The Influence of Carriers During the Drying of Honey with a Spray Dryer

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Abstract. The aim of this study explores the impact of different carrier agents, including Maltodextrin, Dextrin, Gum Arabic, and N-Zorbit, on the spray drying process of honey. The drying was conducted under controlled conditions with an inlet temperature of 215°C, an outlet temperature of 95°C, a disc atomizer rotational speed of 22,000 rpm, and a feed rate of 2.8 mL/s. Honey solutions (50% and 60%) were combined with varying concentrations of carrier agents (10–25% MD, 30–40% GA, 10% DX, and 10% NZ) before being subjected to drying. The obtained powders were analyzed for their structural integrity, flow characteristics, and sugars composition. Results indicated that Gum Arabic provided the highest powder recovery, whereas Maltodextrin, Dextrin, and N-Zorbit enhanced flow performance but exhibited increased adhesion to the drying chamber. Additionally, processing conditions played a key role in defining the final product properties, highlighting the importance of optimizing formulation and drying parameters for improved efficiency and stability.

1 Introduction

Spray drying is a common unit operation to convert liquid materials into powders for preservation, ease of storage, transport, handling, and other economic considerations. Besides the food industries, spray drying is used by many other industrial sectors such as pharmaceutical, agrochemical, light and heavy chemicals, detergent, pigment, biotechnology, ceramics, etc.[1]

Spray drying of sugar-rich foods such as honey and some drying carriers (Dextrin/Maltodextrin, gum Arabic) is difficult, mainly due to the basic physical characteristics of the low molecular weight sugars present in such products.

Spray drying is a fast process that produces a dry product in an amorphous (glassy) form. When in a glassy state these sugars are thermoplastic (~00s') and very hygroscopic. As a result, during drying, they tend to stick on the inside walls of the drier.[2]

However, in most cases, the following three approaches have been used:

1. Addition of a large amount of drying additives
2. Scraping of the surface of the drier (batch drying)
3. Very low-temperature drying (Birs process). [1]

In a practical sense, the amount of drying aids necessary for successful drying depends upon three major factors: The composition of the product, the temperature of drying, and the properties of the drying aids.[3]

Honey powder is an attractive substitute for liquid honey, whose application in food and pharmaceutical industry is limited due to high density and viscosity. Despite advancements, the production of powdered honey continues to pose challenges for both the industry and researchers. These challenges stem from the unique chemical composition of honey, particularly its elevated levels of sugars and organic acids. The process of creating honey powder necessitates the selection of optimal carriers, drying aids, and/or enriching components, as well as the implementation of suitable drying methods and parameters. Furthermore, specific pretreatment techniques may be utilized before the drying phase.[4]

Honey powder, which is characterized by its long shelf life, is an important alternative to liquid honey. In the literature, it is reported that powdered honey is used as a food additive in turkey meat, bread, cake, cookie, and some beverages.[5] The addition of honey powder improved dough rheology and textural properties in bread.[6] made cookies replacing sugar with honey powder, increasing the mineral content and total phenolic compounds.[7] Used honey powder in grilled meat, slowing down the microbial growth of

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enterobacteria and increasing the shelf life of the product.[8] Honey in this powder form is easier to handle and more easily dispersed evenly with other ingredients. It is expected to be one of the solutions to the problem of raw honey products.[9]

In drying honey into powder, adding fillers aims to prevent heat damage, coat flavor components, and increase volume and total solids. This addition is also to avoid the formation of sticky lumps.[10] Arabic gum and maltodextrin are commonly used for making honey powder. Arabic gum's Tg is approximately 126 to 194.5°C.[11]

However, an excessive amount of gum arabic (beyond 30%) can lead to increased viscosity, which may subsequently affect the hardness of the food products incorporating it.[12] Maltodextrin is a starch-based carbohydrate that exhibits excellent encapsulation properties due to its ability to form stable emulsions and its low viscosity combined with high solubility. It serves as a filler material and protective barrier, helping to preserve the activity of enzymes throughout the drying process.[13] In addition, the advantages of maltodextrin are that it can form colloids when heated and have the ability as an adhesive, and is not toxic. However, it has the disadvantage that its properties as an emulsifier could be better.[14]

N-zorbit plating agent allows to transform a broad array of oil-and water-soluble liquids–including thick honey and chocolate syrups into cost effective powders that not only flow freely through processing equipment but also mix evenly into food and beverage formulations.[15]. These materials (Md, GA, DX) are defined by their low glass transition temperature (Tg). At this temperature, the state of the components shifts from a rigid, brittle "glass" with a very high viscosity (around 10^2 Pa·s) to a flexible, viscoelastic "rubbery" state with a viscosity between approximately 10^6 and 10^8 Pa·s.[16] The temperature at which this phase transition occurs is distinct for each substance and generally exhibits an upward trend with increasing molecular weight within the same class of compounds. In the case of honey, the elevated concentrations of fructose and glucose play a crucial role, as they are associated with notably low Tg values -10°C for fructose and 36°C for glucose. These low transition temperatures can significantly influence the physical properties and stability of honey during processing and storage.[17]

Honey powder has several disadvantages: During the drying process, some of the beneficial enzymes, antioxidants and nutrients found in raw honey can be reduced. Honey powder can be expensive, especially when considering the potential for add carriers.

2 Materials and Methods

Sunflower honey obtained directly from a local bee-keeper (villages of Plovdiv Bulgarian) with a total solid mass concentration of 82.0±0.1% d.b. (water content 17.6±0.1% w/w). Maltodextrin 150 (MD, England) gum Arabic (GA,Saint Aubin, France) Dextrin (Ingredion England), and N-Zorbit (Ingredion Germany) were used as drying agents. An experimental plan for spray drying honey with Maltodextrin, Dextrin, gum Arabic, N-zorbit, and the mixture of drying agents is presented in Table 1.

Due to the large number of samples and the capacity of the spray dryer, the solutions from 6 to 8 liter shave been prepared, with different concentrations of solids. The total concentration of solids in the solutions was 13 - 15% s.c.

The purpose is to increase the percentage of honey. In the first sample, the ratio of honey solids/GA-MD solids was 2:1 (honey 50%, GA 25%,MD 25%). The second ratio (honey content 60 and 40% GA). In the third sample while with the use of GA and MD, the ratio of honey solids/drying agent solids was (honey content 60, 30% Gum Arabic, and 10% Maltodextrin). The fourth sample was (a honey content of 50%, 40% Gum Arabic and 10% Dextrin). The fifth sample was (content honey 60, 30% GA, and 10% N-Zorbit).

2.1 Honey Spray Drying

The drying of the honey was carried out using a spray drying installation produced by the company Anhydro-Denmark. The dryer is the 1m internal diameter, equipped with a rotating atomizing disc using the following process parameters: inlet temperature 215°C, raw material feed rate 2.8ml/s, the disc rotational speed was 22.000 rpm. During drying, the inlet and outlet air (95°C) temperature was controlled and both values remained constant.

2.2 Powder Analysis

2.2.1.Bulk Density

To determinate this parameter, 50g of the sample is poured very carefully (without schocks and shaking) into a measuring cylinder of 250 cm³. With the help of the brush, the surface is smoothed and the volume *(Vn)* is read. For this purpose, two parallel samples are conducted.[18]

2.2.2.Tapped Bulk Density

The density after tapped is determined as the sample placed (50g powder) in the mensur 250ml, started tapped (1-3 min). As a rule, the volume after tapped is reduced.[18]

2.2.3. Cohesiveness

The cohesiveness of the powders was assessed using the Hausner ratio (HR), which is calculated from the loose bulk density (*db*) and tapped density (*dt*) of the powder. The formula used for this calculation is:

$$HR = \frac{dt}{db}$$

2.2.4. Dissolving time

The solubility of the powders was evaluated by adding 2 g of the sample to 50 mL of distilled water at a controlled temperature of 26°C, using a 100 mL low-form glass beaker. The mixture was continuously stirred with a magnetic stirrer operating at 890 rpm, utilizing a stirring bar measuring 4 mm by 10 mm. The total time taken for the powder to dissolve completely was carefully recorded.19]

2.2.5. Hygroscopicity

A sample of the product, weighing between 8 and 10 g, is placed in a Petri dish located in the upper section of a desiccator. The desiccator is maintained at a temperature of 25°C with a relative humidity of 75%, achieved by using a saturated sodium chloride (NaCl) solution placed in the lower part of the desiccator. The volume of the salt solution should be no less than 1l. The tests are measured three times during 2h 30m on the first day. The samples are weighed for 10 days until a equilibrium is reached in the moisture content above the sample and the saturated solution of the corresponding salt in the dessicator at a certain temperature. The measurement accuracy is ±0.1mg.[19]

2.2.6 Moisture content

Duplicate powder samples, each weighing approximately 1 g, were subjected to drying at 105°C for a duration of 4 hours. The weight loss, primarily attributed to water evaporation, was measured before and after the drying process. The percentage change in weight, which corresponds to the amount of moisture lost, was calculated and expressed as a percentage of the initial sample weight.[20]

2.2.7. Sugars in honey

The honey sugar content was analyzed by HPLC, with an ELSD evaporative light scattering detector (Shimadzu Prominence, Japan), according to the International Honey Commission, with some modifications. Honey was diluted at 6.25 mg/mL, using methanol at a concentration of 25 mL/100 mL, and filtered in a MILIPPORE membrane of 0.45μm. The separation of sugar was performed in a Grace Davison Prevail Carbohydrate Es column (5 μm, 250 mm × 4.6 mm), using acetonitrile as mobile phase B and ultrapure water (Direct Q3® system, Millipore, USA) as mobile phase A. The mobile phases were delivered at 1 mL/min in a binary gradient mode: (0.01-15 min: from 75 % to 60 % of B; 15.00-15.01 min: from 60 % to 75% of B; 15.01-20 min: 75% of B). Measurements were carried out at 25 °C, and the sample injection volume was 10 μL. Sugar content quantifications were achieved in triplicate by the standard curve of glucose ($Y=2x10^6x-10^6$, r^2 = 0.9991, retention time: 6.09 min), fructose ($Y=2x10^6$ x-10^6, r^2 = 0.9992, retention time: 6.87 min), and sucrose ($Y= 2x10^6$ x-691932, r^2 = 0.9992, retention time: 7.84 min). The sugar content was expressed as grams of sugars (fructose, glucose, and sucrose) per 100 g of honey. [21]

3 Results and discussion

After drying several samples, only 5 samples were selected for forther analysis, in the 2th sample has been managed to obtain a larger amount of powdered honey in the cyclone (about 400g). In the other samples, has been obtained a small amount of powdered honey, but to take samples for analysis, the walls of the chamber have been wiped.

During drying with Maltodextrin, Dextrin, and N-Zorbit, there was a large amount of stickiness on the chamber walls, the only carrier Gum Arabic was the one that brought more amount of dried honey, but from the physico-chemical analysis of gum arabic, the values were higher, such as: hygroscopicity cohesiveness.

Tab.1 Research Design

Exp	Honey	GA	MD	DX	NZ
1	50%	25%	25%		
2	60	40			
3	60	30	10		
4	50	40		10	
5	60	30			10

The type of drying agent used significantly influenced the bulk density of the powders, with variations observed depending on the agent employed. Different drying agents can affect the packing and structure of the powder particles, leading to changes in the overall bulk density.[22] as typically bulk density increases upon particle size decrease.[19] The Bulk and Tapped density of honey powder was in the range of 0.55-0.65 and 0.63-0.83 g/ml. In experiment 1 where was used 50% honey, 25% gum Arabic, and 25% Maltodextrin, the bulk density values were low, compared to experiment 5 which had higher bulk density values from the experiment they were used; 60% honey, 30% gum arabic and 10% N Zorbit.

The Hausner ratio exhibited a notable dependence on the type of drying agent employed as well as the weight ratio of honey to drying agent in the dried solution. Variations in these factors led to significant changes in the powder's flowability and cohesiveness, as the combination of the drying agent and honey ratio influenced the particle structure and packing behavior.[22] The Hausner ratio (HR) values of the produced powders ranged between 1.35 and 1.50, reflecting the impact of cohesiveness on their consistency and flow properties. The cohesiveness of the powders plays a crucial role in determining their consistency and flow properties. Generally, lower cohesiveness corresponds to better flowability, indicating a more easily manageable powder.[23]

In the 3rd and 5th experiments, there was the lowest percentage of cohesiveness, as it seems the same percentage of gum Arabic of 30% in both experiments, has made the result to be the same. That is, the percentage of cohesiveness is low. In experiments 2 and 5 there were higher percentages of cohensiviness because the percentage of gum Arabic is 60% and 40%.

Honey powder formed amorphous particles completely which made it easier to clump when dissolved in water so that the dissolving time of honey powder is longer. The dissolving times were between 1.25 – 3.90 min. The results showed that honey with the addition of Maltodextrin and N-Zorbit has a better dissolving time than honey with gum Arabic. The addition of Maltodextrin can decrease food powder's time to dissolve [24].

Tabl.2 Physical properties of produced powders

Exp	Outlet air Temp °C	Bulk Density kg/m³	Tapped Density kg/m³	Cohesiveness	Dissolving time S
1	93.3	0.55	0.63	1.42	150
2	90	0.63	0.71	1.46	125
3	91.6	0.61	0.77	1.35	270
4	93.3	0.62	0.66	1.50	225
5	91.6	0.65	0.83	1.35	230

The moisture content of the powders varied between 1.05% and 3.2% (wb), as indicated in Table 3. This range is comparable to the moisture content observed in honey powder spray-dried with Maltodextrin, but significantly lower than that of honey powder spray-dried with Arabic gum. The moisture content was found to be highly significantly influenced by both the inlet and outlet air temperatures. The analysis of the first-order terms using coded variables demonstrated that the moisture content decreased as both the inlet and outlet temperatures were increased. This behavior is characteristic of spray-dried products, where heat and mass transfer play a crucial role in moisture evaporation and overall product quality.[25]

The inlet air temperature was inversely related to the moisture content of the powder, with higher temperatures leading to a reduction in moisture levels. Conversely, higher outlet air temperatures were achieved by lowering the flow rates, which increased the contact time between the feed and the drying air. This extended contact time facilitated more efficient heat transfer, promoting a higher rate of water evaporation. As a result, the moisture content of the powder was further reduced, highlighting the crucial role of air temperature and flow rate in optimizing the drying process.[26]

After the 17-day stay of the samples in the desiccator, hygroscopicity ranged from 21.48 to 28%/8 g. Honey powder, owing to its high sugar content, is highly hygroscopic, which means it has a strong tendency to absorb moisture from the surrounding environment. This characteristic is a result of the presence of soluble sugars, such as glucose and fructose, which attract and retain water molecules, potentially affecting the powder's stability and flow properties when exposed to humid conditions. In the first experiments, with normal hygroscopic values were the powders obtained using 50% Honey with 25% Gum Arabic and 25% Maltodextrin. Powders produced with the addition of gum Arabic and Maltodextrin were recorded in two consecutive groups characterized by significantly higher hygroscopic values. While the powders containing only gum Arabic were in extreme hygroscopicity values.

Tab.3. Chemical properties of produced powders

Exp.	Hygrosco	Moisture %	Total sugar %	Reducing sugar %
1	21.48	1.34	66.5	26.7
2	28	1.90	63.4	55.8
3	27.39	1.28	64.3	61.6
4	23.95	3.2	68	48.9
5		1.05	63.4	59.4

The percentage of the sugars in the tested samples was analysed with HPLC carbohydrates profile. The content sugars of liquid honey is, Reducing sugar 62% and Total sugar 71%. Reducing sugars are sugars that have free aldehyde groups in their chemical structure. The reducing sugar content shows a product's number of simple sugars, such as glucose and fructose.[27] The finding presents that gum arabic reduces sugar content in honey powder compared to Maltodextrin addition.[28]

Tabl 3 gives a detailed report of the results of sugar testing for all honey samples. In the samples where were used a percentage of 30-40% of gum Arabic there was the lowest percentage of total sugar (63.4%) and reducing sugar (26.7%), while when using Maltodextrin and Dextrin, there was a higher content of total sugar (68%) and reducing sugar (61.6%).

4 Conclusion

Spray drying honey using carriers such as Maltodextrin, Dextrin, Gum Arabic, and N-zorbit effectively converts the liquid honey into a stable powder form, enhancing its shelf life and handling properties.

Each carrier influences the physical characteristics of the honey powder differently; for instance, Maltodextrin and Dextrin provides good dissolving and small density, properties of honey powder with both carriers (MD/DX) were within the allowed values. But has a pronounced stickness to the walls of the spray dryer and a small amount of honey powder profit.

Liquid honey processing using the spray drying method produced higher yields of honey powder when gum Arabic was used. Gum Arabic enhances emulsification and encapsulation efficiency. However the properties of honey powder were outside the standards, such as Hygroscopicity.

The biggest expectations were during the use of the new N-Zorbit carrier, which helped achieve fine powder with low moisture content. But there was a lot of sticking to the dryer walls, and the benefit of a small amount of powder.

Honey powder represents a promising area of research with broad applications across multiple industries. As scientists continue to uncover its benefits and optimize its production, honey powder is poised to become a staple in health-conscious and sustainable product development.

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