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Development of indigenous spray dryer to improve the physiochemical properties of food powder

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***Abstract*---**In the Spray Drying process, the particles of solvent and solute can be emulsifying, homogenize and encapsulated for different biochemical reactions. Spray dryer is an instrument which is used to reduce the moisture using hot air in contact with the material. Spray

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dried products can be protected from bacteria by decreasing their moisture content and the shelf life enhanced of the product. There are four major steps will be kept in mind for designing and fabrication of spray dryer. Material which is used for designing and manufacturing of material used should be food grade and economical. Stainless steel material is used for designing of Spray Dryer, so that contamination can be reduced. During powder formation the different size of particles may coagulate and agglomeration may occur. To avoid from this type of agglomeration malt dextrin will be added. The particle formation has different which hindered the agglomeration. Atomizer will convert the slurry into droplets, then hot air and slurry becomes in contact in the drying chamber. After that powdered material is collected through the cyclone separator. Temperature, Pressure, particle size, and particle geometry is important factors during spray drying. The powder will be characterized on the basis of geometry and size of particle. In addition, the cost of spray dryer will be justified with respect to designing and manufacturing of spray dryer.

***Keywords*---** Spray dryer, Physiochemical properties, Food Powder

Introduction

According to the current studies, milk waste in Pakistan is 15% (Yaqub *et al.*, 2016). This wastage of milk can be reduced by proper handling the milk. Many techniques are used to increase the shell A process in which atomization and drying take place to convert a liquid into solid by reduction of moisture level using co-current or counter current interaction between a liquid and hot air (Keshani *et al.*, 2015). This technique has become industry friendly technique spray drying technique involves in versatile application like drying of liquids like milk and juices capacity and ability to manage feed stock for different behavior production specific particles and flowing of these particles, size and large production of yield spray drying is operated on the basis of convection process mode the principal for doing work in spray drying technique is removal of moisture by providing heat energy to the fluid and controlling of humidity spray is based removal of moisture evaporation by in contacting the liquid with spray of air mostly with the temperature of 120^{o}C due to which drying is improved (Jones *et al.*, 2020).

The phenomenon of spray drying can be better understood by studying the four most important constituents of spray drying. When liquid is entered into the spray it converts into revised of transformations before confession into powder the change is due to these four steps (Aghbashlo *et al.*, 2012)

1- Conversion of particles into atomized droplets (Atomization)

2- Contact of hot air with liquid material

3- Removal of moisture.

4- Formation of Particle and Separation of particle.

1. Atomization

The primary process that the feed undergoes during spray drying is atomization, which is the key component of spray drying. There are a few implications of atomization, but Samuel Percy identified one that is important and equally intriguing: "putting fluid or solid material into a condition of minute division." By lowering internal protections against moisture migration from the drop to the integrating medium, the division of bulk liquid into limitless dabs propels the remaining stages of the shower drying process. (Piñón-Balderrama *et al.*, 2020). Atomization is procedure of splash drying because of which a large portion of the properties influenced for instance Shape, structure, Velocity and size dissemination.

2. This process, and the ensuing technique experiences of spray drying, set up molecule game-plan orchestrate. With the mass feed atomized into minor spots, the going with stage is to pass on the drops into private in contact with hot air provided through the heater. It connects brisk dissipating of drenched state from the outside of the huge number of globules in the uniform way. Here, basic need is to provide gas of which the particles uniformly distributed stream as all bits of the spray drying chamber. When spray-air contact happens, the globules normally met spread in the sprinkling chamber, it may happen in two ways one is co-current and counter current process as it is shown in diagram. (Leung *et al.*, 2017)

3. Change of glass temperature is very important an element of time temperature relation as a second order ward progress, which is portrayed through an intermittence in electrically, mechanically and physically warm, different physical properties for a material. Glass Transition temperature is that temperature at which the framework transferred from the basically unbending lustrous formation to a rubbery condition that is related through item gelatinous in spray drying chamber divider in spray drying (Truong, Tett, Pasolli, Huttenhower, & Segata, 2017).

Time for spray drying is a variable is significant for two viewpoints – to be specific, concerning total drying of feed beads to accomplish ideal item determinations, and in the control of molecule temperature to limit smell misfortune and warm corruption of warmth delicate materials. The molecule home time (RT) additionally influences item quality records, for example, solvency and mass thickness. RT is isolated into two sections: essential and optional living arrangements. The essential RT is determined from time taken for beads leaving the spout to effect on the divider or leave at the outlet. The optional habitation time can be characterized time taken by molecule to slide along the divider from the effect position to the exit. While forecast of RT in a spray chamber is tentatively troublesome, late headways in displaying and ground-breaking computational reproduction systems help in effectively ascertaining the RT. (Lewandowski, Zbiciński, & Jaskulski, 2020).

A brutal breeze separator, as often as possible fused through a splash dryer, is a static and mechanical contraption that utilizations emanating power for detach solid beads through the conveyor hot air(gas) Fig. 1.14 that involves a top cylinder

formed, suggested such as barrel, and a lower side pipe molded frame, insinuated through the cone of the cylinder of lower part. The hot gas stream, stacked with spray dried particles leaving the spray dryer enters digressively as the most elevated purpose of the drying chamber and voyages dropping inner side of the cone, molding an outside of the vortex. The growing velocity in the outside vortex applies a transmitting power for the spray dried particles, disconnecting these from the hot gas of stream. Exactly when the stream of the hot gas accomplishes by the bottom part of the cone, an internal hole (vortex) is made, along these lines changing its course and forgetting about upper part of the dryer as immaculate air (gas). The solid particle moves downward from the top get-together into the spray dryer joined towards the base of twister (Behboudi-Jobbehdar *et al.*, 2013)

The spray dryer which used air to dry liquid material. It is the most important type of spray dryer because wastage of air does not happen through this spray dryer because the air used is recirculated in the spray dryer is reused. The advantage for this spray dryer is the air which is used don't need to filter again and again. Once the air is dried it is used for many times. (Lintinen *et al.*, 2018)

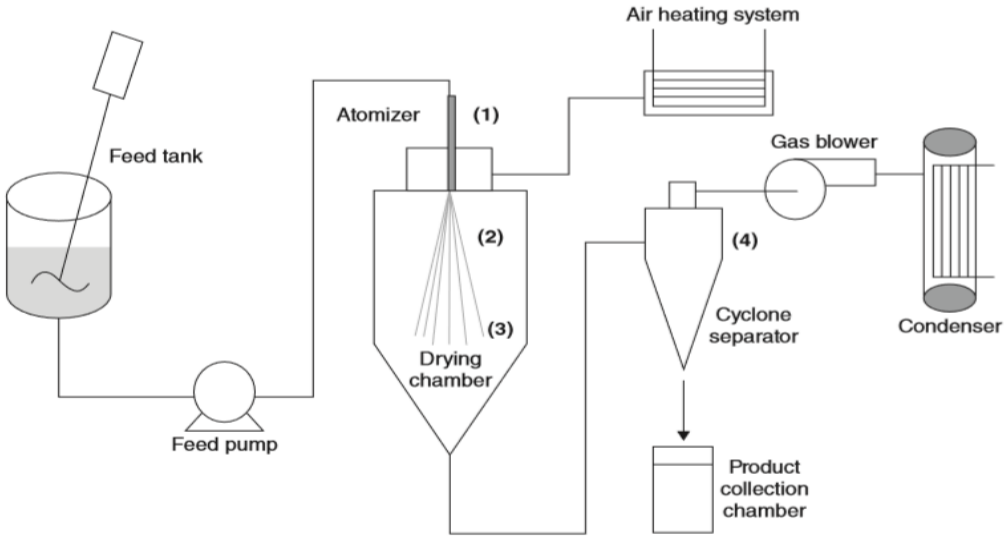

Fig 1.1 Schematic proposed diagram of spray dryer

Atomization

This is a direct result of the mass fluid's massive surface area expansion as the dab separation process progresses, with its uncertainty increasing in line with atomization power. Because of its effects on the particle's form, structure, speed, and size distribution, as well as the final product's particle size and type, atomization is essential to the sprinkle drying process. Approximately 2 1012 homogeneous 100 micron-sized particles are present in a cubic metre of liquid, providing a surface area of more than 60,000 m2 at full scale (Robin et al., 2021). This increased surface-to-volume ratio uses sprinkle drying to have a quicker drying period (as drying time is with respect to the square of the particle estimation). It justifies understanding the development in the thoughts on

atomization wonder throughout the years. This will in like manner help in esteeming the investigation of globule game plan from an atomizer. Through his test recognitions, Joseph Plateau was the first to depict liquid precariousness in 1873. From the beginning of a relentless range, a liquid stream descends vertically due to gravity. The liquid length increases and fulfils a crucial purpose. The fly divides into a stream of dabs at this crucial value, losing its round and empty shape as a result of the surface tension reduction (Figure 1.2). In 1878, Ruler Rayleigh expressed his approval to the idea that had just been conveyed and provided an analytical justification for the physical discernment. He provided logical support for the "Liquid fly theory," often known as the breakdown of non-viscous liquid in laminar stream circumstances. When the fastest-creating exacerbation reaches a wavelength (for example, a pick of 4.51d, where d is the fundamental plane broadness), Rayleigh considered the fundamental condition of a laminar fly emanating from a round opening (Maugin, 2016) and estimated the advancement of small disrupting impacts that produce detachment. The load of length 4.51d becomes a spherical drop after detachment.p. Likewise, from this time forward, can be approximated to a hover of proportional volume. Atomization study leads us to study the particle size, bulk density of the particles, tapped density of the particles and provide an idea about temperature for particles formation, it also describes what will be the outlet temperature when particles has been formed and hence, we can estimate moisture analysis of spray dried powder. All these parameters can be studied on the basis of atomization. Atomization helps us to understand the preparation of slurry which is made for the spray drying. Atomization explains about the encapsulation on spray dried powder, how the material can be encapsulated in the symmetrical manner. All questions will be answered by atomization.

Objectives

1. To analyze the quality and physiochemical properties of the spray dried powder e.g. milk
2. To increase the efficiency of the spray dryer by improving the recovery of the product.

Material and Methods

The material used for development of spray dryer is food grade and made from stainless steel 316S. The spray dryer was developed in engineering workshop near Ghulam Muhammad Abad Faisalabad. The material was collected from different shops of the market like Motor Market Jhang Road, Samundri Road market of spare parts and from Bilal Gunj Market Faisalabad

First of all, the sheet was taken from the market and mold into a circular path through Leith machine and hammering. Then the second sheet was designed around the first sheet. There is a risk of heat exchange during the process of spray drying. If heat loss during spray drying, then efficiency of the spray dryer may decrease. To improve and maintain the efficiency of spray dryer the chamber was developed as double jacketed. If the spray drying chamber is double jacketed, then it may improve the efficiency of the spray drying as well as heat loss can be reduced.

Specifications of Spray Drying Chamber

Parts	**Measurements**	
Length of the Drying Chamber	39.5 in	1.0033m
Length of Spray Dryer	53	1.346m
Internal Diameter of Cylinder	19.3 in	0.4921m
External Diameter of Cylinder	19.7 in	0.5048m
Circumference of Cylinder	69.0 in	1.7526m
Space between two Cylinders	0.625	0.0158m

Table 1 Specifications of spray drying chamber

Process Diagram

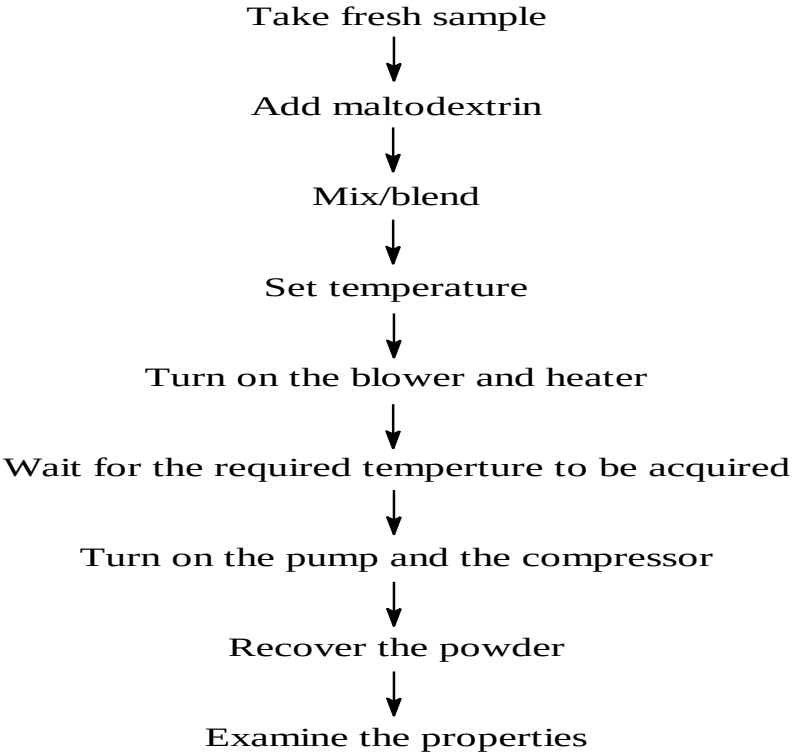

Fig:1 process flow diagram

Maltodextrin and milk mixture was prepared as earlier in the Spray Drying process. After the mixture is prepared, it is kept in a water bath to make the mixture approach the room temperature.

Physical Properties

1. Moisture
2. Size of the Particle

3. Density in Bulk Amount (Bulk Density)
4. Tapping Density
5. Carr's Index
6. Hausner's Ratio
7. Flow-ability
8. Cohesion
9. PFSD (Powder Flow Speed Dependency)
10. Dissolution Time
11. Scanning Electron Microscope (SEM)

Process for Moisture Analyzer

The equipment was turned on, 5.000g of the sample was mounted on the plate of the moisture analyzer. The flap was closed and the operation was started as soon as the START button was pressed. The moisture analyzer was observed to be burning the sample. After a span of 5-10 min, the moisture analyzer displayed the moisture content on the screen (Bourne, 2017).

Principle of Particle Size Analyzer

Size of particle analyzer is very important equipment that works on phenomena of vacuum suction and beam operation. An amount of the sample is put into the analyzer; it is later on sucked in for the beam ray operation (Elfversson & Sjögren, 2020).

For Bulk Density, a measuring cylinder was taken and weighed empty first. Then filled to the level of 120ml and weighed again. The powder weight was found out by;

Powder Weight = Total Weight – Empty Cylinder Weight

The cylinder was tapped gently up to 5-6 time to settle the particles of the powder down and to level the surface of the powder. After this, the Height and the Area were found out. Formula for area used,

$\text{Area} = \pi d^2/4$

Multiplying the area and height, the volume was obtained and then the (Density= mass/volume) formula was used. The mass of the powder was already found out so the formula was just used.

Finding bulk density is also a part for finding the flow-ability this plays an important role in the finding the flow-ability conditions of the powder (Wang, Dufour, & Zhou, 2015).

Process for tapped density

Same type of measuring cylinder as in Bulk Density was used in the experiment. Weighed the empty and then filled cylinder. Determined the powder weight. Instead of tapping it 5 or 6 times, the cylinder was tapped up to 300 times from an approx. height of 14mm. After going through this process, the powder weight was found out again. The weight was noted and the density was determined by using the same formulae as bulk density

The bulk and the tapped density were determined and in order to find out the Carr Index, a formula was used which is given below;

$$\text{Carr Index (CI)} = \frac{Tapped\ density - Bulk\ density}{Tapped\ density}\ x\ 100$$

Hausner Ratio

$$Hausner\ Ratio\ (HR) = \frac{Tapped\ density}{Bulk\ density}$$

Hausner Ratio & Bulk Density, both were in use for determining the flow-ability of the powders. A scale is used by which the flow-ability could be determined. Its tells if the powder has a good flow-ability or poor (Veronica, Goh, Kang, Liew, & Heng, 2018).

Flowability	Carr Index (CI), %	Hausner Ratio (HR)
Excellent	0-10	1.00-1.11
Good	11-15	1.12-1.18
Fair	16-20	1.19-1.25
Passable	21-25	1.26-1.34
Poor	26-31	1.35-1.45
Very poor	32-37	1.46-1.59
Very, very poor	>38	>1.60

Table 2 Specifications for flow ability of the powder

Principle for Flow-Ability

A powder flow analyzer works on the principle of running blades through the sample which maybe granular or powder form. The blades movement senses the inter-particle forces or stickiness between the samples and gives out results in four different terms (Fournaise *et al.*, 2020).

Powder Flow Speed Dependency (PSFD)

Powder Flow Speed Dependency (PFSD). It is the hindrance the powder being pushed at a conditioned flow, i.e., the inter-particle resistance for the flow of the powder. After the tests were carried out, the results and the graphs were saved on excel sheets (Ramavath *et al.*, 2013).

Principle for Dissolution Time

A dissolution tester works on the principle of a moving paddle which moves with a specific speed which is fed into the instrument. Usually, the solvent used is water. The instrument has a water-bath also for maintaining the temperature. Paddle of the tester keeps rotating and mixing until the operator finds out that the solute is completely dissolved in the solvent (Braig, 2019).

Principle of SEM

A checking electron magnifying lens (SEM) is a sort of electron magnifying instrument that produces pictures of an example by filtering it with an engaged light emission. The electrons cooperate with particles in the example, delivering different sign that contain data about the example's surface and creation (Goehner, Huell, & Voigt-Radloff, 2016).

Table 3. Comparison of different parameters of quality from spray dryer and commercial dryer

Material Properties	Spray Dried	Commercial Powder
Moisture Content (%)	3.02	1.765
Bulk Density (kg/m^3)	442.87 ± 2.62	295.5±4.465
Tapped Density (kg/m^3)	598.47 ± 4.62	463.22±7.14
Particle size (μm)	244.22± 27.89	260.33±9.50
True Density (kg/m^3)	1217.7±3.75	1830.9±706.7
Carr's Index	26.00	36.21
Hausner Ratio	1.35	1.57

Results and discussions:

The moisture content of spray dried powder is 3.02 %. The standard values for spray dried milk powder are 3 to 4%. Moisture content is a crucial aspect in food powders as it is associated with increased cohesiveness, due in part to inter-particle liquid bridges. Controlling the moisture content results in increased shelf life of the powdered milk. The percentage of moisture content can be decreased by

increasing inlet temperature. Particle size powders produced have relatively uniform characteristics and are collected from the spray dryer. Spray drying usually provides particles with a mean particle size below 10µm, preferably 5µm. The small sized particles provide good flow ability to the particle. The optimum bulk density for spray-dried milk products is 344 to 475 kg/m^3. The optimum values for tapped density is 344.8-475.7 kg/m^3. Common indicators of powder flow are the angle of repose and bulk properties such as Carr's index and Hausner ratio. They are indirect methods measuring the bulk properties of the powder that are described in the *USP General* Chapter 1174, alongside flow rate through an orifice and shear cell methods. When the compression test is used to gauge the flow behaviour, the grained and cohesive solids exhibit the low unconfined value of yield strength. Shear testing is thus one of the most accurate, dynamic, and distinctive techniques for determining the yield limit or locus of advanced bulk solids and powder in a consolidated condition. The test is static, the vertically loaded bulk solid is subjected to an increasing stress, and the resulting growing force is measured. Measurements are made of the different powder flow behaviour transitions from no-flow to flow. The parameters yield loci, shear stress-strain, and others are obtained (Guo et al., 2016). In order to enhance the flow of powder, different strategies are being created and studied. The true density for spray-dried powder is 500 to 800 Kg/m^3. The values for spray dried particle are 1217 Kg/m^3. The Carr's index value for excellent values is 0-10 values. The values for good spray dried particles are 11 to 15. The values obtained in the sample mixture was 26% and the value for commercial spray dried particle is 36. It means that the quality of spray dried particle is comparatively better. Readings between two powders are presented with the help of graphical approach which shows visual representation of the data

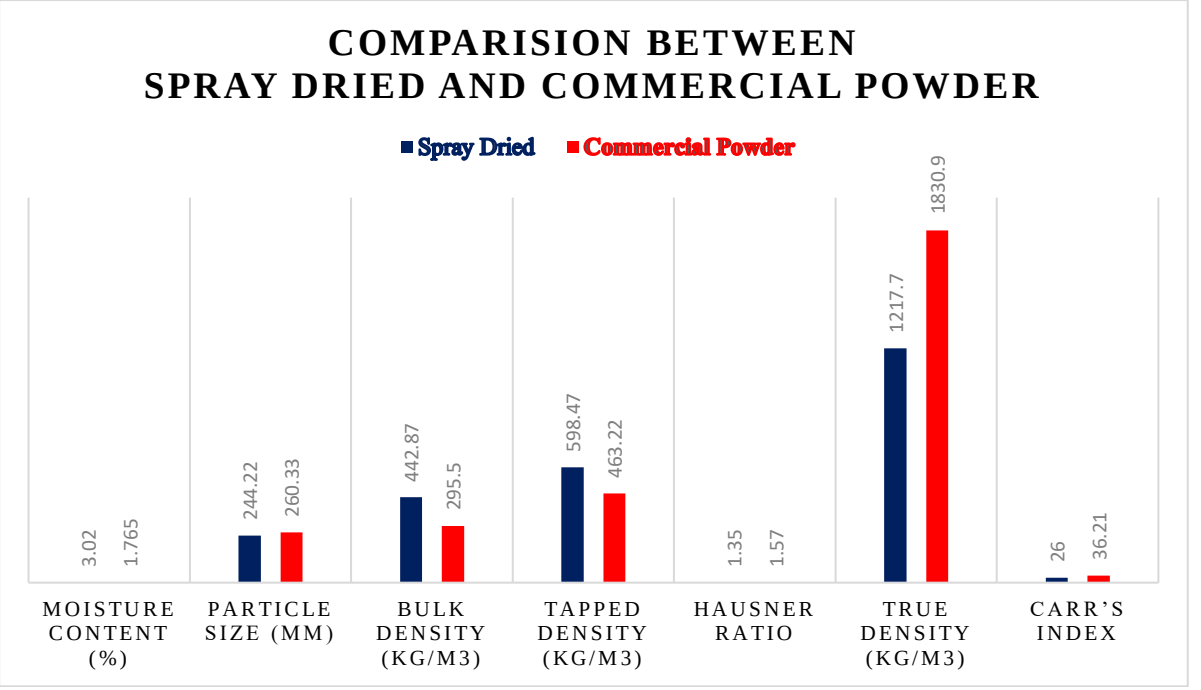

Fig 2: Comparison between spray dried and comercial powder

Conclusion:

The equality of variances (Homoscedasticity) between two powders, spray dried and commercial powder Leven's test has been used. With the help of SPSS (Statistical package for social sciences), We analysis the spray dried and commercial powder. Leven's test shows that p value is 0.682 greater than 0.001 ($p>\alpha$) which means there is homoscedasticity between spray dried and commercial powder. The spray dried powder has the best particle size, quality and flow-ability, if the yield is ignored. The cases where the quality of powder matters, spray drying is suitable (Afshar-Mohajer, 2015). Whilst the cases where there are no quality limitations as in case of sugar production. The commercial powder had some more compounds added to it like 1% Silicon solutions and potato starch that is why it has been giving good results in moisture content. This could help increasing the yield as well, which is actually lowest in the spray drying case.

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