Kinetics and Thermodynamics of Gellan Gum in Solid State

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Advanced thermal technology, pyrolysis, has been widely applied for reducing the quantity of ash and flue gas volume as well as recovering energy. Recently, biomass decomposition has attracted significant attention for the one single process of pyrolysis, which is the leading method for producing biofuel/bio-oil due to various advantages[1-3]. Biomass pyrolysis is an efficient and promising process to convert biomass into liquid products and chemicals[4]. High carbon containing materials can be extracted in a form[4] of biofuel/bio-oil with up to 80% yield from dry biomass feedstock. The oily organic fraction (pyrolysis oil, bio-oil), which can contain 75% of the starting energy content, is typically the desired product[5], is very easy to transport, and helps cut down about 87% of biomass transport costs[6]. Polysaccharide material Gellan Gum (Fig. 1) is studied in this research project[7].

Objective

- Characterization of the thermal behavior of gellan gum. Determination of the kinetic parameters corresponding to their thermal decomposition reactions.

Methods

- **Thermogravimetric Analysis (TGA)**
  - Three 7 mg samples of gellan gum (Fig. 2 & 3) were heated in a nitrogen atmosphere at 10 °C/min from room temperature to 650 °C independently.
- **Computation Analysis**
  - A kinetic model[7] was used to analyze the resulting data.
  - The final mass was the final weight recorded.

Analysis

Kinetic Model for Pyrolysis

$$Raw\ material \xrightarrow{k} Char + Volatiles$$

The order *n* of reaction is given by

$$n = 0.1368 \cdot \exp[5.3635 \cdot (1-\alpha)_m]$$

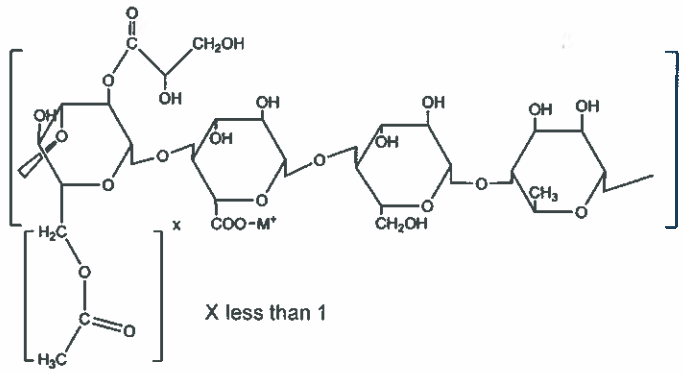
The rate of pyrolysis decomposition is defined as

$$\frac{d\alpha}{dt} = k(1-\alpha)^n = A \cdot \exp(-\frac{E}{RT}) \cdot (1-\alpha)^n$$

where A is the pre-exponential factor, E is the activation energy, dα/dt is the rate of change of reactant per rate of change of time, *k* = change in α per second (*dα/dt*) and exp means exponential or *e*.

§ All contributed equally.

Figure 1: Chemical Structure of Gellan Gum



X less than 1

Figure 2: TGA Data for Gellan Gum

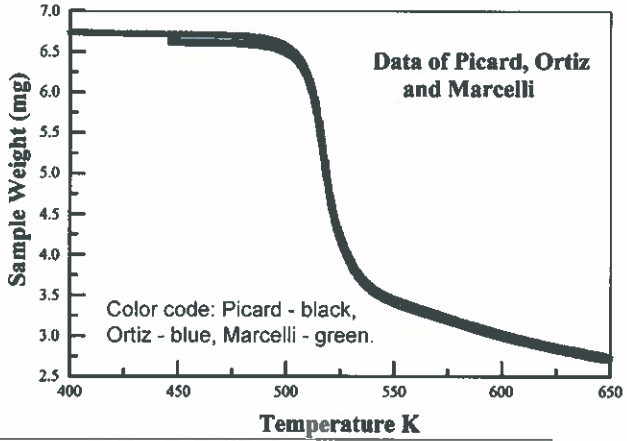
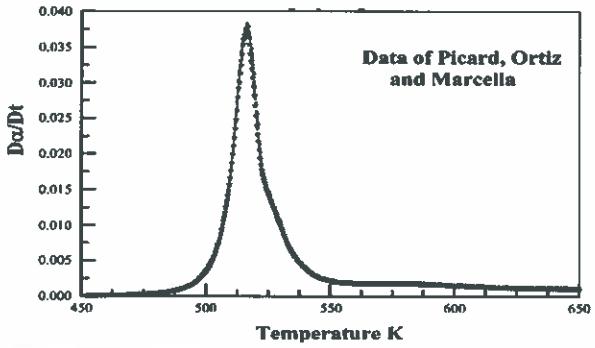


Figure 3: Decomposition Rate (Da/Dt) vs Temperature for Gellan Gum



Results

	1st Order	nth Order
E_a (KJ mol^{-1})	226	717
A (sec^{-1})	1.1 E + 21	2.0 E + 71
n	1	6

Discussion

- The peak maximum was at 516 K with Da/Dt max of 0.038 and alpha max of 0.295.
- The peak started at 490 K and ended at 537 K.

Preliminary Conclusions

- The decomposition of gellan gum is a completed reaction with a reaction order of 6.
- Each mole of gellan gum will yield at least 226 Kj/mole of energy.

References

1. Oasmaa, A.; Kuoppala, E.; Solantausta, Y. Fast Pyrolysis of Forestry Residue. 2. Physicochemical Composition of Product Liquid. *Energy & Fuels* 2003, 17, 433.
2. Oasmaa, A.; Kuoppala, E. Fast Pyrolysis of Forestry Residue. 3. Storage Stability of Liquid Fuel. *Energy & Fuels* 2003, 17, 1075.
3. Oasmaa, A.; Kuoppala, E.; Selin, J.-F.; Gust, S.;Solantausta, Y. Fast Pyrolysis of Forestry Residue and Pine. 4. Improvement of the Product Quality by Solvent Addition. *Energy & Fuels.* 18, 1578-83 (2004).
4. Lappas, A.; Samolada, M.C.; Iatridis, D.K.; Voutetakis, S.S.; Vasalos, I.A. Biomass pyrolysis in a circulating fluid bed reactor for the production of fuels and chemicals. *Fuel* 2002, 81, 2087.
5. Bridgwater, A.V.; Peacocke, G.V.C. Fast pyrolysis processes for biomass. Renew. Sustain. *Energy Rev* 2000, 4, 1.
6. Bridgwater, A.V. The production of biofuels and renewable chemicals by fast pyrolysis of biomass. *Int. J. Global Energy Issues* 2007, 27, 160.
7. Bragg, S.; Verma, M.; Moser, R.J; Balendiran, G.K. Kinetics of the Solid State Pyrolysis of Gellan Gum and Paper Pulp. *Journal of Biobased Materials and Bioenergy* (2015), 9, 1-8.

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