

**STUDIES ON THERMAL DECOMPOSITION AND COMBUSTION
MECHANISM OF BAGASSE UNDER NON-ISOTHERMAL CONDITIONS**

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ABSTRACT

The kinetics of thermal decomposition and combustion of bagasse was investigated by thermal analysis and gas-solid chromatography in the temperature range of 20-600°C. Apparent activation energies (E_a) and an order of reactions (according to non-isothermal thermogravimetry results) were determined. The comparative analysis of processes in inert and oxidizing media enabled the influence of oxidizing medium on the release and combustion of volatile substances to be established.

INTRODUCTION

Bagasse is sugar cane wastes (after sugar extraction). It is widely used as fuel in tropical countries. It is also a valuable raw material for the production of pulp, paper, board, etc.

Bagasse, being of biological origin, contains about 98% of organic compounds with quite different physico-chemical properties. Since in the oxidizing medium not the whole bulk of bagasse but only its pore surface is accessible to the oxidant, the combustion process is inevitably accompanied with thermal decomposition. The mechanism of organic matter degradation during gasification, combustion, etc. is very complex and at present is not fully elucidated. It is also complicated by a number of simultaneous reactions of different kinetics.

EXPERIMENTAL

The kinetics of bagasse decomposition and combustion was studied on a Du Pont 1090 thermal analyzer with a chromatographer. The investigations were performed under programmed heating conditions with a rate of 10°/min at an air or helium flow rate of 50 ml/min. From the thermogravimetric data the topochemical equation of decomposition reaction and kinetic parameters of the process were determined according to the method proposed by Šatava [1]. To calculate TG-curves, the programming for a MK-54 microcalculator was performed.

Bagasse samples from Cuban sugar cane of Ja-60-5 species were used. The chemical composition of bagasse is given in Table 1.

Table 1

Composition	Content, wt %
Cellulose	50-57
Hemicellulose	21-24
Lignin	21-24
Saccharose	2-4
Ash	1.5-3

RESULTS AND DISCUSSION

The thermal decomposition of bagasse (Fig.1) is a multistage process where both exo- and endothermic reactions of degradation of organic components are observed accompanied with the release of volatile components and the change of macromolecular structure. From the DTA results the process of thermal decomposition of bagasse can conventionally be divided into 6 characteristic stages. At the initial period of decomposition (Fig.1) the evaporation of free moisture and the removal of adsorbed substances occur (I). With further temperature increase (II), from the point of fibre saturation, the removal of bound moisture and polysaccharide hydrolysis start, a lower order of the reaction in the range of 110-170°C (Table 2) shows that the processes of thermal decomposition are complicated by the diffusion of volatile components.

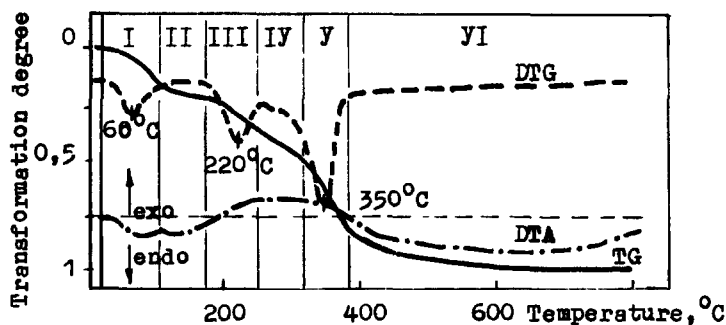


Fig.1. Differential thermal analysis of a bagasse sample in helium

Above 170°C (III) the change of macromolecular structure, the break of weak bonds, and the formation of stronger ones take

place. First of all, such oxygen-containing groups as hydroxyls, carboxyls and methoxyls degrade. During this period CO_2 , CO and H_2O are preferably formed (Table 2). Further temperature increase results in the degradation of carbohydrates and the release of volatile products (IV). The exothermal process of cellulose degradation occurs with the release of CO_2 and CO as well as hydrocarbons. As an intermediate product of cellulose degradation, levoglucosan is formed.

At the next phase of bagasse decomposition (V) the exothermal degradation of lignin and extractives takes place. The kinetic law of this stage of thermolysis corresponds to the first-order reaction. The gaseous products have a high CO content. At the temperatures of 450-900°C the endothermal process of C-C bond breaking occurs.

Table 2
Kinetic parameters of thermal decomposition

Temperature range, °C	20-110	110-170	170-250	250-310	310-380
Apparent activation energy E_a , kJ/mol	35.0	21.0	14.0	64.0	188.0
Reaction order	0.9	0.1	1.0	0.4	1.0
Gaseous products	H_2O	H_2O	$\text{CO}_2, \text{CO}, \text{H}_2\text{O}$	$\text{CO}, \text{CO}_2, \text{H}_2$	CO, CH_4

The oxidation process is quite different in its nature and can conventionally be divided into 5 stages. At the initial stage of sample heating (I), as in a helium atmosphere, the weight loss is observed due to the evaporation of free moisture and the removal of adsorbed substances. At 110-170°C the desorption of bound moisture and the removal of degradation products of hydroxyls, carboxyls and other groups due to the addition of oxygen molecules to hydrogen free radicals take place. The process is characteristic of higher activation energy and a lower reaction order (Table 3).

Further temperature increase (III) leads to higher rates of endothermal degradation of the least stable bagasse compounds resulting in the release of volatile substances. It should be noted that this process is more active in oxygen than in an inert atmosphere (Fig.2). The decomposition reactions yield a considerable amount of volatile substances. The ignition and combustion of volatile substances in the range of 245-380°C is accompanied with

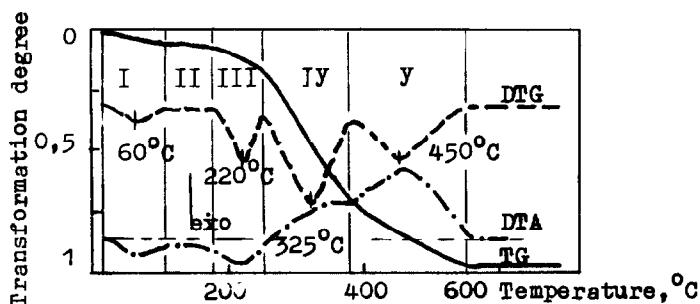


Fig.2. Differential thermal analysis of a bagasse sample in air.

the temperature increase of the sample and the acceleration of the decomposition process. The reaction is highly exothermal, with about 40% of bagasse burnt out. The combustion process at this stage (IV) is limited by the diffusion of volatile substances at the interface.

Table 3
Kinetic parameters of bagasse oxidation and combustion in air

Temperature range, °C	20-110	110-170	170-245	245-380	380-570
Apparent activation energy, E_a , kJ/mol	34.0	46.5	214.0	74.8	33.2
Reaction order	0.8	0.4	0.9	1.0	0.6

At the last stage simultaneously proceeding reactions of combustion of volatile components and active combustion of "coke residue" are observed. It is the most prolonged stage of the process, its rate is not greatly dependent on the temperature.

CONCLUSIONS

It has been established that oxygen contributes to more intensive degradation of a peripheral part of bagasse macromolecules, it determines the amount of volatile substances. The most prolonged stages of oxidation and combustion of bagasse proceed under diffuse conditions.

REFERENCES

- 1 W.W. Wendlandt, Thermal methods of analysis. Second edition. Wiley, New York 1974.
- 2 P. Roque-Diaz, V.Zh. Shemet et al., Khimicheskaya tekhnologiya 6 (1984) 32.