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Investigation of Effect of Spray Drying on Quality Characteristics of Probiotic Apple Juice Powder

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A study was carried out to investigate the effect of spray dryer variables namely atomizer type and inlet air temperature and additive type on the various quality attributes of probiotic apple juice powder. The results revealed that increasing inlet air temperature from 150°C to 170°C reduced the moisture content, bulk density, water activity, survival of *Lactobacillus acidophilus* and increased the solubility of the spray dried probiotic apple juice powder. The moisture content, bulk density and water activity of the spray dried probiotic apple juice powder ranged between 1.93 and 4.92 per cent (w.b), 0.416 and 0.693 g/cm^3 and 0.236 and 0.391 respectively. Among the atomizers and additive materials studied, rotary wheel atomizer and maltodextrin showed reduced level of moisture content, bulk density and water activity compared to gum arabic and twin fluid pressure nozzle atomizer. It was evident from the results that, gum arabic added probiotic apple juice, spray dried using rotary wheel atomizer recorded the highest solubility value. The maximum survival (*L.acidophilus*) of 31.43 per cent was achieved for the powder obtained using twin fluid pressure nozzle atomizer, 150°C inlet air temperature and maltodextrin as additive material. Compared to gum arabic and rotary wheel atomizer, maltodextrin and twin fluid pressure nozzle atomizer showed good survival of *L.acidophilus*. Based on the above results, maltodextrin, rotary wheel atomizer and 160°C inlet air temperature were optimized for spray drying of probiotic apple juice.

Key words: Apple juice, spray drying, *Lactobacillus acidophilus*

Probiotics are defined as "live microorganisms which when administered in adequate amounts confer a health benefit on the host" (Anonymous, 2002). At present, it is generally recognized that an optimum 'balance' of microbial population in our digestive tract is associated with good nutrition and health (Rybka and Kailasapathy, 1995). The microorganisms primarily associated with this balance are *lactobacilli* and *bifidobacteria*. Increasing evidence of health benefits of probiotics indicates that consumption of 'probiotic' microorganisms can help to maintain such a favourable microbial profile and results in several therapeutic benefits. Consumption of probiotic bacteria via food products is an ideal way to re-establish the intestinal microflora balance. Adequate numbers of viable cells, namely the 'therapeutic minimum' needs to be consumed regularly for transfer of the 'probiotic' effect to consumers.

Fruit juice has recently been suggested as a good medium for functional ingredients such as probiotics (Tuorila and Cardello, 2002) because it has a wide consumer appeal and is generally recognized as a healthy product. Furthermore, fruits do not contain any dairy allergens that might prevent usage by certain segments of the population (Luckow and Delahunty, 2004). Methods of production of probiotic fruit juice powders should be such that adequate numbers of viable probiotic bacteria are maintained in the dried powder following manufacture, and also retention/stability of probiotic properties should be ensured throughout the shelf-life of powder. Both freeze-drying and spray-drying can be used for manufacture of probiotic fruit juice powders on a large scale. Freeze drying is an expensive process with low yields, where as spray drying offers an alternative inexpensive approach yielding higher production rates. It is one of the common methods used to prepare food adjuncts which are dry, stable and occupy small volume.

Drying is the one in which the probiotic apple juice powder properties are defined, what makes the domain of the employed technology essential in obtaining a high-quality product. The quality of spray-dried food is quite dependent on the spray-dryer operating parameters and these quality aspects determine its acceptance in the market. Hence, the Probiotic apple juice powder quality should be quantified by the relationship between the operational process variables that best describe these properties. This work is aimed at investigating the effect of spray dryer variables namely atomizer type and inlet air temperature and additive type on

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the various quality attributes such as moisture content, solubility, bulk density, water activity and survival of probiotic *L.acidophilus* of probiotic apple juice powder.

Materials and Methods

This study was carried out in the Department of Food and Agricultural Process Engineering, Agricultural Engineering College and Research Institute, Tamil Nadu Agricultural University, Coimbatore during 2007-2008. The apple fruits (Delhi apple) were purchased from local market and probiotic bacterium (*Lactobacillus acidophilus* MTCC447) was obtained from the MTCC (Microbial Type Culture Collection), Institute of Microbial Technology, Chandigarh, India. The additives gum arabic (food grade) and maltodextrin (DE = 20) were procured from M/s Viveka Agencies, Coimbatore for use in this study.

Probiotic apple juice preparation

The juice was prepared by using the mixer-grinder (Philips mixer grinder) and strained through the previously washed and dried muslin cloth. The filtered fruit juices were pasteurized at 72ºC for 15 s by keeping in a water bath (Genuine Equipment MFRS, Coimbatore) and allowed to cool until it reached 37ºC at room temperature. The probiotic culture was grown at 30ºC for 24 hours in de Man Rogosa Sharpe (MRS) broth and used as an inoculum. One per cent inoculum of probiotic bacterial culture was pipetted out using a micropipette and distributed into fruit juice and mixed thoroughly. The probiotic fruit juice was incubated at 37ºC (Prajapati *et al*., 1986) by keeping it in a BOD incubator (Genuine Equipment MFRS, Coimbatore) for 48 hours for encouraging faster multiplication of probiotic bacteria.

Spray drying of probiotic apple juice

Drying studies were conducted in a pilot model vertical co-current type spray drier (M/s GOMA Engineering Private Ltd, Mumbai, India) having a water evaporation capacity of 1.5 kg/h (Fig.1). For the optimization of process parameters for the production of probiotic apple juice powder the independent variables selected were inlet air temperature of spray drier (150, 160 and 170ºC), type of nozzle used in spray drier (Rotary wheel atomizer and Twin fluid pressure nozzle atomizer) and additives (Maltodextrin (DE 20) and Gum Arabic (20 % w/v)) and water activity, bulk density, moisture content, solubility and survival of probiotic bacteria were selected as dependent variables. The results were statistically analyzed to optimize the process parameters in the spray dryer that produced a best quality probiotic apple juice powder.

Operational conditions of the spray drier

Rotary wheel atomizer

Rotational speed of the atomizer 18,000 rpm, feed rate 1.5 L/h, air flow rate 110 kg/h and different air inlet temperatures of 150, 160 and 170°C.

Twin fluid pressure nozzle atomizer

The pressure of compressed air flow of the spray was adjusted to 5 bars (Shaikh *et al*., 2006), feed rate 1.5 L/h, air flow rate 110 kg/h and different air inlet temperatures of 150, 160 and 170°C.

Physico-chemical analysis

Physico-chemical and microbiological analysis are very much important to assess the quality of fresh and spray dried fruit juice. It is important to evaluate the relative loss in quality during drying and storage. The various physico-chemical analyses *viz*., moisture content, water activity, bulk density, solubility and microbiological analysis were carried out by adopting standard methods.

Analysis of spray dried probiotic apple juice powder

Water activity

The concept of water activity is important in determining product quality and safety in a particular environment. Water activity meter (M/s Aqua Lab, USA) was used to measure the water activity of the spray dried probiotic fruit juice powder. The sample was taken in a container and placed the container in a sealed chamber. The knob was closed and the water activity of the probiotic fruit juice powder was recorded with respect to atmospheric temperature.

Bulk density

Bulk density of the probiotic fruit juice powder was determined by tapping method (Bhandari *et al.,* 1992). Two grams of powder was loosely weighed into 10 ml graduated cylinder. The cylinder containing the powder was tapped on a flat surface to a constant volume. The final volume of the powder was recorded and the bulk density was calculated by dividing the sample weight by volume.

$$\text{Bulk density } (g/cm^3) = \frac{\text{Weight of the probiotic fruit juice powder}}{\text{Volume of the sample}}$$

Moisture content (per cent w.b)

The moisture content of probiotic fruit juice powder was estimated as per the procedure described in Indian Standards Institution, (1981). Five grams of powder was accurately weighed into an aluminum dish with a cover previously dried and weighed. The dish containing the powder was heated uncovered in an oven at 98 ± 2 °C and cooled in a desiccator. The weight was taken with the cover on. The process of drying was repeated every three min until consecutive results showed not more than one mg difference. The per cent moisture was calculated from the loss of mass.

$$\text{Moisture content, } \% = \frac{\text{Final weight (g) - Initial wieght (g)}}{\text{Initial weight (g)}} \times 100$$

Solubility

Solubility was determined according to the method described by Chauca *et al* ., (2004). One gram of powder was added in 100 ml of distilled H_2O and mixed at high speed in a mixer for 5 min. The solution was placed in a tube and centrifuged (Plate 3.5) at 3000 × g for 5 min. An aliquot of 25 ml of the supernatant was placed in previously weighed petri dishes and immediately oven-dried at 105ºC, for 5hours. Solubility (per cent) was calculated by weight difference.

Enumeration of L.acidophilus

For bacteriological analysis, powders were sampled in duplicate and a 1 in 10 dilution was prepared by rehydrating 1 g of powder in 10ml sterile distilled water and incubating at room temperature for ~1h, prior to plating. Viability of probiotic bacteria in the powders was then assessed in duplicate on MRS pour plates after 3 days of incubation at 37°C. Per cent probiotic survival was calculated as N/N_0 x 100, where N_0 is the number of bacteria before drying and N is the number in the powder (both expressed as per gram of dry matter). MRS media was prepared according to the manufacturer's instructions and sterilized in the autoclave for 15 min at 121°C (Gardiner *et al*., 2002).

Results and Discussion

Effects of spray drying on the quality attributes of probiotic apple juice powder

The effects of spray drying on various quality attributes of probiotic apple juice powder viz., moisture content, solubility, bulk density, water activity and survival of probiotic *L.acidophilus were* statistically analyzed using factorial completely randomized block design (FCRD) and the results are tabulated and discussed below.

Table 1. Effect of atomizer type, inlet air temperature and additive type on the solubility of the probiotic apple juice powder

Additives	Per cent solubility of probiotic apple juice powder at various inlet air temperatures		
	150°C	160°C	170°C
Rotary wheel atomizer			
Maltodextrin	96.4	97.6	98.3
Gum arabic	97.4	98.7	99.1
Twin fluid pressure nozzle atomizer			
Maltodextrin	95.2	96.5	97.7
Gum arabic	96.2	97.4	98.5

Effect of atomizer type, inlet air temperature and additive type on the moisture content of the probiotic apple juice powder

The variables and their interactions for the treatments were statistically significant. Effect of additives, atomizer type and inlet air temperature on the moisture content of the probiotic apple juice powder samples is presented in Fig. 2. The moisture content of the probiotic apple juice powder ranged

Table 2. Effect of atomizer type, inlet air temperature and additive type on the bulk density of the probiotic apple juice powder

Additives	Bulk density (g/cm^3) of probiotic apple juice powder at various inlet air temperatures		
	150°C	160°C	170°C
Rotary wheel atomizer			
Maltodextrin	0.542	0.465	0.416
Gum arabic	0.571	0.492	0.454
Twin fluid pressure nozzle atomizer			
Maltodextrin	0.616	0.553	0.502
Gum arabic	0.693	0.600	0.578

between 1.93 and 4.92 per cent (w.b). Among the additives and nozzles studied, probiotic apple juice spray dried with maltodextrin using rotary wheel atomizer showed reduced moisture content when compared to probiotic apple juice spray dried with

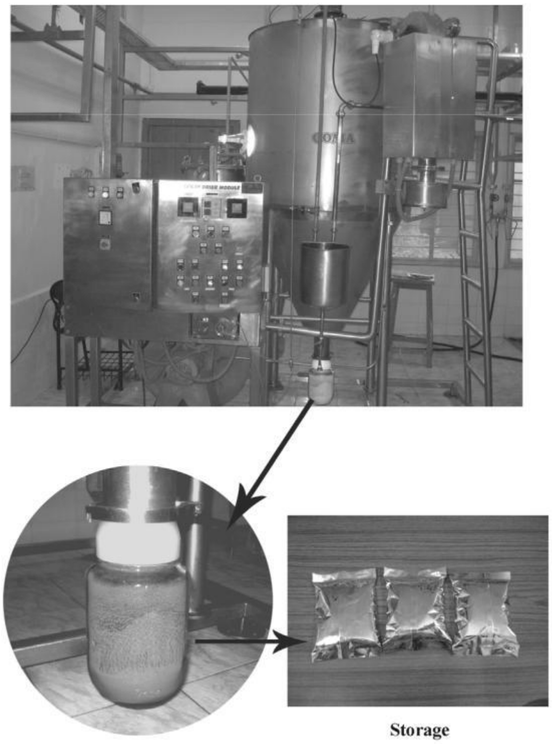

Fig. 1. Production of probiotic apple juice powder in the spray drier

gum arabic using twin fluid pressure nozzle atomizer.

From figure 2, it can also be seen that increasing inlet air temperature gradually reduced the moisture content of the spray dried probiotic apple juice powder. This might be due to the increased drying rate at higher inlet air temperature. Similar types of results for spray dried *Lactobacillus acidophilus* with milk solids-not-fat were reported by Espina and Packard, (1979). The probiotic apple juice powder obtained using twin fluid pressure nozzle atomizer and gum arabic as additive material at 150°C inlet air temperature recorded the highest moisture

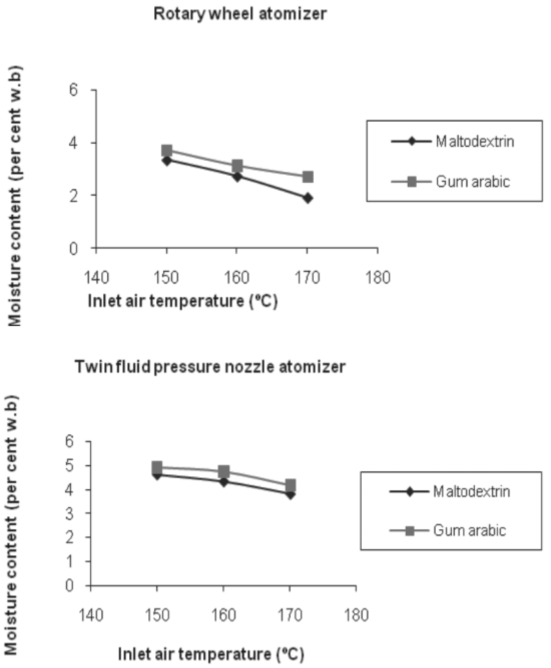

Figure 2. Effect of atomizer type, inlet air temperature and additive type on the moisture content of the probiotic apple juice powder

content of 4.92 per cent (w.b). Lowest moisture content of 1.93 per cent (w.b) in probiotic apple juice powder was recorded when the air inlet temperature in the spray drier was 170°C, fitted with rotary wheel atomizer and maltodextrin used as additive material.

Table 3. Effect of atomizer type, inlet air temperature and additive type on the water activity of the probiotic apple juice powder

Additives	Water activity of probiotic apple juice powder at various inlet air temperatures		
	150°C	160°C	170°C
Rotary wheel atomizer			
Maltodextrin	0.307	0.284	0.236
Gum arabic	0.347	0.291	0.288
Twin fluid pressure nozzle atomizer			
Maltodextrin	0.376	0.294	0.278
Gum arabic	0.391	0.314	0.293

Effect of atomizer type, inlet air temperature and additive type on the solubility of the probiotic apple juice powder

Among the treatments, significant differences were observed in all the variables but there were no significant differences found in their interactions except atomizer type and inlet air temperature. Effect of additives, atomizer type and inlet air temperature on the solubility of the probiotic apple juice powder samples is presented in Table 1. It was observed from the values that solubility of the probiotic apple juice powder ranged between 95.2 and 99.1 per cent and the powder obtained from the rotary wheel atomizer recorded the highest solubility value. Also among the additives, gum arabic added probiotic apple juice spray dried powder recorded higher solubility values than the maltodextrin irrespective of the nozzle type and inlet air temperature. This might be due to the lower moisture content level of gum Arabic.

The results indicated that the solubility of the probiotic apple juice powder increased with increase in the inlet air temperature. The increase in solubility of the probiotic apple juice powder is attributed to the increase in the inlet air temperature resulting in the decrease in the bulk density and availability of more surface area of the probiotic apple juice powders in this range. These results are in confirmation with the findings obtained for β – carotene powder by Rao (1993).

Effect of atomizer type, inlet air temperature and additive type on the bulk density of the probiotic apple juice powder

Significant differences were observed among the variables and their interactions. Effect of additives, atomizer type and inlet air temperature on the bulk density of the probiotic apple juice powder samples is presented in Table 2. From this table, it is evident that the bulk density of probiotic apple juice powder varied from 0.416 to 0.693 g/cm3. Among the different treatments studied, bulk density was maximum (0.693 g/cm3) in probiotic apple juice spray dried with gum arabic using twin fluid pressure nozzle atomizer at an inlet air temperature of 150ºC. The minimum bulk density (0.416 g/cm3) was recorded in probiotic apple juice spray dried with maltodextrin using rotary wheel atomizer at 170ºC

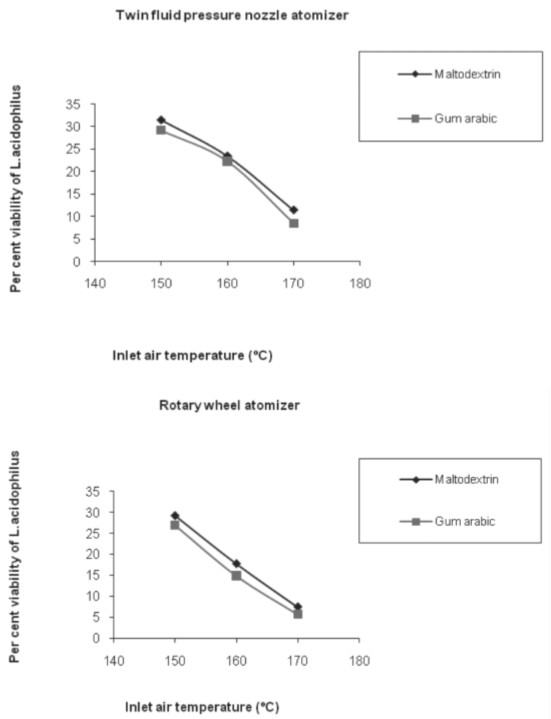

Fig. 3. Effect of atomizer type, inlet air temperature and additive type on the survival of *L. acidophilus* in the probiotic apple juice powder

inlet air temperature. It was also observed from the results that the bulk density of the probiotic apple juice powder obtained from the rotary wheel atomizer recorded the lower values ranging between 0.416 to 0.571 g/cm^3 than the powders obtained using twin fluid pressure nozzle atomizer and it ranged between 0.502 to 0.693 g/cm^3. Lower bulk density of the probiotic apple juice powder obtained using rotary wheel atomizer could be attributed to the lower moisture content level of the powders obtained from the atomizer. Among the additive materials studied maltodextrin recorded the lower bulk density values with respect to the inlet air temperature compared to the gum arabic.

It was clear from the results that the bulk density of probiotic apple juice powder decreased with increase in inlet air temperature irrespective of the additive material and atomizer type. This might be due to the fact that a product of higher moisture content would tend to have a higher bulking weight caused by the presence of water which is considerably denser than the dry solid. Similar results were reported by Chegini and Ghobadian (2005) for spray dried orange juice powder.

Effect of atomizer type, inlet air temperature and additive type on the water activity of the probiotic apple juice powder

The variables and their interactions for all the treatments were found highly significant. Effect of additives, atomizer type and inlet air temperature on the water activity of the probiotic apple juice powder samples is presented in Table 3. It was observed

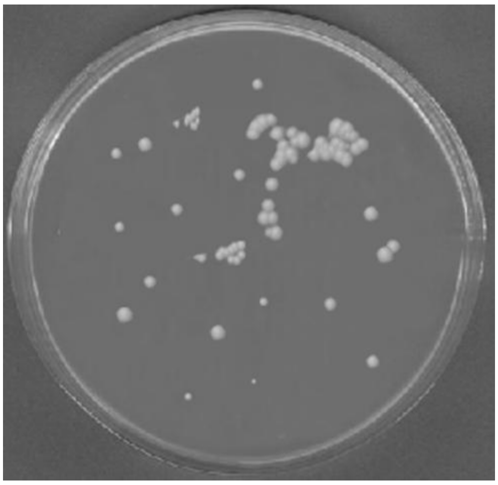

Fig. 4. Probiotic apple juice powder

from the results that water activity of probiotic apple juice powder samples decreased with increase in the inlet air temperature for the different treatments studied ranging between 0.236 and 0.391. Among the nozzles studied, rotary wheel atomizer recorded the lower water activity values compared to twin fluid pressure nozzle atomizer. This difference in the water activity might be due to the final moisture content of the dried products. The probiotic apple juice powder was packaged in aluminium foil pouches, heat sealed and stored in dry place for further studies. Troller and Christian (1978) stated that in food materials, almost all microbial activity could be inhibited at a water activity level below 0.6. Hence, it is clear that the probiotic apple juice powder is safe from microbial contamination.

Effect of atomizer type, inlet air temperature and additive type on the survival of L. acidophilus in the probiotic apple juice powder

Statistical analysis revealed that the variables and their interactions for all the treatments were highly significant. Effect of additives, atomizer type and inlet air temperature on the survival of probiotic *L.acidophilus* in the probiotic apple juice powder samples is presented in Fig. 3. The powder obtained using maltodextrin and twin fluid pressure nozzle atomizer showed the maximum survival of 31.43

Fig. 5. Survival of *L.acidophilus* in probiotic apple juice powder (10^6 cfu/g)

per cent at 150°C inlet air temperature. The minimum survival of 5.71 per cent was recorded by the powder obtained using gum arabic and rotary wheel atomizer at 170°C inlet air temperature. Twin fluid pressure nozzle atomizer produced the probiotic apple juice powder with smaller particle size compared to rotary wheel atomizer. This might be due to the reason for maximum survival of *L.acidophilus* in the powder obtained using twin fluid pressure nozzle atomizer, because, the fact of large particles are subjected to greater heat damage than smaller ones under any given set of drying conditions. Microorganisms entrapped in the particles are also subjected to more heat, as that of the outer surface of the particle.

Among the additives and nozzles studied, maltodextrin and twin fluid pressure nozzle atomizer showed good survival compared to gum arabic and rotary wheel atomizer. It was also observed from the figure that there was a sharp decrease in number of survivors as the inlet air temperature increased from 150°C to 170°C. This might be due to the fact that, as water activity (a_w) decreases at the surface of the particle, wet bulb temperature is exceeded. It is at this point that the bacteria may be subjected to lethal temperatures. Similar results of reduction of viable *bifidobacteria* after spray drying was reported by Lian *et al*., (2002).

Conclusion

Based on the quality attributes of probiotic apple juice powder, rotary wheel atomizer was optimized for the production. Though the per cent survival of *L.acidophilus* in the powder obtained using twin fluid pressure nozzle atomizer was higher compared to rotary wheel atomizer, the difference was not much and other quality parameters did not favour the twin fluid pressure nozzle atomizer for spray drying. Among the additives studied, maltodextrin was found to be suitable for the production of probiotic apple juice powder. Solubility of the powder produced using gum arabic was little higher compared to maltodextrin added powder. However, the results of all other main quality parameters recommended the use of maltodextrin as additive material for the production of probiotic apple juice powder. The survival of *L.acidophilus* in probiotic apple juice powder produced at 150°C inlet air temperature was higher, compared to 160 and 170°C inlet air temperature. The other quality parameters such as moisture content, solubility, bulk density and water activity values were higher in this temperature range and this affected the overall quality of the final product and yield also very less as the materials cohered to wall chamber and cyclone. Increasing the inlet air temperature showed good results of above mentioned quality parameters but the number of survivors was reduced and 170°C inlet air temperature recorded the very minimum number of survivors. Considering the above results, 160°C inlet air temperature was stardardized for spray drying of probiotic apple juice.

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