

POTENTIAL OF RICE BRAN PROTEIN POWDER PRODUCTION TO INCREASE PADDY INDUSTRY PRODUCTIVITY

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ABSTRACT

The demand for alternative protein sources has been steadily increasing due to concerns about sustainability and animal welfare. Rice bran, a byproduct of rice milling, is a potential source of protein with high nutritional value. This study aims to investigate the production of rice bran protein powder using a pilot-scale ultrasonic spray dryer. The research methodology involves several key steps. First, rice bran is collected from the milling process and undergoes a series of pretreatment steps, including defatting and protein extraction. The extracted protein solution is then concentrated and purified to remove impurities and enhance protein content. The resulting protein solution is then fed into a pilot-scale ultrasonic spray dryer for powder production. The pilot-scale ultrasonic spray dryer offers advantages such as precise control over particle size, improved solubility, and reduced agglomeration. The drying conditions, including inlet air temperature, feed rate, and atomization pressure, are optimized to obtain a high-quality protein powder with desirable physicochemical properties. The produced rice bran protein powder is characterized for its protein content, amino acid profile, functional properties (such as solubility, emulsifying capacity, and foaming ability), and particle size distribution. These properties are evaluated to assess the feasibility of using rice bran protein powder in various food applications, including bakery products, beverages, and nutritional supplements. The results of this study provide insights into the potential of rice bran protein as an alternative protein source and highlight the effectiveness of pilot-scale ultrasonic spray drying as a production method. The findings contribute to the development of sustainable protein ingredients and support the utilization of rice bran, a byproduct that would otherwise be underutilized or discarded.

Keywords: Rice bran protein powder, Rice milling, Ultrasonic spray dryer, Solubility, Purification.

INTRODUCTION

For an important proportion of the world's population, especially Asians, rice (*Oryza sativa*) serves as the main source of food (1). Due to its natural nutritional richness and high energy content, rice is essential to human livelihoods. Most rice grains are eroded into cooked rice, and only a small portion are employed as ingredients in food and non-food processing (2). One-step, two-step, and multi-stage milling are the three milling systems that are used (3). The purpose of rice milling systems is to remove the rice kernel of its husk and bran coating, making the rice edible and free of contaminants. The rice should have as few broken kernels as is feasible, depending

on the customer's needs (usually 12–15%) (4,5).

Rice germ, husks, and bran are among the by-products of the milling process, along with finely broken rice (6). In the past, these products were discarded as waste (7) however, they are presently employed in business and possess bioactive qualities that are advantageous to both people and animals (8). The common by-products produced during the rice milling process are rice husk is the protective outer covering of the rice grain. It is removed during the milling process and is commonly used as a source of fuel, animal feed, or as a material for building and industrial applications. Next is rice straw

refers to the stalks and leaves of the rice plant. After harvesting, the straw is often used for various purposes such as animal bedding, mulching, composting, or as a raw material for paper and board production and rice germ is the embryo of the rice grain, containing valuable nutrients and oils. It is separated during the milling process and is sometimes used for oil extraction to produce rice bran oil, which is known for its health benefits. Lastly, rice bran is the outer layer of the rice grain, rich in fiber, minerals, and vitamins. Rice bran is widely used as a dietary supplement, animal feed, and in the production of rice bran oil.

The efficiency of the milling method and the variety of rice have a significant impact on the composition of rice bran (7). The annual production of rice bran is thought to be 76 million tonnes worldwide (9). The outer covering of the rice kernel is removed during milling to obtain the actual bran, which only takes up around 5-8% of the overall rice kernel but has a high nutritional value and is made up of 15-22% lipids, 34-52% carbs, 7-11% fibre, 6-10% ash, 8-12% moisture, and 10-16% protein, is frequently eaten as a quick meal. These percentages demonstrate that rice bran has the potential to be a valuable source of fibre, protein, and fat that may benefit human health. The sole naturally occurring source of -oryzanol, rice bran is a rich source of the B complex vitamins (niacin, thiamine, pantothenic acid, and pyridoxine) and the E complex vitamins (tocopherols and tocotrienols). Rice bran used to regularly

show up as a waste component and was either thrown away or composted in the past (10,11).

Rice bran contains sizeable levels of protein that are rich in essential amino acids. By extracting the protein from rice bran, a concentrated supply of high-quality plant-based protein is created. This protein can be added to food products to enhance their nutritional profiles. The by-product of milling rice, rice bran, which contains protein, is typically underutilized. By removing protein from rice bran, it enables the efficient usage of this by-product, avoiding waste and optimizing the value received from the rice production process. Utilizing rice bran protein enhances sustainability initiatives. By utilizing a by-product that would otherwise be wasted, it promotes the rice industry to use its resources more efficiently. Rice bran protein extraction is sustainable because plantbased proteins have a smaller environmental impact than animal-based proteins. Four various extraction techniques, including alkaline, enzymatic, microwave-assisted, and ultrasonic-assisted extractions, were used to get protein fractions. The rice bran protein will take solution form after extraction. The protein in rice bran may not dissolve well in water or other liquids. This might cause lumps or clumps to form, making it challenging to incorporate the protein into recipes or drinks. To maximize its use and functioning, rice bran protein's solubility must be improved. Additionally, rice bran protein solutions may be unstable, particularly in specific environmental circumstances like

temperature, pH, or storage time. The quality and shelf life of products containing rice bran protein can be impacted by problems including protein precipitation, aggregation, or disintegration. The extraction is required to remove unnecessarily component in rice bran for human consumption. But, the process will lead to the solution-based production which required large storage and reduce the shelf life of product. Therefore, the drying process are required to produce the powder-based rice bran protein.

Two commonly known types of spray drying are conventional spray dryer and ultrasonic-assisted spray drying. Conventional spray drying is the most widely used method for transforming liquid solutions or suspensions into solid powders. It involves atomizing the liquid feed into small droplets using either a rotary atomizer or a high-pressure nozzle. These droplets are then sprayed into a drying chamber where hot air rapidly evaporates the liquid, leaving behind solid particles. The conventional spray dryer consists of a drying chamber, an atomizer, a hot air source, and a collection system. The atomizer disperses the liquid into droplets, and the hot air stream removes the moisture from the droplets as they fall through the drying chamber. The dried particles are collected at the bottom of the chamber or through a cyclone separator. Ultrasonic technology can be employed as a complementary technique to enhance the efficiency and control of the conventional spray drying process. Ultrasonic-assisted spray drying involves the application of high-

frequency sound waves (ultrasonic waves) to the liquid feed before it is atomized. The ultrasonic waves can help break down larger particles or clusters in the liquid into smaller, more uniform droplets. This promotes better drying and particle formation during the subsequent drying stage. The ultrasonic waves can also improve the dispersion of heat and mass transfer within the droplets, leading to increased drying rates and improved product quality. By integrating ultrasonic technology into the spray drying process, it is possible to achieve finer particle size, narrower size distribution, improved drying efficiency, and better control over the final product properties.

High temperatures are frequently used in spray drying to evaporate the solvent and generate dried particles. On the other hand, ultrasonic spray drying is a modification of the traditional spray drying method that uses ultrasonic energy. In ultrasonic spray drying, the liquid feed is atomized using ultrasonic waves into tiny droplets, which are subsequently exposed to hot air in a drying chamber. By increasing the surface area accessible for evaporation, the ultrasonic energy increases drying efficiency by contributing to the formation of smaller droplets. When compared to conventional spray drying techniques, this can lead to shorter drying durations and better particle properties.

METHODOLOGY

Collection and Storage of Rice Bran

The sample of rice bran will be from the near

factory. About 10 kg of rice bran will be removed from the plant. After gathering the raw rice bran, clean it by removing contaminants and unwanted objects. To get rid of pollutants, clean the rice bran. To achieve the necessary amount of moisture content, dry the rice bran. The sample will be heated in the microwave, packaging in vacuum containers and storage at about 4-5°C as the method of pre-treatment. This method may 46 prevent oxidative rancidity and rice bran hydrolytic rancidity (RB) (12) also studied rice bran prevention of hydrolytic rancidity.

Pre-extraction process by using the autoclave technique

The sample is extract using autoclave technique. In this process, thermal extraction process is facilitate based on temperature to create the environment for the water based thermal extraction process. In this study autoclave will be utilized to run the heat treatment process extraction. Rice bran was mixed with distilled water in Schott bottle at ratio of 1:10 at 121°C for 20 minutes. Heat treatment process extraction enhance extractability and functional properties of protein thus, results in increase of extraction yield (13). The rice bran extract is allowed to cool in room temperature. Then, the extracts were filtered. The supernatant is collected for spray drying process.

Rice bran solution filtration

To perform filtration using a Whatman filter paper for removing solids from rice bran extraction protein:

1. Set up a clean funnel in a filtration flask or beaker to prevent leakage.
2. Cut a piece of Whatman filter paper to fit the funnel and fold it into a cone shape.
3. Wet the filter paper with distilled water to create a seal and improve filtration.
4. Pour a small amount of distilled water or the same liquid being filtered onto the filter paper.
5. Carefully pour the rice bran solution into the funnel, ensuring it doesn't exceed the funnel's capacity.
6. Observe the filtration process as the solids are trapped by the filter paper and the liquid passes through.
7. Place a clean container below the funnel to collect the filtered liquid (filtrate).
8. Optionally, rinse the collected solids on the filter paper with distilled water to remove impurities.
9. Remove the filter paper with the retained solids and dispose of it properly.
10. Compost or discard the organic solids in accordance with local waste disposal guideline

Rice Bran Protein Powder Production Using Pilot Scale Ultrasonic Spray Dryer

Spray drying produces powders with consistent particle size and shape, which is advantageous for various applications. The fine droplets generated during atomization tend to form spherical particles, leading to uniformity in the final product. This enables better flowability, dissolution, and reconstitution properties. The removal of moisture through spray drying helps increase

the shelf life of products by inhibiting microbial growth and chemical degradation. The low moisture content in the powder reduces the potential for spoilage and preserves the product's quality over an extended period.

That's a comprehensive description of a pilot-scale ultrasonic spray dryer and its applications. Pilot-scale ultrasonic spray dryers are indeed used in various industries and research settings to convert liquid solutions or suspensions into powdered form. They offer a middle ground between laboratory-scale spray dryers and larger industrial ones, allowing for testing and optimization before moving to full-scale production. The key principle behind an ultrasonic spray dryer is the generation of small liquid droplets using ultrasonic vibrations. These droplets are then dried by a stream of hot air, resulting in the formation of fine powders. This technique provides precise control over particle size, morphology, and composition, leading to highly uniform and homogeneous powders. The versatility of pilot-scale ultrasonic spray dryers makes them suitable for a range of industry sectors, including pharmaceuticals, food and beverage, chemicals, and materials research. By using these dryers, scientists and manufacturers can assess the feasibility, scalability, and performance of spray drying methods before investing in larger-scale production equipment. One of the advantages of using an ultrasonic spray dryer is the ability to achieve exact control over particle size and

distribution. This control allows for better product quality and consistency. Additionally, the shorter processing times offered by this method can be beneficial in terms of efficiency and productivity. Another significant advantage is the ability to create powders with enhanced bioavailability and purity. The precise atomization achieved through ultrasonic vibrations helps to improve the dissolution and absorption properties of the resulting powder, making it more bioavailable. Furthermore, the controlled drying process aids in maintaining the purity of the final product.

Operation conditions

The feed to the spray drying will be 500 mL of rice bran extract solution. The 500mL of each group's separated liquid was then spray-dried at Universiti Malaysia Perlis (UNIMAP) using a pilot-scale ultrasonic spray drier. When functioning in desolate situations, it manipulates several conditions at once utilizing a single fact. 130°C, 150°C, 160°C, 180°C, 190°C, 200°C for temperature, 10%, 15%, 20%, 25%, 30%, 40% for feed flowrate, and 225L/hr, 250L/hr, 325L/hr, 350L/hr, 425L/hr, 450L/hr, 525L/hr, 550L/hr, 625L/hr for flowrate as shown in Table 1. The protein powder made from spray-dried rice bran, which was the end product, will now be subjected to a yield study.

In order to determine the weight after spray drying, the product vessel and the rice bran protein powder that was produced as a result of spray drying were both weighed. As a result, the protein powder yield will be

determined using Equations (2) and (3). According to Eq. (2), 180 grammes of raw rice bran will theoretically dissolve in 1800 milliliter of water to produce 20 grammes of rice bran powder for every 200 milliliter of feed.

$$\text{Yield (\%)} = \frac{\text{Total Weight} - \text{Empty weight}}{\text{Raw Rice Bran}} \times 100 \dots (1)$$

$$\frac{180 \text{ g}}{1800 \text{ ml}} = \frac{20 \text{ g}}{2000 \text{ ml}} \dots \dots \dots (2)$$

$$\text{Yield} \frac{\text{g RBP}}{100 \text{ g RRB}} = \frac{\text{A (g)}}{20 \text{ (g)}} \times 100 \dots \dots \dots (3)$$

Preparation of Standard Calibration Curve for Analytical Process

The concentration of the protein from the optimized spray-dried rice bran protein powder will be determined using the standard calibration that will be plotted, and a standard Bovine Serum Albumin (BSA) solution as a reference. The first step is to pipet 98 L of BSA into an empty centrifuge tube labelled sample. Then, 2 mL of the rice bran protein mixture will be pipetted into the centrifuge containing 98 mL of BSA after being diluted in a 1:20 ratio. The mixture will be diluted by one part to fifty (1:50) with the rice bran. Then, two cuvettes were created, one for the sample and one for the control. 20 mL of a diluted rice bran combination will be pipetted into the cuvette labelled sample, while an additional 20 mL of BSA was pipetted into the cuvette labelled control

Next, protein standards will be prepared by referring to the protocol from the manufacturer. A cuvette for each standard will be marked accordingly with its corresponding concentration (0.125mg/ml, 0.25mg/ml,

0.5mg/ml, 0.75mg/ml, 1.00mg/ml, 1.50mg/ml and 2.00mg/ml). Next, 20 µL of each protein standard will be added into its corresponding cuvette. The cuvettes labelled sample and control will then receive 1 mL of Bradford reagent added to them. Pipetting upward and downward was used to combine the solution in the cuvette. The cuvettes will next be incubated for 5 minutes at room temperature. After that, the cuvettes will be visually compared with 54 the cuvette containing rice bran protein mixture and the concentration will predicted visually Finally, a UV-visible (UV-vis) spectrophotometer will be used to calculate the protein absorption value. To determine the average absorbance value, the absorbance value will be reproduced three times. The standard protein calibration curve will then be shown as a graph of protein absorbance value against protein concentration

Analysis of protein concentration

The rice bran protein powder will be diluted with distilled water at ratio of 1:200. The solution was tested with UV-vis (Shimadzu UV-1800) spectrophotometer to measure the absorbance of protein in the rice bran solution.

Characterization of the Quality of Rice Bran Protein Powder

Fourier Transform Infrared Spectrometry (FTIR)

The functional groups included in the rice bran protein powder are identified using an FTIR spectrometer. Potassium bromide was needed as a chemical in the machinery. Basically, rice bran protein powder and

potassium bromide will be combined before the FTIR test is conducted. We captured and studied the rice bran protein powder's FTIR spectra. By applying FTIR analysis with a PerkinElmer Infrared Spectrometer (Germany), it is possible to identify the different types of functional groups contained in the produced rice bran protein powder. For powdered samples, potassium bromide (KBr) pellets are frequently employed. In order to prepare for the FTIR test, the sample and KBr will be combined and dried in an oven overnight. To lessen scattering losses and adsorption band distortion, 1g of KBr will be coarsely ground with approximately 3mg of rice bran protein powder using a mortar. The combination will next be transformed into a transparent disc and carefully inserted into the sample container for FTIR spectrometry. The KBr pellet samples will then be scanned with a resolution of 4 cm⁻¹ between the range of 4000 and 400 cm⁻¹. We will record and examine the rice bran protein powder's FTIR spectra.

Statistical Analysis

Data analysis include analysis of variance (ANOVA) and the standard deviation calculation will be analyzed using Design Expert software. Results was expressed as mean \pm standard error (SE) and were considered significantly different when $p \leq 0.05$ for comparison effects of each parameters. R² coefficient was used to express the second order equation model's adjustment, and the F test (also known as an

analysis of variance, ANOVA) was used to determine its statistical significance (14).

Comparison yield between Pilot Scale Ultrasonic Spray Dryer and Oven Drying

When comparing the yield between a pilot-scale ultrasonic spray dryer and oven drying, several factors need to be considered. Ultrasonic spray drying is known for its high drying efficiency. The ultrasonic vibrations generated during the process aid in the atomization of the liquid into fine droplets, which enhances the drying kinetics. This improved efficiency often translates into higher yields compared to oven drying, where the drying process relies on natural convection and heat transfer. Ultrasonic spray drying is typically faster than oven drying due to the enhanced atomization and drying kinetics. The shorter drying time can lead to a higher yield because the shorter exposure to heat can minimize potential degradation or loss of heat-sensitive compounds. In oven drying, the material being dried is subjected to relatively high temperatures for an extended period. This prolonged heat exposure can lead to thermal degradation, especially for heat sensitive substances. Ultrasonic spray drying, on the other hand, offers a more controlled and gentle drying process, reducing the risk of thermal degradation and preserving the quality of the product. Thus, it can result in higher yields by minimizing losses due to degradation. The nature of the product being dried also plays a role in determining the yield. Some products may be better suited for ultrasonic spray drying, while others may be

more suitable for oven drying. For instance, ultrasonic spray drying is often preferred for producing fine powders or particles with narrow size distributions, while oven drying may be more suitable for bulk drying of larger materials. It is essential to consider the specific requirements of the product and select the drying method accordingly.

RESULT AND DISCUSSION

Evaluating effect of temperature to the powder yield using pilot scale ultrasonic spray dryer

The temperature settings in a pilot-scale ultrasonic spray dryer can have a significant effect on the powder yield. The powder yield refers to the amount of solid powder produced by the spray drying process. Generally, increasing the temperature in a spray dryer can result in a higher powder yield. This is because higher temperatures promote faster evaporation of the liquid solvent in the spray, leading to quicker drying of the droplets and the formation of solid particles. The heat

supplied to the system helps to remove moisture and volatile components from the droplets, leaving behind solid particles in the form of powder. However, it's important to note that the relationship between temperature and powder yield is not linear, and there is an optimal temperature range for achieving the highest yield. Operating the spray dryer at excessively high temperatures can lead to issues such as excessive particle agglomeration or even thermal degradation of the desired product, which may result in lower powder yields or poor powder quality. The optimal temperature range for powder production can vary depending on the specific material being processed. It is often determined through experimentation and optimization. Factors such as the solvent used, the properties of the feed solution, and the desired characteristics of the powder (e.g., particle size, morphology, moisture content) all play a role in determining the ideal temperature settings.

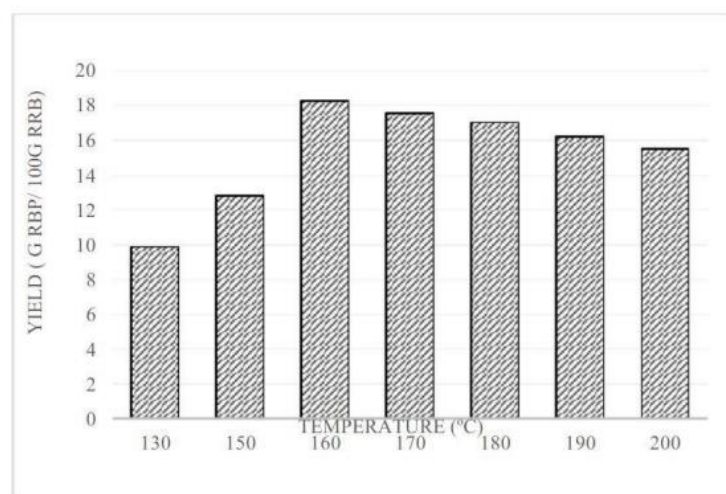


Figure 1: Effect of inlet temperature on protein powder yield from spray drying process

Previous studies discovered that the bar graph in Figure 1 depicts the relationship between inlet temperature and rice bran protein powder yield from the spray drying process. Figure 1 depicts the outcome with a feed flowrate of 20% and an air flowrate of 388 L/hr during the spray drying process. Based on figure 1, the results demonstrate that initially, as the inlet temperature rises from 130°C to 160°C, the yield of RBP powder obtained increases, going from 9.9 g RBP/100g RRB to 18.25 g RBP/100g RRB. At input temperatures of 170 oC to 200 oC, respectively, the RBP powder yield started to fall after 160 oC, from 17.55 g RBP/100 g RRB to 15.5 g RBP/100 g RRB (15). This was because (15)it stated that by increasing the temperature it was causing denaturation of protein and causes a cohesive force between the spray dried particle and the wall of the drying chamber. Therefore, inlet temperature of 150 °C to 180 °C was selected as the range of inlet temperature for rice bran protein powder production from spray drying process.

In this case based on our initial theoretical observation, based on other application of ultrasonic, the optimum temperature may reduce of the process to the lower temperature. The pattern will be expected to be same but the optimum temperature will be reducing to the lower temperature then can be possible increase of the yield. Based on the provided information, the temperature was reduced beyond a certain range in the spray drying process for the production of rice bran protein powder due to protein denaturation. The

researchers mentioned that increasing the inlet temperature caused denaturation of proteins. Denaturation refers to the alteration of the protein's structure, which can result in a loss of its functional properties. In this case, as the temperature increased beyond 160°C, the protein in the rice bran started to denature. Denatured proteins are less effective in forming cohesive forces, which are necessary for the particles to adhere to the drying chamber's wall. Therefore, to maintain the quality and functionality of the rice bran protein powder, it was necessary to reduce the temperature to avoid excessive denaturation. Next, Cohesive Forces: At higher temperatures, the cohesive forces between the spray-dried particles and the drying chamber's wall increased. This means that the particles had a stronger tendency to stick to the chamber's wall instead of being collected as a powder. This can lead to lower yields of the desired rice bran protein powder. By reducing the temperature within the range of 150°C to 180°C, the cohesive forces were minimized, allowing for better collection and higher yields of the protein powder.

Evaluate the Effect of The Feed Flow Rate to The Powder Yield Using Pilot Scale Ultrasonic Spray Dryer

The feed flow rate in a pilot scale ultrasonic spray dryer can have a significant effect on the powder yield. The powder yield refers to the amount of dried powder produced from a given amount of feed material. Generally, increasing the feed flow rate in an ultrasonic spray dryer can lead to a higher powder yield. This is because a higher feed flow rate means

more feed material is being introduced into the drying chamber, resulting in a greater amount of powder being produced. However, it is important to note that there is an optimal feed flow rate for each specific system. If the feed flow rate is too high, it can exceed the drying capacity of the equipment, leading to insufficient drying and lower powder yield. Conversely, if the feed flow rate is too low, it may result in longer residence time in the drying chamber, which can lead to over-drying and potential degradation of the powder, also reducing the powder yield. To evaluate the effect of the feed flow rate on the powder yield, experiments can be conducted at different feed flow rates while keeping another operating parameter constant. The powder yield can be measured by collecting and weighing the dried powder produced during a specific time period. By varying the feed flow rate and measuring the corresponding powder yield, a relationship between these two variables can be established. This relationship can help determine the optimal feed flow rate for achieving the highest powder yield in the pilot scale ultrasonic spray dryer.

Evaluate the Quality of The Powder, Produce by The Pilot Scale Ultrasonic Spray Dryer Using Fourier Transform Infrared Spectroscopy (FTIR)

Fourier Transform Infrared Spectroscopy (FTIR) is a commonly used technique for evaluating the quality of various materials, including powders. By analysing the infrared absorption and transmission of a sample, FTIR can provide information about its

chemical composition and molecular structure. However, the quality assessment of a powder produced by a pilot scale ultrasonic spray dryer using FTIR requires a more detailed understanding of the specific application and the parameters being evaluated. FTIR can help identify the presence of specific chemical functional groups in the powder. By comparing the spectrum of the powder to reference spectra, it is possible to confirm the composition and identify any impurities or contaminants. FTIR can be used to assess the purity of the powder by analysing the absence or presence of unwanted substances. Any additional peaks or shifts in the spectrum could indicate the presence of impurities, which may affect the quality of the powder. FTIR can be used as a tool for monitoring the consistency of powder production. By comparing FTIR spectra of different batches, you can assess whether the process is producing consistent results and identify any variations that may impact the quality.

CONCLUSION

In conclusion, the pilot-scale ultrasonic spray dryer's operating parameters significantly influence the powder yield and quality. Regarding the effect of temperature, the study showed that an inlet temperature range of 150°C to 180°C was optimal for rice bran protein powder production. Temperatures beyond this range caused protein denaturation and increased cohesive forces, leading to reduced yields and lower-quality powder. Adjusting the feed flow rate is crucial; too

high a rate can overwhelm the equipment's drying capacity, while too low a rate can result in over-drying and degradation, both scenarios diminishing the powder yield.

Fourier Transform Infrared Spectroscopy (FTIR) emerged as a valuable tool for quality assessment. FTIR analysis allowed for the identification of chemical functional groups, confirming composition and highlighting impurities or contaminants in the produced powder. It also served to monitor consistency across different batches, ensuring the quality and integrity of the end product.

In summary, a delicate balance between temperature and feed flow rate must be struck to optimize powder yield and quality in the pilot-scale ultrasonic spray drying process. FTIR analysis proved instrumental in verifying the chemical composition, detecting impurities, and ensuring batch-to-batch consistency. These findings underscore the importance of precise control and monitoring of operational parameters to achieve the desired outcomes in powder production. The production of rice bran protein was potentially increased the productivity of rice industry through waste utilization.

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