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# Effect of moisture content and particle size on energy consumption for dairy cattle manure pellets

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**ABSTRACT**

*Physical and mechanical properties of pellets are needed to make pellet form in storage of raw materials and energy consumption. Dairy cattle manure, sieved by a two-level mesh of 30 and 50, were used for making pellets by a hydraulic press with mold diameter of 6 mm, in three moisture levels of 15,17.5, 20, 22.5 and 25% and two pressure levels of 100 and 150 MPa. The results of the tests were analyzed by using EXCEL and MATLAB software.The results showed that the compression energy as well as friction energy of mesh 30 increased with increasing moisture content from 15 to 20% and decreased with increasing of moisture content from 20 to 25% for both pressure levels of 100 and 150 MPa. The compression energy and friction energy of the mesh 50 decreased with increasing of moisture content for both pressure levels of 100 and 150 MPa. The energy consumption of compression was found to be greater at pressure of 150 MPa than the pressure of 100 MPa. The greater amount of energy consumption was used for compression. The maximum amount of friction energy was 16.7% while the minimum was 11.23% for both pressure levels of 100 and 150 MPa.*

**Keywords***:* energy consumption, compression energy, dairy cattle manure, friction energy, pellet, pressure

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## INTRODUCTION

High moisture content, high volume and non-uniformity of the materials in manure are the factors which limits the usage of the manure in agriculture. Normally, because of low specific gravity the transportation of manure fertilizers is difficult and expensive. Biomass is very difficult to handle, transport, store, and utilize in its original form [1]. One of the method that cause to have easy transportation and decrease the costs is to reduce the volume of the manure by compression in pellet form. The compressed manure can be used as the fertilizer in agricultural farms.. This also eliminates the need for manure plants and also reduced the cost of manure[2].

Physical and mechanical properties of pellets are needed to make pellets for storage of raw materials and optimize the consumption energy. Compression of lignocellolegy of materials is complex and in this case there is no coherent theory [3]. There are many ways to compress the biomass materials. Conventional processes for compressing biomass can be classified into three types: Extrusion, die roller and berry-making [4]. From the analysis that was done by Serrano, the moisture ratio should not be too high or too low, because excessive moisture ratio will cause loose pellets due to excessive water between pellets, and this will yield a poor briquetting effect [5]. Nelson used mold and plunger method to quantify the consumed energy for synthesis of pellet form [6].

Researchers have already carried out experiments on biomass materials process in pellet in order to analyze and evaluate the required energy to process the pellet [7,8]. They found that the average hardness of the pellets will increase with decreasing particle size sieve from 2/3 to 8/2 mm. Hara in in Japan, studied on produced pellets by using extruder from animal manure in order to investigate the effect of moisture content and dust levels on pellet strength [9]. The obtained results showed that the strength pellets reduced with increasing moisture content and the percentage of the soil in manure. The most relevant moisture content level was proposed at 45% for forming the pellets and the level below 20% for storage of manure pellets.

The pelleting process has advantages of high adaptability of raw material, wide application of moisture ratio, low power consumption per ton of material and high production, thus making it suitable for application in rural area where straw wastes are extensively disposed [10]. In a research, Kai offered the relationship between velocity of mold (Die) and energy consumption for the pellet form as the theory of modeling, analytical and experimental [11]. Tylzanowski (1975) stated that change in moisture content about 1% cause to mixture of under examination very dry or wet that on next work make effects on the pellet form device[12]. Reinders and Bestelaere stated that after the processing operation, the moisture of mixture should be about 15 to 15.5% [13]. Wellin stated that the most favorable moisture content of the mixture was from 13 to 17%. a substance when have the upper pellet form property that first required the low pressure to form a compact structure and Secondly, it is expected that the dense materials have a high quality and durability [14]. Drzymała presented several criteria of pellet form capabilities for the materials (More piston displacement for the same pressure for better storage capability of the masses) and offered multiple pellet form capabilities related to building mass and testing hardness [15]. The main objective of this research is to determine effects of moisture content and particular size of dairy cattle manure on consumption energy of compression and friction energy to make pellet form.

## MATERIALS AND METHODS

### Materials

Required dairy cattle manure was collected from rural dairy cattle and prepared in different particle size for testing. The manure was considered enough and crushed and storage by grinding electric in the Department of Agrotechnology, College of Abouraihan, University of Tehran. According to ASTM standards for testing manure bed the samples were prepared with the desired mesh (Standard S358.2) The initial moisture content of the manure was determined in five replications by drying of the samples in the oven at temperature103 ±3˚C for 48 hours. The moisture content was determined according to Eq.1 in terms of wet basis [16].

In this equation:

$$MC(w.b.)\% = \frac{m_w}{m_w + m_d} \times 100\ \% \quad (1)$$

MC (w.b.)% = Moisture content of fresh manure (%)
$m_w$ = mass of water in the manure (g)
$m_w$ = mass of dry matter in the manure (g)
To achieve the desired moisture for preparing the samples, an amount of distilled water was added to the manure based on Eq.2.
In this equation:

$$m_w = \frac{m_i(M_{wf} - M_{wi})}{1 - M_{wf}} \quad (2)$$

In this equation:
$M_{wi}$ = initial moisture content of fresh manure (%, w.b.)
$M_{wf}$ = final moisture content of manure (%, w.b.)
$m_i$ = initial mass of manure (g)
$m_w$ = mass of added distilled water(g)

After adding distilled water the samples were kept 5°C in the refrigerator plastic package temperature for 72 hours until the moisture is distributed uniformly in the samples. In this study, samples were taken at three moisture levels 15, 17.5, 20, 22.5 and 25% (w.b.).

The hydraulic press device that was built in the College of Abouraihan, University of Tehran. was used for measurement of compression and movement of the pellet form. The device was equipped with a Ohmic ruler with an accuracy of 0.01 mm to measure the piston motion and the 1000 kgf load cell Fig.1, The press device has ability to measure the force on the piston during the compression and movement the pellet form within the framework simultaneously and both were connected to data logger and data were transferred to a computer for further calculation.

**Methods**

For calculating of consumption power in order to make pellet form in die roll, it is necessary to consider moisture content and particular size effects on compression and friction energy, And also compression and friction energy ratio to total consumption energy. This study was performed with using the method of Nielsen et al.2009.

For each test an amount of 0.75 g of material was weighed by a digital balance and charged into the closed mold and compression was conducted at two pressure levels of 100 and 150 MPa, which adjusted by pressure control valve.

The valves were removed to exit the pellets and the pellet was moved inside the die for 3.5mm to measure the friction energy. A flow control valve was used to have a constant speed of 127 mm/min during the movement of the pellet inside the die. (Nilsen et al.,2009).

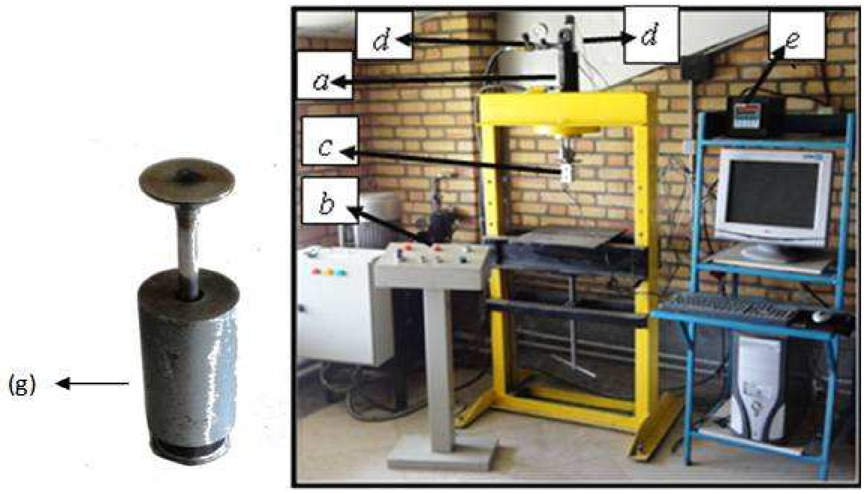


**Fig. 1, hydraulic presses; a) Cylinder hydraulic, b) motion control system, c) load cell, d) ruler measure, e) data logger, f) flow control valve g) Mold**

The force on the piston was calculated using Eq. 3:

$$P = \frac{F}{A} \quad (3)$$

in which;
P= pressure inside the mold ( MPa)
F= force on piston (N)
A= area of mold ($mm^2$)
Force on the rod (288 and 433 kgf) were calculated.

The consumption energy for compression and friction was calculated and analyzed by programming in MATLAB and Excel for all experiments. Because of Abundant of data, Figures show the example of the output. In Fig.2, where the maximum pressure 100 MPa with 15% moisture and mesh 30 has been compressed and the following chart shows the level of compression energy. In Fig.3, where the maximum pressure 100 MPa with 15% moisture and mesh 30 has been compressed and the following chart shows the level of friction energy.

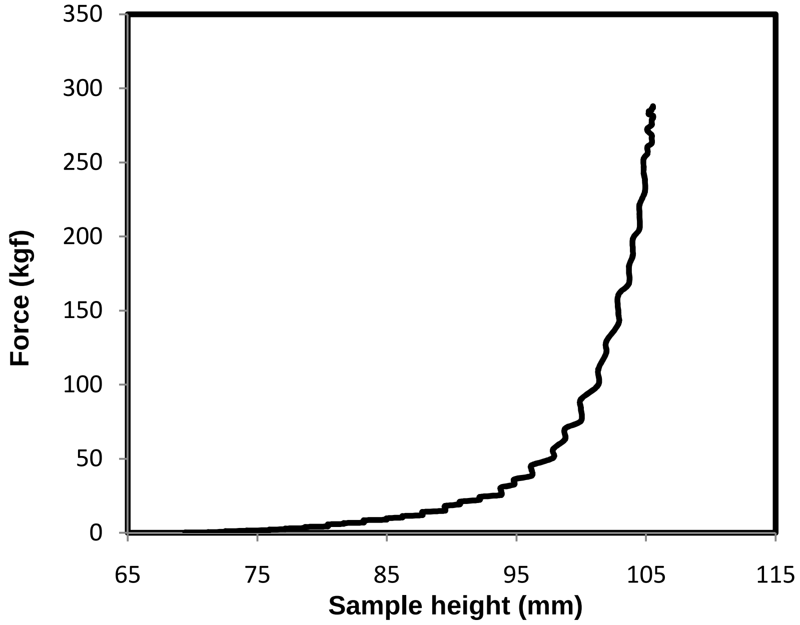


**Fig. 2, the below area of the graph shows compression energy in maximum pressure of 100 MPa, moisture 15% and mesh 30.**

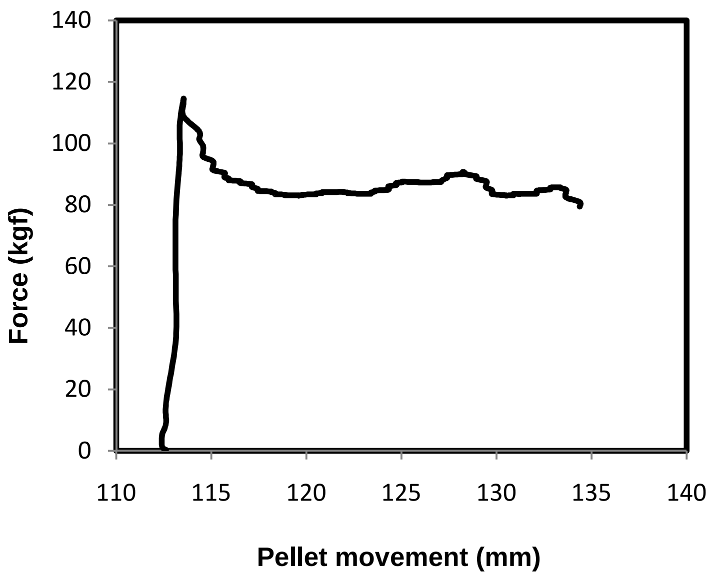


**Fig. 3, the below area of the graph shows friction energy in maximum pressure of 100 MPa, moisture 15% and mesh 30.**

## RESULTS AND DISCUSSION

The Fig. 4, shows the compression energy at pressure 100 MPa for the mesh 30 at moisture content ranging from 15 to 25%. The compression energy increased with increasing moisture from 15 to 20% and decreased with increasing moisture content from 20% to 25%. The compression energy for mesh 50 decreased with increasing moisture content and in range of 15-25 %. The compression energy for mesh 50 was always higher than the mesh 30 except at moisture range of 15 – 16% which it was equal at moisture content of 16% for both meshes. The rate of compression energy was more 20% moisture content was almost equal for both meshed while it was different at moisture content lower than 20% .

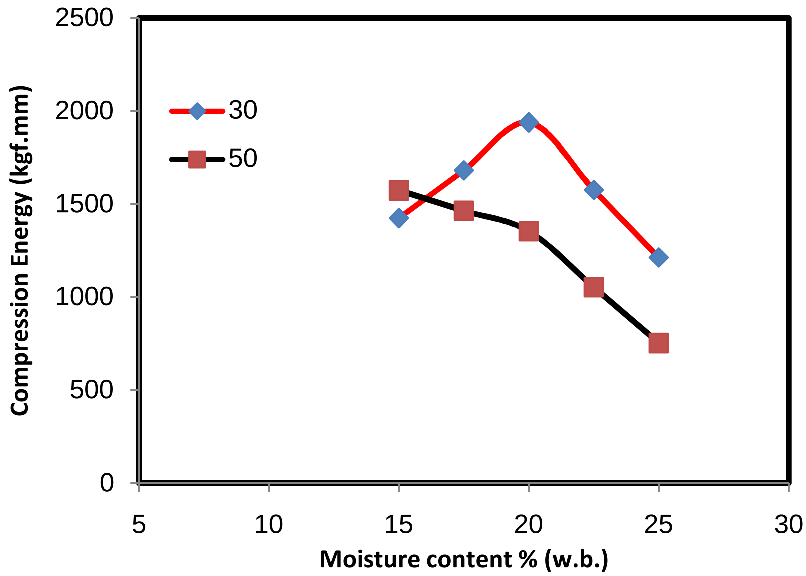


**Fig. 4, the effect of particle size and moisture content on compression energy pressure at 100 MPa.**

The friction energy at pressure of 100 MPa increased for mesh 30 with increasing moisture from 15 to 20% and decreased with increasing moisture content from 20 to 25%. The friction energy for mesh 50 decreased with increasing moisture content. The energy consumption reduced and the loss rate of friction energy consumption is greater than the loss rate of the energy consumption compression and in range from 15 to 17.5% of moisture the energy consumption of mesh 50 is more than mesh 30 and in 17.5% moisture the energy in both the mesh is equal and in the range of 20-15% of moisture the rate of energy loss mesh 50 and the rate of increase mesh 50 is equal and in the range 20-25 % of moisture the loss rate for both is equal. Fig. 5.

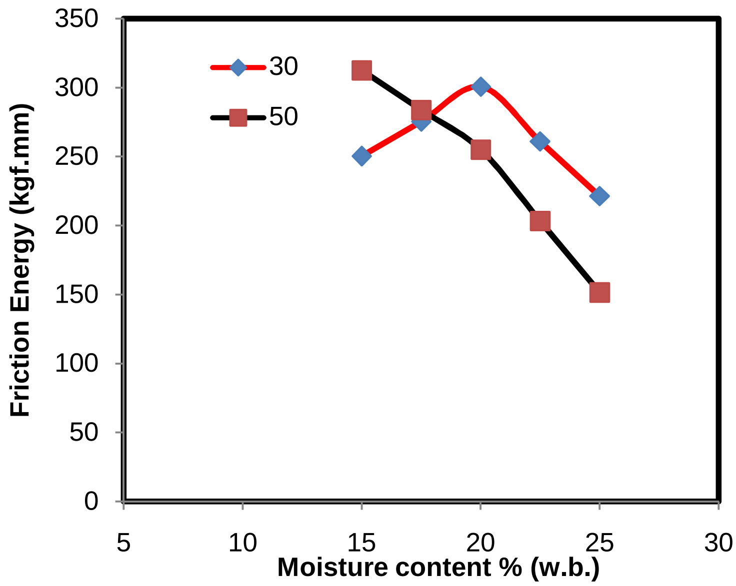


**Fig. 5, The effect of particle size and moisture content on friction energy pressure at 100 MPa.**

Compression energy in pressure of 150 MPa is greater than the pressure of 100 MPa. In range of from 15 to 17.5% moisture, compression energy in mesh 50 is more than that of mesh 30 and in 17.5% moisture the compression energy in both is equal and in range of 15-20% the increasing rate of consuming the compression energy of the mesh 30 and in the range of 15-20% moisture the reducing rates of consuming the compression energy in the mesh 50 and mesh 30 is equal and in the range of 20-25% the reducing rates of consuming energy in mesh 30 is greater than mesh 50 Fig. 6.

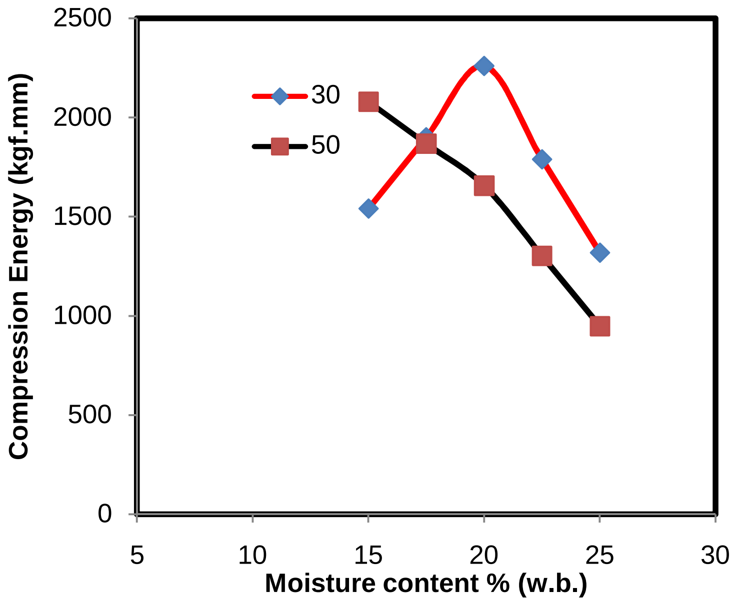


**Fig. 6, The effect of particle size and moisture content on friction energy pressure at 150 MPa**

The friction energy was higher at pressure 150 MPa than the pressure of 100 Mpa. The rate of the friction energy was greater than 100 Mpa and . The friction energy in the range 15 to 17.5% moisture content for the mesh 50 was greater than the mesh 30 and it was equal for both meshes at 17.5% moisture content. In the range of 15-20% moisture the reducing rates of consuming the compression energy in the mesh 50 and mesh 30 is equal but in the mesh 30 the reducing rate is more than mesh 50 Fig.7. Studies of Nielsen et al. (2009) on the sawdust to pellets form show that friction and compression energy decreased with increasing in moisture content and also the compression energy was more than the friction energy.

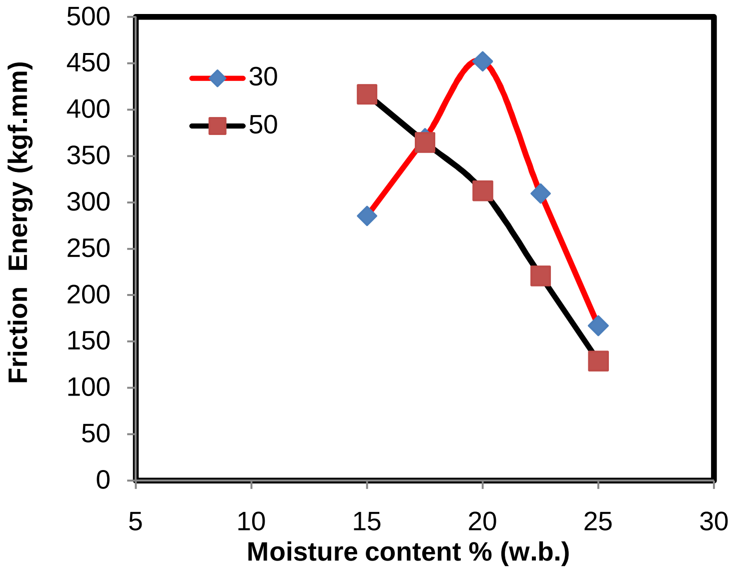


**Fig. 7, the effect of particle size and moisture content on friction energy at pressure at 150 MPa**

At pressure of 100 MPa the highest percentage of friction energy belongs to mesh 50 and moisture content of 25% which is equal to 16.7% and the lowest percentage of friction energy is related to mesh 50 and moisture content of 15% which is equal to 13.42%. The results indicate that a greater share of energy has been spent on compressed and a smaller percentage to overcoming friction. Table. 1

**Table 1. the percentage of energy used in compression and friction pressure of 100 MPa and a mesh size of 30 and 50 and the moisture levels of 15, 20 and 25%**

| Moisture content (%) | Mesh number | Compression energy% | Friction energy (%) |
|---|---|---|---|
| 15 | 30 | 84.54 | 15.45 |
| | 50 | 86.57 | 13.42 |
| 20 | 30 | 84.57 | 15.42 |
| | 50 | 83.43 | 16.57 |
| 25 | 30 | 84.15 | 15.84 |
| | 50 | 83.29 | 16.70 |

The highest percentage of the friction energy at pressure of 150 MPa is anent to the mesh 50 and the moisture content of 20% which is equal 16.7% and the lowest percentage of friction energy is anent to mesh 30 and the moisture content of 20% that is equal to 11.23 % The results indicate that in both pressure level of 100 and 150 MPa the greater percentage of energy used to compression and the least percentage have been used for friction Table 2,

**Table 2. percentage of energy compression and friction that used in pressure of 150 MPa and the mesh 30 and 50 and at moisture contents of 15, 20 and 25%**

| Moisture content, (%) | Mesh number | Compression energy% | Friction energy (%) |
|---|---|---|---|
| 15 | 30 | 84.37 | 15.62 |
| | 50 | 83.32 | 16.68 |
| 20 | 30 | 88.76 | 11.23 |
| | 50 | 83.30 | 16.70 |
| 25 | 30 | 84.12 | 15.87 |
| | 50 | 88.02 | 11.97 |

## CONCLUSIONS

The results indicated that the compression and friction energies for the mesh 30 first increased then decreased by increasing moisture content from 15 to 25% whereas for mesh 50 the compression and friction energy decreased by increasing moisture content from 15% to 25%. The consumption energy for mesh 30 was always greater than mesh 50. For both meshes the percentage of the compression energy was greater than percentage of the friction energy.

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