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Effect of spray drying process parameters on particle morphology for fermented beetroot powder

Priti JainDOI: <https://doi.org/10.22271/chemi.2020.v8.i2n.8880>**Abstract**

This study covers the morphological changes during the production of spray-dried fermented beetroot juice powder to keep the product quality. Particle morphology was observed by different processes parameters such as inlet air temperature, airflow rate, feed flow rate, and maltodextrin concentration. Particle morphology was analyzed by Scanning Electron Microscopy (SEM). It was remarked from SEM images of the particle that agglomeration potential was directly proportional to airflow rate and feed flow rate whereas smooth surface and larger sizes of particles were perceived at higher inlet air temperature and maltodextrin concentration.

Keywords: Beetroot, fermentation, spray drying, morphology, scanning electron microscope

Introduction

Beetroot (*Beta vulgaris* L.) named 'chukander', is mainly cultivated in India for its juice and vegetable value. It is a biannual crop. It is the most powerful source of nutrients available for overall human health. Beetroot powder is reported to have medicinal properties, particularly to improve digestion and blood quality ^[1, 2].

Dehydration through spray drying is one technique widely used in the food industry, and under optimal processing conditions, it has been proven to be an effective method to obtain various products. During the drying process, the feed solution is sprayed in droplets in a stream of hot air ^[3]. The quality of the spray-dried powder is quite dependent on the spray-dryer operating parameters. These parameters include: drying agent material, feed flow rate, airflow rate, inlet, and outlet air temperature should be tested.

The shell structure of a drying droplet plays an important role in determining the morphology of the final dried particle ^[4]. The main characteristics of spray-dried powders are the particle size (granulometry) and particle shape (morphology). The morphology of powder particles indicates their physical structure. The physical structure of particle changes due to process parameters which affect the powder properties. Particle morphology and particle size distributions are two critical factors in determining properties of dried powder (wettability, stability, and cohesiveness or dispersibility) and their application in composite ^[5, 6].

Different electron microscopy techniques including transmission electron microscopy, scanning electron microscopy, cryo-SEM, cryo-TEM, and environmental scanning electron microscopy have been employed for the evaluations related to the process of food. Scanning electron microscopy is a very useful tool to visualize food structure because; it combines in many ways the best features of light microscopy and transmission electron microscopy. SEM process is mostly used for the analysis of particle structure. These include relatively simple sample preparation, a wide range of magnification, high depth of field and the fact that the image is a representation of electronic data allowing for image analysis and quantification.

However, the morphology study for spray-dried fermented beetroot powder has not been previously reported. Therefore, the main goal of the current work is to investigate the effects of spray drying process parameters on particle morphology for fermented beetroot powder.

Materials and Methods**Raw Materials and fermented juice preparation****Corresponding Author:****Priti Jain**

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Freshly beetroot was procured from the local market, Jabalpur (M.P.) for this study. The beetroots were cleaned with water to remove all dirt adhering and the pesticide residues. The sorted beetroots were cut into small pieces and juices were extracted. Prepared juice was fermented with the culture (*saccharomyces cerevisiae* MTCC 178) of 10% (v/v) inoculum and it was incubated at 25 °C for 24 hr. Then maltodextrin was added in it with the help of magnetic stirrer.

The spray drying process for the development of powder

The powder was produced using a lab spray dryer (Labultima LU-222 Advanced Model, Twin Cyclone) with a different combination of process parameters. During the drying process, the fermented beetroot juice was sprayed in droplets in a stream of hot air. The liquid droplets of juice were dried in seconds as a result of the highly efficient heat and mass transfers. Process parameters for the production of powder were taken as inlet air temperature (140, 142, 144, 146 and 148 °C), airflow rate (49.56, 51.92, 54.28, 56.64 and 59 m³/h), feed flow rate (120, 127.5, 135, 142.5 and 150 ml/h) and maltodextrin concentration (4, 5, 6, 7 and 8 %). They were optimized by response surface methodology of design expert 8.0.7.1. The obtained powder was then collected and weighed for analysis.

Electron microscopy of spray-dried fermented beetroot powder

Scanning electron microscopy was used for morphology study of different samples which were prepared by the spray drying process. SEM images of dried samples were recorded using a variable pressure scanning electron microscope (LEO 435VP) at AIIMS New Delhi. The samples were atomized on a small barrel. Then they were covered with a fine layer of gold through sputter coating attachment of Balzers, in vacuumed evaporators. For observation, a Scanning Electronic Microscope (Levi Zeiss Machine) working with a voltage of 15 kV was used. The microphotographs were carried out with a camera coupled to the microscope. The samples were systematically observed with 750 and 1500x of magnification (Fig 1).

Fig 1: Particle morphology by Scanning Electron Microscopy

Results and Discussion

The morphology of spray-dried fermented beetroot powder is an essential parameter because it determines the physical construction of the particle. In this process, particles were affected by different process parameters such as inlet air temperature, airflow rate, feed flow rate, and maltodextrin concentration. Obtained particles from different drying conditions were found in different shape, size and agglomeration potential. Scanning electron microscopy

images of spray-dried fermented beetroot powder obtained at different process conditions were studied as the following explanation.

Effect of inlet air temperature

The effects of inlet air temperature on particle morphology were showed in (Fig 2). An increase in inlet air temperature from 140 to 148 °C resulted in a greater number of particles with a smooth surface and larger sizes, i.e. particles were produced at high temperature with a smoother surface. This may be due to rapid water evaporation means higher drying rates and higher pressure inside the particles during microencapsulation preventing shrinking. At low temperature, Water diffusion allows more time for the particles to deform, wrinkle, and collapse. Similar results were reported by Beirao-da-Costa *et al.*, Medina-Torres *et al.*, and Tonon *et al.*, [7, 9]. Some of the larger particles show some “deflating”, due to softness of the shell during drying, which collapses as moisture is lost from the inside of the particle (Fig 3).

Fig 2: Microphotographs of particles obtained at inlet air temperature (148 °C) and constant other parameters: air flow rate of 57 m³/h, feed flow rate of 120 ml/h and maltodextrin concentration of 6%

Fig 3: Microphotographs of particles obtained at higher inlet air temperature (148 °C) and constant other parameters

Effect of airflow rate

The increase in airflow rate from 49.56 to 59 m³/h increased agglomeration potential for any other constant parameters such as inlet air temperature, feed flow rate and maltodextrin concentration. Higher aspirator speed resulted in reduced residence time in the drying chamber and the consequently larger amount of residual moisture in the end product. Microphotographs (Fig 4) of beetroot powder obtained at

lower air flow rate show a spherical and varied in size with a high proportion of agglomerates.

Fig 4: Microphotographs of particles obtained at lower air flow rate (49 m³/h) and constant other parameters: inlet air temperature of 144 °C, feed flow rate of 120 ml/h and maltodextrin concentration of 6%

Effect of feed flow rate

Agglomeration potential was higher with an increase in feed flow rate from 120 to 150 ml/h. The possible explanation for an increase in agglomeration potential may be because the capacity of the air volume was not sufficient to reduce the moisture content as high as possible, resulting in high agglomeration potential of the end product. Agglomeration occurs due to retained moisture in a particle as a result of adhesion forces between particles. In (Fig 5), clusters were seen which are collapsed. Depression ducts are there due to shrinkage. Thick Concentrated Clusters are visible due to more moisture, rock type clusters, variation in size is definite.

Fig 5: Microphotographs of particles obtained at higher feed flow rate (150 ml/h) and constant other parameters: inlet air temperature of 144 °C, air flow rate of 57 m³/h and maltodextrin concentration of 6%

Effect of maltodextrin concentrations

Larger particles were found with an increase in a maltodextrin concentration from 4 to 8% to the fermented beetroot juice before spray drying. Image of spray-dried fermented beetroot juice powder obtained at maltodextrin concentration of 8% is shown in (Figure 6). It is verified that the concentration of maltodextrin increased, the particles became more spherical and more scattered. As explained by Ferrari *et al.*,^[10] also, particles produced with lower maltodextrin concentrations were smaller.

Fig 6: Microphotographs of particles obtained at higher maltodextrin concentration (8%) and constant other parameters: inlet air temperature of 144 °C, air flow rate of 57 m³/h and feed flow rate of 120 ml/h

Conclusion

The present study was concluded that the particle morphologies for fermented spray-dried beetroot powder were affected with different process parameters. Agglomeration potential was directly proportional to the airflow rate and feed flow rate. Particles were perceived at higher inlet air temperature and maltodextrin concentration with a smooth surface and larger sizes. The spherical shape of particles varied in size with a high proportion of agglomerates and visible cracks on surface predominant fermented spray-dried beetroot powder. With an increase in the concentration of maltodextrin the particles tended to become more spherical, more scattered. The SEM photographs indicated the most desirable microstructure of powder in fermented beetroot juice powder.

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Conflict of interest Statement: The authors declare that there is no conflict of interest.

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