

Bioethanol Production from Municipal Solid Waste

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Background: MSW - rubbish or resources?

Composition of MSW	Average % Wt in MSW ¹	Biodegradability Fraction (%) ¹	Overall Biodegradability (%) ¹
Paper and card	27.8	100	27.8
Organics	34.3	100	34.3
Fines (< 10 mm)	1.3	60	0.8
Textiles	4.4	50	2.2
Miscellaneous combustible	10.5	50	5.2
Glass	7.5	0.0	0.0
Other non-combustibles	1.6	0.0	0.0
Plastic film	5.0	0.0	0.0
Ferrous metal	3.0	0.0	0.0
Non ferrous metal	0.9	0.0	0.0
Waste electrical and electronic equipment (WEEE)	0.3	0.0	0.0
Household hazardous waste (HHW)	0.2	0.0	0.0
Dense plastic	5.5	0.0	0.0
Total	100.0	-	69.3%

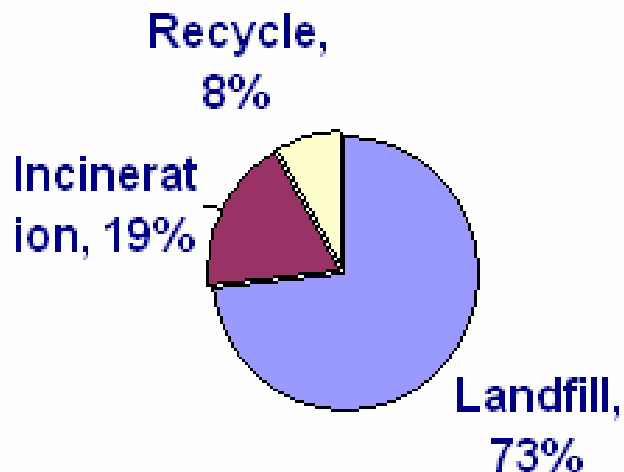
4.4 Million tonnes MSW produced in London in 2003

3% rising every year

- **Source:** Burnley S J, Coleman T and Gronow J R (1999) "The Impact of the Landfill Directive on Strategic Waste Management in the UK", Sardinia 1999 International Conference on Landfill.
- ¹ Dry matter basis

Background: MSW as Feedstock?

MSW disposal methods in London in 2003:

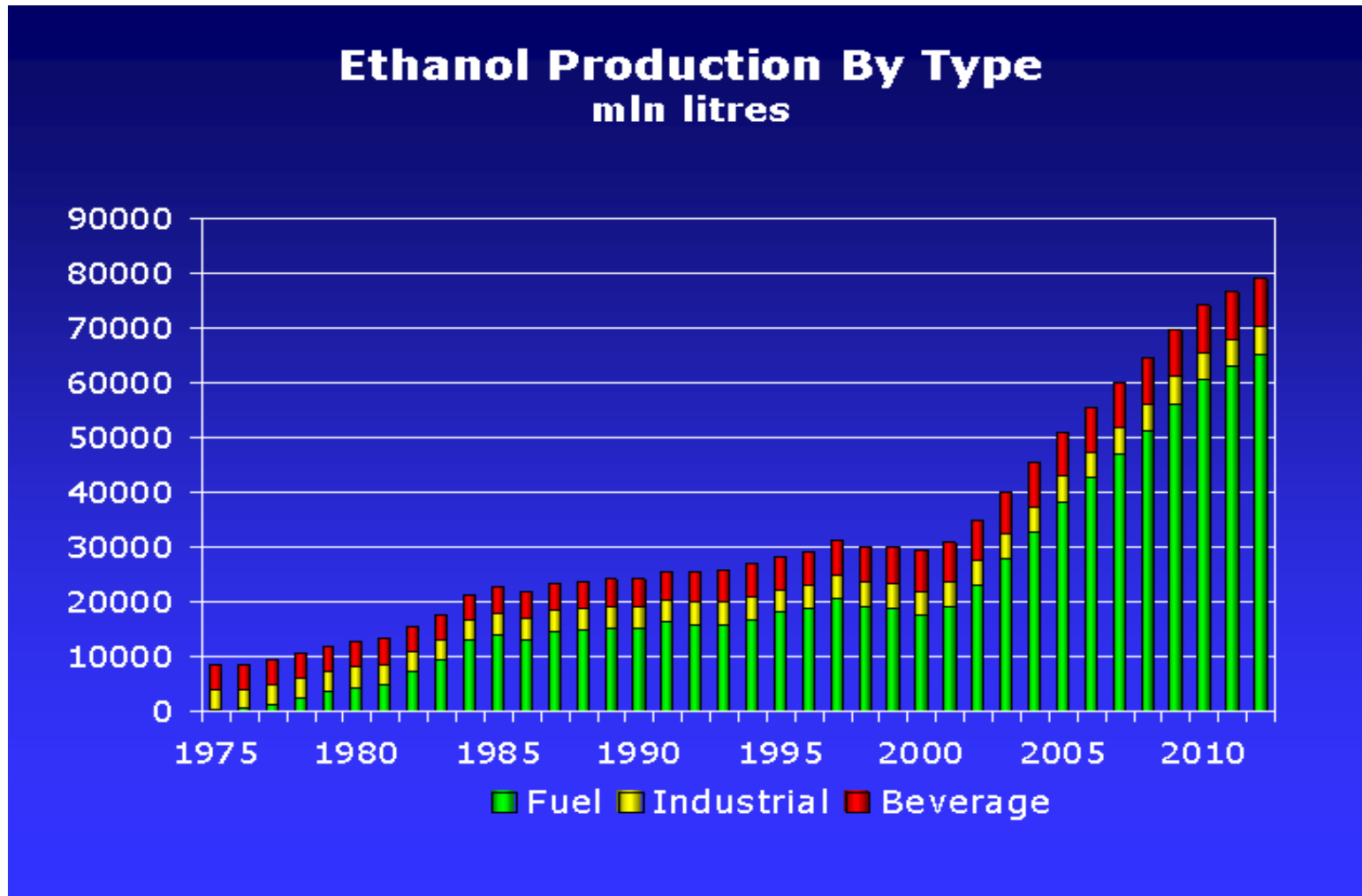


Source: Defra, UK

Reasons for MSW as biomass feedstock:

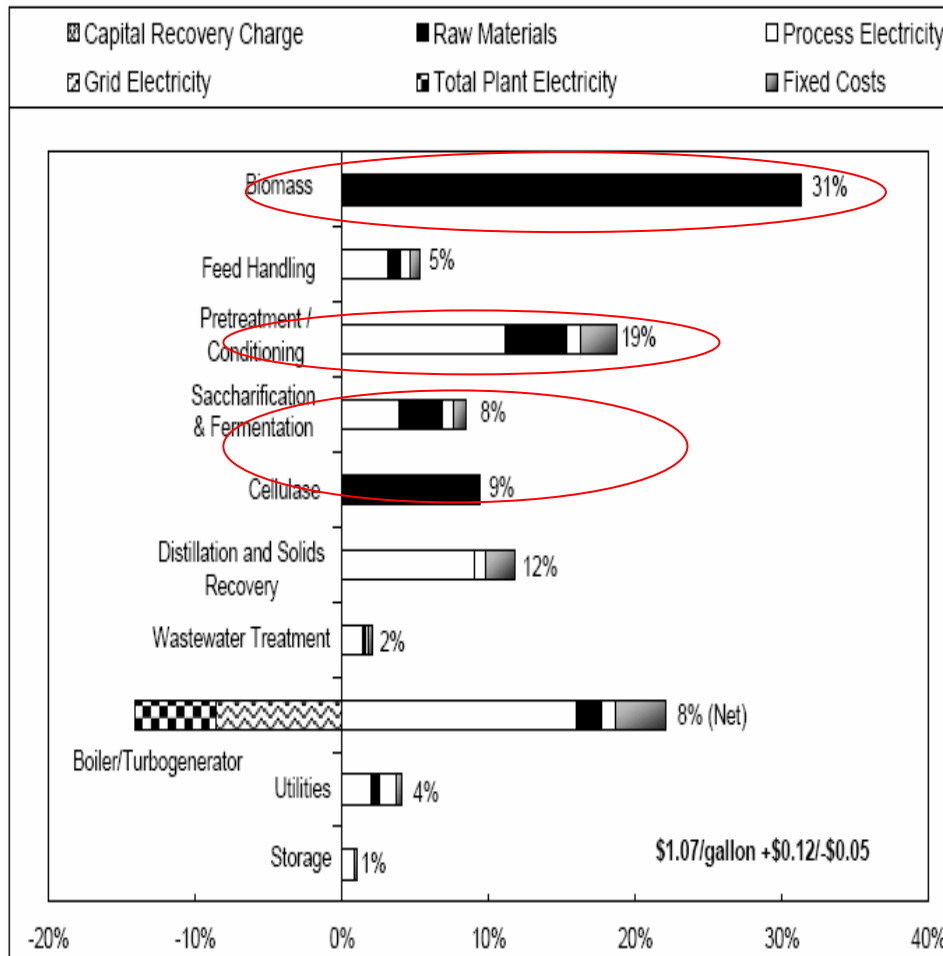
- Potential large biodegradable fraction: around 70% of total
- E.U. Directive 2003/30/EC requires to reduce biodegradable fraction to landfill by 25% by 2010, 50% by 2013, 65% by 2020
- Large quantity, low cost
- Economic benefits of “Rubbish to fuel (bioethanol)”

Background: Ethanol Market



- **Source:** Berg, C. (2004). World fuel ethanol analysis and outlook. F.O. Licht, Commodity Analysts. [URL: <http://www.distill.com/>]

Background: Ethanol process challenges



Cost Contribution Details from Each Process Area (% of Ethanol Selling Price)

Source: Wyman, C. E. (1999). Biomass ethanol: Technical progress, Opportunities, and Commercial Challenges. *Annu. Rev. Energy. Environ.* Vol 24. pp. 189-226.

Improving technology to reduce cost:

- Producing ethanol from abundant and cheap waste biomass
- Improved efficient pretreatment
- Increasing use of genetically-engineered organisms with improved properties for hydrolysis and fermentation
- Integrating process steps to reduce capital and operating cost

Previous Studies

- **Single Substrate**

Study on **used newspapers**, pretreated with aqueous ammonia-hydrogen peroxide solution¹, stated that more than 80% enzymatic digestibility can be obtained after 72 hours hydrolysis.

Most of the previous investigations have focused on **single substrates**, using **grass, corn stover** etc

- **Multi-substrates**

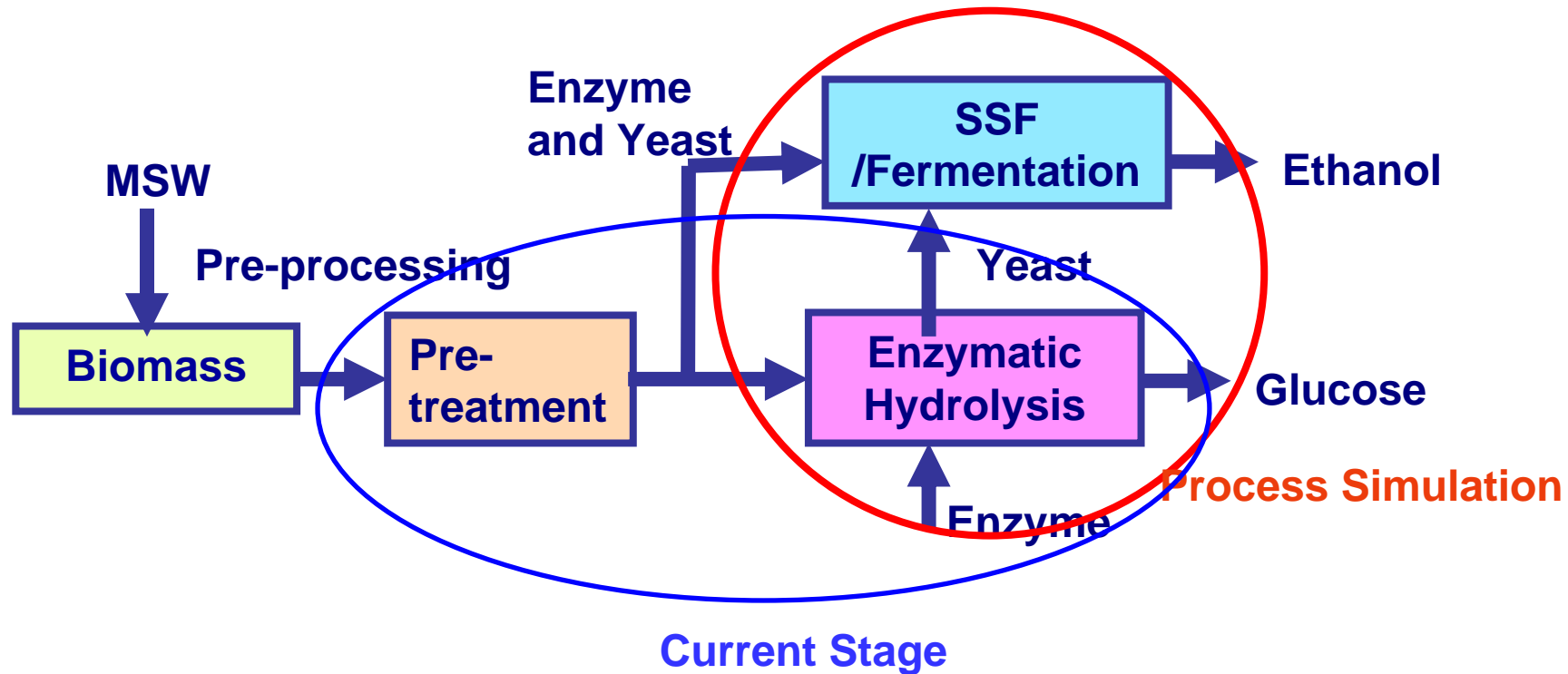
Investigation Of mixed waste, by combining **construction lumber waste, almond tree prunings, wheat straw, office waste paper, and newsprint**, with pretreatment method of dilute-acid hydrolysis², reported that 80-90% theoretic of glucose yield can be obtained with enzyme loading of 66 FPU after 100 hours hydrolysis.

Sources:

¹Kim, S. B. & Moon, N.K. (2003). Enzymatic digestibility of used newspaper treated with aqueous ammonia-hydrogen peroxide solution. Applied Biochemistry and Biotechnology. Vol. 105-108. pp. 365-373.

² Nguyen, Q. A., Keller, F.A., Tucker, M.P., Lombard, C.K., Jenkins, B. M, Yomogida, D. E., and Tiangco, V.M. (1999). Bioconversion of mixed solids waste to ethanol. Applied Biochemistry and Biotechnology. Vol. 77-79. pp. 455-472.

On-going Project

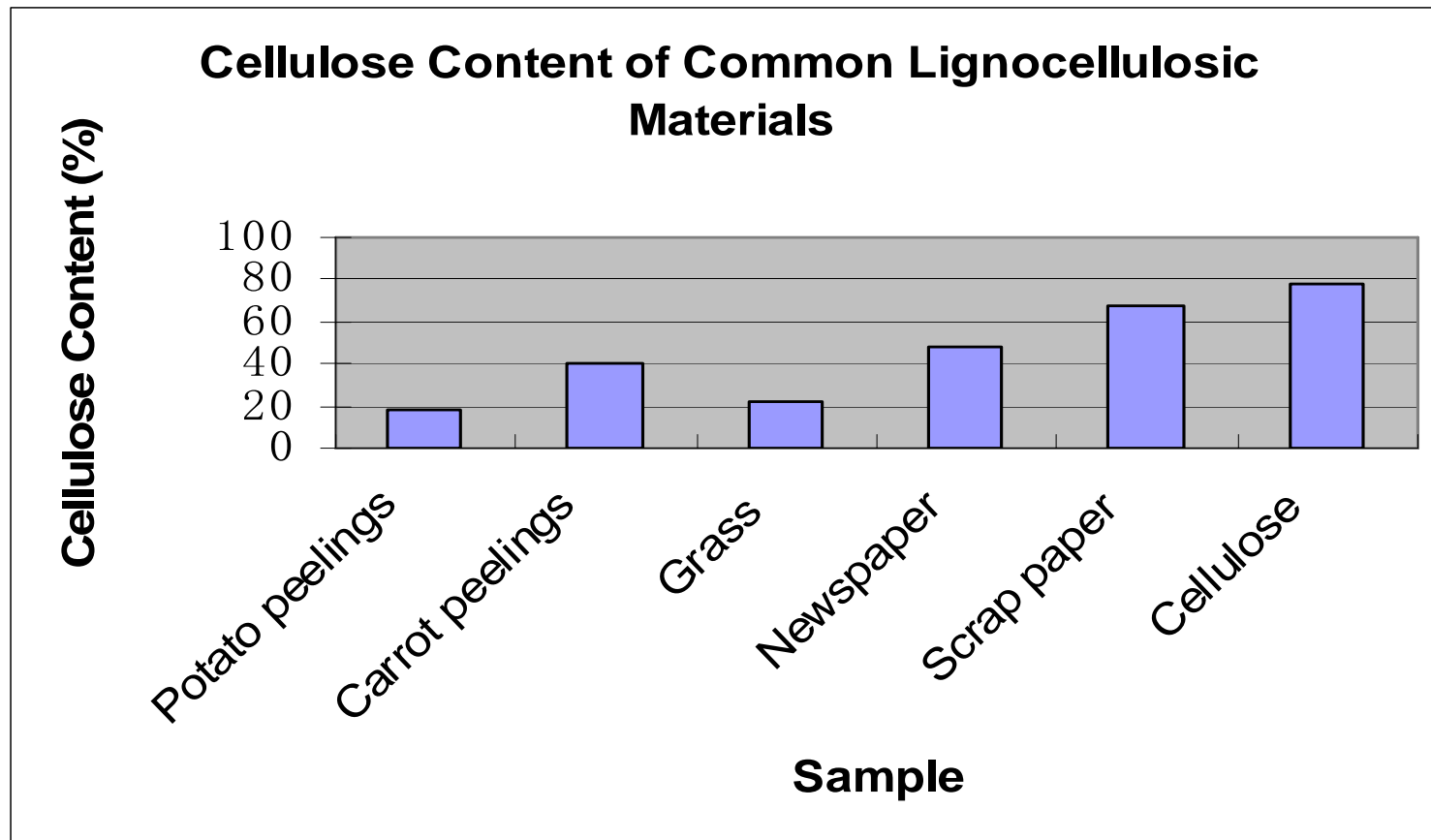


- MSW: Municipal Solid Waste
- MSW samples: Carrot peelings, potato peelings, grass, newspaper and scrap paper
- SSF: Simultaneous Saccharification and Fermentation

Ongoing project aims

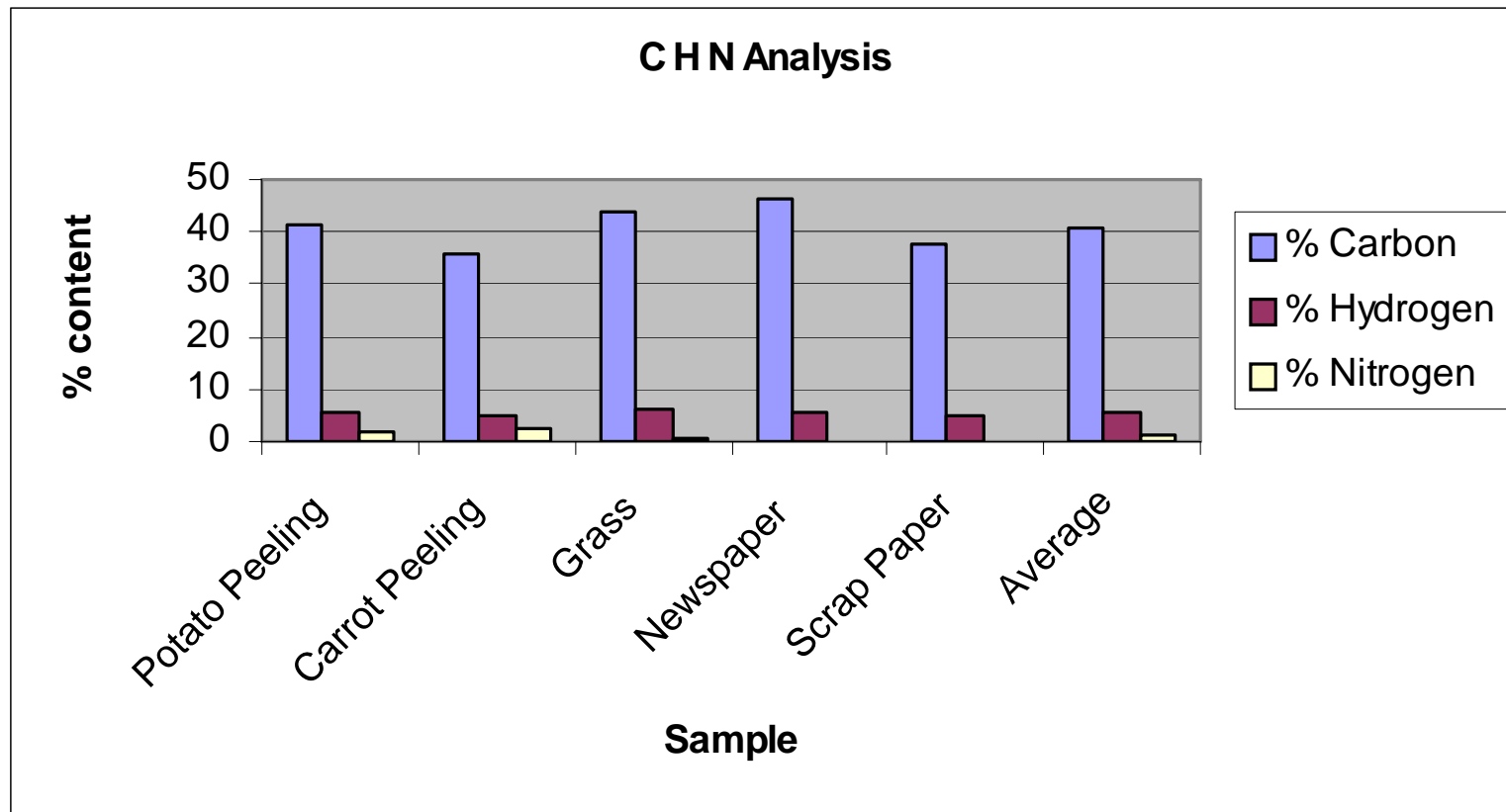
- Waste characterization
- Studying the possibility of MSW as biomass feedstock
- Investigation of effective pre-treatment methods
- Factorial experimental design with Design Expert software package
- Optimizing enzymatic hydrolysis process

Waste Characterization: cellulose content



Note: dry matter basis

Waste Characterization: CHN Analysis



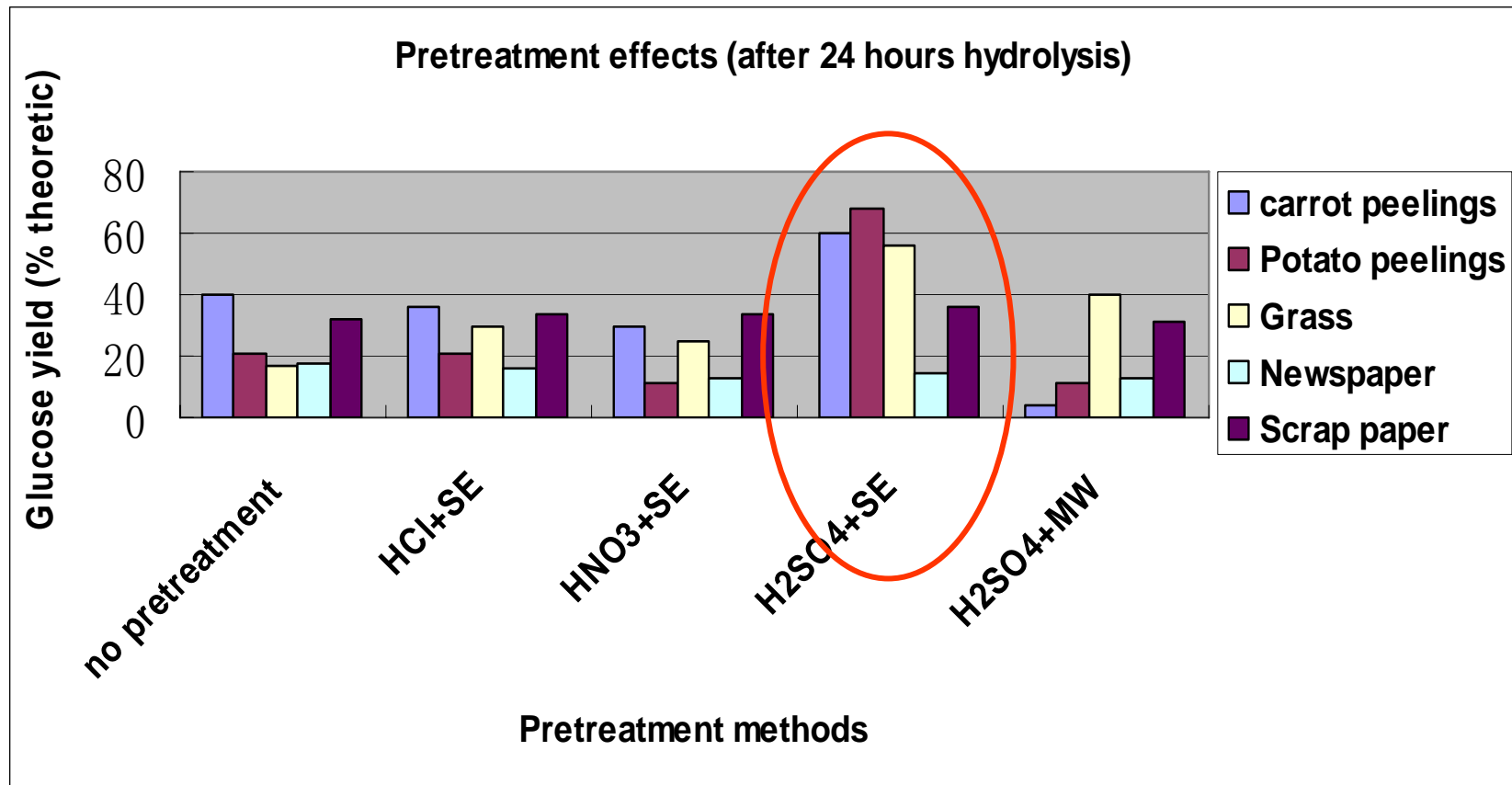
Note: dry matter basis

Waste characterization: Ethanol potential

- According to our preliminary studies, 1kg of selected wastes contains 0.41 kg carbon (average carbon content is 41.05%)
 - Percentage of carbon in glucose molecule ($C_6H_{12}O_6$): 40.00%
 - If 100% of the carbon present in selected wastes was converted to glucose, then the possible potential yield of glucose from **1 kg** of selected waste can be calculated.
 - Then, possible mass of glucose : 1.03 kg
 - Percentage of carbon in ethanol molecule(C_2H_6O) : 52.17%

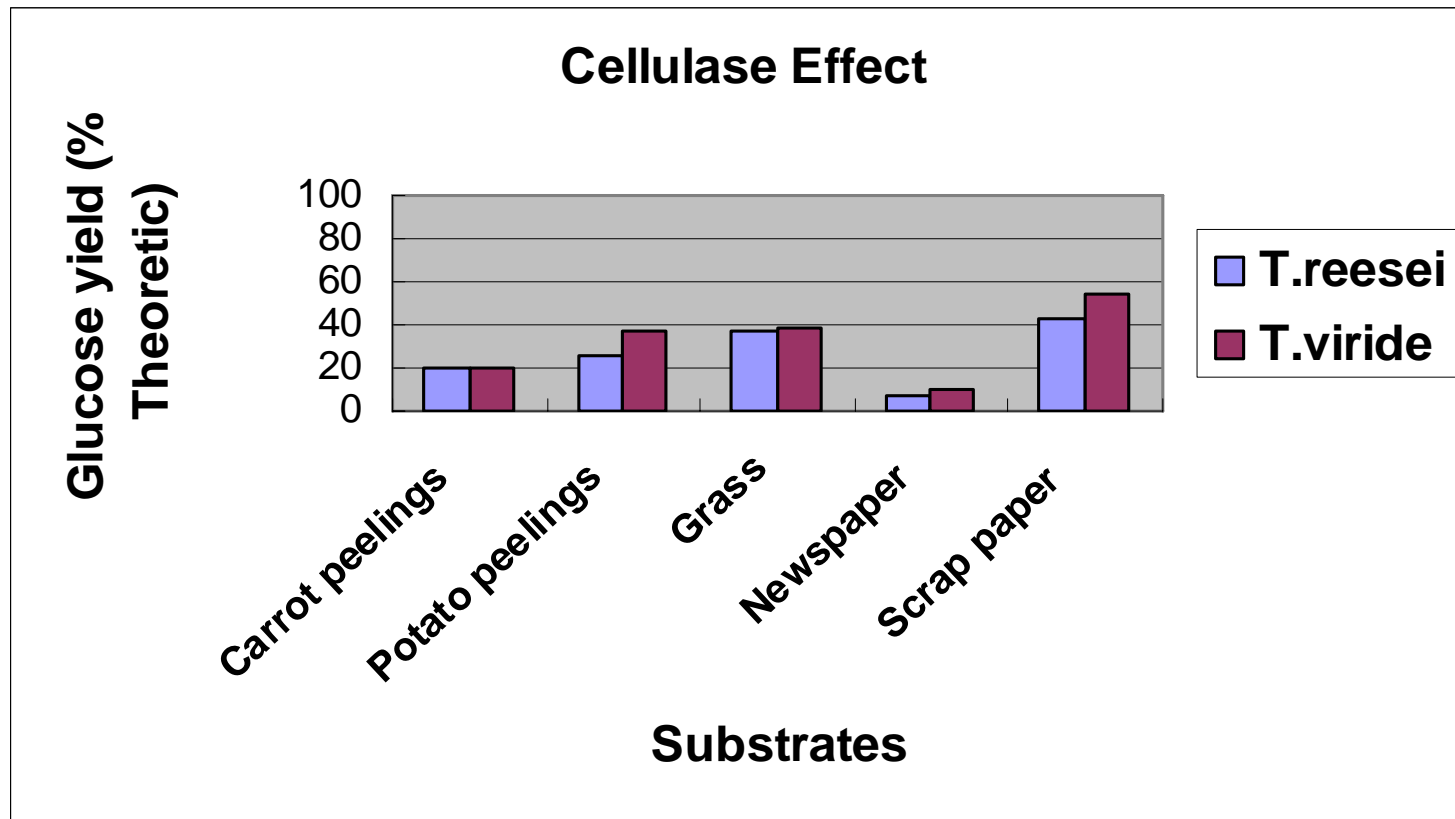
Therefore, the possible mass of ethanol that we could obtain from 1 kg of selected waste is **0.79 kg**

Current results: Pretreatment effects (24 hours)



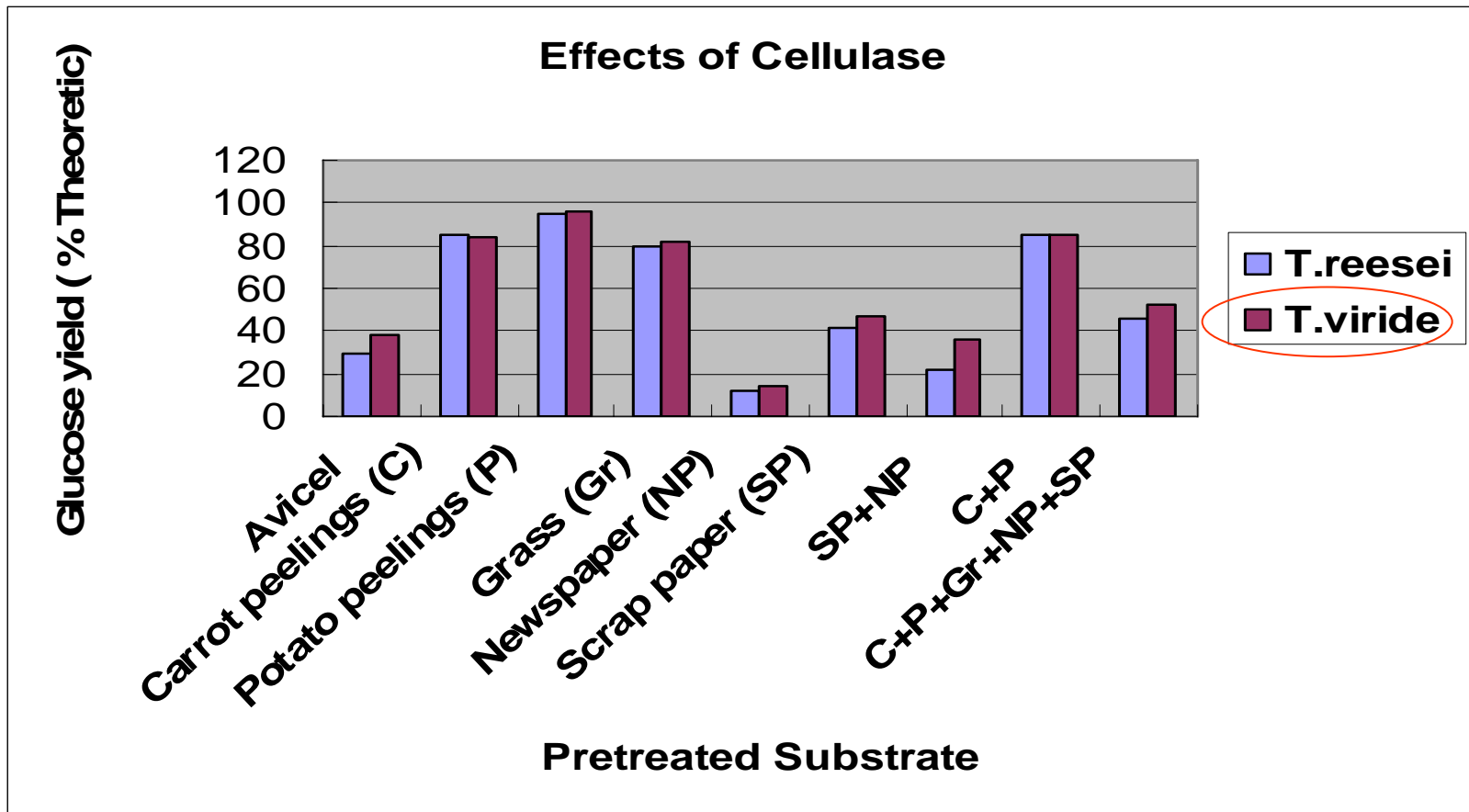
- HCl+SE: Dilute acid (Hydrochloric acid) hydrolysis + Steam Explosion
- HNO₃+SE: Dilute acid (Nitric acid) hydrolysis + Steam Explosion
- H₂SO₄+SE: Dilute acid (sulphuric acid) hydrolysis + Steam Explosion
- H₂SO₄+MW: Dilute acid (sulphuric acid) hydrolysis + Microwave treatment

Results: cellulase effects (without pretreatment)



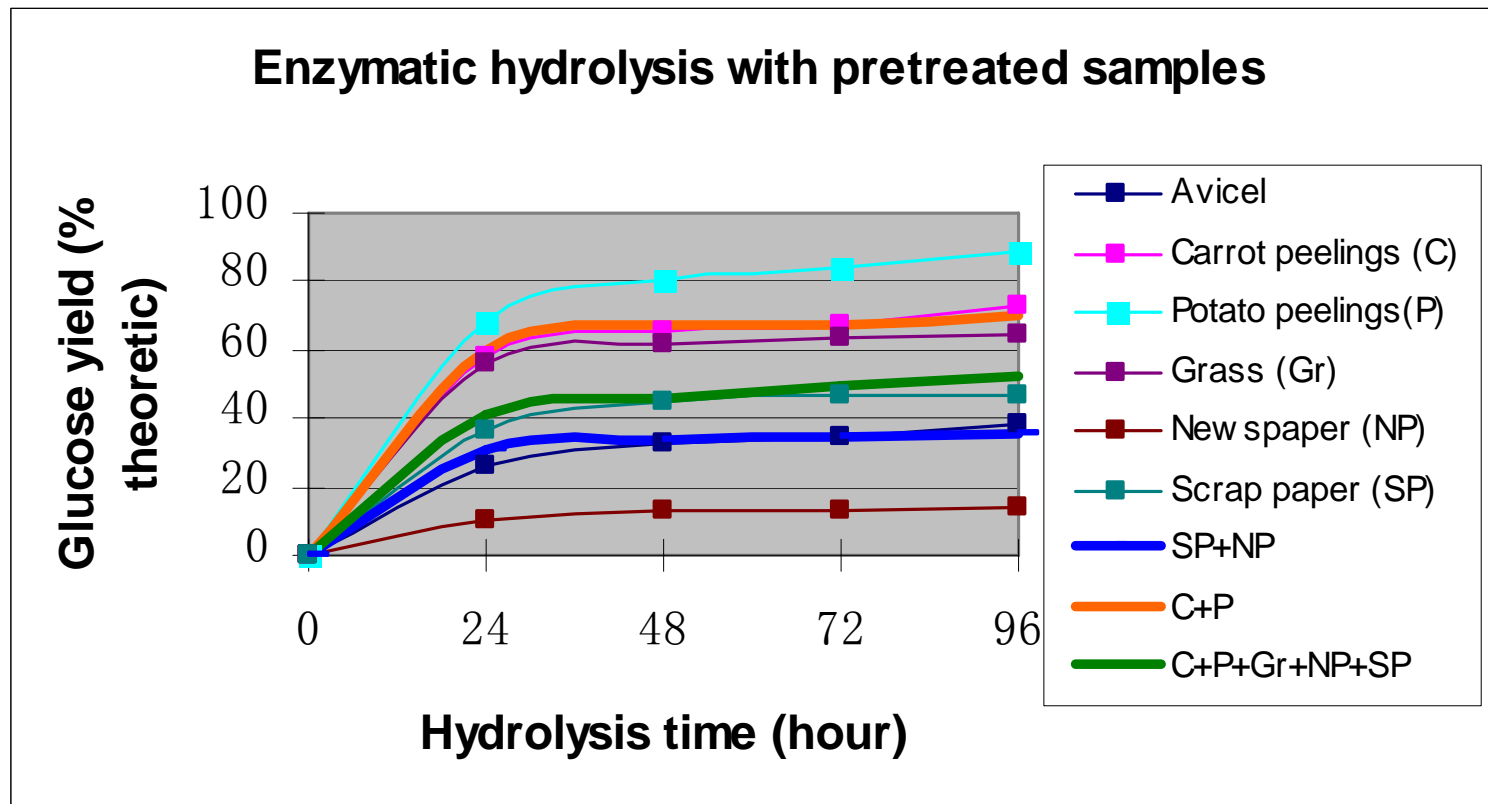
Hydrolysis condition: temperature 50°C, ph 4.8, enzyme loading 60 FPU, time 96 hours

Current Results: Cellulase effects (with pretreatment)



Hydrolysis condition: temperature 50°C, ph 4.8, enzyme loading 60 FPU, time 96 hours
 Pretreatment: H₂SO₄ + SE

Current results: Glucose yield (after pretreatment)



- Hydrolysis condition: temperature 50°C, ph 4.8, enzyme (*T. viride*) loading 40 FPU

Factorial experiment design

- **Sample:** Carrot peelings
- **Factors:** A, Acid concentration: 1% and 4%
 B, Temperature 121 and 134 °C
 C, Enzyme loading: 10 and 60 FPU

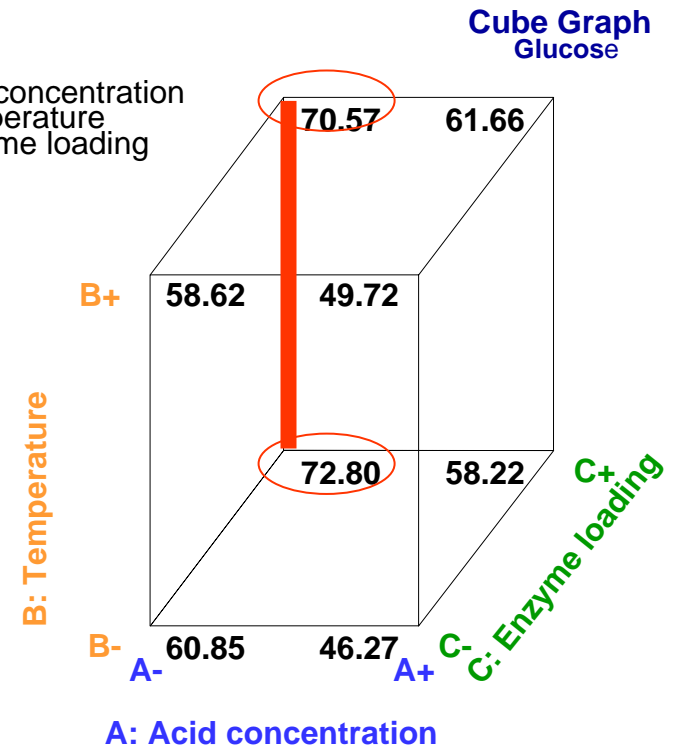
Time: 72 hours, pH 4.8
 Treatment: H₂SO₄ + SE
 Enzyme: T. viride
 Hydrolysis temperature 50°C

Experimental results

Run No.	Temperature (°C)	Acid concentration (%)	Enzyme loading (FPU)	Glucose yield (%)
1	121	4	60	61.16
2	134	1	60	72.50
3	134	4	60	61.16
4	121	1	10	65.21
5	134	4	10	50.22
6	134	1	10	56.70
7	121	4	10	43.34
8	121	1	60	68.45

Results from DESIGN-EXPERT Plot

X = A: Acid concentration
 Y = B: Temperature
 Z = C: Enzyme loading



Factorial experiment design

- **Sample:** Carrot peelings
- **Factors:** A, Acid concentration: 1% and 4%
 B, Temperature 121 and 134 °C
 C, Enzyme loading: 10 and 60 FPU

Time: 72 hours, pH 4.8
 Treatment: H₂SO₄ + SE
 Enzyme: T. viride
 Hydrolysis temperature 50°C

Comparison of Actual Value (AV) and Predicted Value (PV)

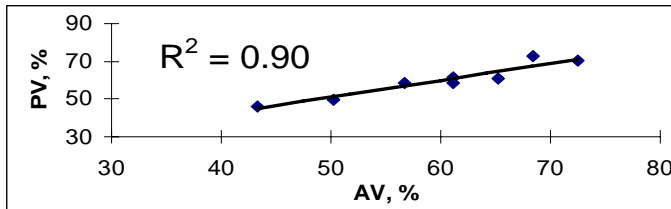
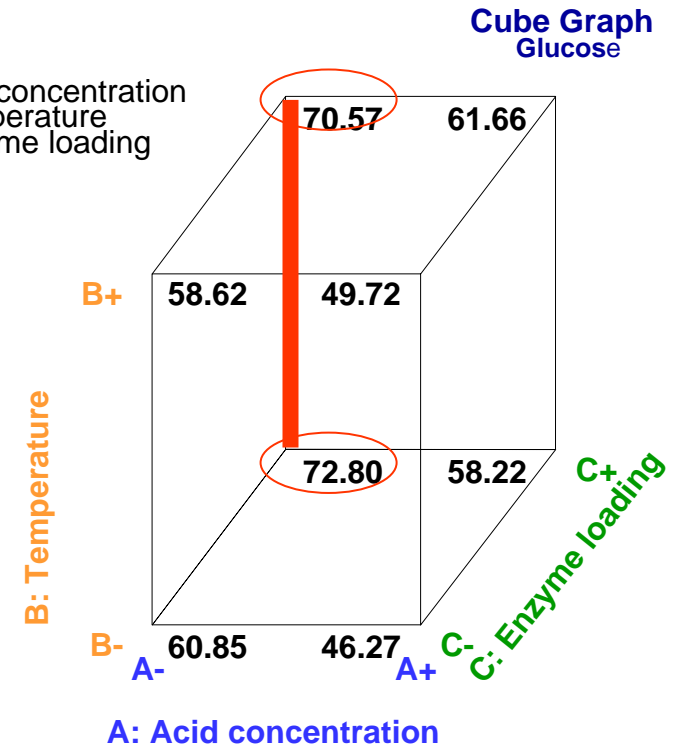


Table of factor effects

Factor	Effect	% Contribution
A (Acid concentration)	13.12	47.70
B (Temperature)	0.04	0.13
C (Enzyme loading)	13.58	49.39
AB (Acid concentration*Temperature)	0.76	2.78

Results from DESIGN-EXPERT Plot

X = A: Acid concentration
 Y = B: Temperature
 Z = C: Enzyme loading



Conclusions

- Pretreatment of **dilute sulphuric acid hydrolysis** followed with **steam explosion** did increase in general the rate at which the **maximum yield of glucose** was formed. However, this pretreatment did not give higher yields for newspaper wastes.
- Enzyme of **T.viride** is more **effective** on the selected wastes in general as well as the **multi-substrates** by combining the single substrates.
- This investigation reported the **glucose yields** produced by multi-substrates are higher than the average yield by single substrate.
- This study proved the possibility of using multi-substrates as ethanol feedstock and encouraged the **conversion of MSW to ethanol**.
- The **factorial experiment** results showed that **acid concentration** and **enzyme loading** have a **higher effect on glucose yield** within the temperature range of 121-134 °C.

Future work

- Greater biomass yield
- Other sugar analysis: including xylose, mannose, galactose, and arabinose
- Feedstock from pretreated waste (directly from bin, or separated)
- Ethanol production from fermentable sugars

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