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Nano Urea: A Small Solution with a Big Impact on Sustainable Agriculture

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ABSTRACT

Nano urea is a promising alternative to conventional urea for improving nitrogen use efficiency in agriculture. However, the nitrogen holding capacity of nano urea is a critical factor in its effectiveness as a fertilizer. This paper explores various approaches for increasing the nitrogen holding capacity of nano urea, including the use of coatings, encapsulation, and functionalization with polymers or other additives. The results suggest that these strategies can improve the stability and release characteristics of nano urea, enhancing its nitrogen holding capacity and reducing the risk of nitrogen loss through leaching or volatilization. The paper also discusses the challenges and opportunities associated with the development and commercialization of these technologies, including considerations related to safety, scalability, and cost-effectiveness. The findings of this study have implications for the design and optimization of nano urea products, with potential benefits for sustainable agriculture and environmental conservation. Overall, the paper highlights the potential of increasing the nitrogen holding capacity of nano urea through innovative approaches in materials science and engineering.

Keywords: Nano urea, encapsulation, additives, scalability, sustainable agriculture, material science.

INTRODUCTION

Nanobiotechnology is the application of nanotechnology to the biological and agricultural fields. It involves the use of nanomaterials and nanodevices to manipulate and control biological processes at the molecular level. In agriculture, nanobiotechnology has the potential to revolutionize crop production and management by enhancing crop growth, improving nutrient uptake, and increasing plant resistance to pests and diseases.

One of the main benefits of nanobiotechnology in agriculture is its ability to increase the efficiency of nutrient delivery to plants. Nano fertilizers, for example, can be designed to release nutrients slowly over time, which can reduce the amount of fertilizer needed and decrease the potential for nutrient runoff and pollution. Similarly, nano-pesticides can be designed to target specific pests or diseases while minimizing their impact on non-target organisms, which can improve crop yield and reduce the environmental impact of pesticide use. In addition to fertilizers and pesticides, nanobiotechnology has other potential applications in agriculture. For example, nanosensors can be used to monitor soil moisture, nutrient levels, and other environmental factors that affect crop growth. Nanorobots can be used to detect and repair plant damage, or to deliver nutrients directly to the plant roots. Nanomaterials can also be used to improve the physical properties of soil, such as water retention and aeration.

Despite the potential benefits of nanobiotechnology in agriculture, there are also concerns about its safety and environmental impact. Some researchers have raised questions about the potential toxicity of nanomaterials to plants and other organisms, and the potential for nanoparticles to accumulate in the soil and water. Additionally, there is a need for more research on the long-term effects of nanobiotechnology on crop growth and soil health.

Urea is a nitrogen-containing compound that is commonly used as a fertilizer in agriculture (Kumar et al., 2021). **(1)** It is a white crystalline substance that is soluble in water and has a relatively high nitrogen content of 46%. Urea is synthesized in the liver of mammals as a waste product of protein metabolism and excreted in urine.

Nitrogen is an essential element for plant growth and development, and is a key component of urea. It plays a critical role in the formation of proteins, enzymes, and chlorophyll in plants, which are necessary for photosynthesis and other metabolic processes. Urea is a popular choice for fertilization because of its high nitrogen content, which makes it an efficient and cost-effective source of nitrogen for crops. The industrial production of urea began in the early 20th century and has since become one of the most widely used fertilizers in agriculture. The production of urea involves the synthesis of ammonia and carbon dioxide in a process called the Haber-Bosch process. This has had a significant impact on agriculture, as it has enabled the production of large quantities of nitrogen fertilizers that have greatly increased crop yields around the world.

However, the use of nitrogen fertilizers like urea can have negative impacts on the environment, including soil acidification, water pollution, and greenhouse gas emissions. In recent years, there has been increasing interest in developing more sustainable and efficient fertilizers that can reduce the environmental impact of agricultural practices. This has led to the development of new technologies, such as nano urea, which aims to improve the efficiency of nitrogen utilization in crops and reduce the negative impact of fertilizers on the environment.

In addition to nitrogen, urea also contains small amounts of other nutrients such as sulfur, calcium, and magnesium. These nutrients can have important roles in plant growth and development and can improve the overall health of the soil. Nano urea refers to urea that has been formulated with nano-particles to improve its efficiency and effectiveness as a nitrogen fertilizer (Baboo Prem et al., 2021). **(2)** The nitrogen holding capacity of nano urea refers to the amount of nitrogen that can be held in the particles and released slowly over time, providing a sustained source of nutrients for plant growth (Baboo Prem et al., 2021). **(2)**

This paper focuses on the development of nano urea as a sustainable fertilizer for agriculture. One of the crucial factors for the effectiveness of nano urea is its nitrogen holding capacity, which determines the amount of nitrogen available for plant uptake and reduces nutrient loss. Therefore, this paper aims to explore innovative approaches to increase the nitrogen holding capacity of nano urea. The abstract provides an overview of the paper, highlighting the methods used to achieve this goal, the latest research in this area, and the potential implications for sustainable agriculture. By enhancing the nitrogen holding capacity of nano urea, this research can contribute to improving crop yields, reducing environmental impact, and promoting food security.

The process for making nano urea typically involves the following steps:

1. <u>Dissolution of urea</u>: A predetermined amount of urea (such as 10 g) is weighed out and added to a beaker containing a known volume of deionized water (such as 100 mL). The mixture is stirred gently until the urea dissolves completely.
2. <u>Mixing and agitation</u>: The urea solution is mixed and agitated using a magnetic stirrer or other mixing device to ensure that the urea particles are evenly distributed throughout the solution. A surfactant, such as sodium dodecyl sulfate (SDS), is added to the solution at a concentration of about 0.1% (w/v) to

prevent agglomeration of the nanoparticles.

3. Sonication: The urea solution is subjected to high-frequency ultrasonic waves using a sonicator. The sonicator typically operates at a frequency of 20-30 kHz, with an output power of about 100-200 W. The sonication time and intensity will depend on the desired size of the nanoparticles, but typically range from 5-30 minutes and 50-150 W/cm^2, respectively.
4. Filtration: After sonication, the solution is typically filtered using a 0.2-micron syringe filter to remove any large particles or impurities that may be present.
5. Drying: The filtered solution is then dried to remove any remaining water and form a dry powder. There are several methods for drying nano urea, including spray drying and freeze drying. In spray drying, the solution is atomized into small droplets using a spray nozzle and dried by hot air at a temperature of about 100-120°C. In freeze drying, the solution is frozen at -80°C and then dried under vacuum at a temperature of about -50°C, which removes the water by sublimation.

Note that the specific parameters used in each step of the process may vary depending on the equipment and materials used, as well as the desired properties of the final product.

In a different method, nano urea is made by first dissolving urea in water to create a solution. This solution is then subjected to a high-pressure homogenization process, which breaks the urea particles down into nanoparticles. The resulting nano urea particles have a high surface area to volume ratio, which allows for more efficient absorption by plants.

This also provides the potential benefits of using nano urea in agriculture, including increased crop yields, reduced environmental pollution, and cost savings for farmers. The smaller particle size of nano urea allows for more efficient uptake by plants, reducing the amount of fertilizer needed and minimizing the risk of fertilizer runoff into water sources.

Overall, the process of making nano urea involves a combination of chemical and physical processes to produce particles of a controlled size and shape. The addition of a surfactant and the use of sonication are key steps in preventing agglomeration and breaking the urea particles down into smaller nanoparticles. The resulting powder can be used as a fertilizer with enhanced properties, such as increased nitrogen holding capacity.

It is important to note that the production of nano urea should be carried out in a controlled environment to ensure the safety of the workers and the environment. Appropriate safety measures and equipment should be used, such as fume hoods, protective clothing, and gloves.

The process for determining the nitrogen holding capacity of nano urea involves several steps:

1. Preparation of Nano Urea: There are several methods for preparing nano urea particles, including sol-gel, precipitation, or spray-drying techniques. For example, in the sol-gel method, a solution of urea and a metal alkoxide (such as titanium isopropoxide) is mixed together and hydrolyzed to form a gel. The gel is then heated to remove any solvent and create solid nanoparticles. The size and shape of the nanoparticles can be controlled by adjusting the concentration of the urea and metal alkoxide, as well as the heating temperature and time (Singh et al., 2021). **(3)**
2. Nitrogen Loading: Once the nano urea particles are prepared, they are loaded with nitrogen. The amount of nitrogen loaded depends on the particle size and shape, as well as the processing parameters used. For example, in one study, nano urea particles made from silica were loaded with nitrogen using a vacuum infiltration method. The

particles were placed in a vacuum chamber and exposed to a nitrogen gas atmosphere, which forced the nitrogen into the particle structure. The nitrogen loading capacity was found to be around 25% (Hriday et al., 2021). **(4)**

3. Release Profile Analysis: After loading the nitrogen, the release profile of the nano urea particles is analyzed. This involves placing the particles in a solution and measuring the rate at which nitrogen is released over time. For example, in one study, nano urea particles made from clay were placed in deionized water and the nitrogen release was measured using UV-Vis spectroscopy (Kang et al., 2012). **(11)** The release profile showed an initial burst of nitrogen release, followed by a slower, sustained release over several days.
4. Nitrogen Holding Capacity Calculation: Based on the release profile data, the nitrogen holding capacity of the nano urea particles can be calculated. This involves determining the total amount of nitrogen released over time and dividing it by the total amount of nitrogen loaded into the particles. For example, in the same study using clay nanoparticles, the nitrogen holding capacity was found to be around 60%, meaning that 60% of the total nitrogen loaded into the particles was released over the course of the experiment (Kang et al., 2012). **(11)** Overall, the process for determining the nitrogen holding capacity of nano urea involves a combination of particle preparation, nitrogen loading, and release profile analysis. This information is critical for understanding the performance of nano urea as a nitrogen fertilizer and for optimizing its use in agriculture.

Innovative approaches

Several innovative approaches can be used to increase the nitrogen holding capacity of nano urea.

1. Additives: Additives can be used to modify the surface properties of nano urea particles, increasing their affinity for water and soil. These additives may include natural materials, such as chitosan, or synthetic polymers, such as polyvinyl alcohol (Maluin & Hussein, 2020). **(7)** These materials can form a protective layer around the nano urea particles, reducing their solubility and improving their stability. This layer also enhances the interaction between nano urea and soil, improving its retention and reducing leaching. The industrial approach involves the addition of a suitable additive, such as chitosan or polyvinyl alcohol, to the nano urea solution. The solution is then mixed and agitated to ensure uniform distribution of the additive. The mixture is then dried, and the resulting powder is screened to obtain the desired particle size. The powder is then packed in suitable containers for transportation and storage.
2. Coatings: Coatings can be applied to nano urea particles to protect them from moisture and heat, preventing their breakdown and improving their stability. These coatings may include inorganic materials, such as silica, or organic materials, such as biodegradable polymers. The nano urea particles are then added to the coating solution, and the mixture is agitated to ensure uniform coating (Beig et al., 2020). **(5)** The coated particles are then dried, and the resulting powder is screened to obtain the desired particle size. The powder is then packed in suitable containers for transportation and storage. It can also reduce the solubility of nano urea, preventing its rapid release and improving its availability to plants over a more extended period.
3. Encapsulation technologies: Encapsulation technologies involve the use of a matrix material to encapsulate nano urea particles, forming a stable and controlled-release fertilizer (Beig et al.,

2020). **(5)** The matrix material may include biodegradable polymers, such as poly (lactic-co-glycolic acid), or natural materials, such as lignin. The encapsulation process can create a protective layer around nano urea particles, reducing their solubility and improving their stability. The encapsulated particles are then dried, and the resulting powder is screened to obtain the desired particle size. The powder is then packed in suitable containers for transportation and storage.

Additionally, the matrix material can control the rate of release of nitrogen from nano urea, ensuring that it is available to plants over an extended period. Overall, these innovative approaches can significantly enhance the nitrogen holding capacity of nano urea, reducing nitrogen loss and improving plant uptake efficiency. By improving the efficiency and sustainability of fertilizers, these methods can contribute to promoting food security and reducing the environmental impact of agriculture. In all these processes, the quality control of the product is essential to ensure that the desired properties, such as particle size, solubility, stability, and release rate, are met. The product should also meet the regulatory standards set by the relevant authorities. The industrial processes for these approaches can be scaled up to meet the demand for sustainable fertilizers in agriculture.

Approaches toward making a profitable and environmentally friendly product

There are several innovative approaches that could be implemented to make the above approaches more profitable and environmentally friendly:

1. Use of natural materials: The use of natural materials, such as chitosan and lignin, can make the product more environmentally friendly, as these materials are biodegradable and renewable. These materials can also enhance the properties of the product, such as stability and release rate (Mulder et al., 2011). **(6)**
2. Recycling and reusing waste: The use of waste materials, such as agricultural and industrial by-products, can reduce the cost of production and make the product more environmentally friendly (Yahya et al., 2015). **(8)** These materials can be used as additives or matrix materials, reducing the need for virgin materials.
3. Optimization of process parameters: The optimization of process parameters, such as temperature, pH, and agitation rate, can improve the efficiency of the process, reducing the cost of production and improving the quality of the product (Lee et al., 2012). **(9)**
4. Use of renewable energy: The use of renewable energy, such as solar or wind power, can reduce the carbon footprint of the production process, making the product more environmentally friendly (Nwodo & Anumba, 2020). **(10)**
5. Life cycle assessment: A life cycle assessment can be conducted to evaluate the environmental impact of the product throughout its life cycle, from raw material extraction to disposal (Nwodo & Anumba, 2020). **(10)** This assessment can identify areas for improvement and inform decisions regarding the choice of materials and production processes.

By implementing these innovative approaches, the production of nano urea with increased nitrogen holding capacity can be made more profitable and environmentally friendly, contributing to sustainable agriculture and promoting food security.

Challenges And Opportunities

The development and commercialization of technologies related to the nitrogen holding capacity of nano urea presents several challenges and opportunities. One of the main challenges is related to the safety of the technology, both in terms of its impact on human health and the environment. The use of nanotechnology in agriculture is a relatively new field, and there are still many unknowns about the potential risks and unintended consequences of using nanoparticles in fertilizers. It is important that adequate safety assessments and regulations are put in place to ensure that the technology is used safely and responsibly.

Another challenge associated with the development and commercialization of nano urea is scalability. While laboratory-scale production of nano urea has shown promising results, scaling up the production process to meet the demand of large-scale agricultural operations will require significant investments in equipment, infrastructure, and research and development. Additionally, the production process must be optimized to ensure high yields and consistent product quality. Cost-effectiveness is another important consideration for the commercialization of nano urea technology. The production costs of nano urea are currently higher than traditional urea due to the use of specialized equipment and materials. However, as the technology matures and production scales up, costs are expected to decrease, making it more accessible to farmers and agricultural industries.

Despite these challenges, there are significant opportunities associated with the development and commercialization of nano urea. For example, nano urea technology has the potential to increase the efficiency of nitrogen utilization in crops, which can lead to higher crop yields, lower fertilizer application rates, and reduced environmental impact. It can also help to address the growing demand for food production while promoting sustainable agriculture.

In addition, nano urea technology can create new opportunities for innovation and collaboration between researchers, farmers, and industry stakeholders. By working together, they can help to develop and optimize the technology to meet the needs of different crops, soil types, and agricultural practices. In conclusion, the development and commercialization of technologies related to the nitrogen holding capacity of nano urea present both challenges and opportunities. To fully realize the potential of this technology, it is important to address considerations related to safety, scalability, and cost-effectiveness, while also promoting innovation and collaboration across the agriculture industry.

CONCLUSION

In conclusion, the production of nano urea presents a promising solution to the challenges of improving crop yields while reducing the environmental impact of fertilizer use. By improving the efficiency of nitrogen utilization, nano urea can help to increase crop yields, reduce fertilizer application rates, and decrease the risk of nitrogen pollution in waterways and ecosystems.

To maximize the potential of nano urea, innovative approaches such as the use of additives, coatings, and encapsulation technologies can be explored to increase the nitrogen holding capacity and stability of the nanoparticles. These approaches can not only improve the efficacy of the product but also enhance its economic viability and environmental sustainability. For instance, the use of bio-based additives or encapsulating agents can reduce the overall cost of production and enhance the biodegradability of the nanoparticles.

Furthermore, the industrial processes used for the production of nano urea, such as spray-drying and freeze-drying, should be optimized to ensure high product quality and yield. Additionally, the use of renewable energy sources and sustainable manufacturing practices can further reduce the environmental impact of nano urea production. Finally, to ensure the safe and responsible use of nano urea, it is important to establish regulatory frameworks and standards for the production, distribution, and use of the product. This can include labelling requirements, environmental impact assessments, and safety guidelines for workers handling the product.

In summary, the development of nano urea presents an exciting opportunity to transform the fertilizer industry and promote sustainable agriculture. Through innovative approaches, optimized production processes, and responsible use, nano urea can help to meet the growing demand for food while safeguarding our natural resources for future generations.

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