Asian Journal of Plant Sciences

ISSN 1682-3974

Asian Journal of Plant Sciences 9 (2): 74-80, 2010
ISSN 1682-3974

Effect of Pellet Processing of Fertilizer on Slow-Release Nitrogen in Soil

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Abstract: Nitrogen is an effective material for improving the crop production. Cow manure is an important resource for organic nitrogen which improves the physical condition of soil. More usage of chemical nitrogen as the fertilizer in soil has raised concerns, because some forms of nitrogen absorbs in soil and causes an increase in pollution of environmental water and costs associated with the manufacture and distribution of nitrogen fertilizer. An effective solution is to apply densification technology with molding of manure compost into pellet and adjusting the nutrient content by adding nitrogen fertilizer. The objective of this study was to understand the response of grain yield of wheat (*Triticium* sp.) and its components under various levels of the portion of urea and manure as well as different compressive forces to determine the potential of slow-release of the fertilizer. The chemical fertilizer was added to the pellets within moisture content of 11 to 24% (w.b.). The results showed that density and porosity of pellets increased with increase in moisture content and applied force. The pellets absorbed moisture up 8% within 24 h depending on temperature and air relative humidity. The effects of slow-release from mixed pellets in wheat yield were also observed. Pellet processing can be used as a method for slow-release of nitrogen fertilizer that reduces leaching losses and enhanced nitrogen uptake, as well as positive effects on both health and soil nutrient levels.

Key words: Manure, urea, pellets, density, moisture sorption, durability and nitrification

INTRODUCTION

Manure produced from dairy cattle is by-product of livestock production system. The manure with high moisture and low density is not suitable to use. The densification of dry manure is the best method for decreasing the volume of manure which also decrease the costs of handling and storage.

Biomass densification means to use some form of mechanical pressure to reduce the volume of grind material and conversion of this material to a solid form, which is easier to handle and store than original material (Erickson and Prior, 1990). There are at least four methods for densification using commercial machines. Pelleting and cubing have been used for animal feeds and biomass wastes (Hernandez *et al*., 2006). There are two kinds of pelleting machine available in the world which shape composted livestock manure into pellets. One kind is disk pelleter for dry material and the other one is extruder type for wet material (Masayuki, 2001).

Pellets are subjected to several loads both mechanical and hydro-thermal during production and transport. Due to the handling and transport product material to the farm level in the countries, pellets have often broke and changed into dust (30-50% dust products have been reported) (Hill and pulkinen, 1988). Therefore, in attention to high mount of wastes, the pellets are subjected to improved quality to optimum condition include of environmental and machines parameters is essential. Durability, an important physical property of pellets, is measure of their ability to withstand the destructive loads and forces during handling and transport. Especially, pellet for transport to far region must are durable than others. Achievement to high quality is related to physical forces that bond the particles together in level of production. Mani *et al.* (2004) described the compaction mechanism of biomass grind using different compaction models and reviewed the biomass pelleting process and the effect of various process parameters on pellet density and durability.

Nitrate can be lost by denitrification and leaching, particularly under wet soil conditions. In addition, both ammonium and nitrate can be tied up through immobilization by microorganisms in the soil as they decompose low-N organic residues (Grant, 2003). Increasing use of fertilizer Nitrogen (N) in agricultural production has raised concerns, because the N surplus is at risk of leaving the plant-soil system causing environmental contamination and also increased costs associated with the manufacture and distribution of N

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fertilizer (Alizadeh and Ghadeai, 2006). Wheat is a type of shallow-rooted crop and the domain root zone was 20 cm below the soil surface, which can lead to considerable nitrate loss by leaching under irrigated or high rainfall conditions (Ren *et al*., 2003a, b).

Looking the economic importance of the wheat crop, this study is an attempt to explore the best nitrogen source for obtaining maximum grain. There are many strategies to improve fertilizer use efficiency. These methods such as use of nitrogen sources fertilizers (encapsulated urea, granular oxamide and oxamid powder), placement techniques, split application of N fertilizers and nitrification inhibitors were researched on yield crop (Rymar *et al*., 1989; Eriksson, 1990; Ahmed *et al*., 2007; Freney *et al*., 1992). In this study, pellet processing of mixed urea and manure were suggested to improve fertilizer use efficiency.

The objectives of this study were to determine mechanical properties of pellets made from manure and quantify the effect of moisture, applied forces and binders on the values of these properties. Then, evaluate the effect of mixed pellet on slow-release and grain yield of wheat.

MATERIALS AND METHODS

Sample preparation: The study was carried out during the 2007-2009 at the Experimental Laboratory and Farm of College of Abouraihan, University of Tehran, Iran. Manure used in this study was obtained animal husbandry around the Tehran. At first dry manure (7.6% w.b) were send to the laboratory. In second stage, before pelleting, the manure was ground using a hammer mill. Then samples were wetted by sprinkling water on them moisture content of 11, 16 and 24% (w.b) and stored in a cooler at 4°C for a minimum 72 h. The moisture content of the ground samples was determined following the procedure given in ASTM standard for coal and coke (ASTM, 1998). To increase the strength of pellet, samples were mixed type of binders (bentonit). In later stage, ground samples were compressed by closed die method with four levels of compressive forces (2, 3, 4 and 5 kN) and changing pellets (Mani *et al*. 2004). To improving quality of pellets, before passing through the pellet die, the temperature of the samples was increased to 75°C by heater (McMullen *et al*., 2005). In this study, a single pelleter setup was designed and manufactured (Fig. 1). This machine such as a material testing machine to have a fixed and movable jaw and a control section, that adjusting ability of applied load, speed loading and time loading as shown in Fig. 1. The samples were compressed by hydraulic cylinder at distinguished pressure and die size. This study was conducted to study the pelleting characteristics of manure grind and to determine process parameters and explore the use of binder that may be crucial to the production of high quality pellet.

The specific objectives of this study were to determine (1) the mean values of physical properties of pellet at different conditions and (2) the effect of pellet processing on decreasing of nitrification.

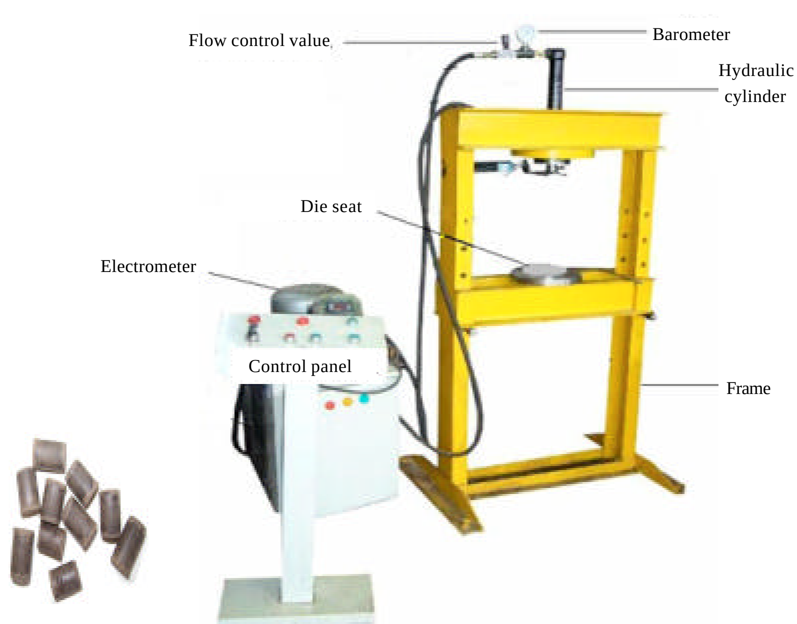

Fig. 1: Hydraulic press setup

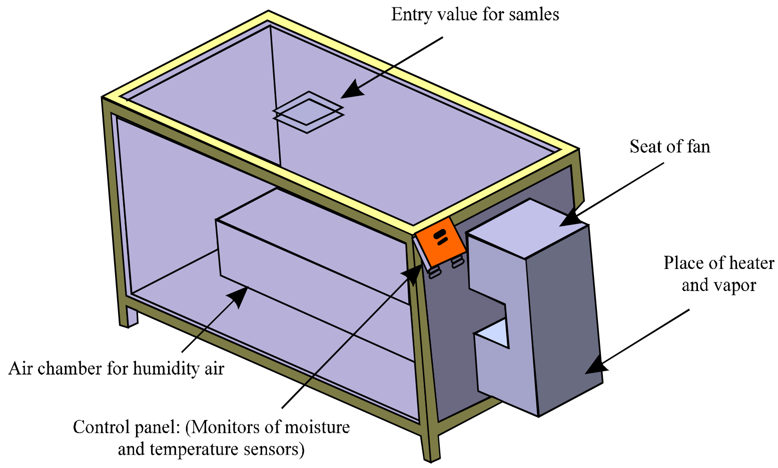

Fig. 2: Schematic of setup for moisture sorption study

Moisture content: The moisture content of the samples were measured by placing 10 g grind samples in an air convection oven set at 130°C for 1 h (ASTM, 1998). The samples classified to 3 levels of moisture content (11, 16 and 24% w.b). Also, moisture content of pellets made by placing 10g pellets in oven set at 103°C for 72 h (ASABE, 2002).

Density and porosity: The diameter (d) and length (L) of 50 pellets from each sample were measured by a digital caliper (Model CD-6CSX, Mitutoyo Corp., Kawasaki, Japan). The corresponding mass (m) of pellet was also obtained with a digital balance with an accuracy of 0.01 g (Model KERN 572, Germany). The volume (V_p) and particle density (ρ_p) were calculated using Eq. 1 and 2.

$$V_P = \frac{\pi}{4} d^2 L \tag{1}$$

$$\rho_P = \frac{m_p}{V_p} \tag{2}$$

Where:
V_p = Volume of pellet (m^3)
$ñ_p$ = Particle density of pellet (kg mm^{-3})
d = Diameter of pellet (m)
L = Length of pellet (m)
m_p = Mass of pellet (kg)

The bulk density was determined according to ASAE standard. This method involves a cylindrical container (300 mm height×310 mm diameter) from a distance of 610mm above its top edge and tapping several times before mass measurements (ASABE, 2002). Bulk density was taken as the ratio of the mass sample in the container to the volume of the container (1137 mm^3). The inter-granular porosity of the pellets were determined from the measured value of bulk density and particle density using Eq. 3.

$$\varepsilon = 1 - \frac{\rho_b}{\rho_p} \tag{3}$$

Where:
ε = Porosity
ρ_p = Particle density of pellet (kg m^{-3})
ρ_b = Bulk density of pellets (kg m^{-3})

Moisture sorption: Moisture sorption tests were conducted in conditioned air chamber (1.8×0.9×0.9 m) at fixed air humidity and temperature (Fig. 2). The temperature-relative humidity combinations of 40°C, 70 and 80% were used for the moisture sorption study. To conduct a test, an amount of 300 g sample was placed in the sample container and rested on the chamber. The sample thereafter exposed to the conditioned air for 24 h. During this time, the pellets would either not absorb any more moisture or would have been almost disintegrated. The weight of the sample was recorded every 30 min.

Achieved data were transferred to the computer and the curve expert software was used to fit an exponential model Eq. 4 to the moisture sorption data.

$$M = (M_i - M_e) \times e^{-kt} + M_e \tag{4}$$

Where:
t = Time
M = Moisture content at time t (w.b.)

Table 1: The treatment of plant sampling

Treatments	Urea (kg ha^{-1})	Manure (kg ha^{-1})	Pressure (bar)
T_1	50	100	75
T_2	100	200	100
T_3	150	300	125
T_4	50	100	75
T_5	100	200	100
T_6	150	300	125
T_7	50	100	75
T_8	100	200	100
T_9	150	300	125
T_{10}	150	-----	----

M_i = Initial moisture content (w.b.)
M_e = Equilibrium moisture content (w.b.)
k = Coefficient of sorption

Plant sampling test: Before pelleting, the manure and urea fertilizer were ground using a hammer mill. Then, the urea fertilizer was mixed with a twofold amount of manure for each treatment. In later stage, ground samples were compressed by closed die method. The experiment was designed as a randomized complete block using 4 replications with ten treatments in each. The Nitrogen levels (N) were 50, 100 and 150 kg N ha^{-1} and levels of compressive pressure of pellet fertilizer were 75, 100 and 125 bar. The treatments contain 9 rats of pellet fertilizer from different levels of urea fertilizer and compressive forces; and a control treatment with an amount of 150 kg ha^{-1} Nitrogen (Eyvazi *et al*., 2008). The treatments are shown in Table 1.

In this study, statistical analysis was done by using SAS software. Also, we used Excel and curve expert software for fitting mathematical models. The specific objectives were to investigate:

- Mean values of physical properties of pellet on the different condition
- To determine the effect of pellet processing on decreasing of nitrification

RESULTS

The particle density and bulk density of pelleted grind manure were about 1226 to 1277 kg m^{-3} and 668 to 681 kg m^{-3}, respectively. The results showed that density and porosity of pellets increased with increase in the moisture content (Fig. 4). The trend lines and the equations of particle density, bulk density and porosity of pellet are shown in Fig. 3 related to moisture content and in Fig. 4 related to compressive force.

Results of moisture sorption test: The results showed that manure pellets absorb certain amount of moisture depending on temperature and relative air humidity (Fig. 5). Figure 5 shows that the pellets can absorb up to 8% moisture content within 24 h of contact with humid air. The standard error of estimate for fitting of Eq. 4 to experimental data was less than 0.09 while the correlation coefficient (R^2) was greater than 0.98 (Table 2).

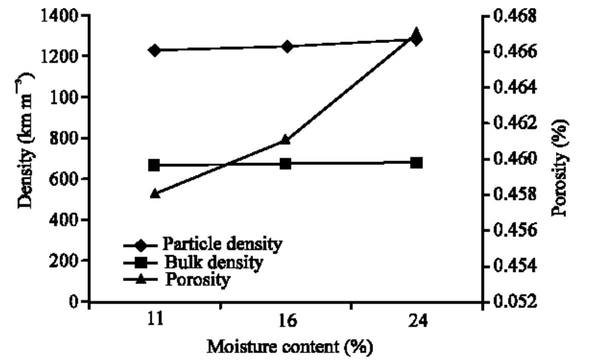

Fig. 3: Effect of moisture content on density and porosity of manure pellets

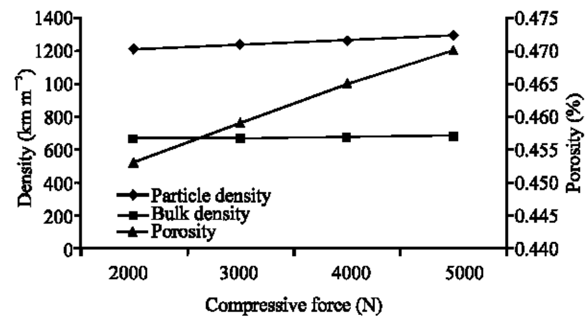

Fig. 4: Effect of compressive force on density and porosity of manure pellets

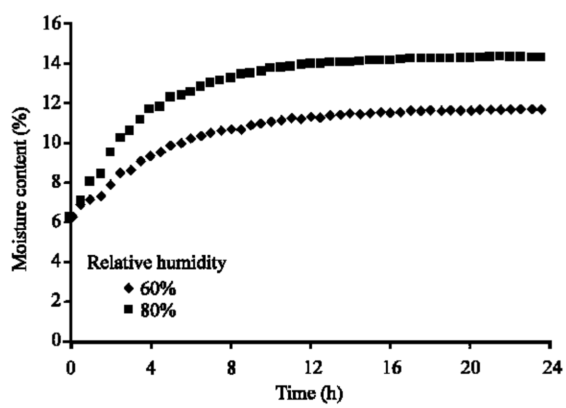

Fig. 5: Effect of relative humidity on the moisture sorption of manure pellets

Effect of slow-release from mixed pellet in wheat yield: The mean grain yield differed significantly between different rates pellet fertilizers ($p<0.01$). The highest

Table 2: Predicted values of k coefficient in moisture sorption

k	R^2	SE	RH (%)
0.2124	0.98	0.078	60
0.2640	0.99	0.089	80

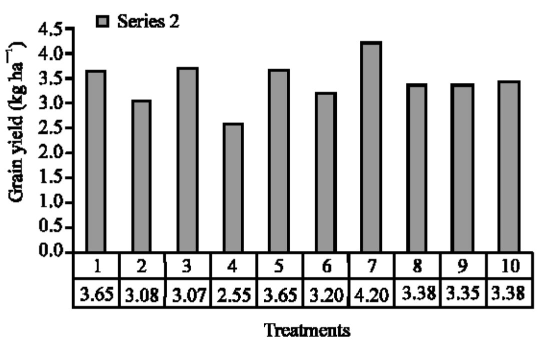

Fig. 6: Effect of different rates of pellet fertilizer on grain yield

increase in grain yield (4.200 kg ha^{-1}) was achieved at pellet fertilizer with 50 kg N ha^{-1} urea and 100 kg ha^{-1} manure with 1875 bar compressive force (T_7). The lowest increase in grain yield (2.550 kg ha^{-1}) occurred by pellet fertilizer with 50 kg N ha^{-1} urea and 100 kg ha^{-1} cow manure with 1500 bar compressive force (T_4), While the control treatment produced 3.375 kg ha^{-1} (Fig. 6).

DISCUSSION

Effects of moisture content and compressive force on physical properties: The most important factor was moisture content of the materials for modeling machine which, greatly influences the hardness and durability of the pellet. The best level of moisture content was about 11% for grind manure. The fluidity of materials falls at lower moisture content and friction resistance increases while the compacted manure passes through the hole of the die. Although, it is postulated that initially wet (less than 10% MC) strengthened the bond between individual particles in a pellet. But, the subsequent increase in volume of the pellets due to increased moisture content was not sufficient to offset these binding forces. Therefore, the strength of the pellets increases. The results were similarly observed by Masayuki (2001) in wet compost and by McMullen *et al.* (2005) in poultry litter. According to Masayuki (2001) the best moisture content is about 40% for an extruder and about 20% for a disk pelleter. Observation from the results indicated that strength of the pellets decreased with increase in moisture content. In general, as moisture content of biomass increased, pellet solidity decreased. Gustafson and Kjelgaard (1963) studied the compaction of hay for a wide range of moisture (28 44% (wb)) and found that the compactness of the product decreased as moisture content increased. Rehkugler and Buchele (1969) reported that there was a reduction in relaxed density of pellet for moisture content ranging between 6 and 25% (w.b). In general, there was a slight increase in bulk density as the moisture content of the manure increased. The amount of storage space that will be required per unit mass of material will therefore increase with increase in moisture content. In contrast, porosity and particle density of the pellets increased with increase in moisture content.

The effect of compressive force on the mechanical properties of manure pellets showed that as compressive load increased, the density of the pellet approached close to the particle density value of sample. This is reason to explain the effect of compressive force. In similarly study by on biomass grind was observed same results (Mani *et al.*, 2006). The effect of compressive pressure on the pellet density of wheat and barley straws, corn stover and switchgrass ground with 3.2 mm hammer mill screen size and 12% (w.b.) moisture content is observed. For all biomass samples, as compressive load increased, the density of the pellet approached close to the particle density value of the sample and increased strength of pellets. This may be due to the stiffness of particles and different elastic properties of manure, which make the particles rigid to compression pressure. Also, when manure grind is more compressed, the lignin in materials became soft and protein make a binding agent between different particle duration compaction.

Effect of relative humidity on moisture sorption of pellets: The results showed that manure pellets absorbed moisture depending on temperature and relative humidity of air and pellets can absorb up 8% moisture content within 24 h of contact with humid air. The results were similarly observed by Fasina (2007) in peanut pellet and by McMullen *et al.* (2005) in poultry litter pellet. According to Fasina (2007) the pellets absorbed up 4.9% moisture content within 48 h of contact with three levels relative humidity of air (45, 60 and 80%) also results of McMullen *et al.* (2005) showed that with increasing temperature and relative humidity, absorbed moisture increased. according received data, maximum absorption (6% moisture content) accrued in 80% relative humidity.

Effect of mixed pellet on slow-release of nitrogen and yield improving.

Pellet fertilizer is a type of Slow-release N fertilizer that Slow-release N fertilizer has long – term effects including reduced leaching losses and enhanced N uptake, as well as positive effects on both health and soil nutrient levels. In similar researches in slow release fertilizers (N as encapsulated urea), Ragasits and Berecz (1996) and Zhang *et al.* (1998) also showed that with decrease nitrification increased wheat yields by 18.3-27.8% and rice yields by 27.5-50.4% as compared with common urea. Ahmed *et al.* (2007) and Kolhe and Mittra (1989) found that slow-release nitrogen fertilizer gave the highest yield of sorghum and wheat, respectively.

Rymar *et al.* (1989) reported that slow release fertilizers (N as encapsulated urea) are more effective than the conventional fertilizers. The proper placement of fertilizer can also increase its use efficiency as reported by Eriksson (1990) also, nitrification inhibitors have been devised to reduce nitrogen losses and improve fertilizer use efficiency (Freney *et al.*, 1992). The split application of N fertilizers is cheaper, but slow-release N fertilizers, when applied at the right time, minimize the risk of N losses by leaching (Ahmed *et al.*, 2007).

Among the mentioned methods, Pellet processing of mixed urea and manure is adequate for slow release fertilizers. This method with compaction of material can be reduced leaching and losses of nitrogen and increased fertilizer usage efficiency. Therefore, it is concluded that in numerous strategies, compacted pellet is an effective source to increase fertilizer efficiency. Because, in this method, both improves the physical condition with compost manure and devised to reduce nitrogen losses. Therefore, fertilizer usage efficiency was improved and decreased the potential risk of nitrate pollution.

CONCLUSIONS

The following conclusion can be drawn from the above study:

- The physical properties of manure pellets are affected by binder, moisture content and applied force. Density and porosity of pellets increased with increase in applied force (1 to 5kN) and increase in moisture content (11 to 24% w.b)
- The storage and handling properties of pellets are affected by relative humidity. The manure pellets absorbed up to 7% percentage points of moisture within 24 h of exposure to humid air
- The effect of mixed pellets from manure and urea on slow- release and yield improving of wheat were observed

ACKNOWLEDGMENT

The authors gratefully acknowledge Iran National Science Foundation (INSF) and Science and Research Branch, Islamic Azad University.

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