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Bioethanol Production from Municipal Solid Waste

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- Previous studies
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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**
Tex[illegible]	[illegible]	[illegible]	**[illegible]2**
Miscellaneous combustible	**10.3**	**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	[illegible]	**[illegible]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%**

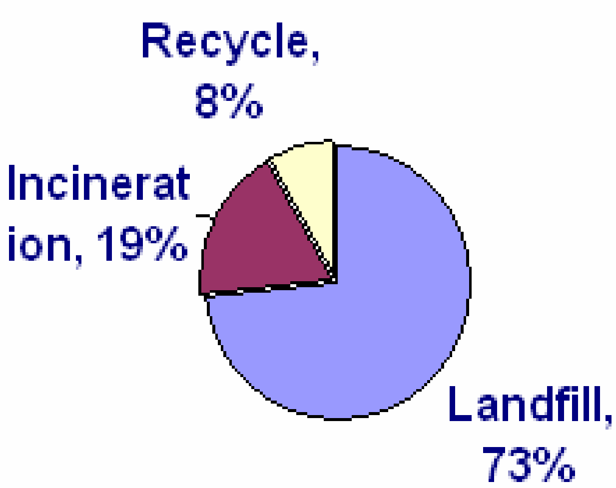
4.4 Million tonnes MSW produced in London in 2003

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:

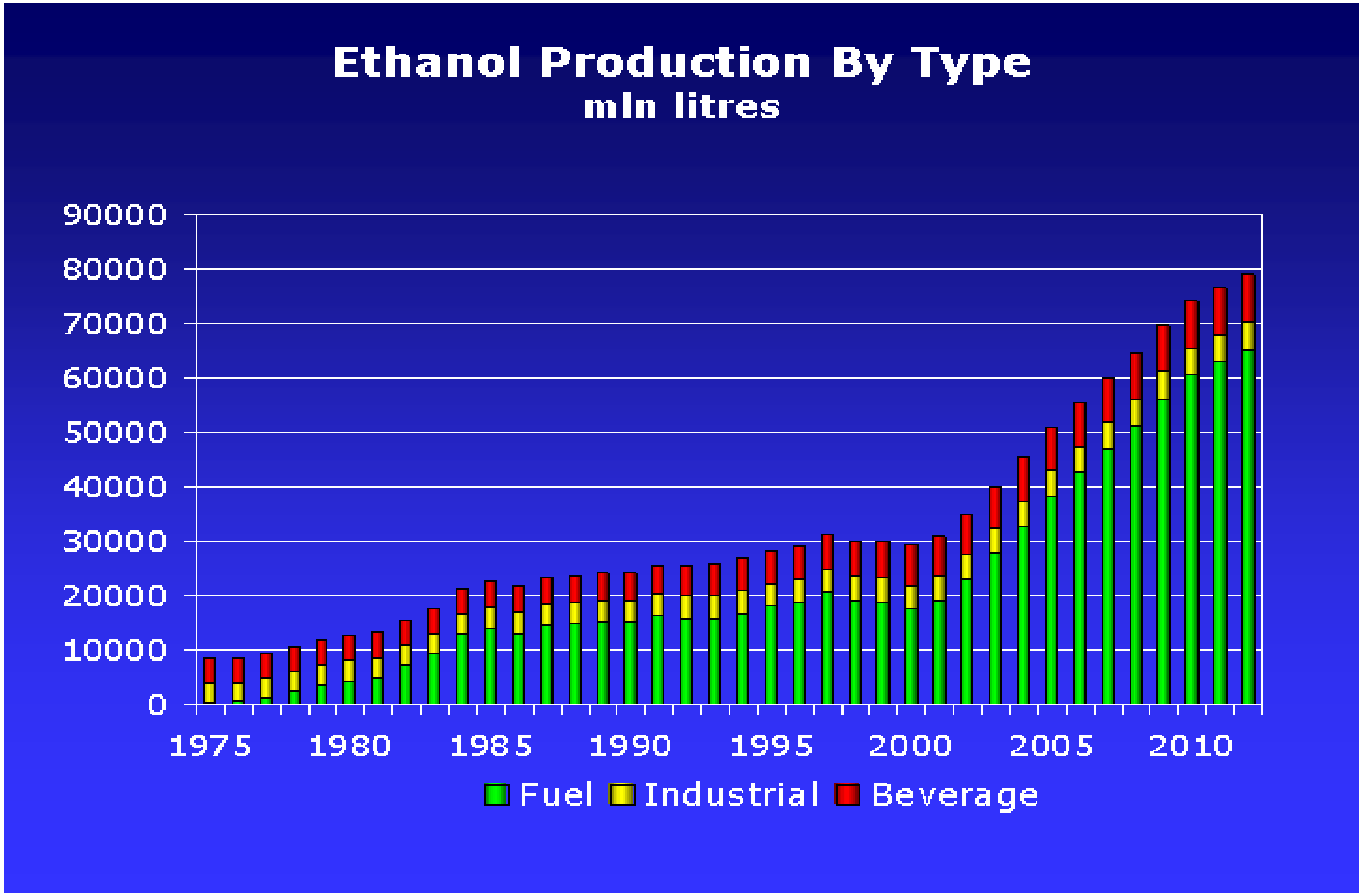


Source: Defra, UK

Reasons for MSW as biomass feedstock:

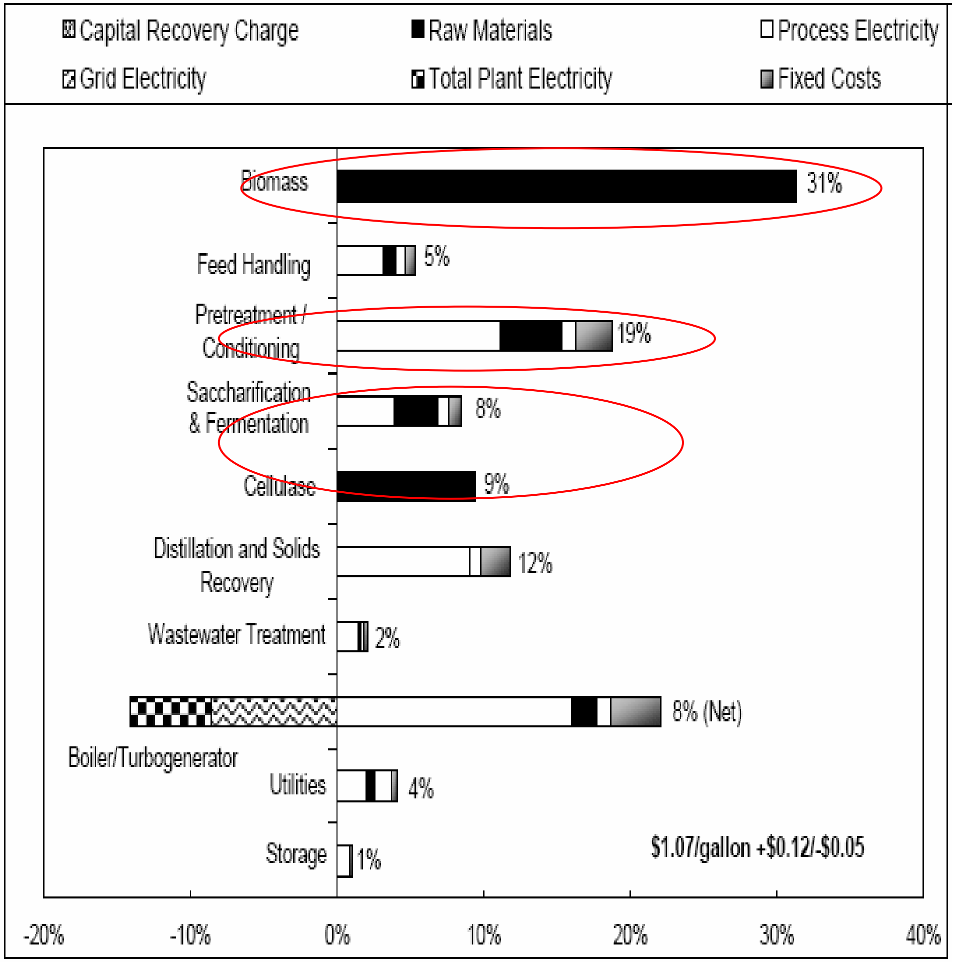
- Potential large biodegradable fraction: around 70% of total
- E.U. Directive 2003/30/EC requires to reduce biodegradable fraction to landfill by 25% by 2010, 50% by 2013, 65% by 2020
- Large quantity, low cost
- Economic benefits of "Rubbish to fuel (bioethanol)"

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 solution[1], 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**

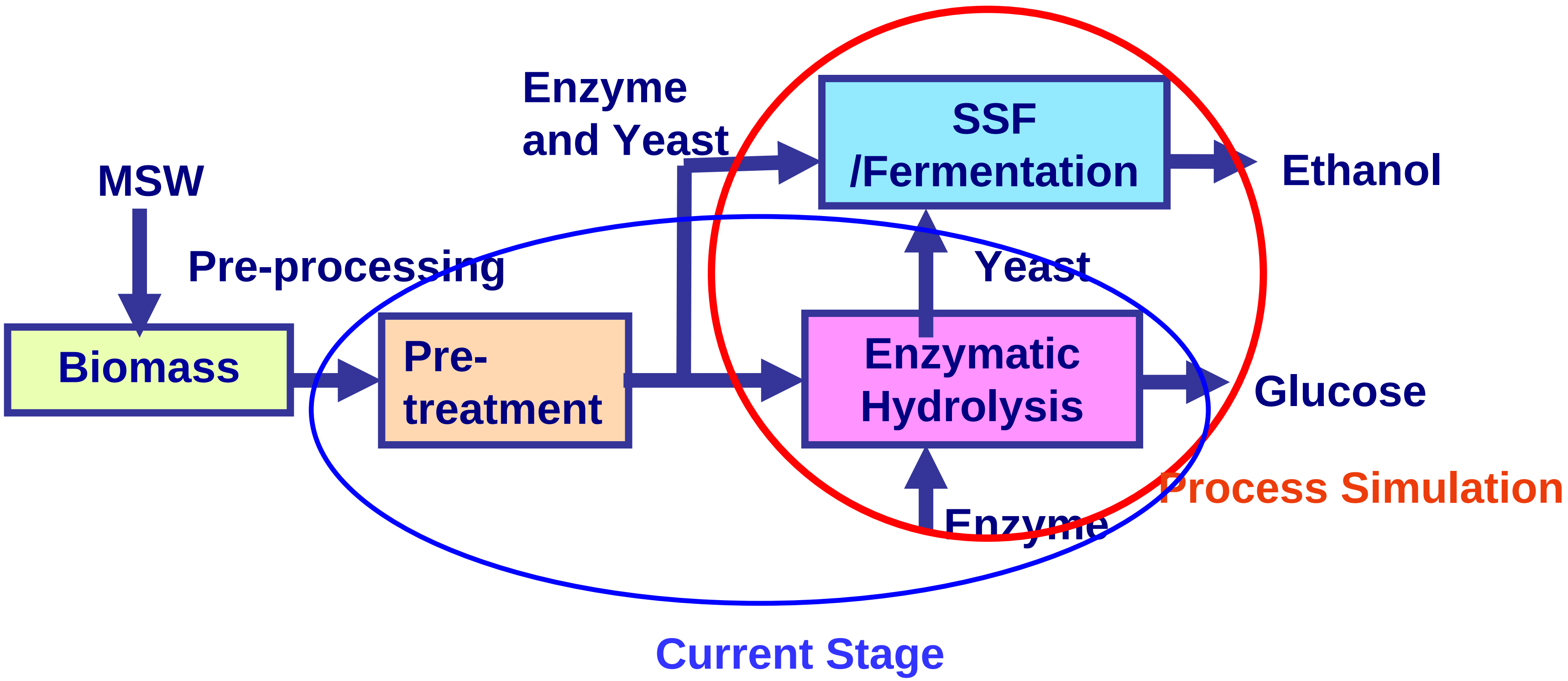
  Investigation of mixed waste, by combining **construction lumber waste, almond tree prunings, wheat straw, office waste paper, and newsprint**, with pretreatment method of dilute-acid hydrolysis[2], reported that 80-90% theoretic of glucose yield can be obtained with enzyme loading of 66 FPU after 100 hours hydrolysis.

Sources:

[1]Kim, 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

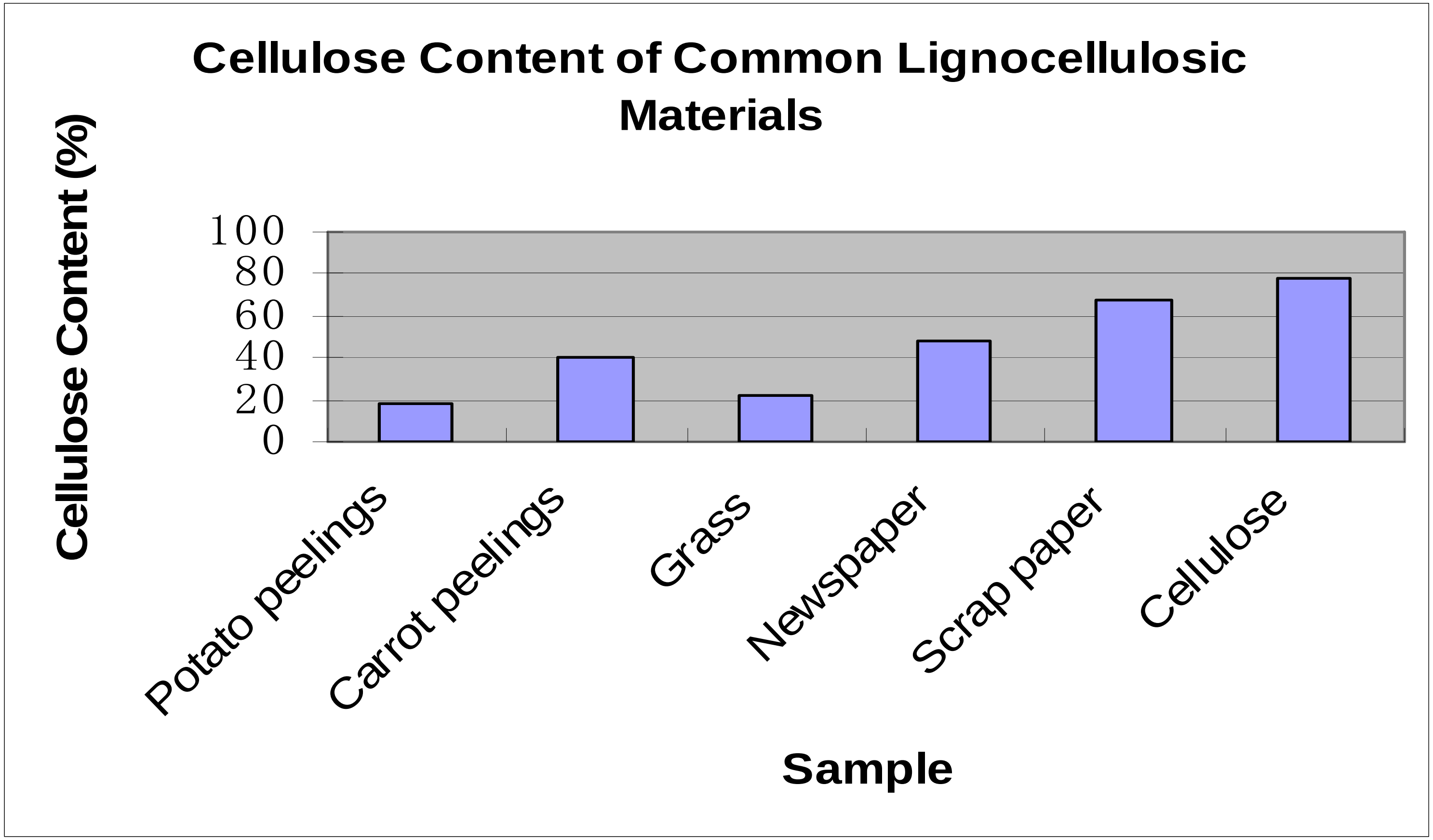


- MSW: Municipal Solid Waste
- MSW samples: Carrot peelings, potato peelings, grass, newspaper and scrap paper
- SSF: Simultaneous Saccharification and Fermentation

Ongoing project aims

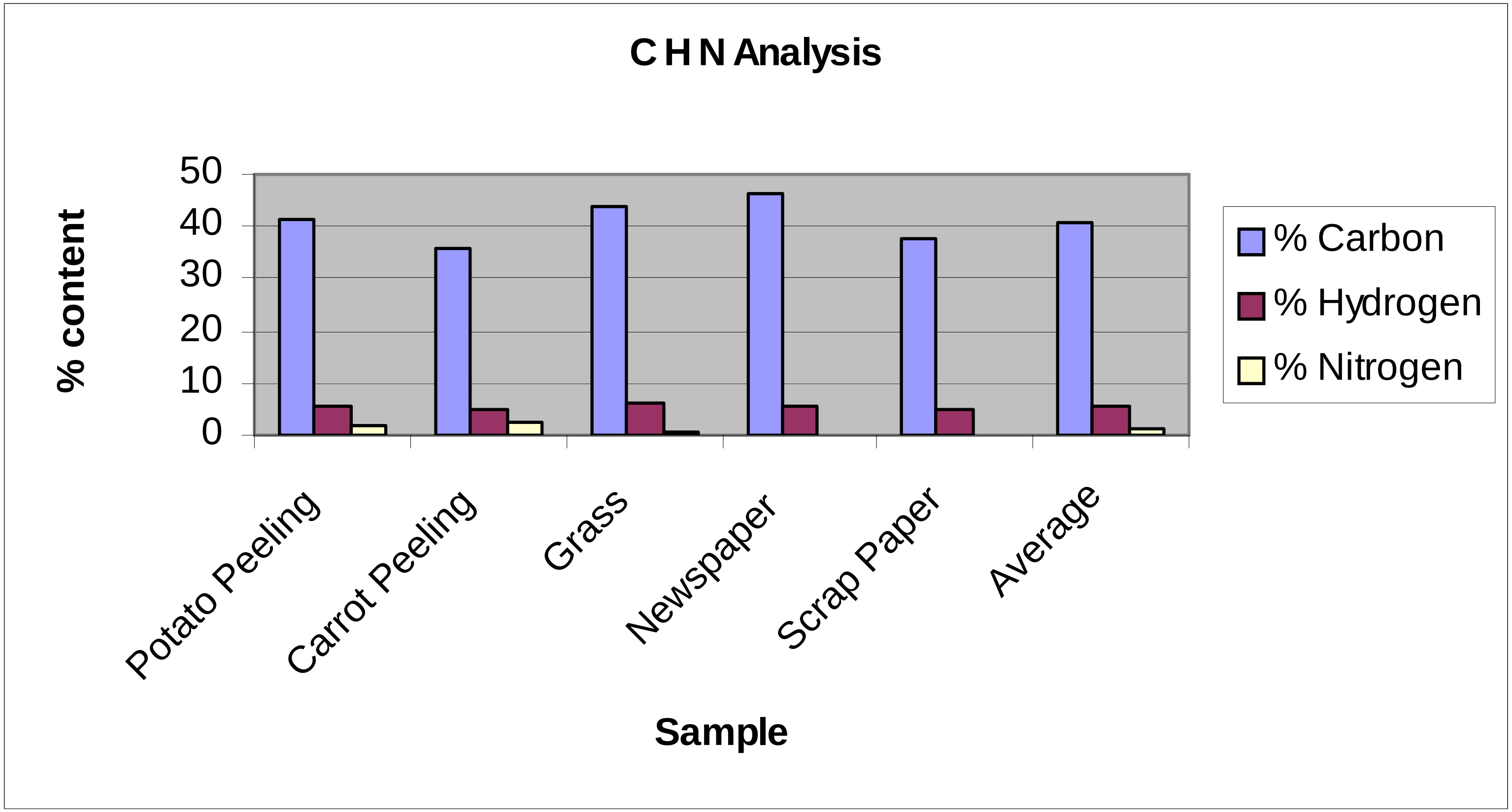
- Waste characterization
- Studying the possibility of MSW as biomass feedstock
- Investigation of effective pre-treatment methods
- Factorial experimental design with Design Expert software package
- Optimizing enzymatic hydrolysis process

Waste Characterization: cellulose content



Note: dry matter basis

Waste Characterization: CHN Analysis



Note: dry matter basis

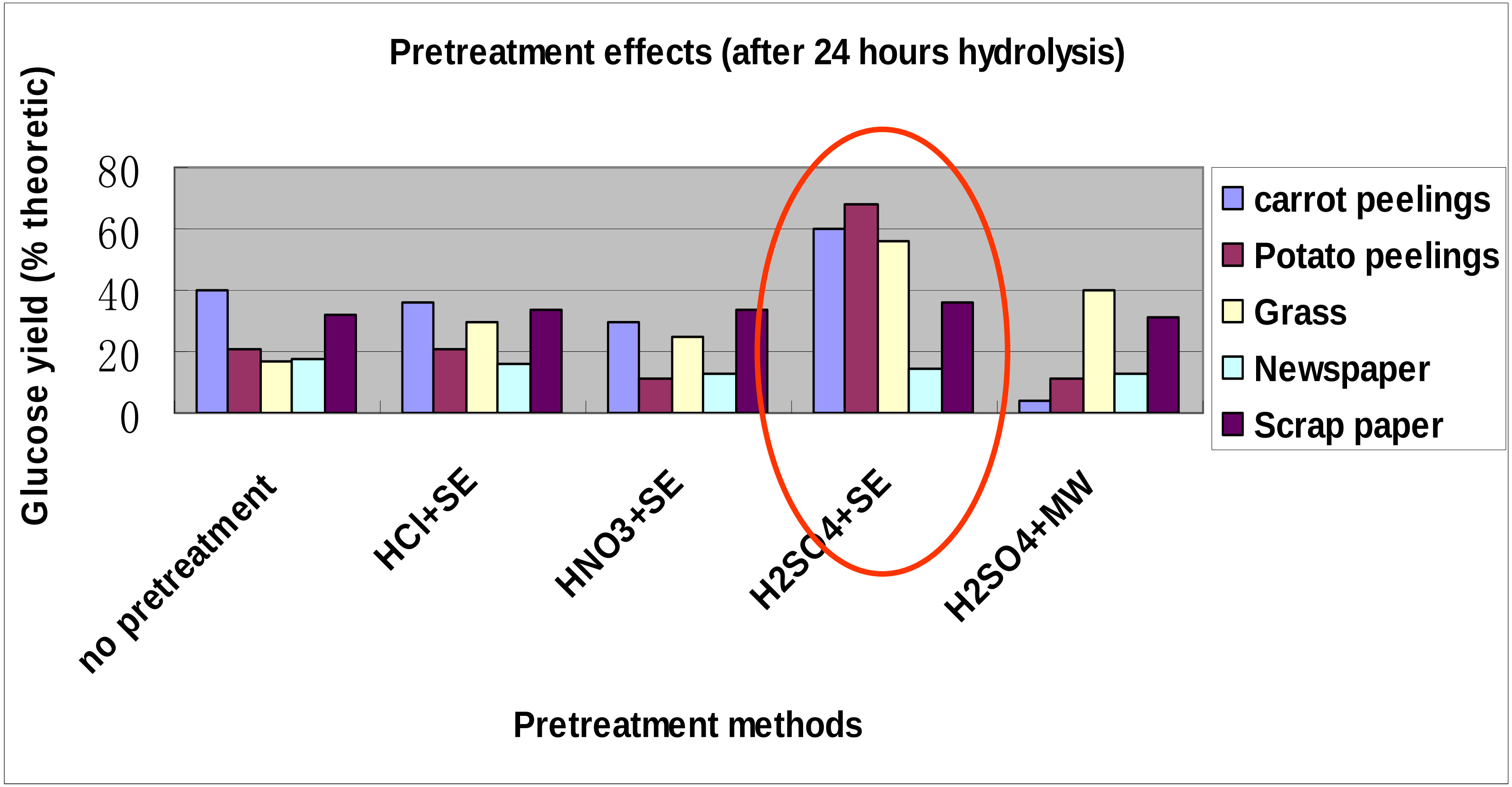
Waste characterization: Ethanol potential

- 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%

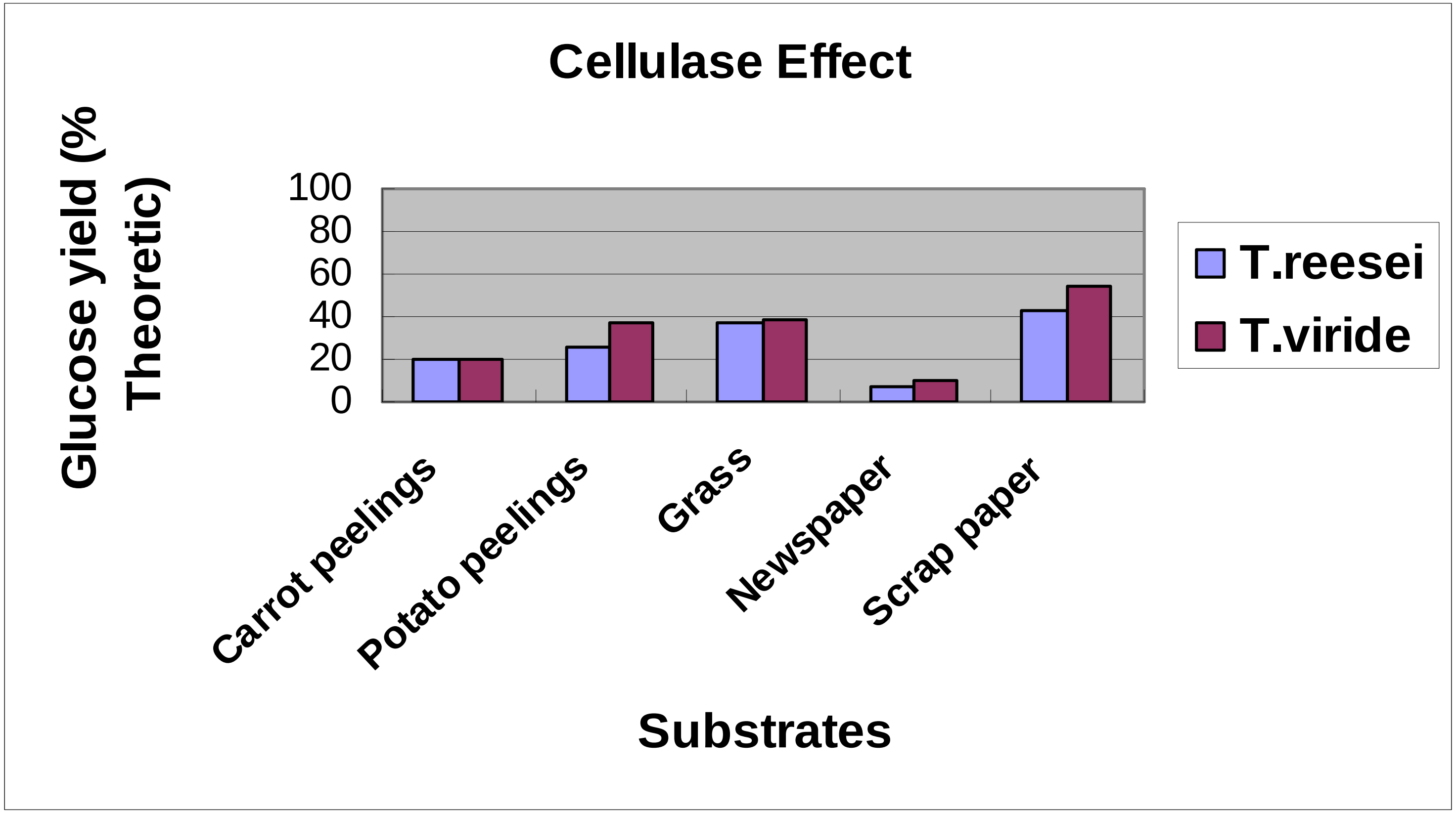
Therefore, the possible mass of ethanol that we could obtain from 1 kg of selected waste is **0.79 kg**

Current results: Pretreatment effects (24 hours)



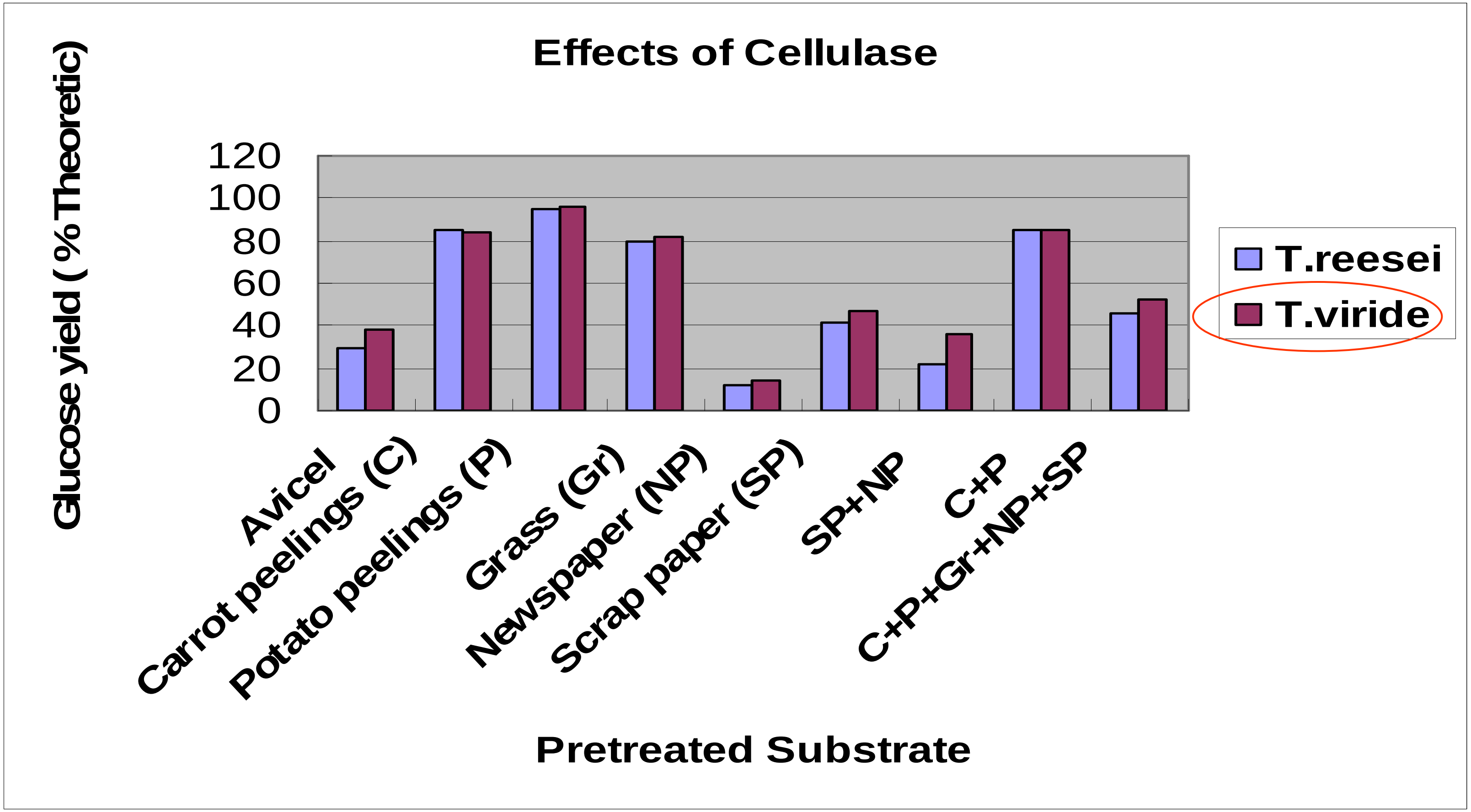
- HCl+SE: Dilute acid (Hydrochloric acid) hydrolysis + Steam Explosion
- HNO_3+SE: Dilute acid (Nitric acid) hydrolysis + Steam Explosion
- H_2SO_4+SE: Dilute acid (sulphuric acid) hydrolysis + Steam Explosion
- H_2SO_4+MW: Dilute acid (sulphuric acid) hydrolysis + Microwave treatment

Results: cellulase effects (without pretreatment)



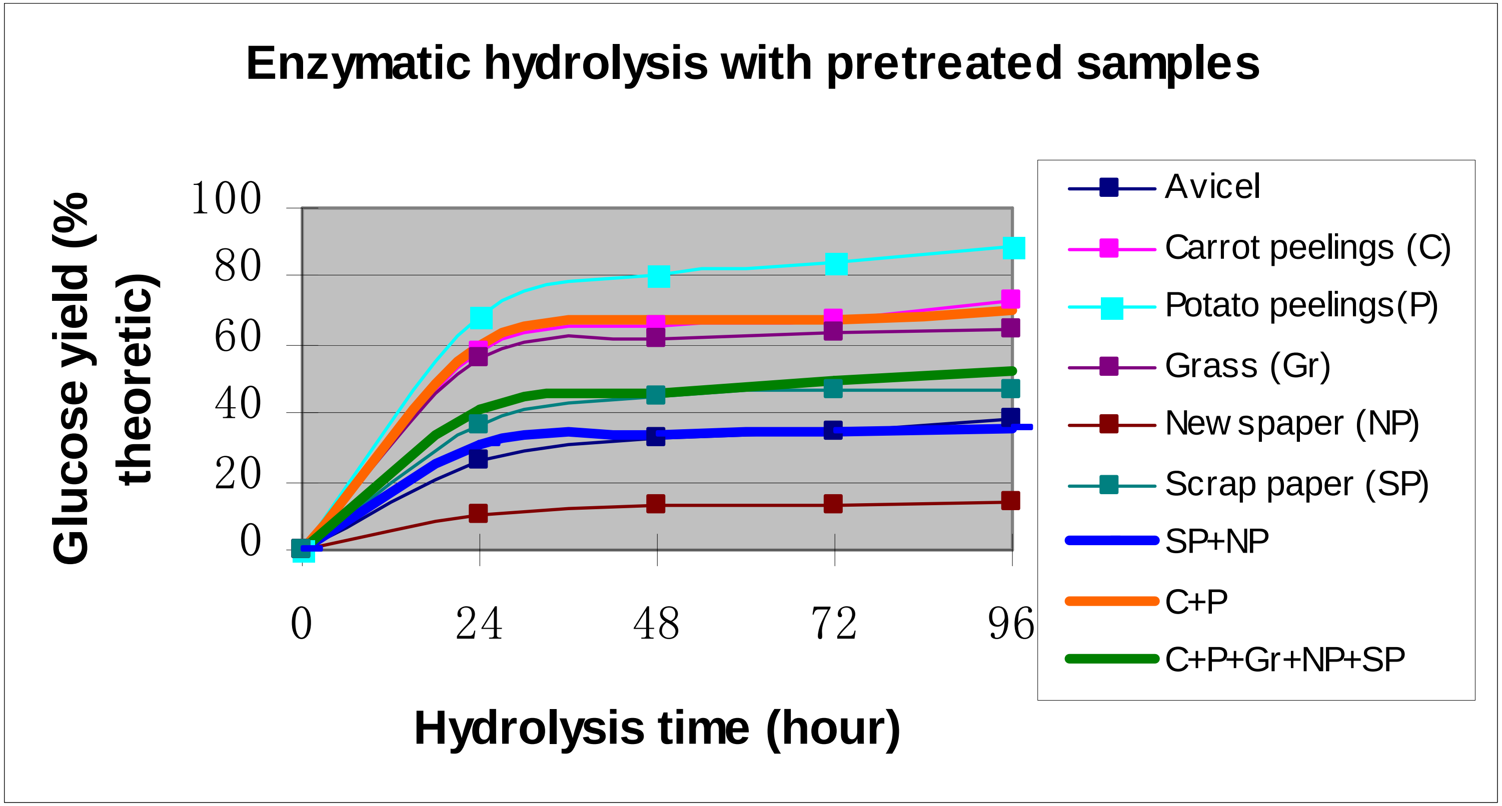
Hydrolysis condition: temperature 50°C, ph 4.8, enzyme loading 60 FPU, time 96 hours

Current Results: Cellulase effects (with pretreatment)



Hydrolysis condition: temperature 50ºC, ph 4.8, enzyme loading 60 FPU, time 96 hours
Pretreatment: H_2SO_4 + SE

Current results: Glucose yield (after pretreatment)



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

Factorial experiment design

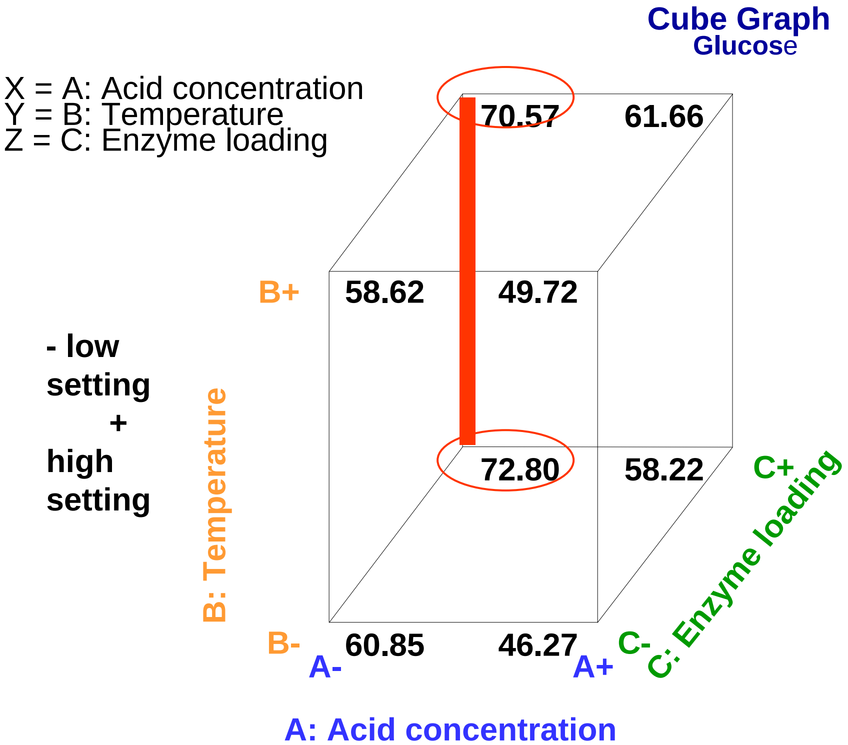
- **Sample:** Carrot peelings
- **Factors:** A, Acid concentration: 1% and 4%
  B, Temperature 121 and 134 ^{0}C
  C, Enzyme loading: 10 and 60 FPU

Time: 72 hours, pH 4.8
Treatment: H_2SO_4 + SE
Enzyme: T. viride
Hydrolysis temperature 50^{o}C

Experimental results

Run No.	Tempera-ture (^{0}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**



Factorial experiment design

- **Sample:** Carrot peelings
- **Factors:** A, Acid concentration: 1% and 4%
  B, Temperature 121 and 134 ^{0}C
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Time: 72 hours, pH 4.8
Treatment: H_2SO_4 + SE
Enzyme: T. viride
Hydrolysis temperature 50^{o}C

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

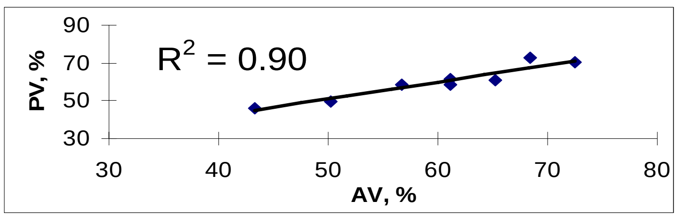
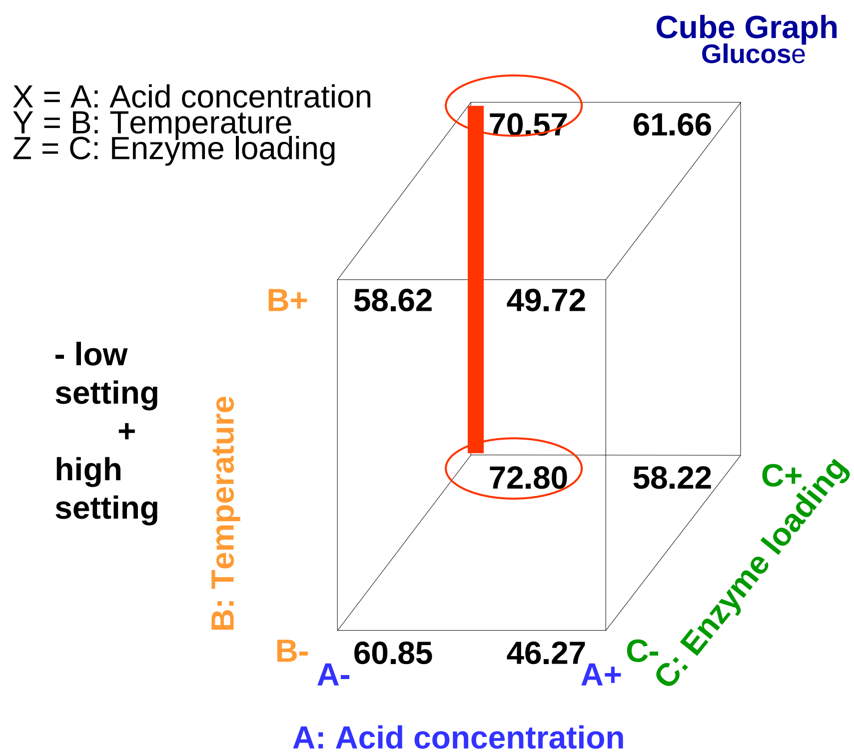


Table of factor effects

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**



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 ^{0}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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