Optimization of spray drying parameters for the preparation of *Carrot milk powder*

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Abstract: In this study a novel carotene enriched milk powder was developed using skim milk and carrots. In recent years, contributions of spray drying in food manufacturing has gained considerable interest compared to other conventional drying methods mainly due to their cost efficiency and enhanced shelf life of the product. In the present study, inclusion of 40 per cent of carrot juice to skim milk (CS₃) was adjudged as the optimum level based on sensory evaluation for the preparation of standardized mix. The mix was spray dried using laboratory model spray drier at different inlet temperatures viz., 165°C, 170°C and 175°C with feed flow rates of 0.2 kg/hr, 0.25 kg/hr and 0.3 kg/hr respectively, keeping a constant outlet temperature of 60°C and compressed air pressure of 2 kg/cm². The inlet and outlet air temperatures of 170°C and 60°C with feed flow rate of 0.25 kg/hr and compressed air pressure of 2 kg/cm² were found optimum after assessing the moisture content of the powder. The physical properties of the spray dried carrot milk powder were 0.535±0.008 g/cc for loose density, 0.606±0.003 g/cc for packed density, 2.280±0.073 ml for insoluble index and 0.378±0.003 for water activity. The nutrient composition of carrot milk powder for protein, fat and fibre were 28.54±0.278, 3.90±0.068 and 1.73±0.027 g/100g respectively. Beta carotene content was 2.038 mg/100g,

Vitamin A was 0.01 mg/100g and Total Polyphenol Compounds (as Gallic acid) were 220 mg/100g. It can be concluded that this product serves as an instant carotene enriched powder that can be consumed by all age groups.

Keywords: Carrot juice, Skim milk mix, Spray-drying, Spray dried carrot milk powder,

Introduction

Milk is a widely consumed beverage that is essential to the diet of several millions of people worldwide because it provides important macro and micronutrients. Skim milk too has a plethora of nutrients viz. protein, lactose, vitamins and minerals. It is gaining importance because of awareness among consumers to consume low calorie diets. Milk though highly nutritious, is a perishable product. However, its shelf life can be increased and extended without substantial loss of quality by converting it into powder. Their functionality can further be enhanced by the application of other food ingredients. Thus a synergy with non-dairy ingredients will improve the functionality of dairy foods and can reach vulnerable groups. Functional foods contain significant levels of biologically active components that provide health benefits apart from providing basic nutrition. The quest for functional foods has increased the global market demand towards fresh fruits and vegetables. Fruits and vegetables are good sources of vitamins, polyphenols including antioxidants. "Functional" attributes of many traditional vegetables and fruits are being discovered, while new food products are being developed with additional nutraceutical components.

Carrot is one of the important root vegetables rich in bioactive compounds like carotenoids, flavonoids, polyacetylenes, vitamins and dietary fibre with appreciable levels of several other functional components having significant health-promoting properties. The consumption of carrot and its products is increasing steadily due to its recognition as an important source of natural antioxidants. Apart from being traditionally used in salad and in the preparation of curries in India, these could commercially be converted into nutritionally rich processed products like juice, concentrate, dried powder, canned, preserve and candy. Carrots are a good source of carbohydrates and

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minerals like Ca, P, Fe and Mg. Zaini et al. (2012) reported the anti-carcinogenic effect of carrot juice extracts on myeloid and lymphoid leukemia cell lines. Darroudi et al. (1988) reported the anti-clastogenic activity of carrot on Chinese hamster ovary (CHO) cells and human lymphocytes. The curative effect of carotenoids and anti-oxidant polyphenols, and dietary fibres against bladder cancer and other carcinomas has also been reported by Teng et al. (2016).

Drying is a well-known technique, which is used to preserve food by removing moisture content. Among the drying techniques, spray drying is widely used to produce fruit juices and powders. It results in powders with good quality, low water activity and easier transport and storage advantage. The physicochemical properties of powders produced by spray drying depend on 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. Therefore, it is important to optimize the drying process, in order to obtain products with better sensory and nutritional characteristics and better process yield. This is used by most of the food industries as it is economical and is a low operating cost technology.

Materials and methods

Fresh skim milk (0.5% fat and 8.9 % SNF) was obtained from the model dairy plant of the Department of Dairy Science, Madras Veterinary College. Carrots (*Daucus carota* L.) were purchased from the local market. Carrot juice was extracted using centrifugal juicer (Prestige make, Model: PCJ 5.0). Sensory evaluation of different ratios of carrot juice to skim milk mix was carried out using 9 point hedonic scale. Proximate analysis (Tulin equipments, Chennai) of the skim milk, carrot juice and carrot juice and skim milk mix (CS mix) was carried out. Table top spray drier (SM Scientech, Kolkata) was used for the spray drying of the optimized carrot juice and skim milk mix. Water activity meter (Make: Novasina) was used to estimate the water activity in the powder. UV-VIS Spectrophotometer was used for estimating Beta carotene and Total Polyphenol Content (TPC), High Performance Liquid Chromatography (HPLC) was used for estimating Vitamin A.

Preparation of carrot juice and skim milk mix (CS mix)

CS mix was prepared as per the method adopted by Jayamanne et al. (2014) with slight modifications. The carrots were peeled, washed and cut into small pieces of approximately 0.5 cm diameter. These are then blanched in hot water at 60°C for 5 minutes. Blanching step is important to retain the colour of CS mix in the powder after spray drying. These are then blended in centrifugal juicer and strained to obtain pure carrot juice. The acidity and pH of the pure carrot juice obtained were 0.147% LA and 6.1 respectively. Carrot juice is added in to skim milk at different

ratios and pasteurized at 71.7°C for 15 seconds and then cooled down to room temperature (Pasteurization of the carrot juice and skim milk mix was done by indirect heating on gas stove).

Standardization and optimization of carrot juice into skim milk for preparing CS mix

CS mix was prepared using different inclusion levels of carrot juice to skim milk as depicted below.

Ingredients (g)	Proportion of composite mixes (per cent)			
	Carrot juice and Skim milk mix (Carrot juice: Skim milk)			
	CS ₁	CS ₂	CS ₃	CS ₄
Carrot juice (C ₁)	20	30	40	50
Skim milk (S ₁)	80	70	60	50

Sensory evaluation of composite mixes of carrot juice and skim milk was performed by a panel of trained judges on a 9 point Hedonic scale (Amerine et al. 1965).

Nutrient composition of control (S₁), carrot juice (C₁) and CS₃

Total solids was found by gravimetric method as per ISO 6731: 1989. Crude fat was estimated using the standard extraction method (AOAC) (Horwitz, 2000) employing Soxhtron fat extractor (Tulin equipment, Chennai). The protein content was determined by Kjeldahl method using Kjeltion protein analyser as described in AOAC (Horwitz, 2000). Crude fibre was determined by standard method of AOAC (Horwitz, 2000) using Fibretron fibre analyser. The ash content was estimated using standard method of AOAC (Horwitz, 2000). Nitrogen Free Extract (NFE) content was calculated by difference method AOAC (Horwitz, 2000) using the formula:

$$\text{Total NFE (\%)} = 100 - (\text{crude fat} + \text{crude protein} + \text{ash} + \text{crude fibre} + \text{moisture})$$

Spray drying

The mix (CS₃) was then subjected to spray drying at different inlet temperatures viz., 165°C, 170°C and 175°C at the feed flow rates 0.2 kg/hr, 0.25 kg/hr and 0.3 kg/hr respectively, maintaining a constant outlet temperature of 60°C and compressed air pressure of 2 kg/cm². The parameters for spray drying of carrot milk were standardized after checking the moisture percentage in the powder. After spray drying control (S₁) is referred as SMP, and CS₃ is referred as CMP.

Moisture content of the spray dried carrot milk powder (CMP)

Moisture percent of the spray dried carrot milk powder obtained from the various inlet temperatures of 165°C, 170°C and 175°C was estimated as per BIS-IS 11623: 2008.

Physical properties of carrot milk powder

Loose bulk density and packed bulk density of the powder were measured as per IDF standard 134A: 2005. Insolubility index of the powder was determined as per IDF method 129A: 1988. Water activity was determined using a water activity meter (Schuck et al. 2005).

Nutrient composition of the carrot milk powder

Fat, protein, fibre contents in the carrot milk powder were estimated as per the methods described in AOAC (2000). Beta carotene content was estimated as per the method AOAC 2012. Total polyphenol compounds were estimated as per the procedure followed by Anesini et al. (2008). Vitamin A content was found as per the method described in AOAC 2016- 2001.13 (20th edition).

Statistical analysis

The data obtained were analysed statistically as per the procedure of Snedecor and Cochran (1980).

Results and discussion

Optimizing the inclusion level of carrot juice into skim milk by sensory evaluation

Table 1 shows the respective mean $\pm$ SE sensory values for control (S_1) (skim milk), carrot juice (C_1) and carrot juice and skim milk (CS) mix prepared by optimizing the inclusion level of carrot juice to skim milk by sensory evaluation using 9 point hedonic scale.

In the present study as seen in Table 1, there was a significant difference in the sensory perception between control (S_1) and different ratios of carrot juice and skim milk mix. The low scores for control were attributed due to the bland taste and lack of appreciable colour of the skim milk. From the sensory scores it was shown that 40:60 ratio of carrot juice and skim milk mix (CS_3) was preferred by panelists over other combinations. There was no significant difference between taste, consistency and flavor of CS_3 and CS_4 , but a significant difference was observed in terms of colour and appearance. The panelists preferred the colour of the sample CS_3 to the highly pronounced colour of CS_4 . Similar observation was made by Singh et al. (2005) where 20 per cent inclusion of carrot juice was preferred in their trials over 10 and 30 per cent in cow and buffalo skim milk for the preparation of carrot milk beverage.

However, the present results are in agreement with Daneshi et al. (2013) who used 30 per cent level of centrifuged carrot juice in

milk for the preparation of probiotic milk/carrot juice mix drink. The present results are also in agreement with Islam et al. (2016) who opined that the addition of carrot juice to skim milk improved smell and taste, body and consistency and also colour and texture.

Nutrient composition of control (S_1), carrot juice (C_1) and CS_3

Table 2 shows a comparison of mean $\pm$ SE values of nutrient composition of the three samples. The results obtained for protein (3.520 ± 0.550) and ash (0.650 ± 0.019) of skim milk almost agrees with the chemical composition of skim milk obtained by Islam et al. (2016) for protein (3.17 ± 0.08) and ash (0.62 ± 0.01). The fat per cent (0.500 ± 0.024) and protein per cent (3.520 ± 0.550) in skim milk were within the range prescribed by FSSA, 2006.

The results of total solids (8.07 ± 0.066), fat (0.920 ± 0.035) and ash (0.320 ± 0.031) values obtained for C_1 almost agree with that of total solids (9.90 ± 0.355), fat (0.95 ± 0.11) and ash (0.23 ± 0.12) values in carrot juice obtained by Rafiq et al. (2016). However, the NFE value was slightly higher than that obtained by Rafiq et al. (2016). This might be attributed because of the variety of carrots used which is in agreement with Singh et al. (2005) who also reported that the composition of carrots varies with the varieties used viz., Selection 21, Carrot 29 and SK 1 used in his study, which were procured from Department of Vegetable Crops, Punjab Agricultural University, Ludhiana.

The reduced level of total solids (8.820 ± 0.017) in CS_3 compared to skim milk (9.420 ± 0.082) was mainly due to lower content of total solids in carrot juice (8.070 ± 0.066) than skim milk used, thereby decreasing the total solids in the CS_3 mix. This agrees with the results obtained by Singh et al. (2005) who also reported decreased total solids with progressive increase in carrot juice inclusion per cent in milk from 10 to 30 per cent.

Spray drying

The inlet temperature for spray drying of carrot milk was standardized after required moisture percentage is obtained in the powder. Fig A shows the spray drying equipment and Fig B shows the spray dried carrot milk powder.

Table 3 shows the moisture per cent in control and carrot milk powder at different inlet temperatures of spray drying. The outlet temperature was set to 60°C based on the studies to obtain required moisture percentage in the powder. Trails made by keeping higher outlet temperature above 60°C made the powder stick to the walls of spray drying chamber resulting in low quality powder and reduction in yield. This might be because of the sugars present in the carrot juice undergoing Maillard reactions. From the table it is seen that there is no significant difference in the moisture per cent of the carrot powder spray dried with inlet temperatures of 170°C and 175°C. However, there is a highly significant difference between them and the powder spray dried at 165°C. Also, the higher moisture per cent in carrot milk powder

Fig A. Spray drying

Fig B. Spray dried carrot milk powder

Table 1 Optimizing the inclusion level of carrot juice into skim milk by sensory evaluation using 9 point Hedonic scale (Mean $\pm$ SE) @

Inclusion level of carrot juice: skim milk (%)	Sensory attributes (9-point hedonic scale)				
	Colour and Appearance	Taste	Consistency	Flavor	Overall acceptability
Control (S ₁) skim milk	3.833 ^a $\pm$ 0.166	3.500 ^a $\pm$ 0.223	5.666 ^a $\pm$ 0.210	4.333 ^a $\pm$ 0.210	4.333 ^a $\pm$ 0.123
CS ₁ (20:80)	6.500 ^b $\pm$ 0.223	6.833 ^b $\pm$ 0.166	6.666 ^b $\pm$ 0.210	6.666 ^b $\pm$ 0.210	6.666 ^b $\pm$ 0.052
CS ₂ (30:70)	6.666 ^b $\pm$ 0.210	6.666 ^b $\pm$ 0.210	6.833 ^b $\pm$ 0.166	7.166 ^b $\pm$ 0.166	6.833 ^b $\pm$ 0.052
CS ₃ (40:60)	8.666 ^d $\pm$ 0.210	8.500 ^c $\pm$ 0.223	8.333 ^c $\pm$ 0.210	8.666 ^c $\pm$ 0.210	8.541 ^d $\pm$ 0.076
CS ₄ (50:50)	7.500 ^c $\pm$ 0.223	8.166 ^c $\pm$ 0.166	8.166 ^c $\pm$ 0.166	8.166 ^c $\pm$ 0.166	8.000 ^c $\pm$ 0.091
F value	73.53**	97.78**	32.87**	75.37*	375.99**

@Average of six trials

Statistically highly significant (Pd⁰0.01)* Statistically significant (Pd⁰0.05)Means bearing various superscripts in the same column differs highly significantly (Pd⁰ 0.01)Table 2** Nutrient composition of control (S₁), carrot juice (C₁) and CS₃ (Mean $\pm$ SE) @

Treatments	Nutrient composition on dry matter basis (%)							
	Total Solids (TS)	Moisture	Fat	Protein	Fibre	Ash	NFE	SNF
Control (S ₁)	9.420 $\pm$ 0.082	90.580 $\pm$ 0.082	0.500 $\pm$ 0.024	3.520 $\pm$ 0.550	ND	0.650 $\pm$ 0.019	4.750 $\pm$ 0.028	8.920 $\pm$ 0.058
Carrot juice (C ₁)	8.070 $\pm$ 0.066	91.930 $\pm$ 0.066	0.920 $\pm$ 0.035	1.400 $\pm$ 0.049	0.583 $\pm$ 0.033	0.320 $\pm$ 0.031	4.846 $\pm$ 0.073	-
CS ₃	8.820 $\pm$ 0.017	91.180 $\pm$ 0.017	0.660 $\pm$ 0.012	2.710 $\pm$ 0.023	0.260 $\pm$ 0.015	0.530 $\pm$ 0.007	4.660 $\pm$ 0.054	-

@Average of six trials

ND- Not Detected

compared to the control was presumed to be due to the hygroscopic nature of the sugars present in the carrot milk powder. The results agree with Moreira et al. (2009) who studied spray drying of acerola pomace extract and found that the moisture per cent in the spray dried extract with inlet temperature of 170°C was reported as 5.43 $\pm$ 0.25 per cent. The findings almost agree

with the results obtained by Narayanan *et al.* (2012) who reported that the moisture per cent in nutraceutical whey based malt drink spray dried at 170°C was 4.85 $\pm$ 0.02 per cent. It was found that having increasing the temperature beyond 175°C caused charring and deposition of the charred particles on the spray drier and

hence 175°C was fixed as the ideal temperature for spray drying of the CS mix.

Physical parameters of carrot milk powder (CMP)

Table 4 showed highly significant difference ($P < 0.01$) in the physical properties between of spray dried control (SMP) and carrot milk powder (CMP) prepared at optimal conditions used for spray drying of CMP.

In the present study carrot milk powder (CMP) showed loose and packed bulk density values lesser than Patil et al. (2014) who

investigated the physical properties of spray dried guava powder for loose and bulk density and reported values 0.75- 0.78 g/ml and 0.88- 0.93 g/ml respectively. Bulk density depends on moisture content and particle size. A high bulk density is preferred in order to reduce the shipping volume, saving packing material and increasing storage capacity. The findings in this study is lower than the bulk density proposed for non-fat dry milk as 0.56 g/cc, millet as 0.64g/cc (www.niro.com.gea). The values for loose and packed bulk density of CMP in the present study were higher than the loose bulk density (0.42 g/cc) and lower than the packed bulk density (0.69 g/cc) of soy-whey beverage powder reported

Table 3 Moisture per cent in control (SMP) and carrot milk powder (CMP) at different inlet temperatures (Mean± SE) @

Inlet temperature	Moisture % SMP	Moisture % CMP	t- test
165°C	4.875 ^{ba} ±0.017	6.174 ^{bb} ±0.041	28.79**
170°C	4.326 ^{aa} ±0.012	5.204 ^{ab} ±0.014	36.28**
175°C	4.308 ^{aa} ±0.015	5.144 ^{ab} ±0.034	22.16**
F value	462.73**	318.36**	

@Average of six trials

**Statistically highly significant ($P < 0.01$)

Means bearing various superscripts in the same row differs highly significantly ($P < 0.01$)

Means bearing various superscripts in the same column differs highly significantly ($P < 0.01$)

Small case shows difference between treatments

Upper case shows difference between samples

Table 4 Physical parameters@ of control (SMP) and carrot milk powder (CMP) (Mean± SE) @

S. No	Physical Parameters	SMP	CMP	t- test
1	Loose Bulk Density g/ml	0.380 ^a ±0.005	0.535 ^b ±0.008	86.09**
2	Packed bulk density g/ml	0.540 ^a ±0.020	0.606 ^b ±0.003	36.37**
3	Insoluble index (ml)	1.300 ^a ±0.031	2.280 ^b ±0.073	12.25**
4	Water activity	0.230 ^a ±0.003	0.378 ^b ±0.003	196.46**

@Average of six trials

**Statistically highly significant ($P < 0.01$)

Means bearing various superscripts in the same row differs highly significantly ($P < 0.01$)

Upper case shows difference between samples

Table 5 Nutrient composition of carrot milk powder (CMP) (Mean± SE) @

Nutrients	Recommended daily intake by ICMR (2010) 6-12 months	Recommended daily intake by ICMR (2010) Adults	ADPI recommendation (2006) for Skim Milk Powder (SMP) standard	Carrot milk powder(CMP)
Protein min. g/100g	1.69 g/ kg/d	55-60 g/day	34	28.54±0.278
Fat g/100g	19g/day	20 g/day	1.5	3.90±0.068
Fibre min. g/100g	—	—	—	1.73±0.027
Beta carotene mg/100g	2800 mg/day	4800 mg/day	—	2.038
Vitamin A mg/ 100g (min)	350	600	—	0.01
Total Polyphenol compounds (as Gallic acid) mg/100g	—	—	—	220

@Average of six trials

by Patil (1980).

The mean values of insolubility index in SMP and CMP in the present study were 1.300 ± 0.031 ml and 2.280 ± 0.073 ml respectively showing highly significant difference.

In the present study highly significant difference ($P < 0.01$) was noticed in the mean water activity in SMP (0.230 ± 0.003) and CMP (0.378 ± 0.003). Most foods have the a_w level in the range of 0.2 for very dry foods to 0.99 for moist fresh foods (www.foodscience.csiro.au/water). The a_w value in the present study is slightly more than the value prescribed for dry foods which might be due to the hygroscopic nature of the sugars present in the carrot powder and less than the value of enteral formulation prepared by Dhruti et al. (2009) who concluded that the enteral immune enhancing formulation had a water activity of 0.4 per cent.

Nutrient composition of carrot milk powder (CMP)

Table 5 shows the nutrient composition of spray dried carrot milk powder (CMP). The carrot milk powder contains more fat than the minimum required ADPI (1999) level for standard skim milk powder. The fibre, beta carotene, vitamin A and total polyphenol compounds were more in the developed carrot milk powder when compared with SMP. However, the protein per cent is less in CMP compared with SMP. This might be attributed due to the reduced level of protein in CS_3 , compared to that of skim milk. The fat and protein contents in carrot milk powder agree with the results obtained by Narayanan et al. (2012) who reported the nutrient composition of nutraceutical whey based malt food as fat (3.22 g/100g), protein (23.35 g/100g). The beta carotene content in the carrot milk powder was found to be 2.038 mg/100g.

Conclusions

Inclusion of carrot juice into skim milk at 40 per cent level (CS_3) was found acceptable by sensory evaluation. The optimum spray dried inlet and outlet temperature was standardized at 175°C and 60°C respectively after assessing the required moisture content. The estimated moisture content of the carrot milk powder was $5.144 \pm 0.034\%$. The physical properties of CMP were 0.535 ± 0.008 g/ml for loose bulk density, 0.606 ± 0.003 g/ml for packed bulk density, 2.280 ± 0.073 ml for insoluble index and 0.378 ± 0.003 for water activity. The micro nutrient composition of CMP for Beta carotene and Vitamin A was 2.038 mg/100g, 0.01 mg/100g respectively and thus carrot milk powder can be concluded to be a product rich in carotene which is ideal for consumption by all age groups.

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