



Spray Drying of Ginger and Physical and Micro Structural Properties of Spray Dried Ginger Powder - An Advance Food Material

P.N.R.J. Amunugoda ^{a,*}, A.B.G.C.J. De Silva ^a, K.V.T. Gunawardane ^a,

R. Pitipanaarchchi ^a, A.M.C.U. Silva, G.W. Thilina Dananjaya ^b

^a Food Technology Section, Modern Research and Development Complex, Industrial Technology Institute, Malabe, Sri Lanka

^b School of Engineering, Sri Lanka Technological Campus, Meepe, Padukka, Sri Lanka.

* Corresponding Author: neville@iti.lk

Received: 30th May 2020, Accepted: 22th October 2020

Abstract: The objective of this work was to optimize the spray drying of ginger juice using maltodextrin and to investigate the effect of carrier agent on physical and micro-structural properties of spray dried ginger powder. A laboratory pilot scale spray dryer was employed for spray drying process and commercial maltodextrin was used as carrier agents. Ginger powder obtained under optimized condition of maltodextrin concentration and 165°C inlet temperature was evaluated for moisture content, water activity, particle size distribution, bulk density, true density, porosity, wettability flowability, dispersibility, and powder morphology. Micro-structural analysis revealed powder particles of various sizes and shapes however properties were within the desired range. Spray dried ginger powder can be used as natural ginger flavouring. Optimized spray drying parameters and powder properties pave the way for testing high sticky food material and mixing of different spray dried powders by surface modification for more advance powder processing.

Keywords: Spray drying, Ginger, Maltodextrin, Powder properties, Surface engineering

1. Introduction

The purpose of perishables drying is to produce stable and easily handled powders from the juice, which reconstitute rapidly to a quality product resembling the original juice. Completely dried perishable powders are often used for making many delicious food products. Spray drying is the simplest and commercially used method for transforming a wide variety of liquid food products into powders in large scale. Spray dryers can use fairly high hot air temperatures because

the drying temperatures drop drastically due to evaporative cooling. Since the particles are finely divided in the spray dryer drying process can be completed within a short period of time. Therefore, the process enables continuously to prepare dried perishable powder without heat damage even at high air temperatures. Because of liquid products are converted into dry powder by quick drying which help in retaining the texture, taste and flavor. Because spray dried food products contain no moisture which helps in inhibiting the growth of microorganisms. Thus, the process completely eliminates manual handling there is no provision of contamination. Therefore, spray dried powder shows extended shelf life [1-4]. Due to increasing demand as raw material for ready-to-eat convenience snack foods preparation the local and global spray dried food market is expected to significantly and continuously increase. The market is segmented on the basis of type such as vegetable, fruit, dairy products, spices, seafood and seasonings, and is used in application such as snacks, bakery products, confectionery, infant formulas, and others. The products are less costly as compared to freeze dried products is another reason for the market growth. Spray dried spices are widely used as a condiment in various savory dishes. Several varieties of Ginger (*Zingiber officinale* Roscoe) are cultivated in Sri Lanka as a commercial crop. The rhizome, which is valued for its flavour, contains two classes of constituents, the essential oil and oleoresins. The essential oil consists of monoterpenes and sesquiterpenes, which contributes to the characteristics flavour of ginger and the more volatile oleoresins, is responsible for the pungent flavour of ginger, a source of anti-oxidant [5]. Temperature of drying is an important variable to preserve the essential oil and oleoresins as they are the volatile compounds. Excess production of ginger from glut period requires high yielding and less thermal damage drying method like spray drying to produce ginger powder. Spray drying of ginger is not yet started in Sri Lanka and process is novel to Sri Lanka's context. Spray drying belongs to the rather complex multiphase convective drying process which involves the atomization of droplets of emulsions, particle transport, evaporation of droplets as well as the interaction between particles and/or droplets and/or dryer walls [1]. Spray drying parameters such as inlet temperature, air flow rate, feed flow rate, atomizer speed, types of carrier agent and their concentration can be controlled to obtain desired characteristics in the final products such as particle size, bulk density, moisture content, yield and hygroscopicity in spray dried foods. The wall material or drying agent is commonly used in order to avoid these technological problem and the selection of suitable carrier depends on the desired physicochemical properties and final application of the powdered product (Fernandes *et al* 2016), High hygroscopicity and thermoplastic nature of sugar enriched powders show the problems of adhesion to dryer walls, difficult to handling and caking [6]. The stickiness of these powders is related to low glass transition temperature (T_g) of low molecular weight sugars.

2. Experimental procedure

2.1 Spray drying process of ginger powder

Ginger rhizomes (10 months in maturity) were cleaned three times by potable water then

by 50 ppm chlorinated water and again cleaned by potable water. Rhizomes were cut into 3-4mm slices and juice was extracted using heavy duty blender (Waring commercial heavy-duty blender). The proportion of addition of drying aid was chosen on the total soluble solid basis of the juice. The total solid content of the juice was calculated from determining the moisture content of the ginger juice. The spray drying experiments was performed using a lab scale spray dryer (Co-current type Kodi Lab Spray Dryer). The experimental trials were conducted with commercial maltodextrin in different ratios of ginger juice, maltodextrin under fixed operating conditions; air inlet temperature, fed rate, feed temperature and nozzle specification. Optimized Maltodextrin was 10° Brix. The sample was fed by a peristaltic pump and the ginger juice was feed to rotary atomizer which rotates at a speed of 25000 rpm. The drying aid (maltodextrin) and ginger juice proportion and atomizer speed was preliminary tested and kept constant. Final powder product was collected into sterilized triple laminated bag and sealed and kept under refrigerated condition (4 °C) for powder parameters analysis (Figure 1).



Figure 1. Image of the spray dryer

2.2 Analysis of powder

Powder recovery, using maltodextrin was calculated and the powders were analyzed for the different physical properties such as moisture content, bulk density, true density, porosity, color, degree of caking, hygroscopicity, dispersibility and flowability. Microstructural analysis of powder samples in terms of morphology of powder particles was done (followed method described in by Bhusari, *et al*2014) [2].

2.1.2. Powder recovery

Powder recovery is one of the main indices of a spray-dryer performance. Total powder recovery of spray dried ginger was calculated as:

% powder recovery = total weight of resulting powder on dry basis/ total solid content in feed 100

2.1.3. Moisture content.

The moisture content was determined using Oven dry method.

2.1.4 Bulk density

Bulk density (g/ml) was determined by gently pouring 2 g of ginger powder into an empty 10 ml graduated cylinder and holding the cylinder and tapping 10 times on a rubber mat from a height of 15 cm. The ratio of the mass of the powder and the volume occupied in the cylinder determines the bulk density.

2.1.5. True density

True density was calculated by filling approximately 1 g of ginger powder in a burette containing toluene. Then rise in toluene level (ml) was measured and true density was calculated:

True density= weight of powder sample (g) / rise in toluene volume (ml):

2.1.6 Porosity

Porosity of the powder samples was calculated using the relationship between the bulk and the true density of the powder as shown below:

$$\text{Porosity} = (1 - \text{bulk density} / \text{true density})$$

2.1.7 Reconstitution of powder

Reconstitution of ginger powder was observed by taking a 4g of ginger powder and dissolved in 100 ml water at 40°C. The powder was completely stirred and any suspended particles of powder in the solution was observed m (Mami *et al* 2002) [7].

2.1.7 Flowability

Flowability, defined as the ability of a powder to flow freely, in a regular and a constant way was characterized by calculating the Hausner Ratio and Carr's compressibility index.

2.1.8 Hausner Ratio (HR)

HR is a number that is correlated with the flowability of a powder or granular material.

$$\text{Hausner ratio} = (\text{bulk density} / \text{apparent density})$$

2.1.9. Carr's compressibility index (CI)

Carr's compressibility index of powder was calculated by the following formula:

$$\% \text{Carr's compressibility index} = [(\text{bulk density} - \text{apparent density}) / \text{bulk density}] \times 100:$$

2.3.10. Dispersibility

Thirteen grams of ginger powder was stirred with 100 g of water at 50 °C in a beaker. Stirring was carried out to make 25 complete back and forth movements across the whole diameter of the beaker for 15 S. The reconstituted ginger powder was then poured through the sieve of 210 μ size. The dry matter of the filtered juice was estimated by measuring its moisture content, keeping the sample in an oven at 105 °C until constant weight was obtained

$$\text{Dispersibility} = [(W+a) \times S_p] / (a \times S_j)$$

where a (g) is the amount of powder used, W is the weight of water taken for reconstitution, Sp (%) is the total solid present in the TPP and Sj is the % dry matter present in the reconstituted TPP after it has been passed through the sieve.

2.3.11. Powder morphology

Micro-morphological characteristics of ginger powder were determined by SEM using LEO 1420 VP model. A sufficient amount of powder was mounted on the SEM stubs, coated with platinum and observed with SEM for image analysis, at an accelerating voltage.

2.4. Statistical analysis

All the tests were carried out in duplicate and the results were reported as the mean values with standard deviation.

3. Results and discussion

According to Phoungchangdang & Sertwasana (2010), bulk density, water adsorption index, 6-gingerole and colour value of ginger powders decreased with increasing inlet air temperature and the best quality ginger powder were achieved at 120 °C inlet temperature [8]. In the present study, free flowing powder was obtained observing the particles movement within the drying chamber and no powder deposition and watery appearance of drying chamber wall by seeing through the glass window of the drying chamber and observing the quality of powder in the collecting tank under different inlet air temperatures. Based on these the best inlet air temperature was selected as 165°C and outlet air temperature of the spray dryer was 75-85°C. Surface properties play a key role in the mechanisms involved during powder production in milling, spray drying, or crystallization, and when use in storage, flow, agglomeration, dispersion and solubilisation. Functional properties of food powders are largely dependent of the surface composition and surface characteristics of the particles [9]. Product powder recovery is one of the main parameters of a spray dryer performance. It was observed that % powder recovery increased with increase of addition rate of carrier agent used in preliminary test trials in the present study. The increase in % powder recovery is due to the reduction in stickiness and deposition of powder particles on the drying chamber wall. Thus, with the increase in carrier agent, it increases the resultant glass transition temperature of the feed mixture of the carrier agent and pulp [9]. Maltodextrin is produced by partial hydrolysis of starch and is commonly used

as wall material in microencapsulation by spray drying, offering advantages such as relatively low cost, neutral aroma, and taste, low viscosity at high solid concentration and good protection against oxidation [1,6]. According to Phoungchandang & Srtwasana, (2010), spray drying of orange juice without any drying aid could not produce dry orange juice powder and maltodextrin increased drying yield of 18-35% [8]. In other study, for the preparation of mango juice 45% of maltodextrin has added (Mani *et al* 2002) [7]. Therefore, in this study we used maltodextrin as a wall material to improve the powder yield. Moisture content and water activity are essential properties to determine the powder stability and storage. The moisture content and water activity of spray dried ginger powder were $5.8\% \pm 0.2$ (wb) and 0.397 ± 0.007 . The % recovery of ginger powder is 70%.

Normally spray dried products are non-homogeneous particulate systems, in which the voids between big particles are filled with smaller particles, increasing the bulk density and thus occupying less volume. Particle size distribution can influence the flow, the blending of different components, and the compaction and segregation of a mixture. According to Phoungchandang and Sertwasna, (2010) particle size of ginger powder increased with inlet air temperature and decreased with increased concentration with maltodextrin [8]. This physical property is very important with respect to powder stability. When the particle size decreases the total surface area increased causing greater affinity for moisture and leading to a greater possibility for caking during storage. The presence of small particles can result in poor instantaneous properties which can make the penetration of water difficult and then adversely affect powder wettability and dispersibility. Wettability is often measured as the time taken for all particles to be completely wetted. Small particles have a high specific area and may not be wetted individually favours clumping. Santana (2010) reported that coconut powder formulated with maltodextrin presented formation for clump, however in the present study no clump formation in the ginger powder [1]. Wettability time of few seconds is desirable for powders with good reconstitution properties. In the present study all the particles are less than $75\mu\text{m}$. The bulk and absolute densities and porosity of the powder system highly depend on particle size distribution. Mean porosity, bulk density and true density of ginger powder is 0.62, 0.5 and 1.3 ± 0.12 respectively. A lower bulk density is not desirable and it required higher volume of package. Spray dried ginger powder showed moderate bulk density and true density. Porosity is property of particulate systems related to the surface area. The surface area is important in all applications where the process is surface dependent, such as mass and heat transfer, flow through packed beds, and fluidization. Higher porosity means higher occluded air among powders leading particles oxidation, and reducing storage stability. An excellent flowability can be expected if the CI is within 5 to 15%, passable to fair flow when CI is between 15 and 24% and poor flowability when CI is above 25%. In the present study according to Hausner Ratio (HR), flowability of the ginger powder is 1.17 that lays the range of medium flowing property. According to Carr's Compressibility Index (CI) flowability is 14.86% that lies in the fair range. Caking is a prevalent situation that can cause problems in operation, equipment surfaces or product yield. The flowability of a powder is an

important property in handling and processing operations, such as storage, transportation, formulation, mixing, compression or packaging. Flowability is highly dependent on particle size distribution and surface chemical composition.

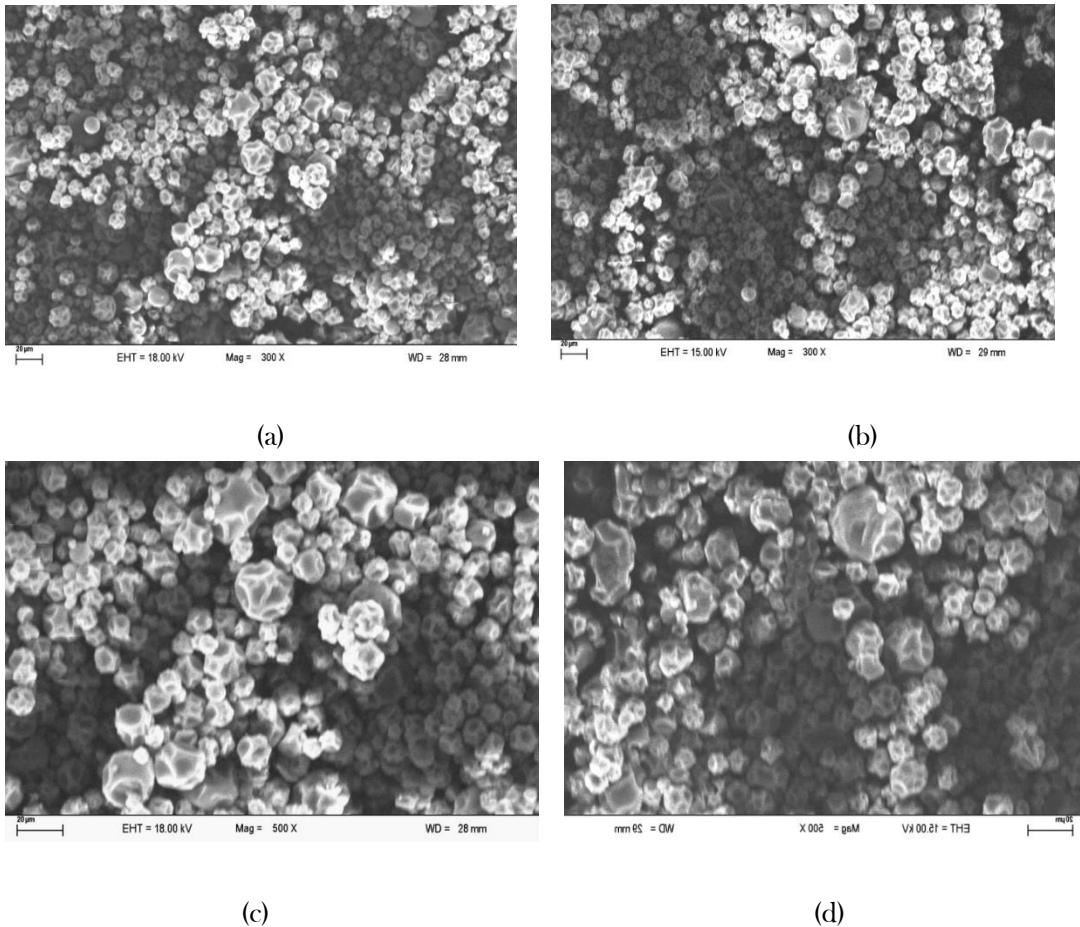


Figure 2. Microstructure images of ginger powder

SEM was used to study changes in morphology in the ginger powder materials. Smooth spherical spray dried particles are desirable due to the greater ingredient protection and retention, higher bulk density and good flowability. SEM images of spray dried ginger particles showed particles of variable size (Figure 2) however comply with the mean particle size distribution. Magnified images show most of particles are not circular in shape and several flat surfaces on the surface, a special surface property of ginger powder.

Surface engineering is a strategic technology for the effective and efficient exploitation materials for structural as well as

functional applications and also designing of advanced and novel food products. Effective surface modification of ginger powder to decrease contact angle, increase surface energy, surface etching thereby increases wettability and reactivity that leads to value-added high-quality spray dried ginger powder product development with functional properties. Use of cold plasma for surface modification of powders includes spheroidization, layer deposition, and enhancement of optical, mechanical and thermal functionality [10]. By this way spray dried ginger powder based nutritionally enriched fruits, vegetable and yams, sugar and other sticky products are being tested and further research are in progress.

4. Conclusion

An inlet air temperature of 165°C and concentration of % maltodextrin can be recommended as the optimized condition for spray dried ginger powder processing. Optimization spray dryer parameters and powder properties are essential to produce good quality ginger powder. Study could be useful to obtain novel and low-cost source of natural ginger flavouring as a powder with good powder properties for the production of ginger-based products. With this results dryer can be tested to produce high sticky products like fruit juices, honey and tamarind juices.

References

- [1] A.A. Santana, L.G.P. Martin, R.A. De Oliveira, L.E. Louise Kurozawa, K. J. Park, Spray Drying of Babassu Coconut Milk Using Different Carrier Agents, *Drying Technology*, 35 (2017) 76-87.
- [2] S. N. Bhusari, K. Muzaffar, P. Kumar, Effect of Carrier Agents on Physical and Microstructural Properties of Spray Dried Tamarind Pulp Powder, *Powder technology*, 266 (2014) 354-364.
- [3] D. Krishnaiah, R. Nithyanandam, R. Sarbatly, A Critical Review on The Spray Drying of Fruit Extract: Effect of Additives on Physicochemical Properties, *Critical Reviews in Food Science and Nutrition*, 54 (2014) 449-473.
- [4] A. M. Goula, T. D. Karapantsios, D. S. Achilias, K. G. Adamopoulos, Water Sorption Isotherms and Glass Transition Temperature of Spray Dried Tomato Pulp, *Journal of Food Engineering*, 85 (2008) 73-83.
- [5] K. S. M. Abeysekera, C. K. Illeperuma, P. N. R. J. Amunugoda, S. W. Wijeratnam, Comparison of Ginger Varieties Dried at Different Temperatures for Oil and Oleoresin Contents, *Department of Food Science & Technology, Faculty of Agriculture, University of Peradeniya, Sri Lanka*, 42 (2005)34-42.
- [6] R. V.de Barros Fernandes, S. V. Borges, E. K. Silva, Y. F. da Silva, H. J. B.de Souza, E. L.do Carmo, D. A. Botrel, Study of Ultrasound-Assisted Emulsions on Microencapsulation of Ginger Essential Oil by Spray Drying, *Industrial Crops and Products*, 94 (2016) 413-423.

- [7] S. Mani, S. Jaya, H. Das, (2002) Sticky Issues on Spray Drying of Fruit Juices, *In ASAE/CSAE North-Central Intersectional Meeting, USA.*
- [8] S. Phoungchandang, A. Sertwasana, Spray Drying of Ginger Juice and Physicochemical Properties of Ginger Powders, *Science Asia*, 36 (2010) 30-45
- [9] I. Murrieta-Pazos, C. Gaiani, L. Galet, R. Calvet, B. Cuq, J. Scher, Food Powders: Surface and Form Characterization Revisited, *Journal of Food Engineering*, 112 (2012) 1-21.
- [10] M.D. Pirzada, M.M. Nawaz, Surface modification of powders, *J Pak Mater Sco*, 4 (2010) 20-30.

Acknowledgements

This works supported by a project (No. TG/ 19/170) funded by Treasury of Sri Lanka under the title of “Spray drying of selected fruits, vegetable juices and yam pulps and innovative spray dried powder-based products development”

Conflict of interest: NIL

About the License: © 2020 The Authors. This work is licensed under a Creative Commons Attribution 4.0 International License which permits unrestricted use, provided the original author and source are credited.