Effect of Honey Addition on Flowability and Solubility of Spray Dried Low Fat Milk Powder

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Abstract. Milk and honey in combination can play a vital role in fulfilling the requirement of food product having nutritional as well as functional properties. This becomes more necessary in today's scenario because of increasing people awareness for food functionality and safety. The present study involves the production of spray dried honey enriched at four levels (5, 10, 15 and 20%) milk powder from buffalo, cow and mixed milk samples and investigated their flow and reconstitution properties. Bulk density remains unaffected while in tapped and particle densities significant difference was recorded. The results of flow properties i.e. Angle of repose, Carr index, and Hausner ratio indicated free flowing nature of prepared powder samples. Wettability and Dispersibility values of all three types of powders indicated good reconstitution properties.

Keywords: milk powder, honey, flow properties, wettability, dispersibility.

1. Introduction

Milk, considered almost a complete food, is responsible for numerous nutritional and health benefits. Milk contains various compounds like lysozyme, lactoferrin, immunoglobulins, growth factors, and hormones, which are responsible for its bioavailability [1]. Honey, sweet in taste, natural solution of glucose and fructose, contains proteins, vitamins, minerals, organic acids, enzymes, and phenolic compounds [2], [3]. Besides using as sweetening agent, it also acts as preservative agent due to its antioxidant activity [4], [5]. The antibacterial and antioxidative effect of honey is due to presence of enzymatic (catalase, glucose oxidase, peroxidase) and non enzymatic substances (Organic acids, Maillard reaction products, amino acids, proteins, flavonoids, phenolics, α-tocopherol, flavonols, catechins, ascorbic acid and Carotenoids) [6], [7]. The health-protective and therapeutic impact of honey is increasing day by day in findings of many researchers [8], [9]. Honey and milk combination act as antibiotic, anti-aging and antibacterial agent. It has been reported that combination of milk and honey shows higher antibacterial activity on *Staphylococcus* bacteria than milk or honey taken alone [10].

The flowability of powders always plays a major role in influencing processing, handling, and transport conditions. Various methods like Hall flow, Hausner ratio, and compressibility index had been employed for measurement of flowability of powdered foods but it always remain a challenge for the researchers [11], [12]. A very small change in surface properties like adsorption, electrostatic charge and ambient conditions of humidity and moisture content can lead to big change in flow and reconstitution properties of food powders [13].

Converting the liquid milk into powders increases the shelf life as well as makes the storage, handling and transport easier [14]. Several drying techniques can be used for the production of powders from liquids like drum, freeze and spray drying. Among them spray drying is the simplest and commercially used method for transforming a wide variety of liquid food products into powder form. It is more beneficial to promote the

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honey based milk products in the market due to its high therapeutic value and health benefit effects. Recently a new technology has been developed in which spray dried milk powder was manufactured enriched with honey. Various spray dried conditions were optimized by [15] by use of Response Surface Methodology. Same spray drying conditions were followed for the preparation of our powdered sample. The present study involves the study of various flow and reconstitution properties of prepared honey enriched milk powder.

2. Material and Methods

Multi floral honey obtained directly from a local bee-keeper with a total solid mass concentration of $79.0 \pm 0.1\%$ d.b. (water content $19.6 \pm 0.1\%$ w/w) was used in the study. Taking into account the solids content of honey and different milk samples, 500mL of solutions with the desired total solids concentration were prepared. Spray drying of buffalo, cow, and mixed (50% cow+ 50% buffalo) milk enriched with four levels 5, 10, 15, and 20% of honey was performed. A reference powder sample without addition of honey was also prepared. The values of honey concentration level were selected in a preliminary study. Spray drying process conditions followed to prepare these powder samples were 200°C inlet air temperature, 90°C outlet air temperature, 10 RPM (1 RPM= 100 ml.h^{-1}) feed flow rate. These conditions were optimized by [15] to prepare same kind of milk powder. The prepared powdered samples were analyzed for physical properties, solubility, Wettability, Dispersibility, and cohesion properties.

2.1. Bulk and Tapped Densities

Powder was gently loaded into a 100 ml tared graduated cylinder to the 100 ml mark and weighed. The volume read directly from the cylinder was then used to calculate the bulk density (ρ_{bulk}) according to the relationship: mass/volume. For the tapped density (ρ_{tapped}), the cylinder was tapped 100 times. The volume of the sample was then read and used in the calculation. The results were calculated from three replicate measurements.

2.2. Angle of Repose

It is the three dimensional angle formed by cone like pile of the material during the determination. The angle of the cone formed was calculated after the product was passed through a funnel. The funnel was placed on a support at 20 cm from table surface, centered over a millimeter-grid sheet on which two intersecting lines were drawn, crossing at the centre. The narrow end of the funnel spout was plugged and the funnel was filled with the product under study until it was flushed with the top end of the spout when smoothed with a spatula. Thereafter, the plug was removed and the powder was allowed to fall onto the millimeter sheet. The radius of the cone base was measured with a slide caliper and the mean value (r) was calculated. Additionally, the cone height (h) was measured and the angle tangent value (α) of the cone was calculated employing the following equation:

$$\tan \alpha = (h/r)$$

2.3. Flowability and Cohesiveness

Table 1: Scale of flowability on the basis of Carr index, Hausner ratio, and Angle of repose

Flow Character	Carr Index	Hausner ratio	Angle of repose (°)
Excellent	≤ 10	1.00-1.11	25-30
Good	15-20	1.12-1.18	31-35
Fair (aid not needed)	16-20	1.19-1.25	36-40
Passable(may hang up)	21-25	1.26-1.34	41-45
Poor(must agitate/vibrate)	26-31	1.35-1.45	46-55
Very poor	32-37	1.46-1.59	56-65
Very very poor	> 38	> 1.60	> 66

Flowability and cohesiveness of the powder were evaluated in terms of Carr index (CI) [16] and Hausner ratio (HR) [17], respectively. Both CI and HR were calculated from the bulk (ρ_{bulk}) and tapped (ρ_{tapped}) densities of the powder as shown below:

$$CI = \frac{(\rho tapped - \rho bulk)}{\rho tapped} x\ 100$$

$$HR = \frac{\rho tapped}{\rho bulk}$$

Classification of the flowability and cohesiveness of the powder based on the CI, HR values and angle of repose are presented in Table 1.

2.4. Wettability

Wettability of the powder sample was determined according to A/S Niro Atomizer [18] with some modifications. An amount of distilled water (100 ml) at 25 ± 1 ℃ was poured into a 250 ml beaker. A glass funnel held on a ring stand was set over the beaker with the height between the bottom of the funnel and the water surface of 10 cm. A test tube was placed inside the funnel to block the lower opening of the funnel. The powder sample (0.1g) was placed around the test tube and then the tube was lifted while the stop watch was started at the same time. Finally, the time was recorded for the powder to become completely wetted (visually assessed as when all the powder particles penetrated the surface of the water).

2.5. Dispersibility

Dispersibility measurement was performed according to the procedure described in A/S Niro Atomizer [19] with some modifications. Distilled water (10 ml), at 25 ± 1 ℃, was poured into a 50 ml beaker. The powder (1 g) was added into the beaker. The stop watch was started and the sample was stirred vigorously with a spoon for 15s making 25 complete movements back and forth across the whole diameter of the beaker. The reconstituted honey based milk powder was poured through a sieve (212μm). The sieved soymilk (1 ml) was transferred to a weighed and dried aluminum pan and dried for 4 h in a hot air oven at 105 ± 1 ℃. The dispersibility of the powder was calculated as follows:

$$\% \ Dispersibility = \frac{(10+a)*\% \ TS}{a*\frac{100-b}{100}}$$

Where a = amount of powder (g) being used, b = moisture content in the powder, and % TS = dry matter in percentage in the reconstituted soymilk after it has been passed through the sieve.

2.6. Statistical Analysis

All measurements were made in triplicate for each sample. Results are expressed as mean $\pm$ standard deviations. A one-way analysis of variance (ANOVA) ($p \leq 0.05$) were used to establish the significance of differences among the mean values of the physicochemical, physical, and reconstitution properties of the spray-dried honey based milk powders. The data were analyzed using Microsoft Excel version 2007.

3. Result and Discussion

3.1. Flow Properties

Bulk and tapped densities of powder are important properties while considering the design of transport vehicle and storage vessel so have major impact on economic, functional and commercial factors [20]. Bulk density is defines as the mass of particles that occupies a unit volume of a container and tapping the container defines the tapped density.

No significant difference ($p>0.05$) was observed among control and all four levels (5, 10, 15 and 20%) added honey in all three type of (buffalo, cow and mixed) milk powders for bulk density (Table 2). Significant difference ($p<0.05$) in tapped density was observed after addition of 10% honey in all three type of milk powders. The significant increase in tapped density is understandable, considering honey sugar, which exhibit higher tapped density values with the rise in percentage of honey addition.

Carr index (CI) indicated that flow ability of control sample in all three types of milk powders was "very good" while upon addition of honey, the flow ability falls in "good" category (Table 2). The reason behind this good flow ability is less contact surface area between powder particles available for cohesive forces and frictional forces to flow [21]. Moreover, low fat content also caused the powder to have good flow properties [22]. Significant difference ($p<0.05$) was observed in carr index between control and 5 percent honey added in all three type of milk powders. Significant difference ($p<0.05$) was also seen among other levels with

control sample in all three type of milk powders. The reason behind this the increase in percentage of added honey which is responsible for increase in carr index by increasing the contact surface area between the particles.

Table 2: Flow properties of honey enriched buffalo, cow and mixed milk powder

Type of milk/ Parameter		BM	CM	MM
Bulk Density	0	0.39±0.00a	0.38±0.00a	0.39±0.00a
	5	0.39±0.02a	0.38±0.02a	0.39±0.02a
	10	0.39±0.02a	0.38±0.02a	0.39±0.02a
	15	0.39±0.00a	0.39±0.00a	0.4±0.00a
	20	0.4±0.02a	0.39±0.02a	0.4±0.02a
Tapped Density	0	0.46±0.00a	0.45±0.00a	0.46±0.01a
	5	0.47±0.02ab	0.46±0.02ab	0.47±0.02ab
	10	0.48±0.02b	0.47±0.02b	0.48±0.02b
	15	0.49±0.01b	0.48±0.01b	0.48±0.01b
	20	0.49±0.03b	0.48±0.03b	0.49±0.03b
Carr index	0	15.22±0.76a	15.56±0.78a	15.22±0.76a
	5	17.02±1.36b	17.39±1.39b	17.02±1.36b
	10	18.75±1.5bc	19.15±1.53c	18.75±1.5c
	15	20.41±1.84c	18.75±1.69bc	16.67±1.5ab
	20	20±1.6c	18.75±1.5bc	18.37±1.5bc
Hausner ratio	0	1.18±0.06a	1.18±0.06a	1.18±0.06a
	5	1.21±0.10ab	1.21±0.10a	1.21±0.10a
	10	1.23±0.10ab	1.24±0.10a	1.23±0.10a
	15	1.26±0.11b	1.23±0.11a	1.2±0.11a
	20	1.25±0.10ab	1.23±0.10a	1.23±0.10a
Angle of repose	0	30.5±0.31a	31±0.31a	30.8±0.31a
	5	31.4±1.26ab	31.6±1.26a	31.5±1.26ab
	10	32.2±1.61b	32±1.6a	32.5±1.63b
	15	34±0.34b	33.8±0.34b	34.1±0.34b

All values are mean of triplicate determinations

Hausner ratio (HR) (Table 2) indicated that cohesiveness of control sample in all three types of milk powders was "low" and become "intermediate" as honey was added to all three type of milk powder samples. The reason behind this is the stickiness of a powder that can be described in terms of cohesion- particle-particle stickiness. Significant increase ($p < 0.05$) in hausner ratio was observed after addition of 15% honey only in case of buffalo milk powder while no significant difference ($p > 0.05$) was observed in case of cow and mixed milk at all four (5, 10, 15 and 20%) levels.

Angle of repose, indicates the flowing properties of powdered foods, is the angle between the horizontal plane and slope of the heap of powdered material dropped from specific height or elevation [23]. The angle of repose varies from 30.5 to 36, 31 to 35.9 and 30.8 to 36.2 in buffalo milk, cow milk and mixed milk powders, respectively (Table 2). Lower angle of repose indicates the free flowing characteristic of powders and vice versa [24]. Significant difference ($p < 0.05$) was observed in angle of repose after addition of 10% honey in all three type of milk (buffalo, cow and mixed) powders. The increase in angle of repose may be due to increase in moisture content also.

3.2. Wettability

Wettability is a measure of ability of powder to penetrate the surface of still water [20]. No significant difference (p>0.05) in Wettability was observed in all three type of milk powders at all four levels (5, 10, 15 and 20%) of honey addition (Table 3). There is increase in Wettability as the added honey percentage increases as surface coverage with hygroscopic components (lactose, glucose and fructose) yields good wetting properties because of the small contact angle.

Table 3: Reconstitution properties of honey enriched buffalo, cow and mixed milk powder

Type of milk/ Parameter		BM	CM	MM
Wettability	Control	24±2.68a	22±2.38a	23±2.49a
	5	23±3.22a	21±2.94a	22±3.08a
	10	22±3.3a	21±3.35a	22±3.50a
	15	22±2.42a	21±2.49a	21±3.16a
	20	22±4.00a	21±3.56a	21±4.21a
Dispersibility	Control	95±0.95a	97±0.97a	97±0.97a
	5	96±3.84a	96±3.84a	96±3.84a
	10	96±1.92a	96±2.88a	96±2.88a
	15	96±0.96a	97±0.97a	97±0.97a
	20	96±3.84a	97±1.94a	96±3.84a

All values are mean of triplicate determinations

3.3. Dispersibility

It is the ability of the powder to separate in to individual particles when dispersed in water with gentle mixing [20]. Similar to Wettability, no significant difference (p>0.05) in Dispersibility was observed in all three type of milk powders at all four levels (5, 10, 15 and 20%) of honey addition (Table 3). More than 90 percent Dispersibility is considered as very good [25].

4. Conclusion

The information in this manuscript will definitely provide a roadmap to create awareness about this unique honey enriched milk powder to achieve large increase in productivity, value added, marketed milk. Various flow and reconstitution properties of prepared honey enriched milk powders were investigated. The results of carr index, hausner ratio and angle of repose indicated that prepared powders had free flowing behavior and Wettability and Dispersibility confirms the good reconstitution properties of prepared powders.

5. References

[1]   Ali A. Al-Jabri. Honey, milk, and Antibiotics. *Afr. J. Biotechnol.* 2005, **4** (13): 1580-1587.

[2]   N. Gheldof, X. H. Wang, and N.J. Engeseth.. Identification and quantification of antioxidant components of honeys from various floral sources. *J. Agric. Food Chem*. 2002, 50: 5870–5877.

[3]   I.C.F.R. Ferreira, E. Aires, J.C.M. Barreira, and L.M. Estevinho. Antioxidant activity of Portuguese honey samples: Different contributions of the entire honey and phenolic extract. *Food Chem.* 2009, 114: 1438–1443.

[4]   S.M. Antony, I.Y. Han, J.R. Rieck, and P.L. Dawson. Antioxidative effect of Maillard reaction products formed from honey at different reaction times. *J. Agric. Food Chem*. 2000, 48: 3985–3989.

[5]   T. Nagai, M. Sakai, R. Inoue, H. Inoue, and N. Suzuki. Antioxidative activities of some commercially honeys, royal jelly, and propolis. *Food Chem*. 2001, 75: 237–240.

[6]   The National Honey Board. *Honey-Health and therapeutic qualities*, *390 Lashley Street Longmont.* 2003, www.nhb.org.

[7]   L.M. Al, D. Daniel, D. Moise, O. Bobis, L. Laslo, and S. Bogdanov. Physicochemical and bioactive properties of different floral origin honeys from Romania. *Food Chem*. 2009, 112: 863–867.

[8]   J. McKibben, and N. J. Engeseth. Honey as a protective agent against lipid oxidation in ground turkey. *J. Agric.*

Food Chem. 2002, 50: 592–595.

[9] G. Beretta, P. Granata, M. Ferrero, M. Orioli, and R.M. Facino. Standardization of antioxidant properties of honey by a combination of spectrophotometric/fluorimetric assays and chemometrics. *Analytica Chimica Acta.* 2005, 5433: 185–191.

[10] R. Krell. Value-added products from beekeeping. *FAO Agricultural Services Bulletin No. 124.* Chapter 2. 1996, 14-17.

[11] R. Freeman. Measuring the flow properties of consolidated, conditioned and aerated powders- a comparative study using a powder rheometer and a rotational shear cell. *Powder technol.* 2007, 174: 25-33.

[12] P.A. Kulkarni, R.J. Berry, and M.S.A. Bradley. Review of flowability measuring techniques for powder metallurgy industry, *Proc. Inst. Mech. Eng. E. J. Process Mech. Eng.* 2010, 224: 150-168.

[13] P. Ramavath, M. Swathi, M. Buchi Suresh, and R. Johnson. Flow properties of spray dried alumina granules using powder flow analysis technique. *Adv. Powder Technol.* 2013, 24: 667-673.

[14] Grace. M O'Mahony Kelly, A. James, Alan L. Kelly, and J.O'Callaghan, Donal. Physical characteristics of spray-dried dairy powders containing different vegetable oils, *J. Food Eng.* 2014, 122: 122–129.

[15] V. Bansal, H.K. Sharma, and V. Nanda. Optimization of spray drying process parameters for low-fat honey-based milk powder with antioxidant activity. *Int. J. Food Sci. Technol.* 2014, 49: 1196-1202.

[16] R.L. Carr, Evaluating flow properties of solids. *Chem. Eng. J.* 1965, 72: 163–168.

[17] H.H. Hausner. Friction conditions in a mass of metal powder. *Int. J. Powder Metall.* 1967, 3: 7–13.

[18] A/S Niro Atomizer, Copenhagen, Denmark Determination of wettability. In I. H. S ørensen, J. Krag, J. Pisecky, & V. Westergaard (Eds.), *Analytical methods for dry milk products (4th ed.,* 1978a, 26–27). Copenhagen: De Forenede Trykkerier A/S.

[19] A/S Niro Atomizer, Copenhagen, Denmark. Determination of dispersibility. In I. H. S ørensen, J. Krag, J. Pisecky, & V. Westergaard (Eds.), *Analytical methods for dry milk products (4th ed.,* 1978b, 32–33). Copenhagen: De Forenede Trykkerier A/S.

[20] A. Sharma, A.H. Jana and R.S. Chavan. Functionality of Milk Powders and Milk-Based Powders for End Use Applications —A Review. *Comp. Rev. Food Sci. Food Safe.* 2012, 11: 518–552.

[21] J.J. Fitzpatrick. Food powder flowability. In C. Onwulata (Ed.), CRC Press *Encapsulated and powdered foods* 2005, 247–260.

[22] J.J. Fitzpatrick, T. Iqbal, C. Delaney, T. Twomey, and M.K. Keogh. Effect of powder properties and storage conditions on the flowability of milk powders with different fat contents. *J. Food Eng.* 2004, 64: 435–444.

[23] L. Sang-Cheon, C. Kyu-Seob, P. Young-Deok, and K. Hyun-Ah. Effect of drying method on rheological properties of milk powders. *J Korean Agric Chem Soc.* 1993, 36: 416–23.

[24] V. Ganesan, K.A. Rosentrater, and K. Muthukumarappan. Flowability and handling characteristics of bulk solids and powders-a review with implications for DDGS. *Biosys. Eng.* 2008, 101: 425-435.

[25] A.Y. Tamime. *Dried milk products. Dairy powders and concentrated milk products.* Oxford, U.K.: Blackwell Pub. Ltd. 2009, 231–45.