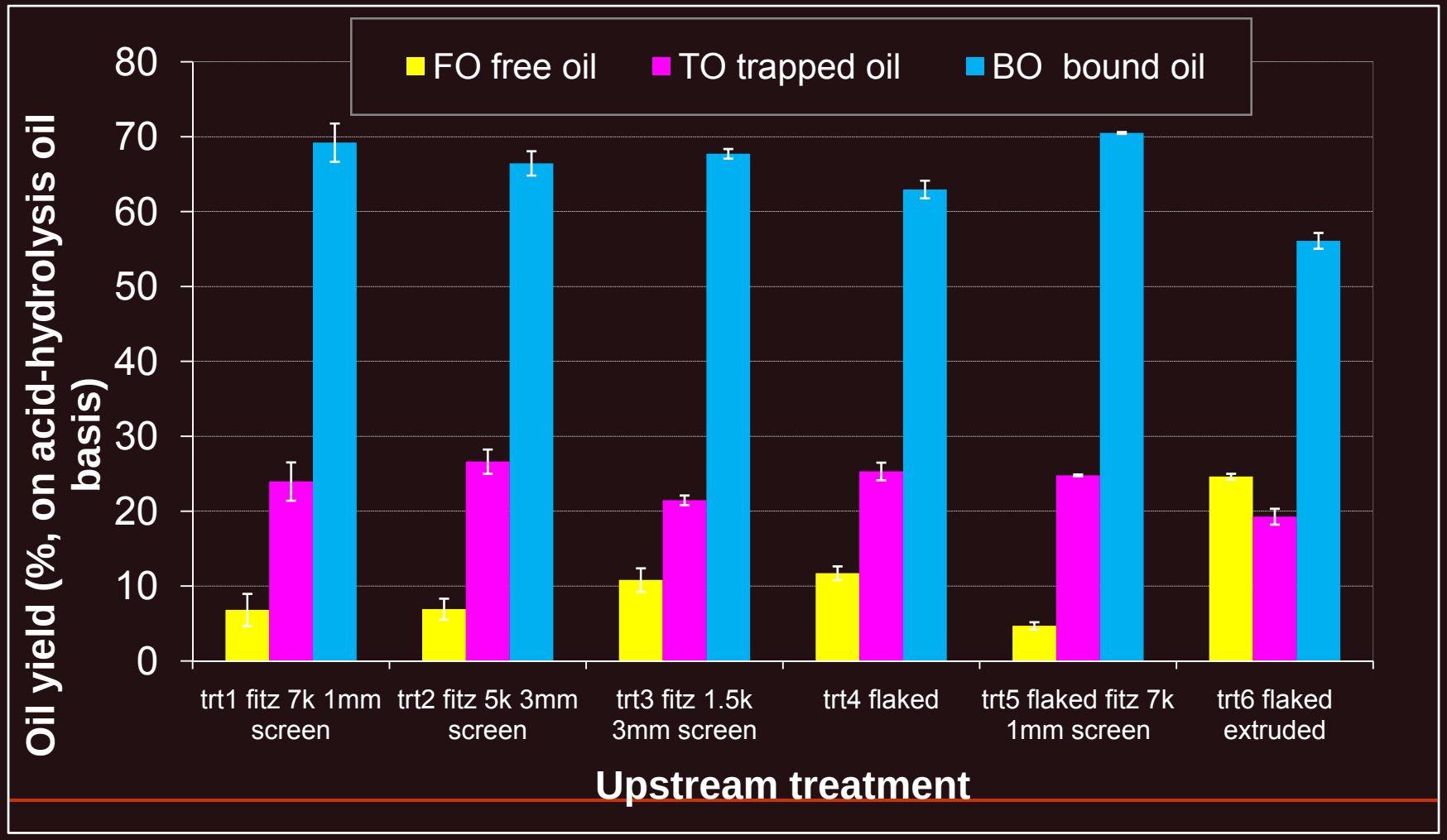
Effect of corn grinding method on dry matter yield and oil partition into thin stillage



Relationship between solid and oil distribution



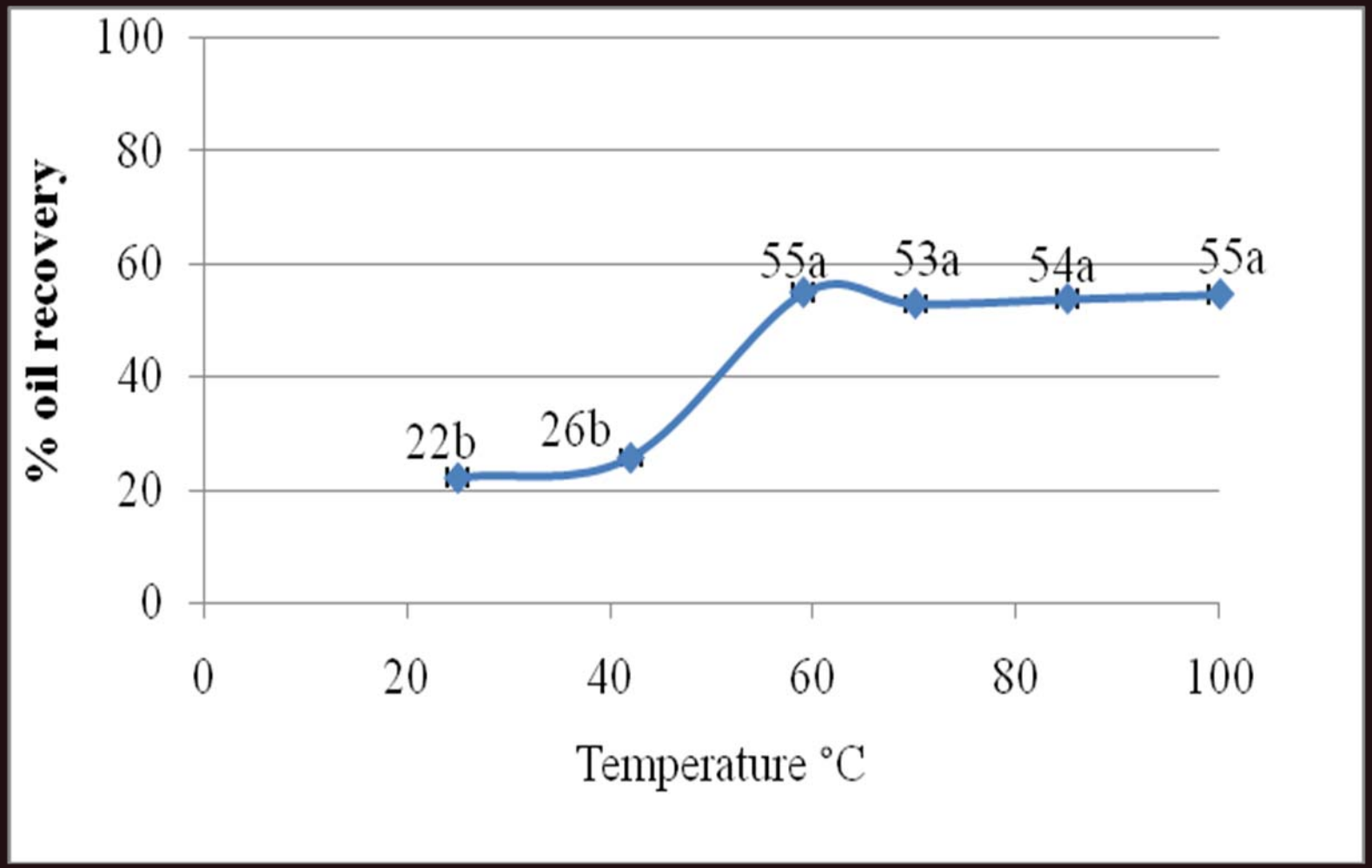
Effect of corn breaking method on the extractability of oil from fermentation mash



Oil recovery from the stillage

- Hypothesized forms of oil in stillage
  - O/W emulsion
  - Oil attached to hydrophobic surface
  - Oil bodies in coarse germ particles
- Enzymatic treatment
  - Cellulases
  - Proteases
  - Hemicellulases
- Physical treatment
  - Heating
  - Churning

Oil recovery – Effect of temperature



Effect of enzymes on oil recovery

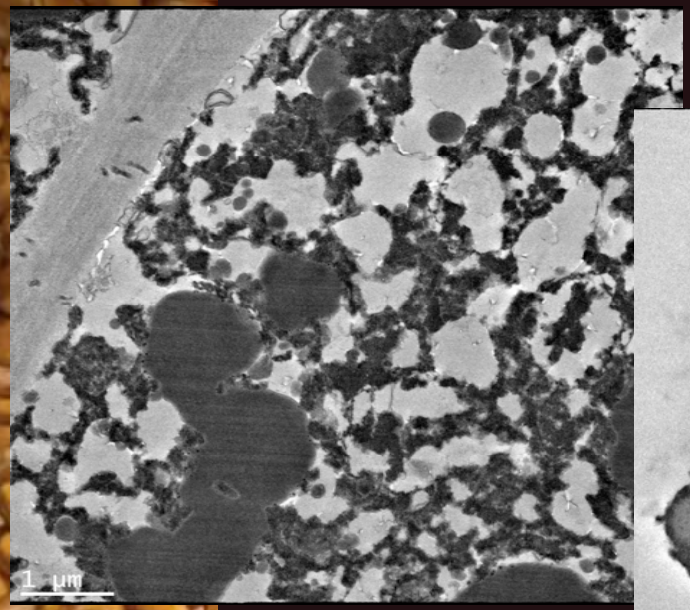
% Enzyme	[a] Acid Protease	[b] Cellulases
	% Oil recovery	
0	64.9 ± 0.3d	60.1 ± 1.9abc
1	68.4 ± 0.4c	62.1 ± 0.4abc
5	69.3 ± 0.5cb	64.0 ± 0.3a ←
10	70.3 ± 0.7ab ←	63.2 ± 1.3ab
15	70.1 ± 0.5ab	57.9 ± 1.9c
20	70.5 ± 0.2a	59.1 ± 3.9bc

- [a] Protex™ 13FL from *Aspergillus niger:* pH 3.0, 50° C
- [b]Multifect® CX GC from *Trichoderma reesei:* pH 4.0, 55° C
- Means followed by different letters in the same column are significantly different

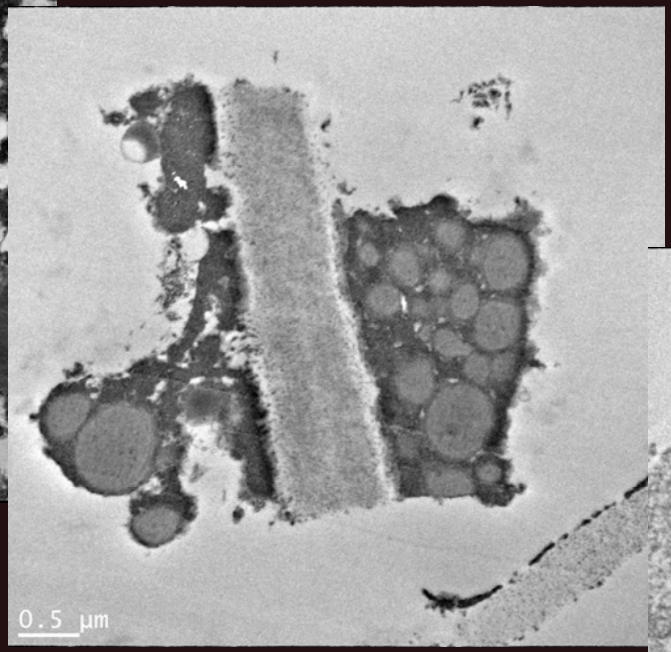
Effect of particle size reduction on oil recovery

Enzyme treatment	% oil recovery	
	No Grinding	Grinding
A combination of enzymes	80.7 ± 1.0ab	82.6 ± 0.9a
No enzyme control	78.4 ± 2.4b	82.2 ± 1.4a

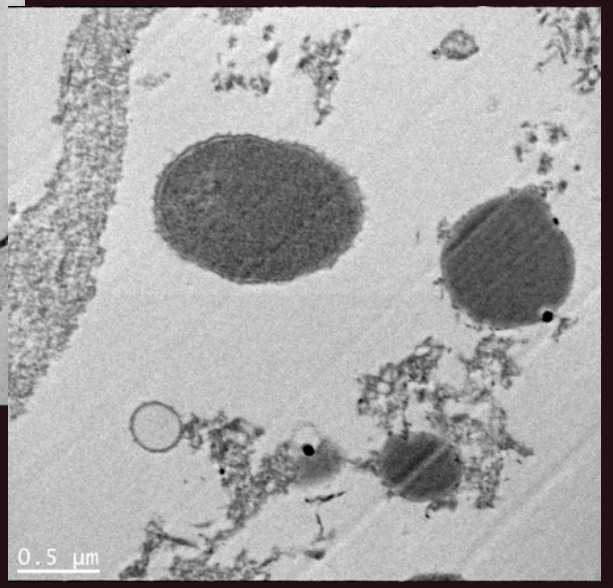
TEM images of treated stillage samples



Original stillage



Residue stillage after blending



Residue stillage after enzymatic hydrolysis

Effect of churning on oil recovery

Treatment	% Average oil recovery	
	3-hour incubation	6-hour incubation
Multifect® FE + Protex™ 15L	78.6 ± 2.9	81.1 ± 14.8
No enzyme control	79.7 ± 1.9	75.0 ± 1.3

Conclusion

- Upstream proc
  - Cell disruption is needed for oil release, but it causes high meal fines in liquid
  - Oil partition in the liquid strongly correlates with solid content
- Downstream proc
  - Enzyme hydrolysis increases oil recovery slightly
  - Heating treatment effectively improves oil recovery
  - Churning is effective in coalescencing oil droplets

Acknowledgements

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