# Investigation on Conventional and Vacuum Spray Drying: A Review

**Swapnil D. Ambhore†, Shriraj D. Gulbhile‡ and Mandar M. Lele†**

†Department of Mechanical Engineering, MIT College of Engineering, Savitribai Phule Pune University, Pune, India.
‡Department of Mechanical Engineering, MIT College of Engineering, Savitribai Phule Pune University, Pune, India.
†Department of Mechanical Engineering, MIT College of Engineering, Savitribai Phule Pune University, Pune, India.

**Abstract**

This research work is comprised of development of an experimental test setup of vacuum spray dryer. The built setup was aimed to acquire the benefits of drying process in vacuum which leads to low temperature drying and also spray drying which leads to increase in heat transfer by providing more surface area of fluid. The compound which is first dried by conventional spray dryer was Maltodextrin solution(Fernanda de Melo RAMOS, 2016). Then another Malodextrin sample was dried by using vacuum. Use of vacuum leads to overall low temperature process than conventional drying. Vacuum was in the pressure range of 20 millibar to 50 millibar(Aoyama et al. 2009). The resultant or products achieved by these two processes then studied. Their properties like size distribution of the particles, water content, water activeness, water solubility and also density was measured and finally compared. Yield of both the processes i.e. conventional drying and vacuum spray drying were calculated and analyzed.

**Keywords:** Conventional drying, vacuum spray drying, vacuum.

## 1. Introduction

In many pharmaceutical industries and food processing industries it is necessity of the product to remove its moisture content. Because moisture content or excess percentage of water leads to biological growth of the micro-organisms, oxidation which turn results in bio-degradation of the products. Hence the food which is processed will definitely result in greater time period sustainability than un-processed food. Drying is one of such processes which can lead food or other pharmaceutical products like powdered proteins, inhalable powders, nutritional supplements, probiotics etc. to greater life span and reduced volumetrically and allow to precise generation of the particles. Out of available drying methods, the process of atomization is conveyed in autoclave or in spray drying chamber. These kind of dryers are consist of two fluid flows which in direct contact with each other to transfer the heat. One flow is of food powder and another is of air at high temperatures. The temperature of this air is around 150$^0$C to 250$^0$C (Parikh DM, 2008). But the main disadvantage of this processes is that it is not convenient for thermos-sensitive food or pharmaceutical products like probiotics, enzymes and vitamin etc. Because many studies have already shown that use of high temperature while drying can degrade or kill the required properties of the compounds which is not desirable.

For this reason another substitutional method of drying is needed to be implemented. In vacuum spray drying, the pressure inside the autoclave or drying chamber is significantly lowered. Decreasing in pressure results in lowering temperature of evaporation of water i.e. removing moisture at lower temperature than conventional drying. As the process temperature is lowered, the thermo-sensitive compounds can be conveniently dried by using vacuum. In this work to overcome the drawback of Iyophilization of making proper mixture which consumes greater time, an atomization is implemented and to overcome the drawback of conventional method of high process temperature, vacuum is introduced, which in turn will provide benefits of both the processes.

In case of vacuum spray dryer (VSD), the whole process is carried out in the temperature range of 40$^0$C-60$^0$C. This temperature is significantly lower than conventional dryer and hence thermos-sensitive

ISSN : 2454-9150 Special Issue - AMET-2018

materials can be prevented from thermal-degradation. It is found that in literature, VSD process can be carried out effectively by lowering temperature by decreasing pressure internal of the drying chamber (100 millibar-200 millibar).

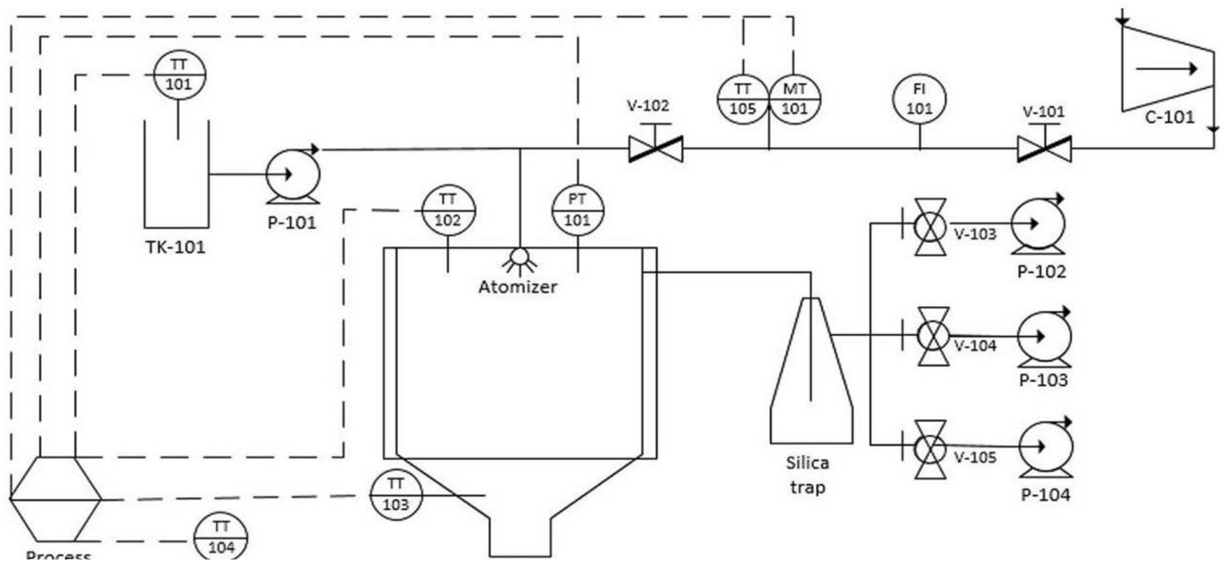
Hence this study was aimed to design and produce the dried compound by this dryer and finally compare the same with conventional dryer product. The results of this comparison involved various properties like particle density, water content, activeness of water, etc.

## 2. Material for drying process

*2.1 Maltodextrin*

For drying processes by conventional spray dryer and VSD, Maltodextrin (MOR-REX® 10DE, Ingredion, Brazil) was selected. It is prepared by partial hydrolysis of starch and is completely soluble in water and comprised of powdered form of sugar.

**Fig. SEQ Fig. * ARABIC 1** Schematic of the Vacuum spray dryer and the process flow (*Fernanda de Melo RAMOS, 2016*)




*2.2 Vacuum spray dryer (VSD)*

Fig.1 represents the schematic of the Vacuum spray dryer and the process flow. The description of the various equipment is TK-101: storage tank of feed solution; P-101: peristaltic pump; P-102: vacuum pump-1; P-103: vacuum pump-2;P-104: vacuum pump-3; C-101: air compressor; V-101: needle valve at compressor outlet; V-102; needle valve after the flowmeter; V-103: ball type valve in vacuum line – Pump-1; V-104: ball type valve in vacuum line – Pump-2; V-105: ball type valve in vacuum line – Pump-3; TT-101:electronic thermometer for feed solution reservoir; TT-102:electronic thermometer at the top of drying chamber; TT-103: electronic thermometer at the bottom of vacuum chamber; TT-104: temperature indicator of ambient air; TT-105: temperature indicator of atomization air; MT-101: relative humidity sensor; PT-101:electronic pressure gauge at the top of the drying chamber; FI: rotameter.

A peristaltic pump (Marterflex®,United States), atomizer for double fluid flow (Labmaq, Brazil), drying chamber made up of stainless steel and an air-compressor MSV 6 (Schulz, Brazil) are integrated to the system. To reach low pressure inside vacuum chamber in minimum time the system is provided with 3 rotary oil sealed high vacuum pumpsRD 4 and RD 6 (Vacuubrand, Germany) and DC8D (DVP, Italy) were provided. The temperature sensors used were (Pt100 resistance thermometers) with accuracy of 0.2°C and linearity 0.99; pressure sensors (ICC-Press, 78703 series); relative humidity and temperature sensor RHT-WM (Novus, Brazil); flowmeter "N" (OMEL®, Brazil), logger of NOVUS data logger (Novus, Brazil) and a remote computer with Field Chart 1.76 software to carry out the readings of working units.

## 3. Experimental setup and methodology of drying processes

*3.1 Vacuum spray dryer (VSD)*

An experimental setup was used to perform the drying process. One preliminary test was carried out to determine the working conditions of the system. Peristaltic pump with 0.0642 liters/hour was used to carry maltodextrin solution to atomizer. The concentration of maltodextrin solution was 40° Brix. Flow rate of feed air was 20 lpm and line pressure was 1200 mbar. There were 3-vacuum pumps used in parallel condition to reach low pressure inside the vacuum chamber. The inside pressure of vacuum chamber was contiusly measured and taken care that it will remain stationary till the process was carried out.

*3.2 Conventional spray dryer*

For conventional spray drying process LM MSD 1.0 (Labmaq®, Brazil) was used. It had provision of drying chamber which was made up of stainless steel. In both drying processes same atomizer was used. The nozzle of atomizer was 1.0 mm in diameter and it had provision of inside and outside mixing. The flow rate of compressed air in case of conventional spray dryer was 40 lpm and that of drying air was 1500 lpm. Concentration of the solution was 40° Brix. Drying air was supplied at constant temperature of 175°C. After that temperature was measured at the outlet of the chamber which was 115°C.

*3.3 Properties to be tested in both the methods*

Subsequent to the finishing of the drying by both the methods, the powder products were studied for the following properties:

1) Moisture content
2) Activeness of water
3) Apparent density
4) Size of particles
5) Solubility in water
6) Yield of the process

Association of Official Analytical Chemists (2005) had established the methodology to determine the water content was used in this experimentation. The solution of powder and distilled water held in oven at 105°C and continuously stirred.

The activeness of water was measured with water activity meter 4TE. The instrument was accurate up to ± 0.002 aw.

Apparent density of the powder was measured by inserting 2g of the product sample in cylindrical glass of volume 50mililters at ambient temperature (Goula *et al.*2004).

A spectrometer which works on the principle of laser spectroscopy was used for measuring particle mean diameter.

Solubility of product can be checked by making its mixture with distilled water and then by heating (Cano Chauca *et al.*2005).In this method 1g of dried product was added to the vessel containing 100ml of water (distilled). Then the mixture was stirred for duration of 5 minutes. Afterwards, an exact quantity of 25 ml of this mixture was taken and placed in the oven at 105 °C till a stationary weight had arrived. And finally by finding weight differences solubility was found out.

Yield of the drying process was defined by the percentage ratio of the mass of the dried product by the process to the mass of the atomized solution in the process.

## 4. Results& Discussion

*4.1 Distribution of particles generated from conventional and vacuum spray drying*

Table1 represents the content of moisture, activeness in water, water solubility from both the processes. Both produced samples were tested and they showed considerable differences in moisture content. In conventional drying, particles with moisture content below 1%were obtained (0.91 ± 0.08). That means in this method water availability is very low for any bio-degradation or bacterial growth. This is because use of higher temperature of drying air (nearly 180$^0$C-200$^0$C) causes higher temperature differential which led to more heat transfer between drying air and the Maltodextrin powder. This in turn evaporated more amount of water and results in very less moisture content.

**Table 1** Results of water content, activeness of water & solubility in water

| Method | Conventional spray drying | Vacuum spray drying |
|---|---|---|
| Moisture content | 0.91± 0.08 | 8.92 ± 0.49 |
| Activeness of water | 0.079± 0.005 | 0.220± 0.032 |
| Solubility in water | 98.99± 0.02 | 99.08± 0.04 |

It is found that, more wetness in particles of VSD which was nearly 10times (8.92 ± 0.49) than in conventional method. This is because there is no heat source to encourage the greater temperature differential and increase the heat transfer. In VSD, evaporation of water takes place by pressure differential not by temperature differential. Hence as a result of absence of enough heat to evaporate more water content, VSD showed higher moisture content.

Activeness of water in case of conventionally dried product was 0.079± 0.005 which lower than 0.1. But in case of VSD, activeness of product found to be 0.220 ± 0.32 which is lower than 0.3. From these results it was clear that activeness of water is pretty low in both the methods which was below 1%.This stabilizes the product and will eliminate chances for any biological and biochemical changes to occur.

The product obtained from VSD has more porous structure. Because of porous structure of the particles in VSD, they had more solubility in water than in case of conventional particles. Still there is no significant difference in solubility because there was only 1% change in solubility in water. Maltodextrin has more solubility in low temperature (Kenyon *et al.* 1988).

*4.2 Apparent density and particle size and size distribution*

**Table 2** Results of size & density of the obtained particles

| Method | Conventional spray drying | Vacuum spray drying |
|---|---|---|
| Particle size (mean diameter in µm) | 23.56± 0.79 | 555.83± 22.26 |
| Density (in g/cm³) | 0.8519 ± 0.0259 | 0.4828± 0.0081 |

Table 2 represents the values of particle size and density of particles by both the methods.The density of particles obtained from VSD was 0.4828± 0.0081g/cm³. In conventional method density was 0.8519 ± 0.0259g/cm³ which was higher than VSD. This was expected as density is related to size of obtained particles.Smaller the particle size will result in higher particle density, because performed agitation while analysis likely to minimization of the spaces between particles, which results in to placing particles more closely i.e. in smaller volume (Al-Kahtani*et al.* 1990). Higher density is bounded to a lower moisture content. (Goula *et al.*2004). Particles from conventional dryer had density higher than 0.8 g/cm³.

Particles obtained from both the methods showed much variation in their sizes. Considerably larger particles obtained in VSD which was 555.83± 22.26 µm mean diameter. In conventional spray dryer it was 23.56± 0.79 µm mean diameter.

As lower air temperature at the inlet used then the particles will remain curled up and will keep smaller diameter and as higher temperature used at the inlet will result in bigger diameter particles because of their expansion.

This study, showed that by using drying air at high temperature led to particles with smaller diameter than VSD method. In case of VSD method the atomization led to expansion of the particlesin vacuum chamber which formed larger particles. And also absence of temperature differential led to less evaporation of water from powder and led to larger particles with higher moisture in them. (Islam *et al.*2016) acquired smaller diameter particles of powder of orange juice of size in between 6.02 µm to 12.84 µm byusing VSD.

The viscosity, atomizer type, concentration of feeding solution also affects the size of the particles of dried product. At stationary speed of feeding, size of atomized drops directly changes with viscosity of feeding solution. Greater viscosity will result in more number of atomized drops and will produce more particles.

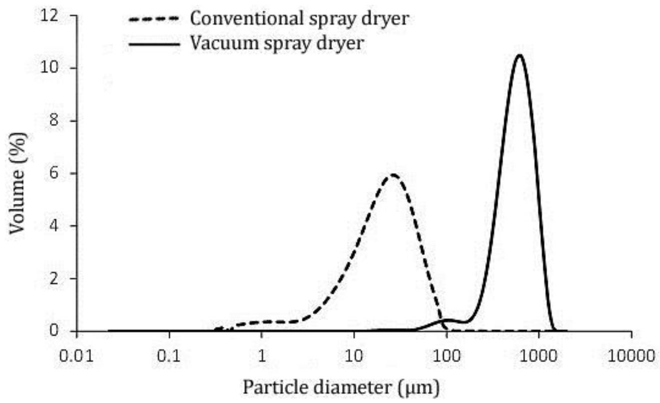



**Fig.2** distributions for the particles produced in VSD and conventional spray dryer according to their sizes*(Fernanda de Melo RAMOS, 2016)*

Fig.2represents distributions for the particles produced by vacuum spray dryer and by conventional spray dryer according to their sizes. Particle volume in case of VSD was observed higher as its mean diameter was 555.83± 22.26 µm. And in conventional dryer particle volume is smaller as its mean diameter was 23.56± 0.79 µm.

*4.3 Yield of drying process*

**Table 3** Yield of drying process by Conventional spray dryer and vacuum spray dryer

| Processes | Conventional spray dryer | Vacuum spray dryer |
|---|---|---|
| Process Yield (%) | 63.98 ± 2.33 | 23.71 ± 1.51 |

Table 3 represents the yield of drying process by both the methods. Process yield is an important parameter for deciding whether the process is suitable for actual application for production of the dried powder. Conventional dryer gave the higher process yield (63.98 ± 2.33)% and VSD gave (23.71 ± 1.51)%. VSD showed lower process yield because of particle accumulation at the internal walls of the vacuum chamber and conventional method showed higher process yield because of use of high temperature. This means use of high temperature results in higher mass and heat transfer which leads to improved process efficiency.

The process yield in case of VSD had unwanted effect of adhesion of particles on the internal walls of the vacuum chamber because of material from the feedstock partially evaporated deposits.

## 5. Conclusions

1) The main findings of these studies is that with the use of vacuum, the temperature of drying processes can be significantly lowered from 50⁰C to room temperature compared to conventional drying processes which as 170⁰C. Hence vacuum

 **DOI : 10.18231/2454-9150.2018.1449**

spray drying (VSD) can be considered as the feasible choice over conventional drying process for heat responsive products.

2) Vacuum spray drying process possesses particles with 555.83± 22.26μmand conventional spray drying possesses 23.56± 0.79μmmean diameter. That means VSD results in larger size particles than conventional drying.
3) The density of VSD product is lower compare to conventional drying. Where as in conventional drying, product obtained has lesser solubility98.99± 0.02and higher density0.8519 ± 0.0259.
4) Vacuum spray drying showed product of greater particle size, higher solubility and less density compared to conventional drying process, which gave particles of lesser water content or moisture with lesser activeness for water.
5) Vacuum spray drying process led to accumulation of the particles because of fractional evaporation of the particles on the internal sidewalls of drying autoclave. This accumulation of the particles led to lesser process yield. This drawback of vacuum spray drying process can be overcome by providing heat to the internal walls of the autoclave or using greater flowrate of vapour at the suction so that accumulation of the particles cannot take place while the process is running. This will also increase the yield of the process.

## References

Fernanda de Melo RAMOS, (2016),Assessment of differences between products obtained in conventional and vacuum spray dryer, *Food Sci. Technol., Campinas*, 36(4): 724-729.

Aoyama, R., Kitamura, Yamazaki, K. (2009). Experimental analysis of spraying and drying characteristics in vacuum spray dryer, *Japan Journal of Food Engineering*, 10(2), 127-133.

Parikh DM, (2008), Advances in spray drying technology: New applications for a proven process,*AmPharm Rev.*, Volume 11, issue 1.

Chaubal M.V., Popescu C. (2008), Conversion of nano-suspensionsinto dry powders by spray drying: A case study,*Pharm Res.*, 25:2302–2308.

Cano-Chauca, M., Stringheta, P. C., Ramos, A. M., & Cal-Vidal, J., (2005), Effect of the carriers on the microstructure of mango powder obtained by spray drying and its functional characterization,*Innovative Food Science & Emerging Technologies*, 6(4), 420-428.

Carneiro, H. C. F., Tonon, R. V., Grosso, C. R. F., & Hubinger, M. D. (2013). Encapsulation efficiency and oxidative stability of flaxseed oil microencapsulated by spray drying using different combinations of wall materials,*Journal of Food Engineering*, 115(4), 443-451.

Fu, W.-Y., & Etzel, M. R., (1995), Spray drying of Lactococcus lactis ssp. lactis C2 and cellular injury, *Journal of Food Science*, 60(1), 195-200.

Goula, A. M., & Adamopoulos, K. G., (2004), Spray drying of tomato pulp: effect of feed concentration, *Drying Technology*, 22(10), 2309- 2330.

Goula, A. M., Adamopoulos, K. G., & Kazakis, N. A., (2004), Influence of spray drying conditions on tomato powder properties, *Drying Technology*, 22(5), 1129-1151.

Islam, M. Z., Kitamura, Y., Yamano, Y., & Kitamura, M., (2016), Effect of vacuum spray drying on the physicochemical properties, water sorption and glass transition phenomenon of orange juice powder, *Journal of Food Engineering*, 169, 131-140.