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Development of spray dried orange juice blended skim milk powder

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Abstract – The contemporary problem faced by the fruit and dairy sectors in developing countries is the lack of a basic infrastructure for handling the deluge in production. Several technologies and innovations have been devised to conserve and utilize the products individually in food formulations and to some extent in combination. Further, additional investigations are required to explore the feasibility of vitamin C enrichment of milk, which could be effectively achieved by incorporation of orange juice. Blends with different levels of orange juice and skim milk were spray dried, viz., 10:90, 15:85, 20:80 and 25:75 at feed temperatures of 45–50 ºC and compressed air pressure of 0.108–0.136 MPa. It was observed that the various processing parameters, such as outlet air temperature, total solids and blend proportions had a profound effect on the characteristics of the resultant powder. As the proportion of juice increased, the acidity and viscosity of the blends increased due to the high citric acid content of the juice. However, an increase in the acidity had no negative effect on the thermal stability of the blends before or after spray drying, due to the low feed temperature (45 ºC) used in the study. It was found that increments in the inclusion of orange solids had a negative effect on the resultant yield of the powder. The increase in solids of the blends up to 30% resulted in a steep increase in the yield, which was adjudged as the optimal total solids for drying the blends. Further increase in total solids of the blends resulted in reduced yields. The outlet air temperatures of the spray drier were optimized at a temperature range of 80–85 ºC for all blends. Sensory evaluation studies affirmed that the blend with a 15:85 ratio of orange juice: skim milk, respectively, possessed the desired sensory characteristics.

Orange juice / skim milk powder / spray drying / vitamin C / sensory evaluation

Résumé – **Développement d'une poudre à partir d'un mélange jus d'orange-lait écrémé séché par atomisation.** Le problème actuel rencontré par les secteurs des fruits et du lait dans les pays en voie de développement est le manque d'infrastructures de base pour traiter l'afflux de production. Plusieurs technologies et innovations ont largement été mises au point pour les conserver et les

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utiliser individuellement dans les formulations d'aliments, mais beaucoup moins en combinaison. De plus, des recherches sont encore nécessaires pour explorer la faisabilité de l'enrichissement du lait en vitamine C, ce qui pourrait se faire effectivement par l'incorporation de jus d'orange. Des mélanges à différents taux de jus d'orange et de lait écrémé ont été séchés par atomisation, i.e. 10:90, 15:85, 20:80 et 25:75, à une température d'alimentation de 45–50 °C et une pression d'air comprimé de 0,108–0,136 MPa. Il a été observé que les différents paramètres opératoires tels que la température de sortie de l'air, la teneur en matière sèche totale et les proportions du mélange avaient un effet important sur les caractéristiques de la poudre résultante. Quand la proportion de jus d'orange augmentait, l'acidité et la viscosité des mélanges augmentait également en raison de la teneur élevée du jus en acide citrique. Cependant, une augmentation de l'acidité n'avait pas d'effet négatif sur la stabilité thermique des mélanges avant et après séchage par atomisation, étant donné la température d'alimentation peu élevée (45 °C) utilisée dans l'étude. L'augmentation de l'apport de matière sèche d'orange avait un effet négatif sur le rendement de la poudre obtenue. L'augmentation de matière sèche des mélanges jusqu'à 30 % résultait dans une augmentation considérable du rendement et était donc adoptée comme teneur optimale en matière sèche des mélanges avant séchage. Des augmentations supérieures de la matière sèche des mélanges conduisaient à une réduction des rendements. Les températures de sortie d'air des équipements de séchage étaient optimisées dans une gamme de température de 80–85 °C pour tous les mélanges. Les études d'évaluation sensorielle ont montré que le mélange jus d'orange/lait écrémé dans un rapport 15:85 présentait les caractéristiques sensorielles désirées.

Jus d'orange / lait écrémé / poudre / séchage par atomisation / vitamine C / caractéristique sensorielle

1. INTRODUCTION

There is an ever-increasing milk production worldwide. India has become the world's largest milk-producing country with an estimated output of 74.5 million tons in 1998 [4]. This phenomenal rise in milk production is not supported well by the existing infrastructure in India to handle fluid milk. The processing plants and associated chilling centers in many instances are handling quantities above their rated capacities. This milk can effectively be converted into milk powder, which acts as a milk balance during the lean season to meet consumer demands and exports. Similarly, in the fruit and vegetable sectors in most of the developing countries, there are reports of high losses. In India alone an estimated loss of around 30000 million Indian Rupees (around 638 million US $) worth of fruits and vegetables was recorded, despite the fact that India produces around 50 to 60 million tons of fruits and vegetables. This problem largely persists in India due to overproduction, lack of planning for packaging and distribution, besides inadequate infrastructure to store the fruit in its natural state. The cost of storage is very high and refrigeration technology has not caught on. Considering the contemporary problems faced by the fruit and dairy sectors, including the lack of a basic infrastructure for handling the deluge in production, one response is the employment of preservation drying techniques, applied to formulate a ready to reconstitute dried product using orange juice-skim milk blends. Several technologies and innovations have been devised extensively to conserve and utilize these products individually in food formulations, and to a small degree in combination. Considering the limited studies in utilizing and conserving these products in combination, as suggested by [1], an attempt was made here to investigate a similar idea using spray drying techniques. Further, the vitamin C deficiencies of milk can be compensated for by orange juices, which are a rich source of ascorbic acid [5]. In view of the above, the objectives included in the investigation were to optimize the processing parameters for production of orange juice blended skim milk powder and to study the physico-chemical and sensory characteristics of the resultant powders.

2. MATERIALS AND METHODS

Orange juice concentrate with 60% total solids was procured from Karnataka Agro-Industries Corporation Ltd, Bangalore, India. Skim milk was procured from the Dairy Farm, University of Agricultural Sciences, Bangalore. Skim milk was condensed using a pilot-scale Anhydro (Anhydro, Copenhagen, Denmark) evaporator by evaporating the skim milk at temperatures between 55 and 60 ºC with vacuum of 400 mm Hg, to one third the original volume to obtain a total solids level of between 30 and 35%. The experimental samples of orange juice-skim milk blends were made by blending orange juice concentrate with condensed skim milk for convenience, with the proportions at the rate of 10:90, 15:85, 20:80 and 25:75 of orange juice and skim milk, respectively, at temperatures not exceeding 45 ºC. An empirical formula was devised to make the blend proportions in terms of ratios of orange juice: skim milk blends. In order to obtain a good quality orange juice blended skim milk powder, various combinations of processing parameters were studied. The blends were dried using a pilot-scale Anhydro (Copenhagen, Denmark) two fluid nozzle spray drier at various total solids levels, viz., 20, 25, 30 and 35 percent and inlet temperatures of 75–80, 80–85, and 85–90 ºC. The drier had a water evaporation capacity of 7–8 kg·h^{-1}. Before taking the feed, it was ensured that the inlet air temperature was stabilized to 180 ºC. The outlet air temperature was maintained at the desired levels by manipulating the compressed air pressure, and subsequently adjusting the feed rate. To standardize the compressed air pressure and feed temperature, a 20:80 blend was spray dried at 30% total solids. The compressed air pressures used were 0.068–0.102 MPa, 0.108–0.136 Mpa and 0.14–0.17 MPa, with feed temperatures of 40, 45, 50 and 55 ºC. The standard control for the study was that of 0:100 (pure skim milk) dried at 30% TS and its yield was considered as 100%. In this investigation, relative yield above 70% was considered as satisfactory output, whereas those below 70% were considered as low outputs. The batch size for all the trials was 1.5 kg of the blend (Feed).

From the various samples that were obtained during the process optimization trials, representative samples of the 4 proportions with the best attributes were selected, based on organoleptic and quantitative observations. These representative powder samples were subjected to various physico-chemical and sensory attributes. A panel of 5 trained judges performed sensory evaluation.

3. RESULTS AND DISCUSSION

The effect of various parameters, such as blend proportions, feed temperature, compressed air pressure, TS of the feed and outlet temperature on the relative yield of the resultant powder was studied, considering the fact that they were responsible for the overall quality of the powder.

3.1. Feed temperature and compressed air pressure

The effect of compressed air pressure and feed temperatures are given in Table I. From the table it is clear that the most acceptable feed temperature was 45 ºC at an air pressure range of 0.108–0.136 MPa. It can be noted that higher air pressures (0.14–0.17 MPa) were not acceptable at all levels of feed temperature. Feed temperature above 50 ºC at compressed air pressures of 0.068–0.102 MPa and 0.108–0.136 MPa resulted in clogging of the nozzle during the operation. A high feed temperature of the

Table I. Effect of feed temperature and compressed air pressures on the yields of powders.

CAP / FT	40 °C	45 °C	50 °C	55 °C
10–15 PSI	LO, CK	LO	LO	LO, CL
16–20 PSI	SO, CK	SO	LO	LO, CL
21–25 PSI	HP	HP	HP	HP

FT: Feed temperature; CAP: Compressed air pressure; CL: Clogging of the nozzles; CK: Caking; HP: Unacceptable high pressure considering drying chamber height constraint; LO: Low output (< 70% relative yield); SO: Satisfactory output (> 70% relative yield).
All samples were 20:80 blends with 30% TS.

blends (⩾ 50 °C) caused an increase in viscosity, and resulted in clogging of the spray nozzle. This can be substantiated by the information provided by [3], who stated that the droplet size varies directly with feed liquid viscosity. On the other hand, feed temperature below 45 °C encountered caking problems at compressed air pressure ranges of 0.068–0.102 and 0.108–0.136 MPa.

It can be noted that droplet size is related to the change in density and surface tension during viscosity changes of the feed at a constant feed rate and nozzle pressure, affecting the spray drying process. [3] found that an increase in viscosity resulted in a larger particle size, which subsequently reduced the surface area between the droplet and drying medium (hot air), resulting in improper drying of the product. Hence the low feed temperature of 45 °C was employed in this study. The compressed air pressure was optimized to 0.108–0.136 MPa after preliminary studies. To overcome the problem of development of high viscosity of the feed, [3] suggested a reduction in the TS level, with or without an increase in the temperature of the feed. In this study the situation was found to be much too complex to accept these conventional methods. Hence the temperatures of the feed were maintained at relatively low levels, since it was a highly acidic product.

3.2. Blend proportions

Five levels of orange juice-skim milk blends were tried, and their effect on relative yield is depicted in Table II. The effect of total blend proportions on the relative yield was significantly different *($P < 0.05$)* between the various levels of dried blends. Among these blends, the highest yield was recorded in the control (0:100), followed by 10:90. It can be noted that as the proportion of orange juice increased, the relative yield decreased, the lowest one being 25:75. Most of the difficulties associated with spray drying of the blends are related to the viscosity of the blend feeds. The viscosities of the blends were directly related to their acidities and pH. High viscosity had a negative effect on the spray drying process, such as clogging of the nozzle. The steep drop in yield between the 20:80 and 25:75 proportions of these blends is attributed to the phenomenal increase in viscosity of the blends.

Table II. Effect of orange juice proportion on the relative yield of powders.

Blend proportions (Orange juice:skim milk)	Relative yield (%)
Control (0:100)	79.92^{e}
10:90	65.63^{d}
15:85	58.05^{c}
20:80	53.05^{b}
25:75	31.19^{a}
Critical difference	0.89
Correlation coefficient	–0.95

Within the right column, mean values bearing at least one common superscript are statistically similar ($P < 0.05$).
Values indicated are mean values of 3 replications.

3.3. Effect of total solids (TS)

The effect of TS of the feed on the relative yield is recorded in Table III. It can be noted from the table that % TS of the feeds has a significant effect ($P < 0.05$) on the relative yield of the powder. The highest yield was obtained at 30% TS and the lowest one was recorded at a 20% TS level. Further, there was a marginal, but significant decrease in relative yield when TS was increased from 30 to 35%. The increase in yield with an increase in TS confirmed the trends indicated by [6], who observed that an increase in TS in condensed milk proportionally improved the spray drying process of milk, with the only constraint being the viscosity of the feed. The drop in the yield when TS was increased from 30 to 35% could be attributed to the high viscosity associated with a blend at this TS level, which had a negative effect on the spray drying process.

Table III. Effect of total solids on the relative yields of orange juice blended skim milk powders.

Total solids ($g \cdot 100\ mL^{-1}$)	Relative yield (%)
20	24.27^{a}
25	50.69^{b}
30	68.72^{d}
35	64.25^{c}
Critical difference	0.89
Correlation coefficient	0.89

Within the right column, mean values bearing at least one common superscript are statistically similar ($P < 0.05$).
Values indicated are mean values of 3 replications.

3.4. Interaction effects of blend proportions and TS

The effect of interaction between blend proportion and total solids (TS) on the relative yield was significantly different ($P < 0.05$) (Tab. IV). The control at 35% TS recorded the highest yield, whereas the lowest yield was observed in 25:75 at a 20% TS level. It can be noted from the table that the optimal TS for blends ranging from 15:85 to 25:75 was 30% and for 10:90 it was 35%. The general trend suggests that there was an increase in the relative yield with an increase in the TS level up to 30%. Further increase in the TS level up to 35% was suitable only for a low proportion of orange solids in the blends (10:90).

Table IV. Interaction effects of orange juice proportion and total solids on the relative yields of spray dried orange juice blended skim milk powder.

	Blend proportions (Orange juice:skim milk)				
Total solids ($g \cdot 100\ mL^{-1}$)	Control (0:100)	10:90	15:85	20:80	25:75
20	47.63^{a}	37.33^{a}	22.88^{a}	27.11^{a}	9.77^{a}
25	68.20^{b}	61.44^{b}	59.77^{b}	48.22^{b}	33.33^{c}
30	78.20^{c}	74.11^{c}	76.00^{d}	73.66^{d}	51.11^{d}
35	93.66^{d}	89.66^{d}	73.55^{c}	63.22^{d}	30.55^{b}
Critical difference			1.79		

Within a column, mean values bearing at least one common superscript are statistically similar ($P < 0.05$).
Values indicated are mean values of 3 replications.

3.5. Effect of outlet air temperature

The effect of outlet air temperature during spray drying of orange juice – skim milk blends is given in Table V. It can be observed that outlet air temperature has a significant effect ($P < 0.05$) on the relative yield. The highest yield was obtained at outlet air temperatures of 80–85 °C, whereas the lowest yield was recorded at temperatures of 70–75 °C. There is a steady rise in the relative yield with an increase in the outlet temperature from 70–75 °C to 80–85 °C. This can be attributed to the fact that a low outlet air temperature resulted in improper drying, resulting in a high moisture content of the powder. High moisture powders stick to the wall of the drying chamber, resulting in lower yields. This trend is in agreement with earlier reports by [2, 7].

Table V. Effect of outlet air temperature on the relative yields of orange juice blended skim milk powders.

Outlet air temperature (°C)	Relative humidity (%)
70–75	45.56^{a}
75–80	52.89^{b}
80–85	57.50^{c}
Critical difference	0.77^{d}
Correlation coefficient	0.99

Within the right column, mean values bearing at least one common superscript are statistically similar ($P < 0.05$).
Values indicated are mean values of 3 replications.

3.6. Sensory evaluation of the orange juice blended skim milk powders

A panel of 5 in-house judges evaluated the powder samples of various proportions of orange juice: skim milk. From Table VI it can be observed that the powder produced from 15:85 blends was adjudged to be the best quality product among the various optimized blends. From the table it is clear that the flavor scores were highest in the 15:85 blend of powder, while the lowest scores were recorded for the 25:75 blends. Further, it can be opined that blend proportions with orange solids above the 15:85 level showed a progressive reduction in the flavor scores. General comments by the judges suggested that the 15:85 blend had a very pleasant and optimal flavor level and the blends with higher orange solids were less acceptable due to a strong aftertaste. The judges felt that the 10:90 blend lacked a distinct orange flavor. The dry appearance scores for the various powders indicated the highest scores for the 15:85 blend and the lowest scores against the 25:75 blends. The scores suggested that in blend proportions with high orange juice solids at 20:80 and 25:75 levels there was progressive reduction in the appearance scores. The general

Table VI. Sensory evaluation of orange juice blended skim milk powders.

Proportion of blend (Orange juice:skim milk)	Flavor score (Max 65)	Appearance score (dry) (Max 15)	Appearance score (reconstituted) (Max 15)
10:90	58.2	12.6	13.0
15:85	61.8	14.0	13.0
20:80	57.2	10.6	12.6
25:75	54.8	8.6	9.6

Values indicated are means of the scores provided by a panel of 5 judges.

comments cited by the judging panel included unacceptable dark color with lumps as defects for powders with high orange proportions. The general perception of the 15:85 powder was that it had an attractive lighter orange color, and was free of lumps and scorched particles. The immediate second choice was that of the 10:90 blend, although it was observed to have low color. The reconstituted appearance scores of the powders suggested that both the 10:90 and 15:85 blends were almost the same, with high scores. The lowest scores were obtained by the 25:75 blend. The major defects observed by the panelists included uneven color, scorched particles, brown specks and sedimentation in blends with higher proportions of orange solids.

4. CONCLUSIONS

Among the blends with different levels of spray dried orange juice and skim milk, the blend with a 15:85 ratio of orange juice:skim milk, respectively, was found to possess desirable physical, chemical, reconstitution and sensory characteristics. The processing parameters during spray drying of the orange juice-skim milk, such as pre-heating, total solids level, compressed air pressure and inlet-outlet temperatures were standardized. Pre-heating temperatures of 45 ºC with compressed air pressure of 0.108–0.136 MPa and inlet-outlet temperatures of 180 ºC/80–85 ºC, respectively, at total solids of between 25 and 30%, gave very good results in terms of physico-chemical and sensory attributes. The potential target industries for the spray dried orange juice blended skim milk powder would be ice cream, yogurt and non-alcoholic beverage manufacturing units. Here the powders would serve as a perennial source of milk solids with the benefits of ready-to-use products.

To conclude, the physico-chemical properties for defining optimal spray dried 15:85 orange juice-skim milk powder are:

1. Appearance: Uniform color light yellow with no dark specks or burnt/scorched particles. The resultant powder is not very hygroscopic, showing a smooth surface without wrinkles with the usual spherical surface.

2. Moisture content between 4 and 5%.

3. Reconstitutability in water reasonably high.

4. Acidity between 280 and 320 m eq/g with corresponding pH of 6.0–6.3.

5. Particle size between 100 and 250 $\mu mol \cdot L^{-1}$.

6. Optimum bulk density of 0.51–0.64 $g \cdot mL^{-1}$.

7. Insolubility index not exceeding 2.5 mL.

8. Dispersability not less than 85%.

9. Yield: Satisfactory yield as compared with that obtained by spray drying control skim milk powder.

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