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HEATING OF GREENHOUSE WITH BIOFUEL PELLETS

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Abstract. *The over-reliance of US economy on imported energy has to change and it is an obvious issue of national security. This dependence has increased our vulnerability to supply disruptions and has amplified the impacts of price volatilities on every aspect of the country including rural communities. The objective of this project was to demonstrate that biofuel pellets can be efficiently used to heat a greenhouse during the typical winter conditions in the state of Alabama. Analysis of the temperature data indicate that the biofuel pellet/furnace combination can maintain the temperature of a standard 24 ft by 96 ft greenhouse at 65 F or higher if the outside temperature is not less than 42 F. Energy savings based on substituting the biofuel pellets for natural gas can be up to 64% depending on biofuel type..*

Keywords. Switchgrass, poultry litter, peanut hull, pellets, renewable resources, agricultural wastes, alternative heating

Introduction

The US economy is presently dominated by technologies that rely on energy from fossil fuels (petroleum, coal and natural gas) to produce power, chemicals and materials. In 2003, about 67% of petroleum consumed in the country ((www.eia.doe.gov/emeu/aer/pdf/pages/sec1_5.pdf) was imported from foreign source. This over-reliance of US economy on imported energy has to change and it is an obvious issue of national security. This dependence has increased our vulnerability to supply disruptions and amplifies the impacts of price volatilities to every aspect of the country including the rural communities. The blackout of 2003 in the Northeastern part of the country and the current record high price of fuel in the country is an indication of the vulnerability of the country to energy crisis. From a sustainable view point, fossil fuels are limited and non-renewable energy source. In addition, there are environmental problems associated with extracting, transporting, and using fossil fuels.

An unavoidable solution to the fossil fuel usage problem is the use of indigenous biomass resources to supplement the U.S. energy supply. Biomass are organic materials that are plant or animal based, and are available on a renewable or recurring basis. These include but not limited to dedicated energy crops, agricultural crops and trees, food, feed and fiber crop residues, aquatic plants, industrial, municipal and agricultural solid wastes, forestry residues and other non-fossil organic materials.

Biomass resources are abundant in United States. It has been estimated that the current total available domestic biomass, beyond its current use for food, feed and forest products, is between 500 to 600 million dry tons per year for the period 2010-2020. These biomass resources represent about 3 to 5 Quads of delivered energy (USDOE, 2004) or as much as 5-6 percent of total U.S. energy consumption. Alabama in particular will benefit from the use of biomass energy because there are over 22 million acres of forestland (www.forestry.state.al.us/Forest_Statistics.htm) (70% of the total land area) and 8 million acres of grassland and cropland that is available in the state. In addition, significant amount of agro-production and processing occur in the state. The byproducts/waste from these activities are significant sources of biomass. For example, in 2002, the U.S. produced over 8.6 billion broilers with almost 60% produced in Alabama, Arkansas, Georgia, Mississippi and North Carolina. About 12% of total US production is from Alabama (NASS, 2003). This equates to between 1.2 and 1.7 billion kg of broiler litter produced in 2002 (Litchenberg et al., 2002; Moore et al., 1998). Approximately half of the peanuts grown in the United States (total of 4.2 billion pounds) are grown within a 100-mile radius of Dothan, Alabama. Using a conservative estimate of 25% hull in peanut (by weight), this implies that close to 1 billion pounds (www.fao.org/ag/aga/agap/frg/afris/Data/489.HTM) of peanut hull is available as biomass that can potentially be used in fossil fuel replacement around the southern part of Alabama

Hence the objective of this study was to demonstrate that biofuel pellets (from poultry litter, peanut hull and switchgrass) when burnt in a pellet furnace can be used to efficiently heat a greenhouse during winter in the state of Alabama.

Materials and methods

Production of biofuel pellets

The biofuel pellets used in this study were obtained from poultry litter, peanut hull and switchgrass. Poultry litter and switchgrass pellets were manufactured by means of a laboratory scale pellet mill (Model CL5, California Pellet Mill Co., San Fransisco, CA – Fig. 1). Poultry litter and switchgrass samples were respectively obtained from the Sand Mountain and the E.V. Experiment Stations of Auburn University. Before pelleting, both samples were ground through a 1/8" (3.2 mm) screen (New Holland Grinder, model 358). The temperature of the ground sample was increased to 75°C in the preconditioner section of the pellet mill , by injecting steam and by the use of a heat gun that blew hot air through the sample. The conditioned sample was then extruded through a pellet die (3/16" diameter). Due to frictional heating during pelleting through the die, the temperature of the pellets exiting the die increased to 85°C ± 2°C. After pelleting, the pellets were cooled in an environmental chamber set at 22°C and 40% relative humidity. The energy consumed during the pelleting of both samples were monitored by means of three watthour (energy) meters attached to the steam generator, the pellet mill and the heat gun (Models 4110 and 4011, Davidge Controls Santa Ynez, CA). Peanut hull pellets that were used in this study were donated by Ag. Fibers, Dothan AL. It was therefore not possible to quantify the amount of energy used in the manufacturing the peanut hull pellets.

Figure 1. Picture of the pellet mill used to manufacture poultry litter and switchgrass pellets

Pellet furnace and greenhouse

The pellet furnace (Fig. 2) used in this study was supplied by Free Heat Inc and was modified from a Traeger GBU 130 corn furnace (Traeger Industries, Mt. Angel, Oregon) with a designed capacity of 130,000 BTU h. The furnace was installed in a 24ft x 96ft quonset greenhouse (currently uses a natural

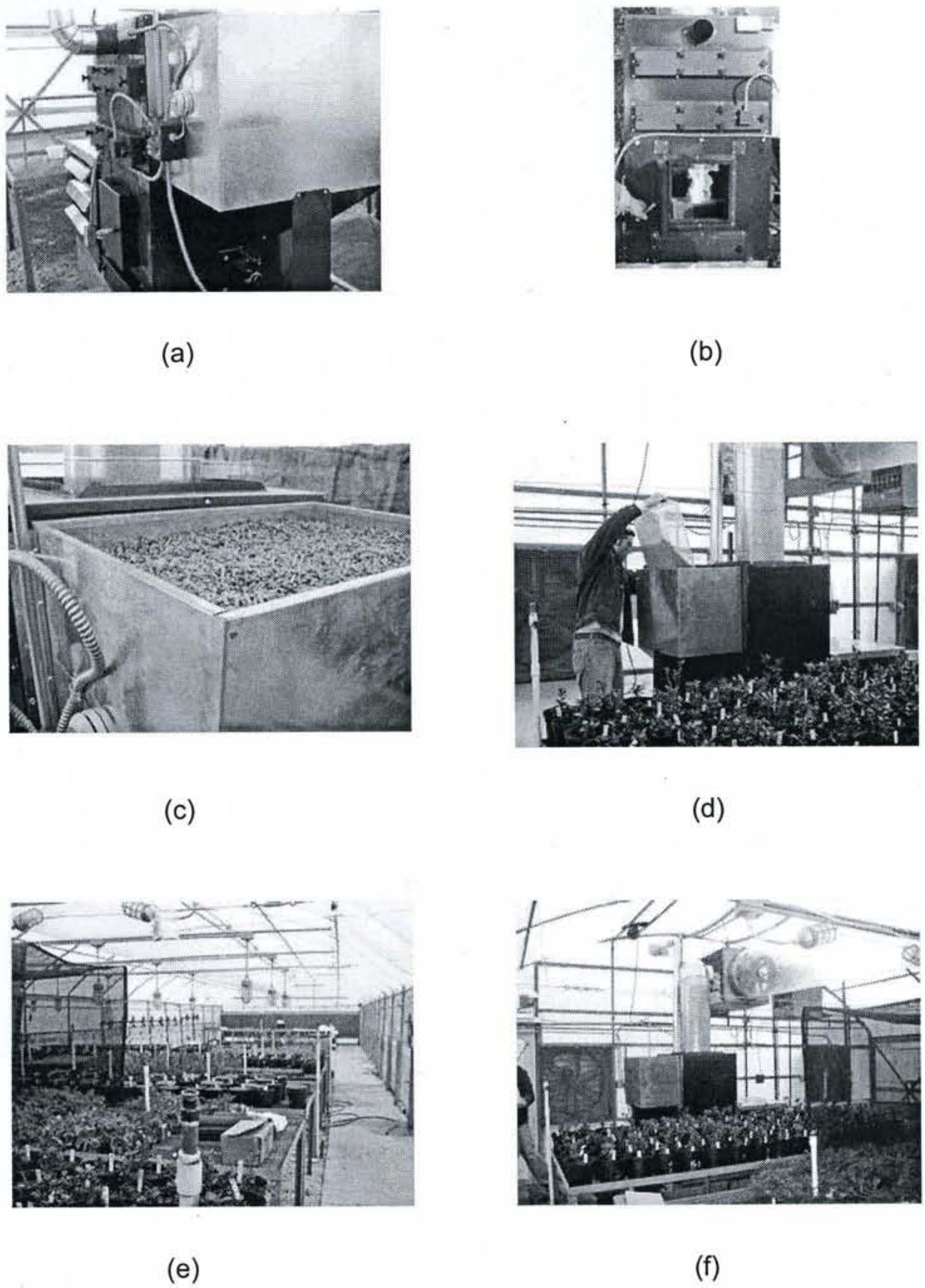

Figure 2. Picture of pellet furnace used in the study – (a) front view, (b) fire pot, (c) feed hopper with swtichgrass pellet sample, (d) loading of feed hopper, (e) greenhouse used for study, and (f) pellet furnace in green house.

gas fired heater) located on the main campus of Auburn University. The furnace has a blower that forces air over the furnace heat exchanger into the existing duct system of the greenhouse. Connection to the existing duct system was made by means of a 20" diameter duct. The furnace heat exchanger houses the firepot where combustion of the biofuel pellets took place.

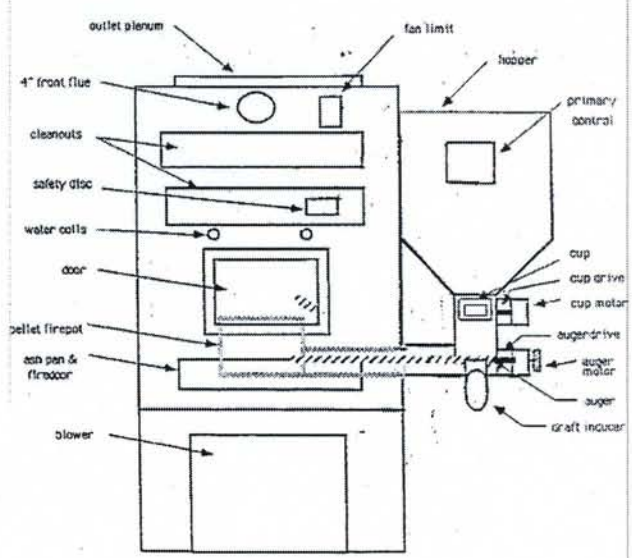

Figure 3. Schematic diagram of pellet furnace

Pellets in the hopper (capacity of 150 kg) flows down to the feed cup. The rotating feed cup is filled with pellets and after turning 180 degrees, the pellets in the feed cup are dumped into the auger. The auger then transfers the pellets to the fire pot, where combustion occurs. The heat of the fire in the fire pot is then transferred to the air (by means of the heat exchanger) that is used to heat the greenhouse. The gaseous product of combustion was then exhaust through the chimney of the furnace. Air is to be used for combustion in the firepot is supplied by means of a small fan draft inducer. A schematic diagram of the furnace is shown in Fig. 3.

A Honeywell model T87F thermostat was used to control the operation of the furnace. The thermostat was set at a temperature of 65 F. The pellet furnace therefore automatically operated when temperature in the greenhouse (as sensed by the thermostat) was less than 65F. In addition, three temperature datalogger (24 ft apart) were also installed in the greenhouse to monitor and record the temperature in the greenhouse during the course of the experiment. Since other researchers at the university were using the greenhouse for plant growth study, the natural gas fired heater that was originally in the greenhouse (design capacity of 125,000 BTU h) was used as a backup to the biofuel pellet furnace by setting the thermostat of the natural gas fired heater to 60F. One of the datalogger was therefore installed close to the natural gas fired heater. This served as a means of detecting when and if the natural gas fired heater turned on.

RESULTS AND DISCUSSION

Temperature data

Figure 4 shows the temperature in the greenhouse as recorded by the data logger (2 and 3) during a 4-day run with peanut hull pellets. As expected, temperature in the greenhouse peaked at mid-afternoons.

This is typical of the temperature profile in a greenhouse as the heat from the sunlight is trapped during the day and results in increase in inside temperature of the greenhouse, peaking at mid-afternoon. The figure also shows that there was no temperature variation in the greenhouse and the temperature of the greenhouse was not less than 60F during the course of the experiment. Most of the heat to maintain the temperature of the greenhouse came from the biofuel furnace with some supplementation by the natural gas fired furnace (explained in the next paragraph).

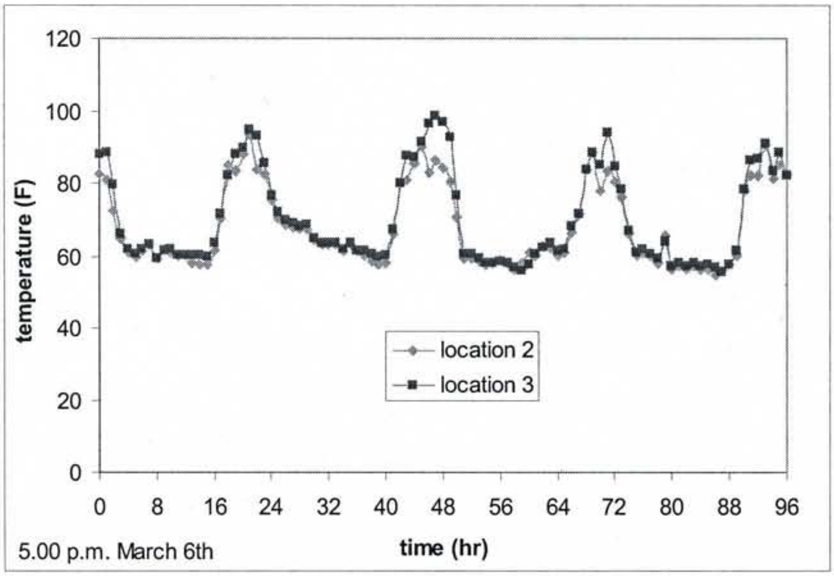

Figure 4. Temperature recordings in the greenhouse (datalogger 2 and 3). Sample was peanut hull pellets and experiment started at 5.00 p.m. on March 6^{th} , 2005.

Figure 5 shows the outside temperature in Auburn AL when peanut hull pellets were combusted in the biofuel furnace. The temperature sensed by the thermocouple near the natural gas fired heater is also shown in the figure. Peaks 1, 2, 4 and 7 are similar to the peaks in Figure 4 and occurred at mid-afternoon. The remaining peaks occurred when the natural gas fired heater came on. As explained in the Materials and methods section, the greenhouse heating system was setup such that the natural gas fired heater is activated whenever the temperature in the greenhouse is below 60F. The first datalogger therefore registers an increase in temperature whenever the natural gas fired heater comes on hence the reason for peaks 3, 5 and 6 in Figure 5. Further analysis of recorded temperature data showed that the natural gas fired heater was activated when the outside temperature was less than 42F. Similar response was obtained when switchgrass pellets and poultry litter pellets where combusted in the pellet furnace (Figs. 6 and 7).

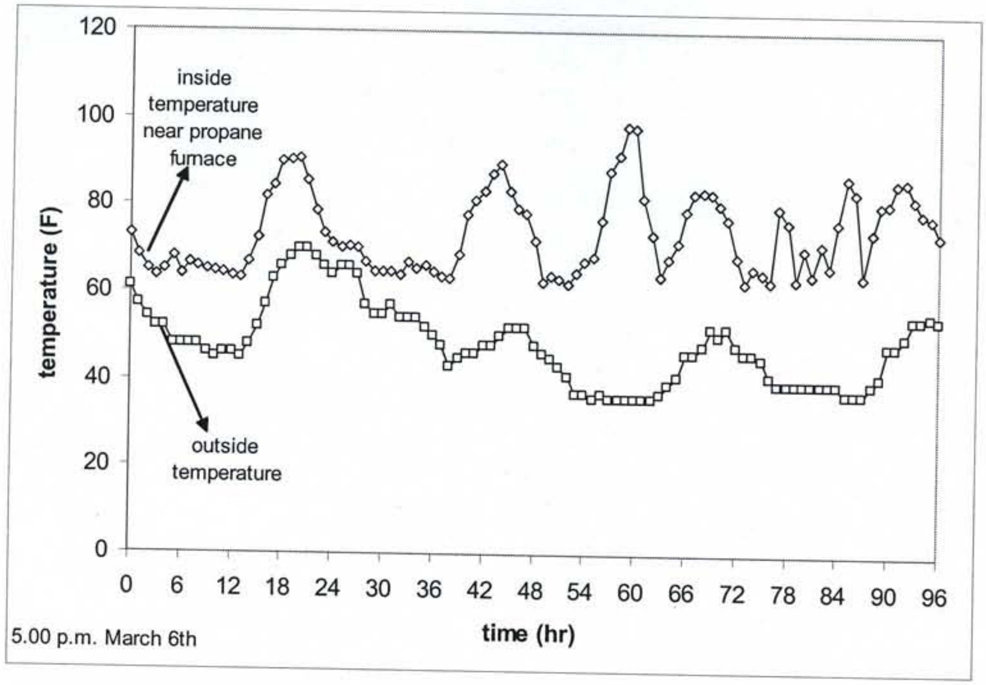

Figure 5. Outside temperature history (Auburn) and propane furnace temperature during the combustion of peanut hull pellets. Experiment started at 5.00 p.m. on March 6th, 2005.

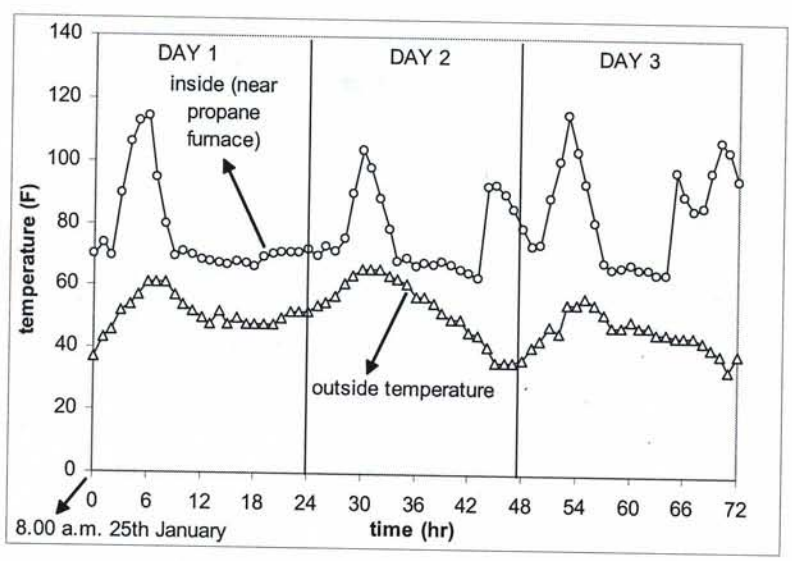

Figure 6. Outside temperature history (Auburn) and propane furnace temperature during the combustion of switchgrass pellets. Experiment started at 8.00 a.m. on January 25th, 2005.

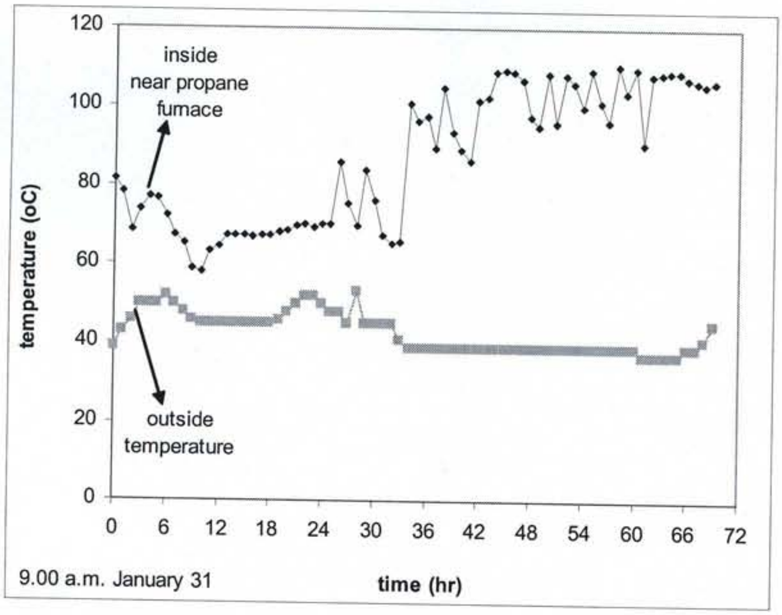

Figure 7. Outside temperature history (Auburn) and propane furnace temperature during the combustion of poultry litter pellets. Experiment started at 9.00 a.m. on January 31st, 2005.

Sample analysis

The ash content of switchgrass and peanut hull pellets were very small (~ 3%) while the ash content of poultry litter was excessively high (~ 35%) – Table 2. We do not know the reason for this high ash content because literature values for ash content of poultry litter is in the range of 17 to 25% (Mitchell and Donald, 1999; Donald et al., 1996). We suspect that some amount of soil was inadvertently incorporated into the poultry litter during storage and during the process of moving from the place of generation to the place of storage. The high ash content of the poultry litter made the burning of the pellets in the fire pot difficult as more ash/residue were generated.

Table 2. Energy and ash content of biofuel pellets

Pellet type	Heat of Combustion BTU/lb dry basis	Ash % dry basis
Switchgrass	8256	2.96
Peanut hull	8570	2.91
Poultry litter	5639	34.39

Energy Efficiency and savings

Data on energy efficiency and savings for the biofuel furnace when placed in the greenhouse (Table) indicate that energy savings for switchgrass, peanut hull and poutry litter pellets were respectively 64.32, 64.29 and 38.62%. It should however be mentioned that (a) the savings is highly dependent on the weather conditions, and (b) that the pelleting costs for peanut hull was assumed to that for switchgrass (since peanut hull pellets were donated for the project). As mentioned in the previous section, the gas fired heater comes on when the outside temperature is less than 42F irrespective of the pellet type that is burnt in the furnace. This might probably account for the low energy savings obtained from poultry litter because the time period during which the outside weather was lower than 42 F was considerably higher than for the other samples. In addition, the significantly higher ash content of poultry litter pellets might have contributed to the lower energy savings since the burning capacity in the fire pot is diminished when there is considerable amount of ash/residue in it.

Table 4. Energy savings and efficiency data

Sample type	Switchgrass	Peanut Hull	Poultry Litter
No. of days	3	7	5
Amount burnt, kg (lbs)	280 (617)	700 (1543)	580 (1280)
Energy for pelleting, kWh	107.52	310.8[1]	70.77
Cost of pelleting ($)	8.60	24.90	5.66
Natural Gas Use Cost ($)[2]	4.98	12.98	41.07
Total heating cost ($)[3]	13.58	37.88	46.73
Heating cost without bioenergy ($)	38.06	95.18	76.14
Savings ($)	24.48	57.33	29.41
Savings/day ($)	8.16	7.64	4.91
Percent saving (without biofuel cost)	**64.32**	**60.20**	**38.62**
Percent saving (with biofuel cost)[4]	**34.89**	**30.78**	**8.16**

[1]value obtained from pelleting of peanut hull in the laboratory; [2]cost of natural gas is $6.1 per million BTU; [3]cost of electricity is 8.1¢ per kWh; [4]cost of purchasing biofuel is assumed to be $40/ton

RECOMMENDATIONS

It was demonstrated in this project that biofuel pellets burnt in a pellet furnace can be used to provide a major part of the heat needed during winter conditions in Alabama. For this approach to be self-sustaining and economical, the user of this technology must be able to produce the fuelstock needed in the furnace. Unfortunately, despite the advantages of pelletizing (especially the uniformity of feeding to firepot), the cost of pelleting may hinder the adoption of this technology by small-scale/rural farmer. It is therefore recommended that a followup project needs to be carried out that will demonstrate the use of unpelleted (raw) biofuel feedstock in a furnace. Obviously, this will require that the feeding system be specially designed to prevent the caking (e.g poultry litter) or bridging (e.g. switchgrass) that can occur in the hopper. A means by which the ash/residue from the firepot can be removed automatically without stopping the system also needs to be incorporated.

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