Development of Spray Dried Powder Using Mandarin, Fig, and Grape Pomace

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Abstract - Creation of fruit-based powders presents a novel way to improve the nutritional value of beverages and value agricultural byproducts. The goal of this study is to use spray drying technology to create a powder with grape pomace, fig juice, and mandarin juice as the main constituents. The main purpose was to assess the final powder's physicochemical and functional characteristics and optimize the spray drying parameters especially the inlet temperature and maltodextrin concentration. The study focuses on using fruit juices and byproducts to reduce food waste and encourage sustainability. When developing a new powder made from a combination of fig juice (source of natural sweetness and dietary fibers), grape pomace (a by-product of winemaking which is a source of polyphenols and other bioactive compounds), and mandarin juice (high in vitamin C and antioxidants), several components are wet combined with drying agents such as maltodextrin to load into a spray dryer and formulate for powder stability. An anticaking agent (E-551) is used to calibrate certain processing parameters that affect the finished product such as the feed flow rate, input output temperatures, and different maltodextrin concentrations (7%, 9%, 11%) to produce an effective powder and reduce or avoid processing problems from clumping or burning. This novel approach demonstrates the potential for converted nutrient-dense fruit by-product into shelf-stable value-added powders. The final powder can be used not only with versatility such as flavored milk but as a premix ingredient in smoothies and other beverages. Future research and practical applications in waste valorization and functional food creation are based on the findings of this study.

Keywords: Spray drying, mandarin juice, fig juice, grape pomace, maltodextrin, anticaking agent (E-551)

1. INTRODUCTION

A person would consider food something that is either in a liquid or solid state, where it can be frozen, dehydrated, or sold, and can be enjoyed for the taste and nutritional value it provides. Anything that is consumed to give health benefits is considered a food. It is usually of plant or animal origin, and contains essential nutrients. Liquid used for energy and nutrition are often called 'drinks' (Sowmiya R. *et al*., 2022). The spray drying process is considered as conventional method to convert liquid form to solid (powder) form process of spray-drying consists of three basic steps atomization, droplet hot air contact, moisture evaporation and separation of dry product from the exit air. Spray drying of fruit drinks involves the use of drying agent which reduce the stickiness and clumping problem during the drying operation (Muzaffar *et al*., 2018). Food is traditionally preserved by drying, which eliminates moisture and water activity. Fruit juice powder is made by spray drying, one of the drying techniques (Srivastava *et al.*., 2022). Because of their ease and nutritional advantages mixed fruits are a market favourite and a nutritional powerhouse. They are a popular choice for customers who are concerned about their health, as they are plenty of important nutrients, including vitamins, minerals, dietary fiber and bioactive substances such as antioxidants, carotenoids and polyphenols, demand for mixed fruit (Pathare *et al*., 2013). Mandarins belong to citrus genus, which are appreciated for nutritional value and ease of peeling. Recent research indicated that a high level of bioactive compounds (vitamin C, carotenoids, flavonoids and phenolic acid) can be responsible for their antioxidant, anti-inflammatory and immensely activity (Predrag *et al*., 2017).

Minerals such as calcium, iron and potassium along with dietary fiber are found in large quantities in fig fruit. Its been known since pre-historic days the edible fig is a nutrient-rich powerhouse (Khapre *et al*., 2011). Figs are loaded with vitamin C and fiber, which is healthy for fortifying the immune system. Fig juice also includes natural polyphenols such as flavonoids and proanthocyanidins that are helpful in stabilizing blood pressure (Nursabrina *et al*., 2018). The need in the contemporary food industry is for longer shelf life and product diversity Is highly significant (Zhang *et al*., 2006).

Wine grape pomace is the residual seed and skin from winemaking contains high phenolic compounds and dietary fiber. There are increasing demand in applying fruit processing wastes as functional food ingredients since they are rich source of dietary fibre and most of the beneficial bioactive compounds remained (Tseng *et al*., 2012). It is estimated that on the production of each 100L of white wine, about 30kg of pomace is generated, mainly constituted of grape skins, residual pulp, stalks, and seeds (Beres *et al*., 2019). Grapes is one of the fruits that have been reported to contain high polyphenols especially in its skin and grape pomace is the main derived product of the wine industry and mainly consists of skin, seeds, stems and the remaining pulp (Erinle. *et al*., 2022).

Currently maltodextrin and anticaking agent is the most widely used additive to obtain fruit juice powders. The physical properties of the juice related to ease of reconstitution include moisture content, apparent density, true density and respective particle porosity the instantiation properties (penetration, wetting, dispersibility and solubility), particle size and distribution. These properties are influenced by the nature of the feed (solids content, viscosity and temperature), type of spray dryer, operational speed, pressure air inlet and outlet temperatures (Hall 1997 and King *et al*., 1984). Spray dried powder can be easily reconstituted, have low water activity and are suitable for transportation and storage at room temperature but a major disadvantage of spray drying of fruit juices is the viscosity and flow problems of the powder all these problems occur because of the presence of high content of low molecular weight sugars and organic acids to overcome this type of problem a carrier material like maltodextrin, anticaking agent, gum, starch or gelatine is used as an additive to the feed material during spray drying of juices (Telis *et al*. 2010).

Spray drying is a commonly used technique for microencapsulation of food ingredients. Spray drying process is suitable for heat sensitive food components because of its low temperature andshort production time (Furuta, 2021). Spray drying has been commonly used in food industry to produce fruit juice powders. This process has been extensively used because of its advantages, such as less nutrient, flavour and colour loss due to instantaneous contact with high temperatures; high productivity and effectual control of variables with high energy efficiency, as well as for acquirement of products with different physical properties (shape, size and density) due to different processing conditions. However, its energy efficiency depends on the physical and chemical properties of the material to be dried, the dryer design and the operating conditions (Thakur, 2024). This process needs support to increase efficiency in both performance and encapsulation of a bioactive component (Marques et al., 2014). Spray drying of drink has economical perspective and represents an alternative for improved fruit conservation. The conversion of liquid juice into a dry form potentially increases product stability, resulting in condensed quantity and packaging and easier handling, transportation and storage (Gupta et al., 2020).

2. MATERIAL AND METHOD

Good quality fruits (mandarins & Fig) gathered or purchased from the local market in Pune. and pomace is collected from NRCG (National Research Centre for Grapes).

2.1. Slurry Preparation

The fruit samples were washed, sorted properly and the juice was extracted using a household juicer. The juice was strained in a muslin cloth and then added maltodextrin (DE-12) with an anticaking agent (E-551) for further.

Collection of raw material

⬇

Washing

⬇

Extracted fruit juice from extractor and extract grape pomace by HWE

⬇

Addition of maltodextrin and anticaking agent

⬇

Blending (Maltodextrin) 10 min

⬇

Homogenization (2500 rpm for 15 min)

⬇

Pasteurization (72 ° C for 15sec) (Agcam *et al*., 2018)

⬇

Cooling

⬇

Spray drying (Inlet air temperature is 160 ºC - 170 ºC) (Outlet air temperature is 70ºC - 80ºC)

(Feed rate used 11-13 rpm) (Air pressure used 3 kg/cm^2)

⬇

Powder

⬇

Packing

2.1.1. Grape Pomace Extraction Process

Heating is the result of hot water extraction. In a 1:10–15 ratio, combine the pomace and distilled water. Stirring occasionally, heat the mixture for 10 to 20 minutes at 40 to 50°C. separating the liquid extract from the solid remains with a fine sieve or muslin cloth.

Let the liquid cool (Moutinho et al., 2023).

2.2. 1. Mechanism of Spray Drying

The atomization process: A nozzle or rotary atomizer is employed to convert the liquid supply into small droplets. Atomization enhances the efficiency of mass and heat transfer by increasing the surface area of the liquid. Contact with Hot Air: When hot air comes in contact with the small droplets, evaporation of moisture occurs rapidly. Depending on product requirements the drying air could have a mixed flow, co-current or counter current design. Evaporation: When the droplets evaporate water from them, they become particles. To avoid heat damage, the process is controlled. Particle Separation: For maintaining a uniform particle size distribution and minimal product loss, the dry powder is collected with bag filters or cyclone separators. (Adhikari *et al.,* 2015).

2.2.2. Yield (%) of Spray-dried powder

The powder yield was determined by using the following equation (Sasikumar1*et al*.,2020):

$$Powder\ yeild\ (\%) = \frac{Mass\ of\ powder\ collected}{Total\ Solid\ in\ feed}$$

2.2.2. The Formulation of slurry for spray drying

Table.1 Formulation of slurry

Ingredient	T_1 (%)	T_2 (%)	T_3 (%)	T_4(%)
Mandarin juice	43	43	43	43
Fig Juice	22	22	22	22
Grape Pomace	16	16	16	16
Anticaking agent (E-551)	2 (w/v)	2(w/v)	2(w/v)	2(w/v)
Maltodextrin (DE-12)	11	9	7	5

DE-12 Variation (Takeiti *et al*., 2010)

2.2.3. Parameter for Spray drying

Table 2. Parameter for Spray drying

Parameter	Optimal Range	Parameter
Inlet temp.	160° C - 170° C	Inlet temp.
Outlet temp.	70° C - 80°C	Outlet temp.
Feed Flow Rate	0.4 - 0.5 L/h	Feed Flow Rate
Atomization Pressure	3.0 bar	Atomization Pressure
Drying Air Flow	Sufficient for uniform drying	Drying Air Flow
Carrier Agent (Maltodextrin)	11%	Carrier Agent (Maltodextrin)
Final Moisture Content	3.6% - 5%	Final Moisture Content
Particle Size Distribution	>0.25	Particle Size Distribution

3.1. Physicochemical Properties of the Spray-Dried Powder

3.1.1. Bulk density: A standard volume of measuring cylinder (10ml) was used in the bulk density measurement. The weight of the empty measuring cylinder was taken. The weight of the powder taken inside the measuring cylinder was recorded and the bulk density of the powder was determined by the following formula (Tze *et al.,* 2012):

$$Bulk\ density\ \ (\rho B) = \frac{Powder\ mass}{Volume\ of\ the\ powder}$$

3.1.2. Tap density: After observing the initial volume the cylinder was tapped and volume was recorded until reached to constant volume. The tap density is calculated by the following formula (Tze *et al.,* 2012):

$$Tap\ density\ \ \rho T = \frac{Powder\ mass}{Final\ tapped\ volume}$$

3.1.3. Hausner ratio and Carr index: The Hausner ratio is a number that is correlated to the flowability of a powder or granular material. It is calculated by the formula below (Tze *et al.,* 2012):

$$Hausner\ ratio\ (HR) = \frac{\rho T}{\rho B}$$

where, ρT = tapped density, ρB = bulk density The difference range for HR in defining the flowability is as below (24). (i) 1.0<HR<HR< 1.25 medium flowing powder (iii) 1.25<HR1.4 very difficult flowing powder.

Carr index represents the compressibility of a powder (25). It is calculated by the following formula:

$$Carr\ index\ (CI) = 100 \times \frac{\rho T - \rho B}{\rho T}$$

where, ρT = tapped density, ρB = bulk density according to Carr (25) an excellent flowability can be expected if the CI is within 5 to 15%. If the value of CI is above 25% it generally indicates poor flowability. (Tze *et al.,* 2012)

3.1.4. Particle size distribution: The particle size of all the powder samples was measured by using a particle size analyzer (Malvern Instruments). Reconstituted powder was placed into the particle size analyzer seive and measured (Tonon *et al*., 2010). The mean particle size of the powder was recorded and reported in micrometers (µm).

3.1.5. Solubility: The solubility was determined according to the (Chau *et al*. 2007) briefly samples were mixed with distilled water (1:10 w/v) stirred for 1 h at room temperature and centrifuged at 1,500 rpm for 10 min. The supernatant was collected dried and weighed.

3.1.6. Hygroscopicity: Hygroscopicity was determined according to the method followed by (Hubinger *et al.,* 2008). Samples of each powder (approximately 1 g) were placed at 25°C in a desiccator containing a saturated NaCl solution (75.29% RH). After one week, samples were weighed and hygroscopicity was expressed as g of adsorbed moisture per 100 g dry solids.

3.1.7. Water Absorption Capacity: Put one gram of the sample and ten ml of distilled water into a centrifuge tube that has already been weighted. After 30 minutes of being at room temperature (30ºC), centrifuge the tubes for 20 minutes at 3000 rpm. Once finished, decant the supernatants. Take the weight of the sediment and calculate the values as follows:

$$WAC = \frac{(weight\ of\ sample\ - weight\ of\ \ sediment)}{initial\ weight\ of\ sample} \times 100$$

3.1.8. Oil absorption capacity: Place 1g of the sample in a centrifuge tube that has been previously weighed. Pour in 10 ml of refined soybean oil.
Using a vortex mixer agitate the slurry for two minutes. After 30 minutes of standing at room temperature, centrifuge it for 25 minutes at 300 rpm. The quantity of oil (in ml) that a gram of flour sample can absorb is known as its oil absorption capacity (mL/g).

$$OAC = \frac{(weight\ of\ sample\ - weight\ of\ \ sediment)}{initial\ weight\ of\ sample} \times 100$$

3.1.9. Colour
The method determines the color of product by comparison with Lovibond glasses of known color characteristics. The color is expressed as the total of the yellow and red slides used to match the color. The powder in a cell of the specified size in the Lovibond Tintometer (Hussain *et al*., 2023).

3.1.10. Water Activity
The water activity of mandarin beverage powder (1 g) was determined by a water activity meter (aw)

3.2. Physico-chemical Analysis (AOAC (1995).
3.2.1. Moisture Content
To obtain a constant weight, the oven-dry method was used to measure the moisture content at 105°C (AOAC, 2003).
5 grams of the material were precisely weighed in a moisture box that had been previously weighed. After 5 hours of oven drying at 105ºC, the sample was moved to desiccators to cool, and 30 minutes later it was weighed once more until a consistent weight was achieved, this process was repeated.

$$Moisture\ (\%) = \frac{(Initial\ weight - weight\ of\ dry\ matter)}{Initial\ weight} \times 100$$

3.2.2. Estimation of Ash
The weighed samples 5.0g were taken in crucibles burnt on a hot plate and then placed in a muffle furnace at 600°C for 4 hours to obtain a light grey ash and the percent ash content was calculated by:

$$Ash\ (\%) = \frac{weight\ of\ ash}{weight\ of\ sample} \times 100$$

3.2.3. Estimation of Fat
Reagent - Petroleum ether (B.P. 60-80oC)
Procedure: Weighed samples of 5.0g each in triplicate were extracted with petroleum ether in the Soxhlet extraction apparatus for 18 hours. The ether extract was filtered through a sintered funnel in a pre-weighed beaker and was washed with a small volume of petroleum ether 2-3 times. The petroleum ether was completely evaporated in water bath and the beakers were weighed.

$$Fat\ (\%) = \frac{weight\ of\ residue}{Initial\ weight\ of\ sample} \times 100$$

3.2.4. Estimation of Protein
Protein estimation was done by Kjeldahl method which comprised three phases: Digestion, Distillation and titration
1. Digestion- 2-gram sample is accurately weighed in kjeldahl digestion flask. 15g $Na2SO4/K2SO4$ + 1g $CuSO4$ were added to the sample as a digestion mixture. Then 25ml conc. $H2SO4$ was added to it. The contents were vigorously boiled until the solution was clear. Heating was continued for 2-3 hours.

2. Distillation The flask was cooled, and 250ml distilled water was added to it. A few zinc granules and 100 ml NaOH were added to it. The distillation assembly was connected. The condenser was immersed well below 1cm in the collecting flask to avoid loss of ammonia (collect 200ml). The excess of acid was titrated with 0.1N NaOH. Blank was carried out. Amount of Nitrogen and Proteins was calculated by the conversion factor.

$$\text{Nitrogen \%)} = \frac{(ml\ hcl\ in\ sample) - (ml\ hcl\ in\ blank) \times normality\ of\ acid\ \times 14.01 \times 100}{initial\ weight\ of\ sample} \times 100$$

3.2.5. Total carbohydrates (NIN, 1983)
The content of the percent available carbohydrates was determined by difference of subtracting from 100. the sum of percent values of moisture, crude protein, crude fat, crude ash and crude fibre. The values were expressed as total carbohydrates (%) in the samples.
Total carbohydrates (%) = 100 - (moisture %+ protein %+ fat % + fibre % + ash %)

3.2.6. Minerals
The mineral composition of cinnamon was analyzed using atomic absorption spectrometry, flame photometry, and spectrophotometry based on the AOAC methods (2003).

3.2.7. TPC

Phenols are reacted with an oxidizing agent phosphomolybdate in the Folin-Ciocalteu reagent under alkaline conditions and result in the formation of blue coloured complex. The molybdenum blue which is measured at 650nm calorimetrically (Bray and Thorpe, 1954)

3.2.8. DPPH radical scavenging activity

The method given by (Mahloko *et al*, 2019) was applied for determining the 1,1-diphenyl-2-picrylhydrazyl (DPPH) scavenging activity of the flours. 0.1mM DPPH solution in methanol was used for this experiment that contained 3.943mg of DPPH in 100ml methanol.

0.2ml extract was mixed with 3.8ml DPPH solution and this solution was incubated in dark for 30 minutes. After 30 minutes absorbance of the solutions was checked at 517nm at room temperature. Control solution was prepared by using 0.2ml of 80% methanol and 3.8ml of DPPH solution. %DDPH radical scavenging activity was determined according to the formula:

$$\% \text{ DPPH} = \frac{Abs\ control - Abs\ Sample}{Abs\ Control} X\ 100$$

Table.3. Physico-chemical analysis of developed powder

No.	Parameter	Value
1	Fat (%)	2.1±0.21 g
2	Protein (%)	4.3±0.21 g
3	Carbohydrates (%)	73.7±0.02g
4	Fiber (%)	13.2±0.23 g
5	Moisture (%)	3.98±0.36%
6	Ash (%)	2.8±0.90 g
7	Potassium (mg/100g)	235±0.03 mg
8	Calcium (mg/100g)	320±0.45 mg
9	Vitamin C (mg/100g)	39±0.78 mg
10	TPC (GAE/100g)	467.35±0.21mg GAE/100 g
11	DPPH (%)	57.22±1.21 Inhibition

Values are mean ± standard deviation (n = 3)

Table 4: Physical and Functional Properties of Developed Powder

No.	Parametersre	Spray dried powder
1	Color values	0.1R + 0.2Y + 1Y + 0.1W
2	Yield of powder (%)	22.27±3.64
3	Hausner ratio (cohesiveness)	1.23±0.32
4	Bulk density (g/ml)	0.71±0.43
5	Tapped density (g/ml)	0.89±0.98
6	Particle size (μm)	40
7	Water activity	0.39±0.02
8	Hygroscopicity (g/100g dry solid)	8.50±0.31
9	Flowability (%) (Carr index)	20.11±0.12
10	Dispersibility (%)	88±1.78
11	Wettability (sec)	130±3.00
12	Solubility (%)	83.22±1.32
13	Sinkability	150±1.87
14	Oil absorption capacity (OAC) (g/ltr)	0.58±0.72
15	Water absorption capacity WAC (g/ltr)	0.85±0.32
16	Foaming capacity (ml)	10±1.21

Values are mean ± standard deviation (n = 3)

Table 5. Experimental Design Set with Their Yield

Experimental Run	Temperature (°C)	Maltodextrin conc. (%)	Flow rate (ml/h)	Yield (%)
1	160	11	400	22.27
2	160	9	400	19.75
3	160	7	400	18.90
4	170	11	400	21.85
5	160	5	400	18.61
6	170	9	400	18.01
7	150	11	400	15.51

3.3. Comparative Study on Value-Added Products Using Developed Powders

Fruit powders are becoming essential ingredients in the creation of innovative food products due to their high nutritional value, extended shelf life, and functional versatility. This study evaluates the applications of mandarin, fig, and grape pomace powders in developing health-focused and value-added products. Each of these powders brings unique properties: mandarin powder is a rich source of vitamin C and antioxidants, fig powder provides dietary fiber and minerals, and grape pomace powder is packed with polyphenols and other bioactive compounds. The potential uses of these powders span multiple product categories, including functional beverages, baked goods, snacks, and health supplements. Mandarin powder can enhance beverages and formulations aimed at boosting immunity. Fig powder, with its high fiber content, is ideal for baked products like energy bars or digestive biscuits. Grape pomace powder, known for its antioxidant properties, can be incorporated into smoothies, chocolates, or nutraceutical blends. This study emphasizes the importance of utilizing these fruit powders to address growing consumer demand for health-conscious and sustainable food solutions. By leveraging the distinct properties of each powder, manufacturers can create diverse and appealing products tailored to specific market needs. (Kamble *et al.,* 2012)

3.4. Reconstitution and Analysis of flavour milk incorporated with spray dried drink powder and compared with distilled water

3.4.1. Preparation of Flavour Milk

Milk was taken standardized to 3.3% fat and 5% SNF pasteurized milk. Milk was concentrated in an open pan at 40 °C boiling temperature with continuous stirring or (at 40 °C on a magnetic stirrer) till the final distribution or consistency is reached. The final powder (Product) was added at various concentrations of 5%, 7%, and 9%. And continuous stirring till the desired consistency of reconstitution in milk. This mixture was then allowed to cool at 8- 9 °C and then served.

Treatments details

T_0 (Control) = 0% powder + 100% milk

T_1 = 5% powder + 95% milk

T_2 = 7% powder + 93% milk

T_3 = 9% powder + 91% milk

Table 6. Reconstitution and Analysis of Flavored Milk and Distilled Water

No.	Parameter	Medium	Result
1.	Reconstitution Time (Magnetic Stirrer)	Milk	55 seconds
		Distilled Water	30 seconds
2.	Wettability	Milk	1 min
		Distilled Water	40 sec
3.	Sinkability	Milk	22 min
		Distilled Water	14 min
4.	Dispersibility	Milk	89% dispersion
		Distilled Water	92% dispersion
5.	Sedimentation Rate	Milk	6% sedimentation
		Distilled Water	2% sedimentation
7.	Foaming Capacity	Milk	8 ml foam
		Distilled Water	3 ml foam
8.	Density of Reconstituted Liquid	Milk	1.15 g/ml
		Distilled Water	1.02 g/ml

3.4.2. Analysis of Flavor Milk by adding mandarin, fig and grape pomace spray dried powder

3.4.2.1. Sensory attributes

The mean of sensory score for color and appearance of flavour milk from 7.0 to 8.5, flavor from 8 to 9, taste from 7 to 9, consistency from 8 to 9, mouthfeel from 7 to 9 and overall acceptability from 7 to 9. It is evident from the data presented in Table 4.3.1. and fig. 4.20 that most of the samples prepared are significantly different from the control sample. The overall acceptability score from the panelist and semi-panelists is shown in Table 15. This optimized flavour milk was finally used for further analysis in the study. This shows that drink spray dried powder incorporation improved the sensory properties of the flavor milk samples up to 9 % level, but further increase led to the sedimentation and effect on consistency and reduction of sensory score. These results are in similarly with banker et al., 2013 and khapre et al., 2015, who studied the preparation of pineapple juice and fig fruit powder, respectively.

3.4.2.2. Mean sensory score for flavored milk prepared at different levels for developing spray dried powder

Table: 07 Sensory Analysis

Level of incorporation (%)	Color and appearance	Flavor	Taste	Consistency	Mouthfeel	Overall acceptability
0	7.50	7	7.5	9	8	8
5	7	7.5	7	7	7.5	7.5
7	8.5	8.5	8	8	9	8.5
9	8.5	8.5	8.5	8	8.5	8

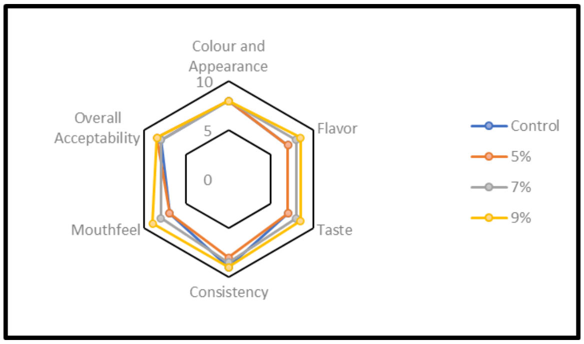

Fig: 12 (Radar Chart) Sensor Analysis representation

The radar chart represents the sensory evaluation of reconstituted powder at different concentrations (5%, 7% and 9%) compared to a control. It assesses key sensory attributes including color and appearance, flavor, taste, consistency, mouthfeel, and overall acceptability. Among the tested samples, the 7% concentration achieved the highest scores across all parameters. It excelled in color and appearance indicating a more visually appealing product. The flavor and tastes of the 7% concentration were also highly rated, reflecting a richer and more balanced profile. In terms of texture, it contributes to a better sensory experience. Consequently, the 7% concentration also garnered the highest overall acceptability score, demonstrating its superior combination of sensory attributes compared to the control and lower concentrations (5% and 7%). This evaluation highlights the preference for a 7% powder concentration as the optimal formulation for reconstitution

4. RESULTS AND DISCUSSION

The study optimized the spray-drying process to produce a stable powder using mandarin, fig, and grape pomace as core ingredients. The formulations tested included varying levels of maltodextrin (5%, 7%, 9% and 11%) under a constant inlet temperature range of 160–170°C. This temperature range was specifically selected to maintain the integrity of the ingredients, ensuring effective drying while avoiding issues such as slurry loss or burning.

Maltodextrin was a critical component in stabilizing the powder. Optimization of spray-drying technology to obtain stable powder consisting of mandarin, fig and grape pomace has been one of the most important technological breakthroughs in functional food preparation. This study investigated formulations with different maltodextrin concentrations (5%, 7%, 9% and 11%) while operating in the inlet temperature range of 160–170°C. Selecting a suitable thermal range made it possible to retain nutritional integrity without having the problem of slurry loss or degradation of the ingredients.

Maltodextrin contributed significantly to drying efficiency and the physicochemical properties of the resulting powder. The high concentrations of maltodextrin significantly reduced the flowability, decreased hygroscopicity and the overall stability. The 11% maltodextrin formulation (T1) resulted in good performance in terms of optimal solubility, maximum moisture retention and desirable water activity, at the same time it had high antioxidant activity as validated by DPPH inhibition and 467. 35 mg GAE/100g Total Phenolic Content (TPC), as well as excellent powder recovery rate. We found that formulations with a low maltodextrin content - 5% and 7% - caused problems such as clumping and reduced reconstitution properties, which demonstrate the importance of adequate maltodextrin content for the production of a functional and shelf-stable product. Addition of a 2% anti-caking agent (E-551,) along with improvements in the powder's flow characteristics, ability to reduce aggregation, and overall quality of the formulation, met FDA requirements also played a significant role.

Reconstitution trials showed the powder's utility as when reconstituted in milk it constituted a taste-enhanced flavor beverage with attractive sensory characteristics. Comparisons with reconstitution in distilled water revealed that while both mediums maintained the powder's solubility and functional attributes, milk provided an added advantage in terms of flavor enhancement and consumer acceptability. These findings position the powder as a promising ingredient for flavored milk products, smoothies, and fruit juice applications at a blending ratio of 5% to 9%. The optimized formulation (11% maltodextrin and 2% anti-caking agent) achieved a shelf-stable powder with a high-quality yield of 19.32%. This study underscores the critical role of maltodextrin levels and consistent spray-drying parameters in developing functional powders with robust stability and reconstitution properties. The recommended temperature range (160–170°C) effectively balanced ingredient preservation and drying efficiency.

In conclusion, the spray-dried powder developed from mandarin, fig, and grape pomace offers a versatile and nutritious solution for various applications. The study recommends its use in milk as a flavored beverage for enhanced taste and functional benefits, alongside its potential in water-based reconstitution. Future research may explore the incorporation of bioactive compounds or natural additives to further augment the nutritional and functional value of the product.

REFERENCE

[1] Azhar, M. D., Abd Hashib, S., Ibrahim, U. K., & Abd Rahman, N. (2021). Development of carrier material for food applications in spray drying technology: An overview. *Materials today: proceedings*, *47*, 1371-1375.

[2] Patil, V., Chauhan, A. K., & Singh, R. P. (2014). Optimization of the spray-drying process for developing guava powder using response surface methodology. *Powder Technology*, *253*, 230-236.

[3] Srivastava, S., Bansal, M., Jain, D., & Srivastava, Y. (2022). Encapsulation for efficient spray drying of fruit juices with bioactive retention. Journal of Food Measurement and Characterization, 16(5), 3792-3814.

[4] Sowmya, C., Reddy, S., Haranath, C., & Madhukar, B. (2012). Formulation and Optimization of Immediate Release Tablet of An Anti Hypertensive Drug by Dry Granulation Method. International Journal of Pharmacy and Industrial Research Vol-02 Issue-03 Jul–Sep 2012, 267, 274.

[5] Saikia, S., Mahnot, N. K., & Mahanta, C. L. (2015). Effect of spray drying of four fruit juices on physicochemical, phytochemical and antioxidant properties. *Journal of food processing and preservation*, *39*(6), 1656-1664.

[6] Fang, Y., Selomulya, C., & Chen, X. D. (2007). On measurement of food powder reconstitution properties. *Drying technology*, *26*(1), 3-14.

[7] G.R. Chegini and B. Ghobadian, "Spray dryer parameters for fruit juice drying,"World J. Agric. Sci. 2007.3(2), pp. 230-236

[8] Chhikara, N., Kour, R., Jaglan, S., Gupta, P., Gat, Y., & Panghal, A. (2018). Citrus medica: nutritional, phytochemical composition and health benefits–a review. Food & function, 9(4), 1978-1992.

[9] Predrag, P., Barba, F. J., Lorenzo, J. M., Gabrić, D., Shpigelman, A., Cravotto, G., & Bursać Kovačević, D. (2017). An integrated approach to mandarin processing: Food safety and nutritional quality, consumer preference, and nutrient bioaccessibility. Comprehensive Reviews in Food Science and Food Safety, 16(6), 1345-1358.

[10] Costabile, G., Vitale, M., Luongo, D., Naviglio, D., Vetrani, C., Ciciola, P., ... & Giacco, R. (2019). Grape pomace polyphenols improve insulin response to a standard meal in healthy individuals: A pilot study. Clinical nutrition, 38(6), 2727-2734.

[11] Dinkarrao, B. V., & Kumar, P. (2016). Optimization of spray drying conditions for production of quality pomegranate juice powder. *Cogent food & agriculture*, *2*(1), 1127583.

[12] Pathare, P. B., Opara, U. L., & Al-Said, F. A. J. (2013). "Colour measurement and analysis in fresh and processed foods: A review." *Food and Bioprocess Technology*, 6(1), 36–60.

[13] Phisut, N. (2012). Spray drying technique of fruit juice powder: some factors influencing the properties of product. *International food research journal*, *19*(4), 1297.

[14] Beres, C., Freitas, S. P., de Oliveira Godoy, R. L., de Oliveira, D. C. R., Deliza, R., Iacomini, M., ... & Cabral, L. M. C. (2019). Antioxidant dietary fibre from grape pomace flour or extract: Does it make any difference on the nutritional and functional value?. Journal of functional foods, 56, 276-285.

[15] Celikli, F. B. (2022). *The Genetic Basis of Fruit Characteristics and Fruit Quality Traits in*

Mandarin Hybrids. University of California, Riverside.

[16] Lopes, J. D. C., Madureira, J., Margaça, F. M., & Cabo Verde, S. (2025). Grape Pomace: A Review of Its Bioactive Phenolic Compounds, Health Benefits, and Applications. *Molecules*, *30*(2), 362.

[17] Khapre, K. M., Sundararajan, S., Alfaro, L., & Sathivel, S. (2011). Development of cantaloupe (Cucumis melo) juice powders using spray drying technology. LWT-Food Science and Technology, 46(1), 287-293.

[18] Wijewardana, R. M. N. A., Nawarathne, S. B., & Wickramasinghe, I. (2016). Effect of various dehydration methods on proximate composition and retention of antioxidants in different fruit powders.

[19] Nursabrina, A. M., Muhamad-Ali, H. A. M., Nur-Amalina, N., Wan-Ladiana, W. A., Hasimah, H., CW, S., ... & Basripuzi, N. H. (2024). Relationship between parasitism with milk yield and body weight of Mafriwal cattle: https://doi. org/10.12982/VIS. 2024.012. Veterinary Integrative Sciences, 22(1), 141-159.

[20] Moutinho, J., Gouvinhas, I., Domínguez-Perles, R., & Barros, A. (2023). Optimization of the extraction methodology of grape pomace polyphenols for food applications. *Molecules*, *28*(9), 3885.

[21] Takeiti, C. Y., Kieckbusch, T. G., & Collares-Queiroz, F. P. (2010). Morphological and physicochemical characterization of commercial maltodextrins with different degrees of dextrose-equivalent. *International Journal of Food Properties*, *13*(2), 411-425.

[22] Adams, J. B., & Hooper, D. C. (1975). The use of the tintometer for determining the colour of food products. *Journal of Food Science and Technology, 12*(3), 145–150.

[23] Kamble, S. K., & Jayaraman, K. S. (2012). Spray drying of fruit juices and influence of carrier materials on product color. *Journal of Food Science and Technology, 41*(3), 232–237.

[24] Mishra, P., Mishra, S., & Mahanta, C. L. (2014). Effect of maltodextrin concentration and inlet temperature during spray drying on physicochemical and antioxidant properties of amla (Emblica officinalis) juice powder. Food and bioproducts processing, 92(3), 252-258.

[25] Sasikumar, R., Das, M., & Deka, S. C. (2020). Process optimization for the production of blood fruit powder by spray drying technique and its quality evaluation. *Journal of Food Science and Technology*, *57*(6), 2269-2282.

[26] Marques, J., R., & Barros, A. (2023). Optimization of the extraction methodology of grape pomace polyphenols for food applications. *Molecules*, *28*(8), 3872.

[27] Sakr, F. M., Gado, A. M., Mohammed, H. R., & Adam, A. N. I. (2013). Preparation and evaluation of a multimodal minoxidil microemulsion versus minoxidil alone in the treatment of androgenic alopecia of mixed etiology: a pilot study. Drug design, development and therapy, 413-423.

[28] Muzaffar, K., Dinkarrao, B. V., & Kumar, P. (2016). Optimization of spray drying conditions for production of quality pomegranate juice powder. Cogent food & agriculture, 2(1), 1127583.

[29] Gülcü, M., Uslu, N., Özcan, M. M., Gökmen, F., Özcan, M. M., Banjanin, T., ... & Lemiasheuski, V. (2019). The investigation of bioactive compounds of wine, grape juice and boiled grape juice wastes. Journal of Food Processing and Preservation, 43(1), e13850.

[30] Gharsallaoui A, Roudaut G, Chambin O, Voilley A and Saurel R (2007) Applications of spray drying in microencapsulation of food ingredients: an overview. Food Res. Intl. 40, 1107–1121.

[31] R. P. Patel, M. P. Patel and A. M. Suthar, Spray drying technology: an overview, (2019) : 02 : 44-47.

[32] King, N., & Adhikari, B. (1984). Effects of maltodextrin concentration and feed viscosity on spray-dried fruit juice powder properties. International Food Research Journal, 19(4), 1297–1306.

[33] Agcam, E., Akyıldız, A., & Dündar, B. (2018). Thermal pasteurization and microbial inactivation of fruit juices. In *Fruit juices* (pp. 309-339). Academic Press.

[34] Tseng, A., & Zhao, Y. (2013). Wine grape pomace as antioxidant dietary fibre for enhancing nutritional value and improving storability of yogurt and salad dressing. Food chemistry, 138(1), 356-365.

[35] Zhang, Y., Selomulya, C., & Chen, X. D. (2007). On measurement of food powder reconstitution properties. Drying technology, 26(1), 3-14.
[36] Karastergiou, A., Gancel, A.-L., Jourdes, M., & Teissedre, P.-L. (2024). Valorization of grape pomace: A review of phenolic composition, bioactivity, and therapeutic potential. Antioxidants, 13(9), 1131.
[37] Erinle, T. J., Oladokun, S., MacIsaac, J., Rathgeber, B., & Adewole, D. (2022). Dietary grape pomace: Effects on growth performance, intestinal health, blood parameters, and breast muscle myopathies of broiler chickens. Poultry Science, 101(1), 101519.
[38] Telis-Romero, J., & Pinheiro, A. C. (2011). Effect of carrier agent type and concentration on the physicochemical properties of spray-dried apple juice powder. Journal of Food Engineering, 106(3), 316–324.
[39] Furuta, T., & Neoh, T. L. (2021). Microencapsulation of food bioactive components by spray drying: A review. Drying Technology, 39(12), 1800–1831.
[40] Thakur, C., & Kaushal, M. (2024). Spray drying technique of fruit juice powder: Some factors influencing the properties of the product. Food and Bioprocess Technology, 18(2), 1181–1220
[41] Moutinho, J., Gouvinhas, I., Domínguez-Perles, R., & Barros, A. (2023). Optimization of the extraction methodology of grape pomace polyphenols for food applications. Molecules, 28(9), 3885.
[42] Tze, N. L., Han, C. P., Yusof, Y. A., Ling, C. N., Talib, R. A., Taip, F. S., & Aziz, M. G. (2012). Physicochemical and nutritional properties of spray-dried pitaya fruit powder as natural colorant. Food Science and Biotechnology, 21, 675-682.