

# Effect of binders on performance of corn stalk pellets

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**Abstract.** In this paper, we compressed the corn stalks harvested in Hubei Province into biomass-forming fuels. The physical properties of the raw materials and the physical of binders were studied. In order to obtain pellets with better performance, we used four different binders to make a new type pellets. We chose the best binders and best molding process by testing their mechanical properties and surface structures. Through the experiment, we obtained the best ratio of different binders to the corn stalk pellets. We also have studied the impact of different types of binders on the different properties of biomass pellets. Among the selected binders, diatomite and CMC can help us make pellets with better performance.

## 1 Introduction

Compared with the energy situation abroad, China's energy state is not optimistic. According to the relevant statistics of the NDRC, the useful life of coal is about 200 years. As a developing country, we have the task of economic development in addition to protecting the ecological environment. Therefore, looking for a new source of energy is very important.

Biomass as the world's fourth largest energy, reserves second only to coal, oil and natural gas, in all the development of renewable energy, is the only convenient storage and transportation of energy, resource reserves are large, widely distributed but not concentrated. There is a great potential for development.

Compared to the traditional baking process of biomass molding technology, direct addition of binders to help biomass molding has some advantages. First, the addition of binders allows the entire molding process to proceed at room temperature, while conventional baking thermoforming techniques require higher temperatures. Second, this method does not destroy the fiber material of the biomass feedstock itself. Third, the thermoforming method of the product although the surface texture of hard, but it is easy to break, in the storage and transportation process has a greater difficulty. Fourth, the use of binder molding of biomass fuels in experimental research and engineering applications in the operation is relatively simple, with excellent development potential and application potential.<sup>[1]</sup>

## 2 Materials and methods

### 2.1 materials and binders

#### 2.1.1 Raw materials

The elemental analysis and industrial analysis of the corn rod are shown in the following table.



Table 1. CHARACTERS OF RAW MATERIALS

Proximate analysis (wt.%), d				
Ad	FCd	V d	—	—
10.36	18.37	71.27	—	—
fiber analysis (wt.%), d				
ligin	hemicellulose	cellulose	extract	—
4.66	26.76	41.26	27.32	—
Ultimate analysis (wt.%), d				
C	H	O	N	S
48.29	6.28	33.27	1.31	0.18

### 2.1.2 Binders

Carboxymethyl cellulose sodium, referred to as CMC-Na, glucose polymerization degree of 100 to 2000 cellulose derivatives, the relative molecular mass of 242.16. It is white fibrous or granular powder.

Starch is a polymer of glucose, colorless and tasteless, and is transparent after heating.

Kaolin is a kaolinite clay mineral-based clay and clay rock, is a kind of non-metallic minerals.

Diatomite is a biogenic siliceous sedimentary rock, its chemical composition is mainly SiO<sub>2</sub>, containing a small amount of Al<sub>2</sub>O<sub>3</sub>, Fe<sub>2</sub>O<sub>3</sub>, CaO, MgO, K<sub>2</sub>O, Na<sub>2</sub>O, P<sub>2</sub>O<sub>5</sub> and organic matter. SiO<sub>2</sub> usually accounts for more than 80%, up to 94%.<sup>[2]</sup>

## 2.2 Equipment and pelletizing process

### 2.2.1 Equipment

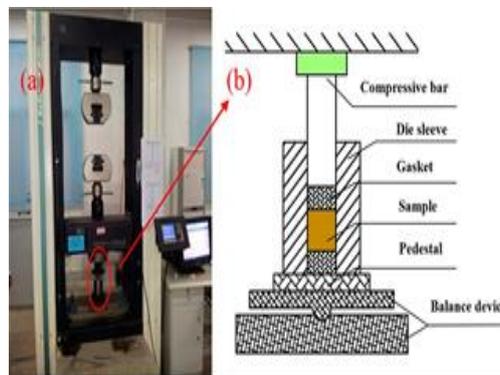


Figure2-1 PICTURE OF EQUIPMENT

Figure 2-1. Schematic of compression system: (a) the mechanical press machine and (b) the piston mold.

Densification was conducted on a universal material testing machine. The mold equipment includes a cylindrical die, a piston (20 mm in diameter and about 80 mm in length), 8 gaskets (20 mm in diameter and 4 mm in length, match the mold), and a pedestal. The values of pressure, displacement and related parameters were recorded in the computer controller.

### 2.2.2 pelletizing processes

1) Grinding the received maize stalk sample into particles less than 120 mesh

2) The ground biomass powder was dried at 105 °C for 24 hours to remove bound water and free water

3) Take 3.5 g of dry biomass samples, add 15% (w / wt) of water to the binder in a certain ratio (0,1/99,2/98,3/97,4/96), mix for half an hour, place in a constant temperature and humidity oven for 24 hours

4) The mixed sample (about 4g) was placed in a 10 mm diameter mold. The mold could be molded at four times. The quality of each sample was  $1.00 \pm 0.01$  g, compressed and molded at different pressures. Compression of the parameters selected as the compression speed of 10mm / min,

5) The speed of the molded sample is 5mm / min drawn out of the mold.

### 2.3 related parameters

#### 1. Energy Used

For biomass pellet preparation, the energy consumption is a critical factor. Energy consumption included compression and ejection of a single pellet. It can be calculated with the following equation.

#### 2. Relaxed density

Biomass-forming fuels are primarily aimed at improving the efficiency of biomass combustion and greatly improving the energy density of biomass feed stocks. And the energy density is directly related to the density of the biomass forming fuel.

#### 3. Compressive Strength

The compressive strength of the biomass pellets was tested using a cylindrical metal probe of 20 mm diameter. Each pellet was placed individually in a horizontal direction in a universal material testing machine with a compression rate of 2 mm/min until the pellet was crushed.

#### 4. Durability

The durability of biomass pellets was tested using 30 pellet samples, which were densified using the three aforementioned biomass types with the binders, by placing them in a 2 mm sieve where they were vibrated for 30 min. Next, the tumbled pellets were weighed, and the final mass was recorded. The durability (I, %) was calculated using the following equation

$$I = 1 - (m_b - m_f) / m_b \times 100\%$$

#### 5. Moisture Absorption

The test method is to put the sample into a constant temperature and humidity box (30 °C, 100% humidity), each time after a fixed time to take out the sample weighing quality. Draw the water absorption curve according to the following formula

$$H = (m_f - m_b) / m_b \times 100\%^{[3]}$$

#### 6. Scanning electron microscope

The scanning electron microscope scans the sample with a narrow beam of electrons. Then we can observe the surface structure of samples by The interaction between electron beam and sample.

## 3 Results and discussion.

### 3.1 Energy Used in Forming Process

In our molding conditions (> 60MPa), each 20MPa increase in the molding pressure, the energy consumption is a certain increase. Among them, the binder-free biomass feedstock is the smallest, about 4.5N / 20MPa due to the loose pore size. Different binders have an increased effect on the molding energy, due to the different effects of different types of different. This property of starch is about 5.5N / 20MPa, 5.7N / 20MPa for CMC, 5.9N / 20MPa for kaolin.,and diatomaceous is 6.1N / 20MPa.

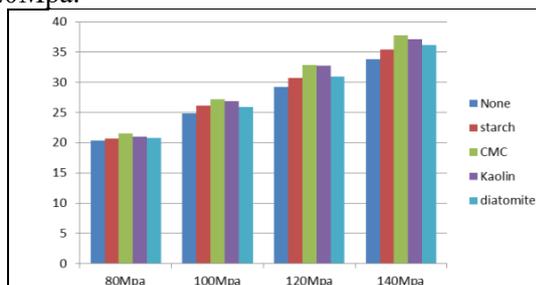


Figure 3-1 effect of four binders on energy consumption

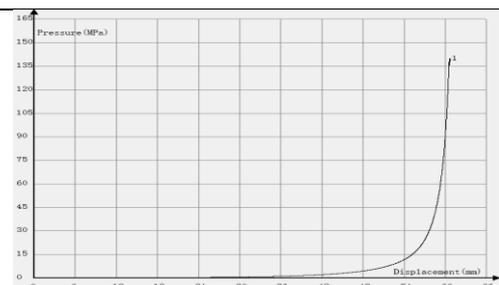
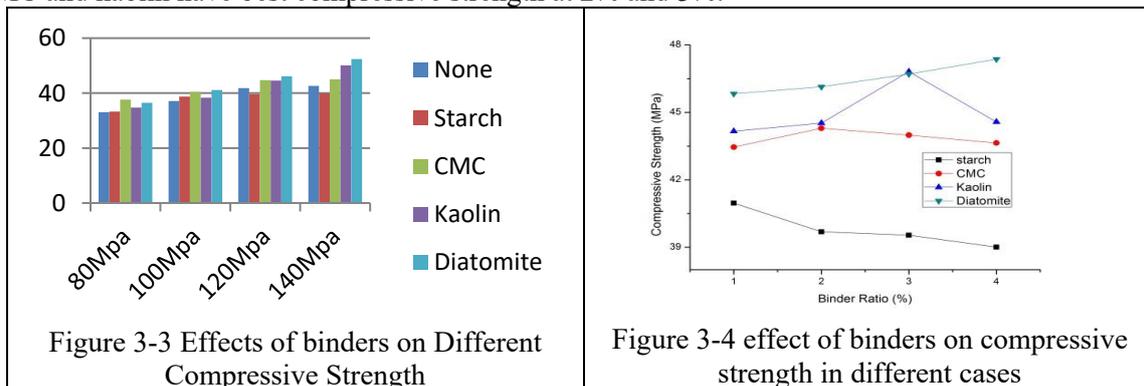


Figure 3-2 Pressure-Displacement Curve in Forming Process

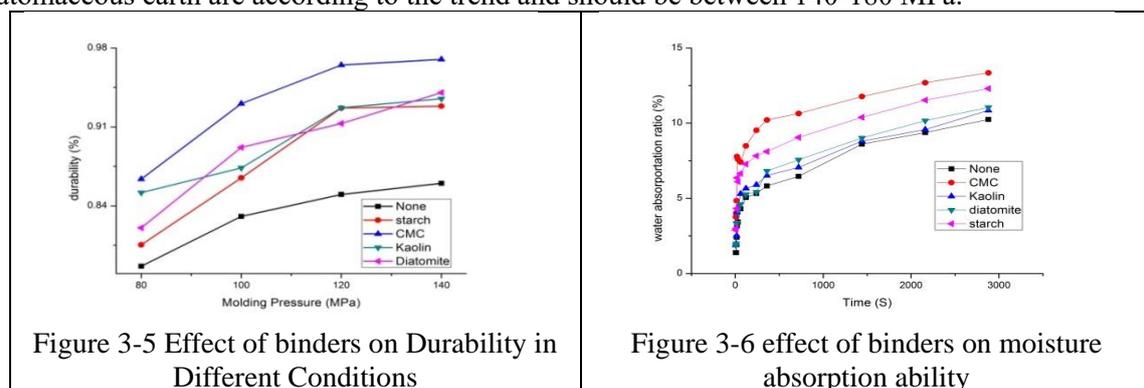
### 3.2 Compressive strength

The figure3-3 3-4 shows the test performance of samples made with different types and different proportions of binders at 120 Mpa. Different types and different proportions of binders are not the same, and there are significant differences. In addition to starch binders, in the 120Mpa molding conditions, the performance of the sample in the test is worse than the performance of pellets without binders. The performance of starch as a binder in the test hardly changes with the change in the ratio. CMC and kaolin have best compressive strength at 2% and 3%.



### 3.3 Durability test

From the figure3-3 we can see that the samples obtained under different pressure conditions do the corresponding test results. Among all the different binders, CMC showed the best, while diatomaceous earth and kaolin and starch are poor performance. We found that diatomite as an binder, the durability will increase with the molding pressure increases. If the optimum molding pressure is exceeded, we can get more harder and better shaped fuel after the test. But after four weeks of storage placed, biomass raw materials will still rebound. It is not a good idea to raise the molding pressure in this case. Different types of binders correspond to different optimum molding pressures, CMC about 120Mpa, kaolin and starch between about 120MPa to 140MPa. The optimum molding conditions for diatomaceous earth are according to the trend and should be between 140-180 MPa.<sup>[4]</sup>



### 3.4 Relaxed Density Test

From the above table we can easily find that the binder on the slack density of pellets this property has a significant help, that is, adding a variety of binder raw materials made of biomass products performance is better than biomass. The expansion of biomass-forming fuels after storage is very significant (at least 40% larger). The corn stalk itself, the material density is very small, so despite the molding of fuel, but the density is still very small<sup>[5]</sup>. It is possible to become larger than the water density (1000 kg / N3) only after the binder with the characteristic ratio. These specific proportions are marked in the table. It is clear that the best mix of different binders is different. CMC is 2%, kaolin is

3%, diatomaceous is 4% or more. These proportions are similar to the best of the previous properties.

Table 3-1 The Relaxed Density

Binder Type	<u>relaxed</u> <u>density</u>	<u>diameter</u> <u>expansion (%)</u>	<u>length</u> <u>expansion (%)</u>
None	<u>872.5</u>	<u>25.44</u>	<u>0.8</u>
<u>2%starch</u>	<u>1022.006442</u>	<u>16.017</u>	<u>0.6</u>
<u>2%CMC</u>	<u>1036.466043</u>	<u>15.32</u>	<u>0.4</u>
<u>3%kaolin</u>	<u>1036.352332</u>	<u>15.326</u>	<u>0.4</u>
<u>4%diatomite</u>	<u>1041.09218</u>	<u>15.064</u>	<u>0.4</u>

### 3.5 Moisture absorption ability

According to the figure 3-4, the moisture absorption performance of the biomass-forming fuel is closely related to the moisture absorption performance of the binder. In the four binders in the experiment, kaolin and diatomite moisture absorption performance is relatively poor, and corn stalk raw materials have a certain moisture absorption capacity. Taking into account the corn stalk raw materials accounted for more than 95% of the binder accounted for only a very small part of the absorption of moisture performance is not good kaolin and diatomite made of fuel absorption of moisture and the original curve is not very different. However, the moisture absorption ability of starch and CMC is very strong. Thus, despite the small proportion of the two binders in the sample, the ability of the sample to absorb water moisture in the air is significantly improved. The ability to absorb moisture is too strong, which mainly reduce the quality of biomass fuels. In particular, in the combustion experiment process, it is necessary to increase the drying process steps, will greatly improve the use of cost. [6]

### 3.6 SEM analysis

The surface of raw material with binder is more level, the void structure is reduced, and pellets is more compact. After adding the binder, the gap between the forming particles decreases. There is a large amount of filler between particles, and there is no obvious rebound phenomenon.

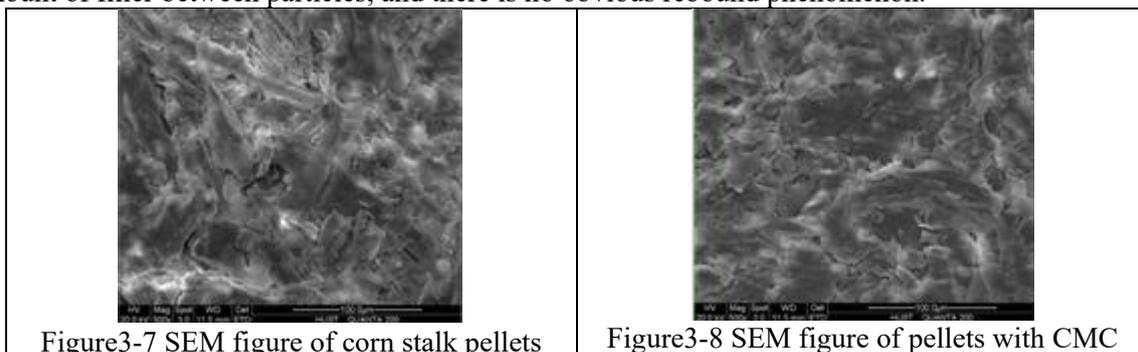


Figure3-7 SEM figure of corn stalk pellets

Figure3-8 SEM figure of pellets with CMC

## 4 Conclusion

In this experiment, we can get s the following conclusions.

1. Biomass forming process has two main stages, the previous stage is mainly plastic deformation, almost irreversible. The second stage is mainly elastic deformation, with a certain degree of recoverability. This mechanical property determines the tendency of the biomass molded fuel to have a form of recovery before the storage stage. We study the properties of biomass-forming fuels, not only to study the performance of the newly made shaped fuel and the fuel which have been stored. The performance of the two has a significant difference.

2. In the case of different binders, including the formation of energy, durability, moisture

absorption capacity, etc. are not the same circumstances. For the newly prepared samples, binders due to the small content of the material, the impact is very limited. While for storage after a period of time after the sample, the binders played a very important role in this test.

3. Although the presence of binders allows the energy consumption of biomass-forming fuels to be higher, the binders can help us make better biomass pellets. Respectively, CMC accounted for 2% of the ratio, diatomaceous earth accounted for 4% of the ratio, kaolin compared with 3% of the situation. The same kind of binders in different ratio of the case is not the same performance. The above ratio is the best of the three binders.

4. Diatomite has a significant effect on the relaxation density test and the compressive strength test. CMC has a greater positive impact on durability and relaxed density testing, but has a negative effect in the evaluation of moisture absorption. Kaolin can improve the compressive strength of the sample, and starch in all aspects of the modification does not work.

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