Relationship between the particle size and nutrient distribution of feces and nutrients in pigs and dairy cows and the efficiency of solid-liquid separation

Junwei Wu\textsuperscript{a}, Xianjin Zhong\textsuperscript{b}

Hefei Technology College, Chaohu, China
\textsuperscript{awjw200@126.com,\textsuperscript{b}645670631@qq.com}

Abstract. In this paper, pig and dairy manure were used as materials, and the particle size distribution of pig and dairy manure was analyzed according to different particle sizes of <0.15, 0.15-0.5, 0.5-1.0 and >1.0mm. At the same time, NPK in four different particle sizes were analyzed. The nutrient content was solid-liquid separated by using XY-type spiral livestock and poultry manure solid-liquid separators under 0.5 and 1.0mm sieve screens. The mechanical solid-liquid separation was used to analyze the solids and nutrients of the corresponding particle size feces. Recovery efficiency. The results show that the particle size distribution of pig and cow manure is mainly <0.15mm small particles. Such small particles account for 57.99% -68.34% of the weight of the manure. The particle size of dairy manure particles is larger than that of pig manure. Less than fattening pigs and lactating cow feces. Nearly 80% of N, P, and K nutrients in pig and dairy manure are water-soluble or exist in small particles <0.15mm. The percentage of N and P nutrient recovery from solids and solids obtained from mechanical solid-liquid separation of feces is higher than the proportion of fecal particles and nutrients from the corresponding screen pore size. %, N, P nutrient recovery rates were 7.14-19.71, 7.38-21.18%, respectively.

1. Preface
The solid-liquid separation technology, as a pre-treatment technology for manure in livestock and poultry farms, has received widespread attention. Foreign countries have been studying solid-liquid separation technology for manure and sewage in livestock and poultry farms since the 1930s, and have developed more mature physical settlement, chemical flocculation, coagulation, mechanical screening, mechanical extrusion and centrifugation, reverse osmosis membrane and other solid-liquid separation technology has been widely used (moller, 2000, Burton, 2007) \cite{1-2}.

Domestic research started relatively late, and it was only in the 1980s that several separation equipment was introduced from abroad. Lin Daiyan et al. (2005, 2007) \cite{3-5} designed an oblique vibrating screen and used it for flushing water in farms. The solid-liquid separation has achieved good results. Li Chong et al. (2006) \cite{6} reported a professional solid-liquid separator for livestock and poultry manure developed by Haimen City, Jiangsu, which solves the technical problem of plugging in use. Xing Ruming (2007) \cite{7} proposed an improved screw extrusion equipment based on the physical and chemical characteristics of livestock and poultry manure in Beijing. The solid-liquid separation effect was further improved. Wu Junwei etal. (2009) \cite{8} used XY-type spiral solid-liquid separator to
optimize the parameters and effects of solid-liquid separation of pig manure. As a result, it was found that solids and nitrogen, The recovery rate of nutrients such as phosphorus is low, and it is difficult to achieve the effects of solids recovery and nitrogen and phosphorus recovery. In order to improve the solid-liquid separation efficiency of livestock and poultry manure, this experiment sampled and analyzed the particle size of pig manure and the nutrient distribution of nitrogen, phosphorus, potassium, etc. in order to provide a theoretical basis for evaluating the solid-liquid separation efficiency and improving the solid-liquid separation equipment and technology.

2. Materials and methods

Materials: Dairy manure was collected from Xinghe Dairy Farm in Haimen City. It was divided into two kinds of manure samples according to lactating and bred cattle. Pig manure was collected from pig farm of Liuhe Base of Jiangsu Academy of Agricultural Sciences. It was divided into two samples according to piglets and fattening pigs. All samples were freshly excreted from pigs and cows, collected at multiple points and stored in a freezer (40°C) for later use. The sampling time was November 2008. See Table 1 for the basic characteristics of pig and cow stool samples.

![Table 1. Basic characteristics of pig and cow feces](image)

|                        | pH  | N(mg/kg) | P(mg/kg) | K(mg/kg) | Water content % |
|------------------------|-----|----------|----------|----------|----------------|
| Fattening pig manure   | 6.8 | 18.7     | 8.1      | 23.1     | 78.4           |
| Lactating cow dung     | 7.2 | 14.5     | 3.8      | 8.9      | 83.5           |

Methods: The sifters with 0.15mm, 0.5mm and 1.0mm pore size were selected to classify the stool samples of pigs and cows. At the same time, the contents of nitrogen, phosphorus and potassium in different sizes of feces of pigs and lactating cows were analyzed.

Using manure from fattening pigs and lactating dairy cows as materials, solid-liquid separation using a XY-type manure solid-liquid separator under 0.5mm and 1.0mm pore size sieve is carried out. The separated solid samples are collected to calculate the solid-liquid separation solid recovery rate and measure Nitrogen and phosphorus nutrients in solid materials.

Project test method: After digestion of fecal samples with concentrated H₂SO₄–H₂O₂, total nitrogen is determined by Kjeldahl method, total phosphorus is determined by vanadium molybdenum yellow colorimetry, and total potassium is determined by flame photometer method.

3. Results and analysis

3.1. Pig milk manure particle size distribution

The results of the particle size distribution of pig and cow manure can be seen (Table 2). The particle size distribution of pig manure and cow manure is mainly composed of small particles <0.15mm (including water-soluble organic matter and salts, the same below). Particles account for 57.99% - 68.34% of the total weight of solids in the feces. The size of piglet feces in pig manure is smaller than that of fattening pigs. The proportion of piglet manure with a particle size of less than 0.15mm is as high as 68.34%, while that of fattening pigs is only 57.99%. Similarly, the particle size of the cow manure produced is also smaller than that of lactating cows, but the difference between the two is smaller than that of pig manure. Compared with pig manure, the particle size of manure is significantly higher than that of pig manure. This difference may be due to the different types of feed used by livestock and the structure of the gastric digestive system (Clanton et al 1991; Kerr et al 2006) [9, 10].
### Table 2. Particle size distribution of pig and cattle manure (%)

| Particle size distribution | <0.15mm | 0.15-0.50mm | 0.50-1.00mm | >1.00mm |
|---------------------------|---------|------------|-------------|---------|
| Fattening pig manure      | 57.99±0.0165a | 14.16±0.0158b | 15.91±0.0232b | 11.93±0.0238b |
| Piglet manure             | 68.34±0.016a  | 15.53±0.022b  | 9.81±0.0007bc | 6.31±0.0053c  |
| Lactating cow dung        | 52.85±0.0077a | 19.36±0.008b  | 15.11±0.0201c | 12.68±0.0204c |
| Cow dung                  | 59.45±0.0205a | 19.9±0.0282b  | 12.5±0.0009c  | 8.08±0.0068c  |

Data are mean ± standard deviation. Different lowercase letters in the same industry indicate significant differences between samples (α = 0.05).

### 3.2. Nutrient distribution in pig and cow dung with different particle sizes

#### 3.2.1. Nutrient content in each particle size.

The N, P, and K contents of pig manure are generally higher than those of cow manure (Table 2). Most of the N, P, and K nutrients of pig manure and cow manure are present in small particles of <0.15mm or water-soluble salts. The nutrient content of N, P, and K decreased with the increase of particle size. The nutrient content of small particles <0.15mm was significantly higher than that of >0.15mm particle size. N, P, and K three kinds of different crop nutrients have the same distribution trend in different particle sizes, but the distribution characteristics are different. The N content gradually decreases with increasing particle size, while P and K nutrients, when the particle size is greater than 0.15 mm, sharply decreased, indicating that the P and K nutrients in the feces were in a water-soluble state or existed in small-sized particles. This trend is consistent with the current sources and composition of feed ingredients and the existence of N, P, and K in animal and plant source feeds.

#### Table 3. Nutrient content of fattening pig manure with different particle sizes (%)

| Particle size(mm) | N  | P  | K  |
|-------------------|----|----|----|
| <0.15             | 2.79 | 1.26 | 3.74 |
| 0.15-0.50         | 0.71 | 0.26 | 0.39 |
| 0.50-1.00         | 0.53 | 0.20 | 0.28 |
| >1.00             | 0.55 | 0.06 | 0.28 |

#### Table 4. Nutrient contents in lactating cow dung with different particle sizes (%)

| Particle size(mm) | N  | P  | K  |
|-------------------|----|----|----|
| <0.15             | 2.15 | 0.59 | 1.45 |
| 0.15-0.50         | 0.70 | 0.18 | 0.29 |
| 0.50-1.00         | 0.57 | 0.16 | 0.23 |
| >1.00             | 0.63 | 0.11 | 0.23 |

#### 3.2.2. The total amount of nutrients in each particle size.

From the data in Table 2 and Tables 3 and 4, it can be obtained (Tables 5 and 6): N, P, and K crop nutrients that are water-soluble or present in small-sized particles account for 78.62-93.94% of the total nutrients in feces.

The nutrient content of N, P, and K crops that are water-soluble or present in small-sized particles in pig manure is significantly higher than that of dairy cow manure. Among different N, P, and K nutrients, the proportion of P and K nutrients is higher. 93.94% of K in pig manure is water-soluble or exists in small particles with a particle size of <0.15 mm.
Table 5. Proportion of nutrients with different particle sizes in fattening pig manure (%)

|       | <0.15mm | 0.15–0.5mm | 0.50–1.0mm | >1.0mm |
|-------|----------|------------|------------|--------|
| N     | 86.63a   | 5.35b      | 4.50b      | 3.51b  |
| P     | 90.57a   | 4.57b      | 3.95b      | 0.90c  |
| K     | 93.94a   | 2.60b      | 2.16b      | 1.30c  |

Note: Different English lowercase letters indicate significant differences between samples (α = 0.05)

Table 6. Proportion of nutrients with different particle sizes in lactating cow dung (%)

|       | <0.5mm | 0.15–0.5mm | 0.50–1.0mm | >1.0mm |
|-------|--------|------------|------------|--------|
| N     | 78.62a | 9.66b      | 6.20b      | 5.52b  |
| P     | 81.45a | 8.85b      | 6.20b      | 3.50c  |
| K     | 86.46a | 6.32b      | 3.95b      | 3.27c  |

Note: Different English lowercase letters indicate significant differences between samples (α = 0.05)

3.3. Comparison of solid-liquid separation effect of XY type fecal solid-liquid separator with estimated values of fecal particle size and nutrient distribution

Using pig manure sewage and cow manure sewage as materials, XY-type manure solid-liquid separator was used to perform solid-liquid separation tests under two sieve apertures of 0.5 and 1.0 mm (Table 7). Under two sieve apertures of mm, after the separation by the XY type solid-liquid separator, the actual solid recovery rate is higher than the proportion of the actual particle weight above this aperture. After the XY type solid-liquid separator, the percentage of N and P nutrients recovered in feces was lower than that of solids, but higher than the proportion of N and P nutrients with corresponding particle sizes. But on the whole, after mechanical solid-liquid separation, more than 70% of solid matter in pig manure and more than 85% of crop nutrients, and more than 50% of solid matter in cow manure and more than 75% of crop nutrients have entered the liquid part Consistent with the results of HBMoller (2002), Rico (2007) and Chastain (2001) [11-13] and others.

Table 7. Comparison of solid-liquid separation effect of XY-type solid-liquid separator with pig manure particle size and nutrient distribution

|                  | Pig dung | Cow dung |
|------------------|----------|----------|
| 0.5mm            | 1.0mm    | 0.5mm    | 1.0mm    |
| Percentage of granular feces larger than this pore size (%) | 27.84 | 11.93 | 27.79 | 12.68
| XY solid-liquid separator solid recovery ratio (%)       | 28.77   | 19.02    | 45.47   | 28.59 |
| Proportion of particulate feces N larger than this pore size (%) | 8.01   | 3.51     | 11.72   | 5.52 |
| XY-type solid-liquid separator N recovery ratio (%)      | 19.77   | 7.14     | 17.71   | 14.12 |
| Percentage of granular feces larger than this pore size (%) | 4.85   | 0.90     | 9.70    | 3.50 |
| XY type solid-liquid separator P recovery ratio (%)      | 11.96   | 7.38     | 21.18   | 19.00 |

Note: The theoretical particle size and nutrient content in the table refer to the particle size distribution and nutrient sum

4. Discuss

The solid-liquid separation is necessary and important for the subsequent high-efficiency of intensive farming manure. Through solid-liquid separation, the concentration of nutrients such as COD and NP in the manure can be reduced to obtain a solid matter with higher NP nutrients. At the same time, it is
easy to transport, and the manure after solid-liquid separation can be used in situ by anaerobic treatment, which reduces the land area requirements for consuming manure (moller, 2000, Burton, 2007) [1-2]. The solid-liquid separation technologies currently used mainly include chemical sedimentation, mechanical sieving, screw extrusion, decanter centrifugal dewatering and other technologies. The solid-liquid separation efficiency is not only different due to different solid-liquid separation methods, but also affected by the way of fecal collection, Storage time and method, and pretreatment (Moller, 2002; Kunz, 2009) [11, 14], etc., Zhang and Westerman (1997) [15] studied the efficiency of different solid-liquid separation technologies, and proposed to understand the particles in fecal sewage. The diameter distribution and chemical composition are extremely important for the evaluation of solid-liquid separation efficiency. Moller (2002) [11] compared the solid-liquid separation efficiency of pig and cow dung by spiral extrusion. The results show that the solid-liquid separation of cow dung The efficiency is higher than pig manure. The reason is that the proportion of particles larger than 0.25mm in cattle manure is much higher than that of pig manure. The results of this test (Table 7) also show that: under a 0.5mm diameter mesh sieve, the solid recovery rate in cattle dung sludge reached 45.78%, while pig manure was only 28.77%. It was also found that under the 0.5mm diameter mesh sieve, The actual recovery rate of solids is much higher than the proportion of granular feces with the same particle size. Burton (2007) [2] believes that this is due to the high mechanical solid-liquid separation feed, fast separation speed, and the distribution, shape and pressure of the mesh sieve. The difference is that part of the material smaller than the corresponding pore size of the sieve cannot be squeezed through the sieve and remains above the sieve, thereby improving the recovery rate of solid materials.

From the results of this test (Table 7), the solid recovery rate of manure by spiral extrusion is higher than nutrients such as nitrogen and phosphorus. From the comparison of the data in Table 2 and Tables 5 and 6, it is not difficult to see that at the same particle size, The proportion of nitrogen and phosphorus nutrients is much higher than that of the corresponding fecal particles, which indicates that the nitrogen and phosphorus nutrients in the feces are mainly distributed in small-sized particles except for some water-soluble ones. At the same time, the nitrogen and phosphorus nutrient recovery rate The reason for the low may also be related to the solid-liquid separation method used for screw extrusion (Moller et al, 2000; Pain et al, 1978) [1, 16]. The recovery rates of nitrogen and phosphorus are different. Moller et al (2007) [17] believes that the recovery of nitrogen and solids in manure is related to the content of dry materials in manure. influences.

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References
[1] H.B. Moller, I. Lund, S.G. Sommer 2000 Solid-liquid separation of livestock slurry: efficiency and cost Bioresource Technology 74: 223-229
[2] C.H. Burton 2007 The potential contribution of separation technologies to the management of livestock manure Livestock Science 112: 208–216
[3] Lin Daiyan, Weng Boqi, Qian Wuqiao 2005 Application effect of FZ-12 solid-liquid separator in large-scale pig farm sewage [J] Journal of Agricultural Engineering 21 (10): 184-186
[4] Lin Daiyan, Weng Boqi 2007 Development and application of solid-liquid separator [J] China Biogas 25 (1): 31-33
[5] Lin Bin, Xu Qingxian, Qian Lei, 2006 FZ-12 Solid-liquid Separator Structural Features and Application in Pig Farm Manure Treatment [J] Fujian Agricultural Science and Technology 6: 60-61
[6] Li Chong, Liu Min, Zhao Guodong, Shen Danbo, 2006 Research and development of key equipment for manure and sewage treatment in large-scale farms [J] Agricultural Equipment
[7] Xing Ruming, Li Haiying 2007 Design of solid-liquid separation equipment for feces [J] Environmental Sanitation Engineering 15 (1): 25-27

[8] Wu Junwei, Chang Zhizhou, Zhou Lixiang, Qian Yuting, Xu Xiao 2009 Study on Dehydration Effect of XY-type Livestock and Poultry Manure Processor [J], Jiangsu Agricultural Sciences (2): 286-287

[9] Clanton, C.J., Nichols, D.A., Moser, R.L., Ames, D.R., 1991. Swine manure characterization as affected by environmental-temperature, dietary level intake, and dietary-fat addition. Transactions of the ASAE 34, 2164–2170.

[10] Kerr, B.J., Ziemer, C.J., Trabue, S.L., Crouse, J.D., Parkin, T.B., 2006. Manure composition of swine as affected by dietary protein and cellulose concentrations. Journal of Animal Science 84, 1584–1592.

[11] H.B. Moller, S.G. Sommer, B.K. Ahring 2002 Separation efficiency and particle size distribution in relation to manure type and storage conditions Bioresource Technology 85 :189–196

[12] Chastain, J.P., Vanotti, M.B., Wingfield, M.M., 2001. Effectiveness of liquid–solid separation for treatment of flushed dairy manure: a case study. Appl. Eng. Agric.17, 343–354.

[13] J.L. Rico, H. Garcia, C. Rico, I. Tejero Characterisation of solid and liquid fractions of dairy manure with regard to their component distribution and methane production Bioresource Technology 98 (2007) 971–979

[14] A. Kunz, R.L.R. Steinmetz, M.A. Ramme, A. Coldebell 2009 Effect of storage time on swine manure solid separation efficiency by screening Bioresource Technology 100: 1815–1818

[15] Zhang, R.H., Westerman, P.W., 1997. Solid–liquid separation of animal manure for odor control and nutrient management. Appl. Eng. Agric. 13, 657–664.

[16] Pain, B.F., Hepherd, R.Q., Pittman, R.J., 1978. Factors affecting the performance of four slurry separating machines. J. Agric. Eng. Res. 23, 231–242.

[17] Moller, H.B., Hansen, J.D., Sorensen, C.A.G., 2007 Nutrient recovery by solid–liquid separation and methane productivity of solids. Transactions of the ASABE 50 (1): 193–200.