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Effect of Honey Concentration on Honey based Milk Powder

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Abstract

Honey based spray dried milk powder is produced by using 2%, 4%, 6% & 8% (v/v) honey and control sample without addition of honey. The physical properties of glass transition temperature, water activity, bulk density, and water solubility index were determined. Statistical significant differences were found in glass transition temperature, water activity, bulk density and water solubility index with variation in honey concentration ($p<0.05$). There was a positive relation observed in the glass transition temperature, bulk density and water solubility index with honey concentration while negative relation was observed between water activity and honey concentration.

Keywords: - *Honey, Milk powder, Concentration*

1. Introduction

Spray drying is a continuous process, which involves the conversion of almost any pumpable liquid into fine droplet and exposing them to the hot drying media to achieve the dry particulate matter (Wendel and Cliek, 1997), having many advantage over the other process for producing powder such as it is a suitable process for heat sensitive products and to produce powder with specific characteristics (Mermelstein, 2001). The physicochemical properties of powders produced by spray drying technique depend upon some process variables, such as the characteristics of the liquid feed (viscosity, particles size, flow rate) and of the drying air (temperature, pressure), as well as the type of atomizer (Souza *et al.*, 2009). Hence it is mandatory to monitor the various process variables during operation.

Milk is an almost ideal or complete food as it is a source of protein, fat, sugar, vitamins and minerals. Milk proteins include all of the essential amino acids, and are easily digested (Shukla *et al*., 1987). According to national dairy development board of India, milk production in India in 2008-2009 was 108.5 million tones. It has been reported that honey and milk mixture have beneficial effect in case of loss of appetite, serious disease of digestive tract, alimentary dystrophy, under nutrition, complete exhaustion and in diet of heart patient (Krell, 1996). Honey and milk combination act as antibiotic, anti-aging and antibacterial agent. It has been reported that combination of milk and honey show higher antibacterial activity on staphylococcus bacteria than milk or honey taken alone (http//findartical.com).

Honey has high therapeutic value, because its proteins that include a number of enzymes (diastase, invertase, glucose oxidase, catalase and others) and eighteen free amino acids, of which the most abundant is proline (White *et al.*, 1962). Honey is also good source of minerals such as potassium, calcium, sodium, phosphorous, magnesium, and iron (Rodriguez-Otero *et al.*, 1992). It is more beneficial to promote the honey based milk products in the market due to its high therapeutic value and health benefit effects. Honey based milk powder is a well suited product; owe to have many advantage over the other products like ease of handling, storage and transportation. Till the date, there is no work has been reported on the honey based milk powder. Hence there is a need to intensify work on the honey based powder.

2. Materials and Methods

2.1 Procurement: - Buffalo milk & Commercial honey (Dabur, India) was purchased from local market of Karnal, Haryana, India.

2.2 Preparation of Honey based Milk Powder

Milk was pasteurized for 30 min. at 63 ºC, pasteurized milk was standardized (SNF 8.5% and Fat 4.5%), standardized milk and honey were mixed up by using 2%, 4%, 6% and 8% (v/v) honey and a control sample was produced of milk without addition of honey.

Flow Diagram of Preparation:-

Receiving of buffalo milk

↓

Pasteurization of milk
(63 ºC and 30 min.)

↓

Standardization of milk

(SNF 8.5% and Fat 4.5%)

Receiving of honey

↓

Blending of honey & milk

↓

Spray drying (Through pilot plant Spray-dryer (S.M. Science tech, Calcutta) at constant feed flow rate, blower speed and inlet temperature)

↓

Collection of powder

↓

Packing in aluminated PE bags

↓

Store in desiccators

2.3 Method of Analysis of Physical Property:-

2.3.1 **Glass Transition Temperature (T_g):-** Differential scanning calorimeter (TGA/DSC, 1 Mettler Toledo.) was used to measure the glass transition temperature. The instrument was calibrated with indium kept in a closed aluminum pan (Roos and Karel 1991; Roos 1995). After the calibration, about 20–25 mg of the material was taken in the sample pan. An empty aluminum pan was used as a reference. During the measurement nitrogen was used as carrier gas (50 ml/60 s). Liquid nitrogen was used for sample cooling at the rate of 10°C/60 s to bring down the sample temperature to 20°C from the atmospheric temperature (30– 34°C). All the scans were taken at the same heating rate of 10°C/60 s from 20 to 170°C. Glass transition temperature was measured for the honey based milk powder samples at same moisture contents. Thermogram thus obtained were analyzed for the onset, mid, and end points of glass transition. Most researchers consider the onset temperature of a thermogram as the T_g (Fernandez *et al.,* 2003).

2.3.2 **Water Activity**:- Water activity was determined by using digital hygrometer (Rotronic hygrolab,3) at room temperature (Laroche *et al.*,2005).

2.3.3 **Hygroscopicity:-** Hygroscopicity was determined according to the method proposed by Cai and Corke (2000). Samples of each powder (approximately 1 g) were placed at 25 °C in a container with NaCl saturated solution (75.29%RH). After one week, samples were weighed and hygroscopicity was expressed as g of adsorbed moisture per 100 g dry solids (g/100 g/week).

2.3.4 **Water Solubility Index:-** The WSI of the powders was determined using the method described by Anderson *et al.* (1969). Spray-dried powder (2.5 g) and distilled water (30 ml) were vigorously mixed in a 100 ml centrifuge tube, incubated in a 37 °C water bath for 30 min and then centrifuged for 20 min at 10,000 rpm (11,410 g.) in a J2-MC Centrifuge (Beckman, USA). The supernatant was carefully collected in a pre-weighed beaker and oven dried at a temperature of 103 ± 2 °C. The WSI (%) was calculated as the percentage of dried supernatant with respect to the amount of the original 2.5 g powder.

2.3.5 **Moisture Content:-** Powders moisture contents were determined gravimetrically by drying in a vacuum oven at 70 ^{0}C until constant weight (A.O.A.C., 1990).

2.3.6 **Bulk Density: -** Bulk density (g/ml) was determined by gently adding 2 g of powder into an empty 10 ml graduated cylinder and holding the cylinder on a vortex vibrator for 1 min. The ratio of mass of the powder and the volume occupied in the cylinder determines the bulk density value (Goula et al., 2004).

2.3.7 **Viscosity: -** A controlled stress rheometer (Bohin CVO 100, malvern) with a cone-plate configuration was used for rheological measurements of samples. Samples were reconstituted as their actual solid content in feed formulation. The rheometer was equipped with a water bath to ensure the measurement temperature was constant at 25°C. About 250 µl sample was placed on the plate of rheometer and sheared in the range of 1 – 100 s^{-1}. Total of 5 data points were recorded in the measurement range at different interval of shear rate (Telcioglu and Kayacier, 2007). The shear stress and shear rate were fitted to some of the common rheological models, such as the Newtonian model [Eq. (2.1)] and Power Law or Ostwald-of-Waele [Eq. (2.2)] model (Steffe, 1996).

$$\sigma = \mu\gamma \qquad (2.1)$$

$$\sigma = k\gamma^n \qquad (2.2)$$

Where σ is the shear stress (Pa), µ is the viscosity (Pa.s), k is the consistency index (Pas^n), γ is the shear rate (s^{-1}), and n is the flow behaviour index (dimensionless).

2.3.8 **Statistical Analysis: -** One way Analysis of variance (ANOVA) and Duncan was applied to find out the statistical significant difference at the level of significance 0.05, with the help of Excel spreadsheets of MS Office 2007 software package and STATISTICA 7 software package. Models were analyzed by STATISTICA 7 software package.

3. Results and Discussion

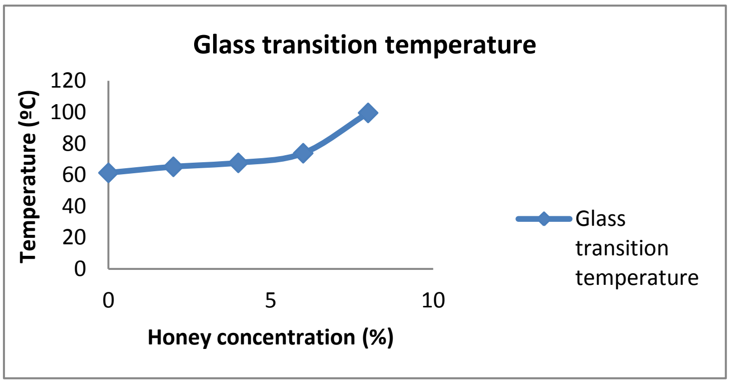
3.1 **Effect of honey concentration on glass transition temperature (T_g):-** The average values of glass transition temperatures of honey based milk powders are shown in table 3.1.1. It was found that glass transition temperature (T_g) of powders follow a trend with concentration of honey, glass transition temperature (T_g) increased with increase in honey concentration. Initially, there was no huge difference among the glass transition temperature (T_g) of samples having honey concentration 2% ,4% and control sample (without addition of honey).

Table 3.1.1 Average glass transition temperatures (T_g) of honey based milk powders

Honey concentration (%)	Glass transition temperature (°C)
Control	61.3±0.47^{d}
2	65.14±1.04^{cd}
4	67.67±1.86^{b}
6	73.80±0.34^{b}
8	99.52±0.88^{a}

Values are means ± SD of 4 determinations. $^{a-e}$ Means with different calculations.

Figure 3.1.1 Show the effect of Honey Concentration on glass transition temperature.



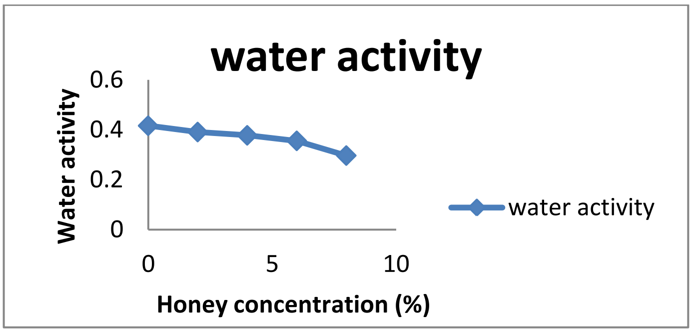
3.2 **Effect of honey concentration on water activity (a_w):-** The average value of water activity (a_w) summarized in table 3.2.1, Water activity was decreased with increase in honey concentration. Control sample had highest water activity (0.416), while sample having 8% honey show lowest water activity (0.296). The decreasing trend of water activity (a_w) with increased in honey concentration was due to the lower moisture content of sample having higher concentration of honey than lower honey concentrated sample. Thankitsunthorn *et al.* (2009) reported that water activity show inverse relation with moisture content of sample. The lower value of water activity of sample having higher honey concentration was also result of higher amount of sugar present in sample having higher honey concentration. Fernandez et al (2003) has reported same finding that water activity of sugar enriched milk powder was lower than regular milk powder.

Table 3.2.1 Average value of water activity (a_w) of honey based milk powders

Honey concentration (%)	water activity (a_w)
Control	0.416±0.003^{a}
2	0.390±0.002^{b}
4	0.377±0.006^{c}
6	0.355±0.003^{d}
8	0.296±0.003^{e}

Values are means ± SD of 4 determinations. $^{a-e}$ Means with different calculations.

Figure 3.2.1 Show the effect of Honey Concentration on water activity (a_w)



3.3 **Effect of honey concentration on hygroscopicity:-** Hygroscopicity (table 3.3.1) of honey based milk powder samples ranged from 7.81 to 23.74 g/100g. The huge difference was observed among the hygroscopicity of samples. Initially hygroscopicity gradually increased with increase in the level of honey concentration up to 4% level of honey concentration and above the 4% an abrupt change was observed. The increase in the hygroscopicity was due to decreased in the moisture content and increased in the sugar content of samples with increase in honey concentration. Slade and Levine (1991) and Goula *et al.* (2004) have reported that hygroscopicity increased with decrease in moisture content and increased with increase in glucose and fructose level. This behavior was observed because glucose and fructose responsible for strong interaction with the water molecule due to polar terminals present in this molecules and lower moisture content increase the moisture gradient between sample and atmosphere. Figure 3.3.1 show the effect of honey concentration on hygroscopicity.

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Honey concentration (%)	hygroscopicity (g/100g)
Control	7.81±0.26^{e}
2	9.68±0.19^{d}
4	12.63±0.21^{c}
6	19.55±0.15^{b}
8	23.74±0.23^{a}

Table 3.3.1 Average value of hygroscopicity of honey based milk powders

Values are means ± SD of 4 determinations. $^{a-e}$ Means with different calculations.

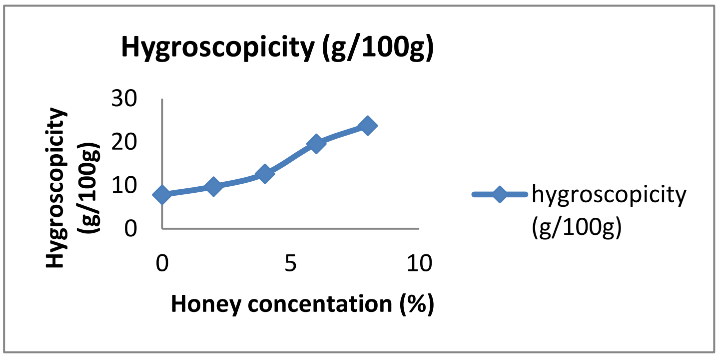


Fig. 3.3.1 Effect of honey concentration on hygroscopicity

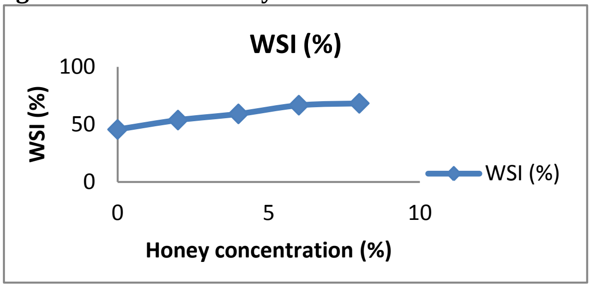
3.4 **Effect of honey concentration on water solubility index (WSI):-** The average value of WSI (table 3.4.1) ranged from 45.52 to 68.25% for the sample. There was a significant increased was observed between the WSI of control sample and sample having 2% honey and then gradually increase in WSI with increase in honey concentration. This show that sugar content significantly affected the WSI of samples due to the amorphous structure of sugar developed during spray drying. Cano-Chauca (2004) has reported that higher amorphous degree of the particle surface results in the increased the solubility of the powder in the water. Conversely, a higher order of particles results in lower solubility. Papadakis *et al.* (1998) and Goula and Adamopoulos (2005) reported that the solubility of the powder was associated with the moisture content and increases with decreased in the moisture content. As honey increased in powder sample moisture content decreased and this factor govern the increasing trend of WSI with honey concentration. The solubility of powders was lower than feed formulation, because of thermally induced denaturation of the milk protein.

Table 3.4.1 Average WSI of honey based milk powders

Honey concentration (%)	WSI (%)
Control	45.52±0.78^{d}
2	53.70±0.84^{c}
4	59.07±0.45^{b}
6	66.62±0.53^{ab}
8	68.25±1.12^{a}

Values are means ± SD of 4 determinations. $^{a-e}$ Means with different calculations.

Fig. 3.4.1 Effect of honey concentration on WSI



3.5 **Effect of Honey Concentration on Moisture Content: -** The average value of honey based milk powder samples are summarized in table 3.5.1. The average moisture content for the powder samples ranged between 3.19% and 6.38%. Table 3.2.1 indicates that the moisture content of honey based milk powder decreased with increase in honey concentration. Moisture content of spray dried powders is affected by many factors including the feed flow rate (Tonon et al., 2008; Souza *et al.*, 2009), the inlet temperature, dry air as well as the amount of drying agent added (Kha *et al.*,2010). In this study spray drying conditions such as feed rate and inlet temperature were constant. Thus the variation in moisture content of the samples was due to fluctuation of humidity in inlet air and also affects the moisture content of the feed of spray drier (Masters, 1991; Pu *et al.*, 2011). As the honey concentration increased in feed, moisture content of feed decease and this was the reason decline in the moisture content of spray dried milk powder with increase in honey concentration .Samples were spray dried on different days changes in humidity of air could have been a possible reason for the difference in moisture content.

Table 3.5.1 Average moisture content of honey based milk powder samples

Honey concentration (%)	Moisture content (%)
Control	6.38±0.04^{e}
2	5.79±0.02^{d}
4	5.07±0.04^{c}
6	4.33±0.03^{b}
8	3.19±0.11^{a}

Values are means ± SD of 4 determinations. $^{a-e}$ Means with different calculations

Fig. 3.5.1 Effect of honey concentration on moisture content

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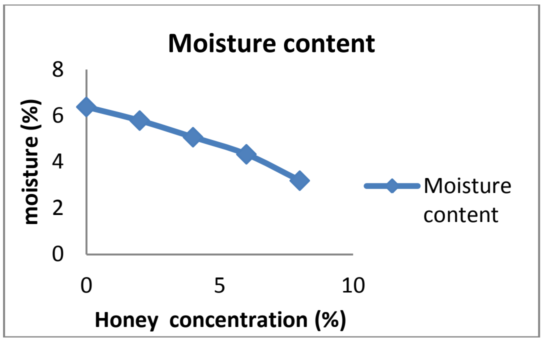


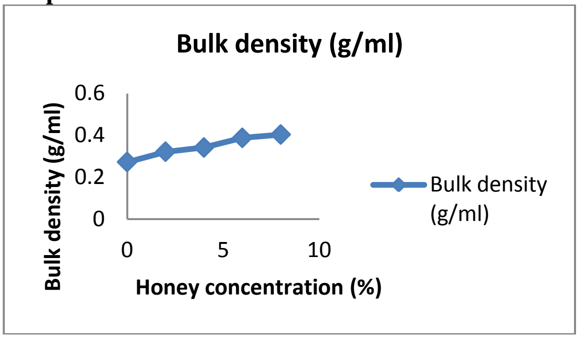
3.6 **Effect of honey concentration on bulk density:-** Table 3.6.1 shows the average value of bulk density for honey based milk powder. The value of bulk density ranged from 0.272 g/ml to 0.403 g/ml for honey based milk powder samples, bulk density show positive relation with honey concentrationWalton and Mumford (1999); Cai and Corke (2000); Goula *et al.* (2004) and Chegini and Ghobadian (2005) reported that bulk density reduce as inlet air drying temperature increased and also affected by other factor such as feed rate, feed composition, atomizer speed. Since in this study the spray drying conditions were kept constant, thus variation in the bulk density was due to the variation in the feed composition and the content of air inside the particle and the amount of air between the particles. Sawhney *et al.* (2010) has reported that the bulk density decrease as air content in particle and between the particles increased, air incorporation in the particle and between the particles affected by air incorporated during feed and atomization. Figure 3.6.1 shows the effect of honey concentration on bulk density. As the honey increased in feed formulation the water content of feed formulation decreased, so porous structure developed by evaporation of water during spray drying decreased, resulted the high bulk density. Nath and satpathy (1998) and Walton (2000) have also reported that the porous structures are favored by the expansion of evaporation of water vapor leaving the empty spaces occupied by the air.

Table 3.6.1 Average value of bulk density of homey based milk powders

Honey concentration (%)	Bulk density (g/ml)
Control	0.272±0.003[e]
2	0.321±0.002[d]
4	0.341±0.006[c]
6	0.387±0.003[b]
8	0.403±0.003[a]

Values are means ± SD of 4 determinations. [a-e] Means with different calculations.

Fig. 3.6.1 Effect of bulk density on powder samples



3.7 **Effect of honey concentration on Viscosity:-** The shear stress and shear rate were fitted to the rheological models, such as the Newtonian model and Power Law or Ostwald-of-Waele model. Figure 3.7.1 shows the shear stress versus shear rate diagram for reconstituted honey based milk powders. The flow parameters are presented in Table 3.7.1 The Newtonian model has shown a R^2 Values between 0.834 and 0.971, while in the The Ostwald-of-Waele (Power Law) model show the R^2 between the 0.945 and 0.994, resulted in the better adequacy of power law model. In case of Power Law model, the flow behaviour index (n) of powders obtained from this model showed values varying from 0.825 to 0.983 indicating that, with addition of honey Newtonian behaviour of sample converted in to pseudo-plastic in nature. As suggested by scalzo et al., (1970) when the magnitude of n was near to 0.9 and Newtonian model was fitted well the product could be considered as Newtonian fluid. Table 3.7.1 indicates that the consistency index (k) varied from 2.03 to 5.07 Pa.s^n and increased with increase honey concentration due to higher viscosity of honey than milk.The consistency index (k) varied from 2.03 to 5.07 Pa.s^n and increased with increase honey concentration due to higher viscosity of honey than milk. Sahin and Sumnu (2006) also reported the Newtonian behaviour of milk and Literature mostly reports honey as a Newtonian fluid (Abu-Jdayil *et al.*, 2002; Bhandari *et al.*, 1999; Lazaridou *et al.*, 2004; Juszczak and Fortuna 2006). However , Mossel *et al.* (2000) cited some papers which have reported thixotropic behavior in honey. Difference in viscosity was attributed to various factors with moisture content and chemical composition including the presence of colloids and crystals being the predominant ones (Juszczak and Fortuna 2006; Yanniotis *et al.*, 2006). The presence of monosaccharides and disaccharides was also an important consideration with disaccharides contributing more to viscosity for the same mass fraction of monosaccharides (Bhandari et al., 1999).

Table 3.7.1 Flow parameters of reconstituted honey based milk powders

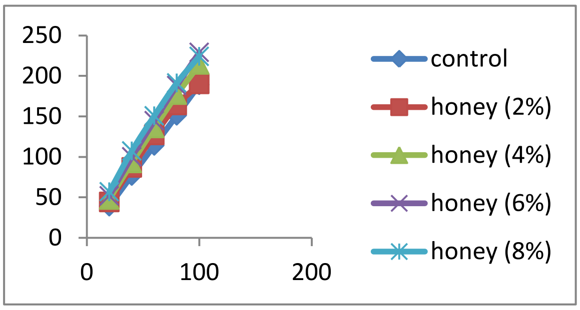
Newtonian model

Honey (%)	Viscosity (mPa.s)	R^2	RMSE	χ^2	%E
Control	1.89	0.971	0.242	0.303	0.565
2	2.05	0.931	1.824	2.27	1.360
4	2.19	0.930	2.142	2.67	1.380
6	2.34	0.906	4.962	5.86	1087
8	2.37	0.834	17.61	22.08	3.304

Ostwald-of Waele (Power Law)

Honey (%)	k ($mPa.s^n$)	n	R^2	RMSE	χ^2	%E
Control	2.03	0.983	0.994	0.009	0.011	0.111
2	2.92	0.917	0.997	0.515	0.644	0.726
4	3.03	0.922	0.998	0.505	0.632	0.651
6	3.44	0.912	0.978	0.253	0.316	0.651
8	5.07	0.825	0.945	2.156	2.690	1.093

Fig. 3.7.1 Shear Stress vs Shear rate diagram honey based milk powder



4. Conclusion

Effect of honey concentration was studied by determining physical properties and morphology of powder particle. Effect of honey concentration on rheological properties of reconstituted honey based milk powder was also studied. The sorption isotherm of honey based milk powder was also carried out to predict the monolayer moisture content.

- Glass transition temperature, bulk density, Hygroscopicity and water solubility index increased with increase in honey concentration, while moisture content and water activity decreased with honey concentration.
- Statistical significant difference was founded in all above physical properties with variation in honey concentration ($p<0.05$).
- Roughness of surface and crystallization of sugar was observed with addition of honey. The surface coverage area by sugar crystal increased with increase in honey concentration.
- Non-Newtonian (Shear-Thinning) behavior of reconstituted honey based milk powder increased with increase in honey concentration.

5. Future Scope

1. There was need to study the chemical characteristics and chemical changes induced during spray drying in honey based milk powder.
2. There was need to optimize the processing condition of spray dryer.
3. The honey based milk powder should be used to produce different dairy product and subsequently their properties should be studied

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