ISSN (Online): 2305-0225
Issue 14(3), April 2014, pp. 404-408

Comparing the efficiency of protein and maltodextrin on spray drying of honey: physical and functional properties, powder production yield

Khashayar sarabandi, seyed hadi peighambardoust, sajad moradi azad

Abstract— In this study, the efficiency of Sodium caseinate (as a dairy model protein) and Maltodextrin was assessed on spray drying process of honey. The obtained results revealed that no powder will be produced in drying process of honey without using supplements, while using protein in spray drying process (as low as 10%), will increase the efficiency up to 50%. Comparing to that, reaching a similar efficiency will need large amount of Maltodextrin (up to 100% w/w based on dry weight of honey). The mechanism of action of proteins has been proven by other scientists using physical property tests, powder production efficiency and glass transition temperature (Tg). Recent study showed that preferential migration of protein to the surface of droplets/particles, which reduces adhesive behavior (stickiness) between particles and dryer wall by the increase in the surface protein coverage of the particles. The mechanism of Maltodextrin to decrease the stickiness is due to the increase in the overall Tg of the honey powders.

Keywords— honey, maltodextrin, protein, spray drying.

I. INTRODUCTION

Spray drying is a common process in food industries. It involves the transformation of liquid feed through a hot medium (air) in order to produce product in powder form. The spray dried powders have longer shelf life and resemble the quality of the original liquid feed. Masters (1996) estimated that more than 15,000 spray dryers of industrial size are in operation throughout the world and approximately double that number in pilot plants and laboratories [1].

In the pharmaceutical industry, spray drying is a common method used to prepare dry powder aerosols [2]. These dry powder aerosols have advantages compared with solution aerosols due to the chemical stability associated with the powder form [3].

Kh. Sarabandi is MSc graduated Department of Food Science and Technology, college of agriculture university of Tabriz, Tabriz, Iran (corresponding author to provide phone: +98-937-4452690; e-mail: sarabandi_21@yahoo.com).

S. H. Peighambardoust is associated professor, Department of Food Science and Technology, College of Agriculture University of Tabriz, Tabriz, Iran (e-mail: peighambardoust@tabrizu.ac.ir)

S. Moradi Azad MSc student, Department of Food Science and Technology, College of Agriculture University of Tabriz, Tabriz, Iran (e-mail: S.moradiazad@yahoo.com).

Honey contains high proportion of inherent low molecular weight sugars, such as sucrose, glucose and fructose [4], which can cause a stickiness problem during spray drying. The stickiness problem of sugars is mainly because of their low glass transition temperatures (Tg), e.g. the lower the Tg, the higher is the stickiness of the material [5].

For example, the Tg of lactose, maltose, sucrose, glucose and fructose is 101 °C, 87 °C, 62 °C, 31 °C and 16 °C respectively, and their relative degree of stickiness increases accordingly [6], [7].

The quantifiable sticky behavior of an amorphous product is observed at temperatures about 20 °C above Tg and the spray drying outlet temperature is generally between 60 and 100 °C [8], therefore, stickiness is ready to occur if the material contains high proportion of low molecular sugars. The strong hygroscopicity of these components also contributes to the problem [9].

The stickiness state of the particle can cause interparticle cohesion or material adhesion on the dryer surfaces, and results in particles sticking to the wall of the dryer and thermal degradation, and/or the product particles clumping together adversely affecting the free-flowing property [7]. In food and pharmaceutical industries, the stickiness problem causes considerable economic losses every year [10], [11].

Some available approaches to reduce the stickiness problem include process based (such as use of low temperature and low humidity air) and material science based (such as introducing of drying aids) methods [6]. However, these approaches also have limitations in practice. For example, large amounts (often>35%) of drying aid (maltodextrin) are required to convert sugar-rich fruit juices into a powder form [12], [13],

ISSN (Online): 2305-0225
Issue 14(3), April 2014, pp. 404-408

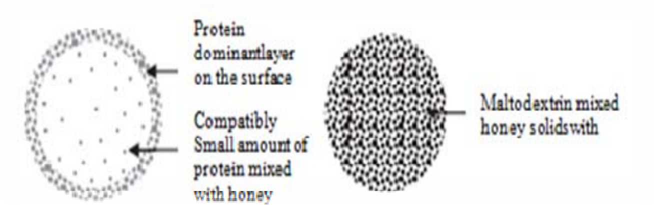

Fig. 1. Illustration of spray dried powder particles with the addition of Protein (left) and maltodextrin (Right).

and 50% maltodextrin was used for spray drying of bayberry juice [14].

Addition of such large amounts of drying aids increases the cost and may alter the original flavor and taste of the product, and risks consumer disapproval. An alternative and novel way to minimize the stickiness problem is to modify the surface properties of the atomized droplets/particles with small amounts of proteins [15], [16].

The surface active property of proteins (preferential migration to air/water interface) with their film forming ability upon drying can overcome the stickiness of sugar/ protein solutions [15]. It is hypothesized that the surface active properties of proteins may also improve the spray drying performance of the sugar rich honey. Different types of proteins have different surface activities, which would result in different powder recoveries [6], [17].

Previous studies have shown that the surface of spray dried protein/ carbohydrate powders to a large extent is covered by protein, even when small protein concentrations are used [15], [18], [19].

The objective of the present work is to compare the stickiness overcoming efficiency of protein and maltodextrin on spray drying of sugar rich honey. Different mechanisms on particle development during the drying process are proposed based on the product recovery and powder characteristics.

II. MATERIAL AND METHOD

A. Solution Preparation

The honey–protein solutions were prepared by heating the solution to 45 ± 5 ˚C and gently agitating with a magnetic stirrer. This range of temperature is well below the denaturation temperature of the proteins used and has no negative effect on the solubility of the samples used. The maltodextrin solid mass ratios to honey were 0.5, 1, 2 and 4 used. NaCas concentrations of 1, 2, 5, 10 and 20% (w/w) Based on dry weight of honey were used. The total solid content of the feed solution was 40% (w/w) in all the cases.

B. Spray Drying Process

Spray-drying of solutions was carried out on a pilot scale spray dryer (maham sanat, neyshabur, iran). A rotary atomizer, that used compressed air as atomizing fluid, was used to atomize the solution into fine droplets. In all experiments, atomizer rotational speed, feed flow rate, feed temperature and atomizer air pressure were kept constant at 16000 rpm, 10 ml/min, 30±1˚c and 4±0.1bar, respectively. The inlet temperature was maintained at 165˚c. The powders were collected from the cyclone and the cylindrical parts of the dryer chamber by lightly sweeping the chamber wall as proposed by [8].

C. Powder Production Yield

The yield was calculated as the ratio of the mass of solids collected after spray-drying to the amount of solids in the feed solutions.

D. Moisture

The moisture content was determined by drying the powder samples in a vacuum oven (Thermoline Scientific, Australia) at 70°C for 24 h using the AOAC method, 927.05 [20]. The samples were removed from the oven, cooled in a desiccator and weighed. The drying and weighing processes were repeated until constant weights were obtained.

E. Water Activity

Water activity (aw) of powder samples was determined using a pre-calibrated water activity metre (Novasina, Switzerland). The temperature was maintained at 25 ± 0.5°C.

F. Solubility

1 g of the powder was carefully added to 100 mL of distilled water under agitation in a Quimis Q-221 magnetic stirrer at 385 g for 5 min. The dispersion was centrifuged at 3000 rpm for 5 min. An aliquot (25 mL) of the supernatant was transferred to a previously weighted Petri dish and vacuum-dried for 3-5 h at 105 ˚C. The final powder weight on the dish was used for determination of the water solubility of the product (g of powder per 100 g of water) [21].

G. Tg Point Measurement

The glass transition temperature (Tg) of all spray dried powders was determined by a Differential Scanning Calorimeter or DSC (a 2010 Modulated DSC, TA Instrument, New Castle, DE, USA). The purge gas used was dry nitrogen (25 mL/min). Indium and zinc (Perkin-Elmer standards) were used for temperature and heat flow calibration. The samples were cooled to desired temperature (−25 ◦C) by fast cooling to reach temperature equilibrium at this temperature. 10 mg of powders were scanned in a hermetically sealed 50 µL DSC aluminum pans (Perkin-Elmer). An empty aluminum pan was

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used as a reference. The tests were conducted −10◦C to 120◦C with a heating rate of 10◦C/min. The transfer of samples from container to DSC pan was done in a sealed "Dry box" containing silica gel with regular N2 flushing, to avoid moisture absorption by the sample.

H. Statistical analysis

One-way analysis of variance (ANOVA) (using SPSS 16.0 statistics software, SPSS Inc., Chicago, IL) was used for the determination of differences between processes. The results were expressed as mean ±standard error (SE) and considered significantly different when ($p<0.05$).

III. RESULT AND DISCUSSIONS

Adhesion of droplets to the walls of the device and long - term remaining of the product in the drying chamber walls in the spray dryer is the main cause of adverse effect on the quality of the product and introducing burnt particles in product [8].

Honey powder production efficiency using 1 to 20% sodium caseinate, increased from 18.63% to 56.18%. In terms of laboratory or pilot scale spray drying process, more than 50% efficiency in powder production represents successful production process.

It was clear that spray drying of honey with protein or maltodextrin resulted in two types of particles (Fig. 1) and has two different particle development mechanisms. The high recovery of honey powder with a small amount of sodium caseinate is mainly due to the surface active properties of protein in solutions. Firstly, the protein preferentially migrates to the air/water to reduce the surface sugar composition of the droplets/particles, which consequently decreases the adhesiveness between the particles and the dryer wall and can easily be carried away from the wall and collected in powder form. Secondly, the migration of protein to the surface of the particles can rapidly form a very thin protein-rich film during spray drying (Fig. 1).

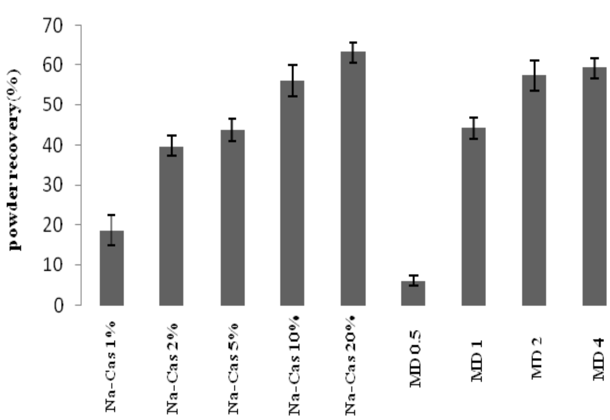

Fig. 1 Recovery of Honey-NaCas and Honey-Maltodexrin powders in spray-drying trials.

This film might have a relatively higher Tg, which can remain in the glassy state to overcome the particle-to-particle and particleto-wall stickiness [15]. However, maltodextrin is not a surface active material in solutions. Because it has a high Tg, it forms a compatible matrix at the molecular level with the solid materials (Fig. 1) to increase the overall Tg of the honey powders, and then, to overcome the stickiness problem during spray drying.

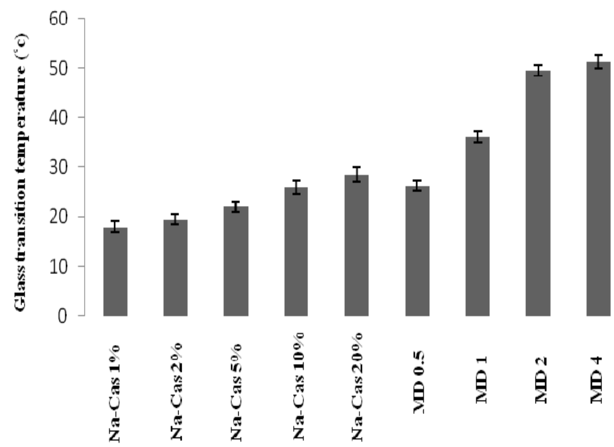

Fig. 2 Effect of protein (Na-Cas) and maltodextrin (DE 18-20) on the glass transition temperature (Tg) of spray dried honey powders (ratios based on dry mass).

Increasing concentration of sodium caseinate is associated with increasing of free and available water for evaporation and will eventually decrease the moisture of powders. Also with increasing of maltodextrin concentration, moisture and water activity of powders increased, which is in agreement with results found by [22].

This is due to the presence of large molecules of maltodextrin which makes the diffusion of water molecules difficult. In their study, high concentration of maltodextrin was used to produce powdered orange juice. Unlike this study, in spray drying of watermelon juice, moisture of produced powders decreases with increasing the amount of maltodextrin [23].

The glass transition temperature of powders was evaluated and adding protein powder did not have a significant effect on increasing of the glass transition temperature, which shows other mechanisms of increasing efficiency and reduction of powder adhesion, especially migration of proteins to surface of particles and the formation of the film and non adherent scaling. This finding agrees with the results of there search of

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Jayasundra and colleagues in 2011 who performed the dry spraying process of sucrose and fructose by using various combinations of sodium caseinate and whey protein isolates and proved that proteins have an effect by migration and formation of surface film [24].

Table 1. Water content (%), water activity, and solubility (%) of spray dried honey powders.

Treatments	Experiments		
Na-Cas concentrations	Moisture content	aw	Solubility
1	1.76±0.31	0.133±0.02	99.3±0.52
2	1.58±0.25	0.126±0.02	98.8±0.28
5	1.41±0.34	0.101±0.01	98.4±0.03
10	1.22±0.28	0.092±0.02	97.2±0.24
20	1.04±0.44	0.87±0.02	96.65±0.19
Maltodextrin to honey ratio (based on dry mass)			
0.5	1.15±0.23	0.074±0.02	99.1±0.44
1	1.24±0.4	0.085±0.02	98.6±0.17
2	1.59±0.48	0.123±0.02	98.4±0.69
4	1.73±0.26	0.138±0.01	97.9±0.38

Solubility of the dried powders with spraying method was also examined. Factors such as size, shape, composition, surface properties, microstructure of the particles and the presence of additives and insoluble compounds can affect the reconstruction of powders [12], [25]. In general, high solubility of the powders is mainly because of the amorphous nature of the produced powders.The solubility of powders were decreased by increasing of protein and maltodextrin concentrations, which is mainly due to the changing of nature and composition of the raw material. In this in a study on the solubility of dried mango powders by spraying method, powder solubility decreased with increasing of maltodextrin concentration [21].

IV. Conclusion

Producing more than 60 percent honey powder by adding sodium caseinate compared with the powder obtained by the use of high amounts of maltodextrin which causes loss of quality, changing of the nature and decrease in consumer's desirability demonstrate the high efficiency and effectiveness of the proteins in spray-drying of adhesive material their use as a dryer aid. According to findings by other researchers and the results of this study, the main mechanism of action of protein activity in increasing the recovery of the powder is by covering the particle surface and reducing the adhesion and preventing particles from sticking to the walls of dryer.

Using small amounts of protein can significantly increase the recovery of powders retrieved from sugar solutions. The main mechanism of maltodextrin action is overcoming the adhesion by increasing the total Tg of the mixture and reducing the adhesion of particles. Increased use of a variety of compounds as dryer aids has caused limitations such as quality decline, reducing the solubility depending on the nature of the material and reducing the usability of the manufactured powder as an additives compound in the industry.

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