Introduction
To produce transportation fuels from biomass derived components it is necessary to remove oxygen. Potential routes for decreasing the oxygen content of biomass components include dehydration, hydrodeoxygenation, and decarboxylation (possibly after controlled oxidation) [1]. The feedstocks for the chemical transformations can include sugars, lignins, bio-oils, and chemicals obtained by biological transformations of sugars and biomass.

Microporous zeolite catalysts are used during catalytic pyrolysis or catalytic upgrading of pyrolysis vapors, where the most significant current problem is the loss of at least 30% of the biomass carbon to char and coke. Designing new zeolite catalysts for production of biofuels (diesel, jet-fuel, gasoline) requires knowledge about which parts of the catalyst need modification and what types of changes are necessary.

To help achieve these objectives, In situ diffuse reflectance infrared spectroscopy (DRIFTS) and solid state nuclear magnetic resonance (NMR) methods are being use to investigate the reactions of biomass oxygenates with different functional groups on zeolites. Different oxygenates with different functional groups, hydrogen to carbon ratio are being used in the investigation.

Materials and Methods
A Thermo Scientific Nicolet 6700 Fourier transform infrared spectrometer was being used for the DRIFTS measurements. Background spectra were recorded at 150, 300, 400, 500 and 600°C. Spectra of the samples were then collected at the same temperatures in ascending order.

Two-dimensional $^{13}$C-$^1$H and $^{29}$Si-$^1$H Frequency Shifted Lee Goldberg-HETeronuclear CORrelation (FSLG-HETCOR) NMR experiments were set-up and performed. These experiments allow us to determine whether the reactants are interacting with Al or Si sites and to map which Si sites on the zeolites are more catalytically active.

Results and Discussion
With DRIFTS, we found that even though the Si:Al ratio of ZSM-5 plays an important role for methanol conversion, it has limited influence on acetic acid and aldehyde conversion. With phenol and guaiacol, substantial amount of coke was formed. Further work to understand the impact of acidic sites on conversion of different oxygenates are in progress.

With FSLG-HETCOR NMR experiments, we found that guaiacol and methanol are associated with different functional groups on the zeolite catalysts.

Significance
Zeolite-based catalysts play a significant role in converting biomass oxygenates to hydrocarbon. However, significant coke formation affects the process efficiency and economics. Further understanding of the interaction of oxygenates with the catalysts could allow us to improve the catalysts or process conditions for successful biofuel synthesis.

Figure 1. IR spectra of methanol over ZSM-5 with Si:Al of 23. Vibrations attributed to the product, dimethyl ether (DME), were also detected.

References