The Resource Utilization of Anaerobic Fermentation Residue

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\section*{Abstract}

The popularization of biogas project produced a large number of anaerobic fermentation residues. The resource recycling and harmless utilization of these residues have become one of the hottest researches of related areas. This article summarizes the current situation about researching and utilization of biogas slurry and residues contained their components, functions and status of study domestic and foreign systematically. This study introduces the basic characters of biogas slurry and residues, and systematically summarizes it’s newly application and investigation all over the world, and also pointed out the shortcomings. Finally, we forecast the new ways of anaerobic fermentation residues utilization from ecological, environmental and economic points of view. (Abstract)

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\section*{0. Introduction}

With the emphasis on Environmental protection, Energy saving and Emission reduction, the number of large-scale livestock concentration of farms are growing year by year, large-scale pig farms and cattle constantly are developing, farms’ wastes treatment has become a issue of concern. The construction of Biogas project uses dung unclean with solid wastes for fermentation materials to get secondary energy-biogas which provides a powerful solution for large-scale wastes treatment. The project not only improves the farms environment, but also avoids the secondary pollution of manure breeding and gets clean energy-biogas. After years of practice, biogas slurry residue has been get rational utilization to some extent, but it should be further studied in the field of gas, liquid and residue’s systematic recycling remains. Thus, the summarization of anaerobic fermentation residue’s resource recycling to support our construction of biogas energy project is great significance.

Anaerobic digestion is the process of producing biogas by the utilize of special microbial community interact with organic matter, its products can be general divided into gas, biogas, biogas residues (gas,
liquid and solid three forms). Biogas can be directly used for energy or filling liquefied gas after purification treatment or connect gas pipeline directly, you can also generate electric power by biogas. Some stratified by different nutrients contained in the upper, middle and lower residues, others stratified by the objects of application etc. [1]. This article focuses on the following aspects to introducing new ways of recycling anaerobic fermentation residue.

1. Biogas slurry

1.1 Composition and Function of Biogas slurry

Compared with the residue, the nutrient content of Biogas slurry is relatively low, but biogas slurry is exiting as rapidly-available. The macromolecules, which contained in the raw materials of fermentation crops, are difficult to absorb by crops. However after decomposed by microorganisms, these macromolecules form by ionized materials which have simple structure are easy to be absorbed by crops. These ionized materials is particularly rich in a variety of nutritive elements such as nitrogen (0.03%~0.08%), phosphorus (0.02% ~ 0.07%), K (0.05%~1.40%) [2], and trace minerals such as calcium, copper, iron, zinc, manganese. These elements can enter into the cell through ion forms and play a role of nutritional substances [3]. There also contains a wealth of monosaccharide, humic acid, unsaturated fatty acid, cellulose and certain antibiotics which in favor of crop growth. For example, Gibberellins (GA) can increase germination rate by stimulating seeds, promote crop stems and leaves to grow fast. Some of the nucleic acid can enhance the drought resistance of crops during the drought; free amino acids and unsaturated fatty acids can protect crops from frost damage at low temperatures; certain vitamins can enhance the disease resistance of crops; these substances can induce plant flowering, prevent falling and fallen fruit and enhance fruit setting rate during crops reproductive stage [4].

There are many amino acids in biogas slurry, such as lysine, tryptophan, methionine, histidine, leucine, isoleucine, phenylalanine, threonine, valine, arginine and so on. Most of them are necessary for animal growth. Biogas slurry also can be used as feed additives as it contains vitamins and hormones which are needed for animal growth [5]. Biogas slurry contains the proline, linolenic acid, fulvic acid and other substances can greatly improve the frost resistance of fruit trees. The main physical and chemical properties of biogas slurry contain: Water 95.50%, Total Nitrogen 4.20g/kg, Total Phosphorus 0.27g/kg, Total Potassium 1.15g/kg, pH value 7.6, Alkeline-N 335.60mg/kg, Available phosphorus 982.00 mg/kg, Available Potassium 895.70 mg / kg, and Available Zn 0.400 mg/kg.[6]

1.2 Recycling of biogas slurry

1.2.1 Slurry as compound feed for animal

Biogas slurry as feed preparation for pigs can promote growth, shorten the fattening period and improve meat feed ratio. According to estimation based on investigation, the feed conservation amount of each pig is 50kg and the fattening period can be reduced 20~40 d by using biogas slurry as a pig feed additive. Also there were no infectious or parasitic diseases with the main organs and meat by anatomical and meat quality analysis after slaughtered [7]. Biogas slurry for fish-farming doesn’t have to be solid-liquid separation and the application weight no more than 450kg per acre pond each time with three times a week. Pounds with biogas slurry can increase the amount of plankton, also the enhancement of photosynthesis with more oxygen and then fish crop is appropriate to increase. At the same time, slurry feed fish can reduce fish diseases and save feedstuff, etc [8].
1.2.2 Biogas Slurry Soaking Seed

Biogas slurry contains large amounts of humic acid ammonium, various kinds of vitamins, IAA and crops required nitrogen, phosphorus, potassium and other trace elements as well as a variety of active substances secreted by microorganisms. These soluble nutrients will be absorbed by seed at varying degrees with the function of osmosis that can effectively activate the enzyme source of seed embryo and endosperm, enhance enzyme activity, stimulate germination and growths of seeds, accelerated the process of nutrient transformation from dormancy and sprout to seedlings, promote metabolism and also kill the pathogenic bacteria at the same time. To soak seeds with biogas slurry can increase sprouting rate significantly because the inhibitory effects on rice root rot, sheath blight, helminthosporium sigmoideum cavara, bakanace disease, anthracnose of cotton, the leaf spot of corn. Studies has shown that compared with the control group, the wheat seeds soaking treatment with 100% original slurry which have better rotten degree and longer fermentation time have seed germination rate increased 13%, the seedling stage 3 days in advance, the leaf length increased 1.70cm, the leaf width increased 0.09cm, the seedlings dry weight increased 0.71g, the maturity stage shorten 2 days, the wheat output increased 25.3 kg per mu yield, the rate of growth is 9.20%[9].

1.2.3 Biogas slurry as fertilizer

Biogas slurry is often used to make liquid fertilizer directly to improve crops yield and quality as its rich content of nutritive elements, and the most application way of slurry is used as foliar fertilizer. The winter wheat with biogas slurry spraying can not only increase the spikelet length and grain number, the thousand-grain weight and yield, but also can inhibit diseases and insects[10]. The study of Liu Xiaogang found that the chlorophyll content of Red Fuji Apple’s leaves is 3.319% higher than the control group and range to maximum relatively when the times of leaf surface spraying slurry as much as 6. Huang Dongfeng’s study has shown that tea leaves with spraying liquids methane can promote the growth of tea plant height, increase the germination rates and weight of single tea leaf and the increasing rate of tea was 9.0% [11]. Zhao Shuguang’s research has shown that with different concentrations biogas slurry spraying on Chili peppers’ leaves surface can increase the content of soluble sugar and capsaicin and improve the agronomic traits of chili peppers which with 50% concentration spraying slurry has maximum yield and 25.42% increasing compared with control group[12]. These above practices have shown that different agronomic crops match different concentrations slurry should have achieved the best results.

Biogas slurry can be directly used as basal soil for the soil irrigation. Many results showed that with the biogas slurry blend into inorganic fertilizer can promote each other with the increasing contents of nitrogen, potassium, phosphorus and other nutrients in soil[13]. The humic acids in biogas slurry play an important role in the formation of aggregates of soil. It can enhance the soil’s capacity of water and nutrients conservation, increase soil enzymes activities and soil respiration intensity, improve soil physical and chemical properties, enhance soil temperature and organic matter, total nitrogen, total phosphorus and available phosphorus of soil, as well as reduce pollution and cut down the fertilizer costs[14]. Through the application of combined biogas and fertilizer on the rice production in cold places, Zuo Xin’s study has shown that rice yield will increases 10% as 50% biogas slurry was intermixed with 50% fertilizer, [15]. Zhang-yuan has approved that the treatment of biogas slurry and inorganic fertilizer used together can serve to significantly improve the yield of rapeseed and increase the VC and sugar content while reducing the nitrate in rapeseed. [16]. Hydroponic rape experiment with biogas slurry by Qiao Yifei has shown that it not only increase the production significantly of rapeseed, but also improve the quality as a certain extent. With the treatment contrast, the circumstance with 0.25 ~ 1.25 ml/L biogas slurry addition has VC content increased by 42.6% and sugar increased 60.1% while the nitrate and total acid content of rape decreased by 16.9 % and 33.6% respectively[17].

Biogas slurry as additional fertilizer has significantly effect on increasing yield and swelling of fruits.
The production of wheat increased 450kg/hm² after fertilization with biogas slurry \[18\]. The number of cabbage’s leaf blade, petiole length and width are higher than those of control group; also the yield of cabbage increased significantly and the maximum yield increased 97.74% \[19\]. The output and income increased remarkably of garlic as the supplement of biogas slurry raised \[20\]. Use chemical fertilizer as basal fertilizer, assisting biogas slurry for celery in the pot culture with 300mL slurry treatment in the mature period compared with fertilizer treatment, the chlorophyll content and catalase activity were increased by 19.06% and 6.52% respectively. By contrast to application of chemical fertilizer treatment, application of biogas slurry treatment with 900ml at one time, VC content and reducing sugar content increased 9.07% and 51.31% respectively while the nitrate content decrease 31.65%. The study also found that there were no significant impacts on quality and yield whether they implement biogas slurry at one time or in parts \[21\].

1.2.4 Biogas slurry can partially substitute pesticides to control pests and diseases

Prevention and combat of pests and diseases with biogas slurry has been confirmed by practical and scientific experiments, it was called biological pesticides as its non-polluting, no residues and non-resistance. The present experiments have shown that biogas slurry can control 23 kinds of diseases and 14 tapes of pests from 13 kinds of agronomic crops such as grain, vegetables, and fruit trees and so on. Some single-use slurry had reached or exceeded the efficacy of drugs and some joined drugs can enhance the effects of control. For example, compared with the non-biogas slurry spraying, the spraying one can significantly reduce the spraying of potato late blight rate and black shank rate lower than 1.6% and 10.6% respectively. With the slurry clarification and filtration spray directly can prevent the pests of yellow and red spiders of citrus. In General, red and yellow spiders’ deactivation period was 3 ~ 4h, death period was 5 ~6h (mortality reached 98.5%) \[22\]. In the experiment of cultivate cabbage with anaerobic fermentation residues, Jiang Wenteng and LinCong \[23\] found that anaerobic fermentation residues possessed a strong inhibiting effect on Escherichia coli, Bacillus paratyphosus and Bacillus erysipelatos-suis, possesses different inhibitory effect on 10 Penicillium and Aspergillus species and varying degrees inhibitory effect on 17 kinds of pathogens. The experiment of pests control with slurry by GanShouwen has confirmed vegetables with slurry spraying can significantly reduce aphid damage and promote the growth of vegetables with an average increase of 8.8% \[24\]. Long-term using of biogas slurry as an auxiliary drug for pests and diseases control will not bring pollution to the environment or produce resistance to the pests and diseases \[25\].

2. Biogas Residue

2.1 The Composition and Function of Residue

Biogas residue is the bottom slag produced by anaerobic fermentation. Because organic matters gradually decompose and transform to methane, carbon dioxide during the fermentation process and the remaining nutrients are retained in the biogas slurry residue. Most of the residue exists as organic and inorganic solid form which is insoluble or difficult to decomposing. Biogas residue is also rich in organic matter, humic acids, nitrogen, phosphorus, potassium and other nutrients as the large amounts of soluble available nutrients on the surface of residue.

2.2 Recycling of Biogas Residue

2.2.1 Soil Improvement with Biogas Residue Directly

Compared with chemical fertilizer, researchers found that the soil with biogas residue has organic
matter, ammonia nitrogen, available phosphorus, available potassium content increased of 31.60%, 28.36%, 26.19% and 12.08% respectively during the experiment of cucumber cultivation with the pig manure anaerobic fermentation residue. The increase of soil organic matter which is conducive to microbial activity and the formation of soil aggregate structure represent the capacity of fertilizer potential and the strengthen stability of soil. The data from Biogas Fertilizer Research Institute of Quxian of Sichuan province has shown that for 6 years dressing residue, the soil organic matter content increased 58.4%, density decreased 16.1%, porosity enlarged 12.9%, cooked layer thicken 8cm and aggregate structure has been improved [26]. The increase of porosity is conducive to the soil permeability and water permeability and improves the physical properties of soil. Biogas residue is the most beneficial form of base fertilizer as its high nutrient content, rich organic matter and humic acid.

2.2.2 Biogas Residue as Fertilizer

It’s shown that both of the number and yield of tomatoes were improved significantly and also flowering period and fruiting period were ahead with biogas residue which was fermentation by cow manure mixed with soil in proportion of 5% and 10% for greenhouse tomato seedling [27]. LiZhebi has found that biogas slurry residue with a certain percentage of the chemical fertilizer can promote the growth of lettuce and also improve the yield and its nutritional quality [28]. Biogas slurry residue combined with chemical fertilizer can improve the content of Vitamin C, amino acids and the reducing sugar of lettuce leaves. Residue can be used with other fertilizers, such as the mixture of biogas residue and phosphoric rock can be made of residue-phosphatic fertilizer which has a significant increase of yield for phosphorus-poor soil [29]. Biogas residue and ammonia fertilizer mixed can reduce the losses of nitrogen. HaoXianjun’s research has suggested that it visibly improved the quality of mini cucumbers with biogas residue as basal fertilizer complemented by biogas slurry spraying plant leaf surface [30].

2.2.3 Biogas Residue as Feed

Chicken have laid larger and thicker skin eggs with biogas residue as feed additive and the laying rate is advanced by about 5% in general. Use of biogas residue feed pigs has been widely applied in practice, according to my experience, the residue must dry in the air and crush and then collation with common feed for pigs. The specific methods of operation is as following, take out biogas residue from biomass pool and remove most of the slurry and then spread to the thickness of 5 to 10 cm evenly when it slightly dry, then exposure until to dry, finally smash with a mill. The amount of residue feed mixture is 15% to 20% for pigs, and 7% to 10% for chicken, ducks and geese, 25% to 30% for sheep, 20% to 25% for cattle [31]. Since residue is rich in nutrients and easy to absorb, pigs with residue feeding can make them appetite vigorous and do not get diseases or seldom ill and the average daily gain (ADG) was 0.5~0.7kg. Use it to raise the same quality pigs can save feed more than 80kg every head on average [32]. Di Ruifang used biogas residue which used pig manure as raw material for fermentation compared with pig dung as stuffing directly for fish culture has increased the content of hydroplankton and about 10% efficiency, reduced fish diseases and shorten fish farming cycle significantly [33].

2.2.4 Biogas as Culture Medium

Biogas residue is full of nutrition and easy to obtain, so using biogas residue to prepare nutrition soil and nutrition pot have been widely adopted. S.Banik’s research showed that the mixture of rice straw with purified biogas residue in 1:1 portion as the culture matrix of mushrooms can significantly improve the protein content of mushroom fruiting body and the content of Na, K, Ca, Fe, Mn, Cu, Zn, P, and other mineral elements and reduced arbohydrate content [34]. Zhao Li used biogas residue as the matrix for vegetable cultivation, such as cucumber, tomato, cabbage, cabbage and so on. The analysis results of biogas residue showed that the physicochemical property, pH and EC were achieved the standard and rich in N, P, K. So biogas residue is an ideal substrate for vegetables cultivation [35]. Biogas residue can also be
the substrate for planting Chinese Herbs. Liu Guosheng used residue to plant high quality Angelica, the effect is significant and the yield rate of increasing achieved 56.7%, however, it has enhanced the medicinal effect of Angelica [36]. There were good results of using biogas residue as matrix for planting peanuts [37].

3. The shortcomings of resource utilization of Biogas Slurry and Residue

With the popularity of a large number of biogas projects, fermentation residue utilization did not undergo any environmental risks tests, so whether the heavy metals including in fermentation residue will cause environmental harm or not, and the questions of risks on crop farming and animal husbandry these are pending further assessment. The mechanism of residue as fertilizer on soil structure and soil microbial communities, and the physiological and biochemical role of metal ions contained in residues on the soil microbial need to be further detailed study. Currently, it is lack of systematic and in-depth research in the aspects of biogas slurry and residue improve crops and fruit quality and control of pests and diseases, especially about the physiological and nutrition effects of biogas slurry on crops. However it is also lack of intensive mechanism studies of control diseases and pests. Biogas slurry as a liquid fertilizer directly irrigation the soil, because of its application rate is large and high liquidity, if not managed well, slurry will be enter into water or groundwater through runoff or leaching then cause water eutrophication. So it is should be further strengthened in the management and monitoring aspects. Fermentation residue utilization of standard system has not yet been established, the policies and regulations about detection, utilization, monitoring, management require further standardized.

4. The Future

No matter from the social benefits or ecological benefits or economic benefits, the recycling of methane fermentation residue is equipped with sustainable development. We can use residue which is a product of a kind of response as the raw materials of another type reaction to recycling and creating a solid resource waste recycling system, which is large ecosystem loop recycling system. Formerly, there were South "pig - biogas - fruit" and the North "Four in one" experiences of comprehensive utilization. Based on summarizing and absorbing domestic and foreign experiences, we must take the industrialization and commercialization road, form industrial chain and develop new markets vigorously, carry out multichannel coordination. Only in these ways, can we exploit and utilize biogas slurry and residue resources effectively and establish a harmonious and unified circulation system of ecological and economic, the operation mode is similar but methods are diversified. We promote the recycling industry that is the complementary and benign pattern of ecological agriculture. This is a set of agricultural planting, cultivation, processing industry and virtuous cycle system integration. The system can be derived into renewable biogas energy, organic compound fertilizer production chain and other sub-chain, each part is independent yet interrelated and all parts compose a new way of biogas slurry and residue recycling.

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