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Effect of Carriers and Temperature in Spray Drying of Pineapple Juice

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ABSTRACT: *The present investigation was carried out to find the effect of a set of variables in the recovery of spray dried pineapple powder. Juice mixed with Maltodextrin (M) or Resistant dextrin (D) in varying proportions based on juice solid and carrier ratios as 70:30 (C_1), 60:40 (C_2) , 50:50(C_3), 40:60 (C_4) was fed to cocurrent spray drier by a peristaltic pump for drying at six different inlet temperatures; 150°C (T_1), 160°C (T_2) 170°C (T_3), 180°C (T_4), 190°C (T_5), 200°C (T_6). Feed rate was varied so as to maintain the outlet temperature at 88 ± 2°C at 4 bar atomization pressure and 2000 rpm blower capacity. Inlet temperature realized a linear increase in feed rates and highest temperature recorded 2.7 times higher feed rates than the lowest one. Resistant dextrin with juice solid and carrier ratio of 40:60 at 160°C inlet temperature led to 85.64 per cent recovery from the feed solid content. Resistant dextrin led to better translocation of powder from chamber to cyclone since powder recovery in the cyclone was 47.09 per cent of the total solids of the feed at these levels which is 2.8 times of the recovery from highest yielding maltodextrin combination. Positive and negative changes in inlet temperatures from 160°C produced unfavorable response in the recovery of solids from the feed mix. Increase in concentration of carrier materials had a marked effect in the recovery of powder since the yield went up by 2.2 times and 2.4 times in cyclone and total powder yield respectively.*

Keywords: *Pineapple, spray drying, inlet temperature, maltodextrin, resistant dextrin*

INTRODUCTION

The magnitude of postharvest losses in fresh fruits and vegetables is estimated to be 5-25% in developed countries and 25-50% in developing countries. In India, the estimated losses range up to 40% depending upon the commodity [1] and only less than 2 per cent of fruits and vegetables produced are processed. This is not only loss of produce of crores of rupees but also wastage of labour, energy and inputs involved in production.

Pineapple is one of the popular fruits which is consumed either in raw or in processed forms as canned slices and juice. The global trade is around 50 per cent as fresh fruit, 30 per cent as canned product and 20 per cent as juice concentrate. India ranks sixth with a share of about 8% of the world production of pineapples. The total area under pineapple cultivation in India is 84000 hectares with a production of about 1341000 tones. The finest quality "Mauritius Pineapple" which is unique in aroma, flavor and sweetness due to its high sugar content and low acidity comes from Kerala. Gajanana *et al.* [2] estimated the total postharvest loss in pineapple as 29.25 per cent, comprising 2.19 per cent loss at the farmer's field level, 16.39 per cent at wholesale level and 10.67 per cent at the retail level

Due to rapid expansion of internal and external market and processing industries, it is essential to develop techniques, which reduce post harvest losses, do value addition and improve product quality. The fast economic development and higher health consciousness have changed the trend of food consumption from calories assurance to diet nutrient enrichment thereby increasing the global market demand towards fruits. In order to take advantage of the potential health benefits of pineapple it becomes imperative to add value in forms of dry powders that are not only stable over a longer storage time but also have desired functionalities. Instant powders offers several advantages over other conventional forms of

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processed products like liquid beverages. Powders offer flexibility for innovative formulations as being replacement for juice concentrates or as shelf-stable ingredient for health drinks, baby foods, nutrition bars, sauces, ice cream and baked goods. Development of instant juice powder may Improve demand for natural beverages and open new market avenues.

Among the drying techniques, spray drying is used in a wide range of products in food industries to produce dry powders and microcapsules. Spray drying process is reported to produce a good quality final product with low water activity and reduced weight, resulting in easy storage and transportation and the fruit powder can be readily reconstituted to a fine product resembling the original. This quick single step drying method with short contact time is considered as one of the best drying methods to convert fluid materials into hygienic solid particles for minimizing the process, maximizing the profit and conserving nutrients. Aghbashlo *et al.* [3] noted wide range of production rates in spray drying and extensive flexibility in dryer apparatus design. Estenvinho *et al.* [4] justified the preference of spray drying in industrial terms for being reproducible, allowing easy scale-up, offering substantial variation in microencapsulation matrix, is adaptable to commonly used processing equipment and produces particles of good quality. Spray drying involves complex interactions of process, apparatus and feed parameters which influence final product yield and quality as reported by Chegini *et al.*[5]. The recovery and physicochemical properties of the final product mainly depend on inlet temperature, air flow rate, feed flow rate, atomizer speed, types of carrier agent and their concentration.

As discussed by Murugan and Orsat [6] carriers for spray drying can be produced by modifying carbohydrate polymers such as starches. Many functional derivatives of starch such as cross-linked, oxidized, acetylated, hydroxypropylated and partially hydrolysed molecules are available in the market, providing an array of techno functional properties. Maltodextrins are the best example in this class and are manufactured by chemical or biochemical starch hydrolysis. Krishnaiah *et al.*[7] reported maltodextrins as main carrier to reduce stickiness and agglomeration problems, thereby improving product stability. Moreover it has bland flavor, high water solubility and low viscosity.

Dextrins are partially hydrolyzed starches) produced by heating starch in the presence of small amounts of food grade acid. Dextrinization results in a drastically reduced molecular weight and the introduction of new glucoside linkages. Resistant dextrin is proposed for use in food as a bulking agent and as a dietary fiber ingredient which can potentially be used to produce dry beverage powder.

Performance and efficacy of the spray drying process also depend upon temperature of the inlet air. Temperature of inlet air can be a controlled variable during the spray drying process. As mentioned by Medina-Torres *et al.* [8] inlet air temperature should be the temperature that can be used safely without damaging the product or creating operational risks. Low inlet temperature leads to lesser evaporation rate, the formation of microcapsules with high density membranes, high water content, poor fluidity, and easiness of agglomeration. However, a high air inlet temperature causes excess evaporation and produce cracks in the membrane inducing premature release of volatiles and degradation.

Though there are a few studies on various parameters that affect spray drying efficiency, any generalization could not be obtained due to contradictory results and the optimized values differ for each material. Higher carrier concentration showed a negative [9] or positive [10] effect on process yield. As Tonon *et al* [11] observed higher process yield with higher inlet temperatures and Chegini and Ghobadian [12] noted lower yield with higher inlet air temperature. These variations may be related to different feed compositions and process conditions during spray drying. Therefore it is essential to optimize the main process parameters that pave way for an efficient production of pineapple powder. Hence, the present work was undertaken to investigate the effect of different factors such as carriers in varying proportions and temperature on recovery of powder. Based on the main and interactive effects of the carriers, proportions and temperature optimum feed rate and powder yield were selected.

MATERIALS AND METHODS

The present investigation was carried out at the Department of Processing Technology, College of Agriculture, Vellyani utilizing the facilities of Kelappaji College of Agricultural Engineering Technology , Tavanur and Cashew Research Station, Madakkathara of Kerala Agricultural University during the period 2014-2015.

Materials

Fully ripe, good quality firm and uniform fruits of Pineapple variety "Mauritius" were collected from farm of Agricultural Research Station, Mannuthy, Kerala Agricultural University . Fruits were washed in running water and peeled with stainless steel knife. The juice was extracted in screw press, strained through muslin cloth and preserved using potassium metabisulphite (KMS) @2.5 g per litre of juice. This juice was stored in well sterilized air tight plastic barrels and used for product preparation. The carrier materials used in the current study were Maltodextrin obtained from Himedia laboratories Ltd, India and Resistant Dextrin (Nutriose®FM06) from Roquette India Private Ltd. Malodextrin is a non sweet soluble white to off white, slightly hygroscopic powder which had reducing sugars of 20 Dextrose Equivalence and Resistant Dextrin is non sweet soluble off white to lightly yellowish powder of 5DE.

Process parameters

Feed for spray drying was prepared by mixing 125 ml juice and carrier materials [Maltodextrin (M) or Resistant Dextrin (D)] in varying proportions based on the total soluble solids. The juice carrier combinations were tried in four different proportions based on juice solid and carrier ratios as 70:30 (C_1), 60:40 (C_2), 50:50(C_3), 40:60 (C_4). Properly mixed feed was then fed to cocurrent spray drier by a peristaltic pump for drying at six different inlet temperatures as 150°C (T_1), 160°C (T_2) 170°C (T_3), 180°C (T_4), 190°C (T_5), 200°C (T_6). Feed rate was varied so as to maintain the outlet temperature at 88 ± 2° C. Other operating parameters were maintained constant as 4 bar atomization pressure and 2000 rpm blower capacity.

Spray drying

A laboratory co-current spray drier (SMST Ltd. India) was used for conducting experiments. At the specified inlet air temperature, water was fed into the nozzle atomizer by peristaltic pump. The feed rate of the water was adjusted such that the outlet temperature of air was maintained at 88 ± 2 °C . When the inlet air temperature reached the desired temperature and the outlet air temperature was stabilized at 88 ± 2 °C, prepared feed mix was fed into the feed bowl. The feed mix after atomization mixed thoroughly with the hot air in the drying chamber and was instantly converted into powder. The feed rate of the mix was adjusted as that the outlet temperature of air was maintained at 88 ± 2 °C throughout the drying process. The powder particles were collected in the conical bottom of the drying chamber and then carried by the blowing air into the cyclone separator. In the cyclone separator powder particles were separated from the air and collected in it. Air was let out to the atmosphere. Powder from the cyclone and loose powder from chamber were separately weighed and then bulked.

Statistical analysis was done for computing main and interaction effects in 2x4x6 factorial design using MINITAB software. Post hoc comparison was done through Tukey's HSD (Honestly Significant Difference) procedure.

OBSERVATIONS

Feed rate- Feed rate was calculated by dividing the mass of feed (g) with the time (minute) taken for spray drying and reported as gram/minute.

Powder Recovery- Powder recovered from cyclone and chamber were weighed separately and reported in per centages of the total solids of feed mixture. Then the powders were bulked and total recovery was expressed in per centage.

RESULTS AND DISCUSSION

Feed rate

Table 1
Main effect of carriers

Carrier	*Feedrate (g/min)*	*Recovery of powder (%)*		
		Cyclone	*Chamber*	*Total*
M	6.89	12.71^a	14.04^b	20.87^b
D	6.8	6.83^b	15.92^a	28.63^a
P value	0.524	<0.005	<0.005	<0.005

Means with the different superscript within same column are significantly different ($P < 0.05$).

The data clearly denote the importance of concentration of carriers (Table 2), inlet temperature (Table 3) and their interaction (Table 6) in realizing higher feed rates while type of carriers (Table 1) or any interaction that involved type of carriers did not show any significance. The feed rate for juice solid and carrier ratio of 40:60 and 50:50 did not differ but the highest carrier level favored higher feed rates than 60:40 and 70:30 by 25% and 42% respectively (Table 2). Higher concentration of carrier led to lower water content for evaporation hence the higher feed rates could be justified and this effect would have much importance in commercial scaling of the process.

Inlet temperature exhibited a linear increase in feed rates and highest temperature recorded 2.7 times higher feed rates than the lowest one (Table 3). More over bare minimum feed rates were needed at 150°C

Table 2
Main effect of Concentration

Concentration	*Feedrate (g/min)*	*Recovery of powder (%)*		
		Cyclone	*Chamber*	*Total*
C_1	5.55^c	0.89^d	2.51^d	3.40^d
C_2	6.3^b	4.96^c	7.38^c	12.34^c
C_3	7.61^a	10.38^b	13.93^b	24.31^b
C_4	7.90^a	22.84^a	36.11^a	58.96^a
P value	<0.005	<0.005	<0.005	<0.005

Means with the different superscript within same column are significantly different ($P < 0.05$).

to maintain the out let temperature as outlet temperature tend to slide down due to insufficient heat for drying.

Table 3
Main effect of Inlet Temperature

Inlet temperature	*Feedrate (g/min)*	*Recovery of powder*		
		Cyclone	*Chamber*	*Total*
T_1	3.81^e	$7.85^{c,d}$	16.88^a	24.73^b
T_2	5.16^d	12.64^a	17.26^a	29.90^a
T_3	5.93^c	11.79^a	15.95^{ab}	27.74^a
T_4	7.98^b	$9.46^{b,c}$	14.79^b	24.25^b
T_5	8.04^b	9.68^b	12.80^c	22.48^b
T_6	10.14^a	7.2^d	12.22^c	19.41^c
P value	<0.005	<0.005	<0.005	<0.005

Means with the different superscript within same column are significantly different ($P < 0.05$).

Critical ranges of temperature were the ten degree increment from 150 to 160°C or 170 to 180°C as it elevated the feed rates by highest margin of 35 per cent. Higher inlet temperature creates higher temperature gradient favoring quicker drying. This may lead to higher outlet temperature and consequently to higher feed rates since feed rates were varied to maintain the outlet temperature as observed by Jittanit *et al.* [13].

Analysis of interaction effects of concentration with inlet temperature (Table 6) reiterate the main effects of individual factors as the higher levels of carriers and inlet temperature favored higher feed rates. Though higher inlet temperature elevated feed rates in all concentration levels, magnitude of elevation was getting waned towards the lowest concentration. This change could be justified since drying rates might be influenced by the higher solid content of feed in higher carrier concentrations.

Powder recovery

Resistant dextrin was found as a carrier which not only increased the total powder recovery but also substantially improved powder recovery at cyclone (Table 1). The improvement was 13%, 87% and 37% in chamber (Figure 1), cyclone (Figure 2), and total powder yield (Figure 3)respectively in comparison to maltodextrin.

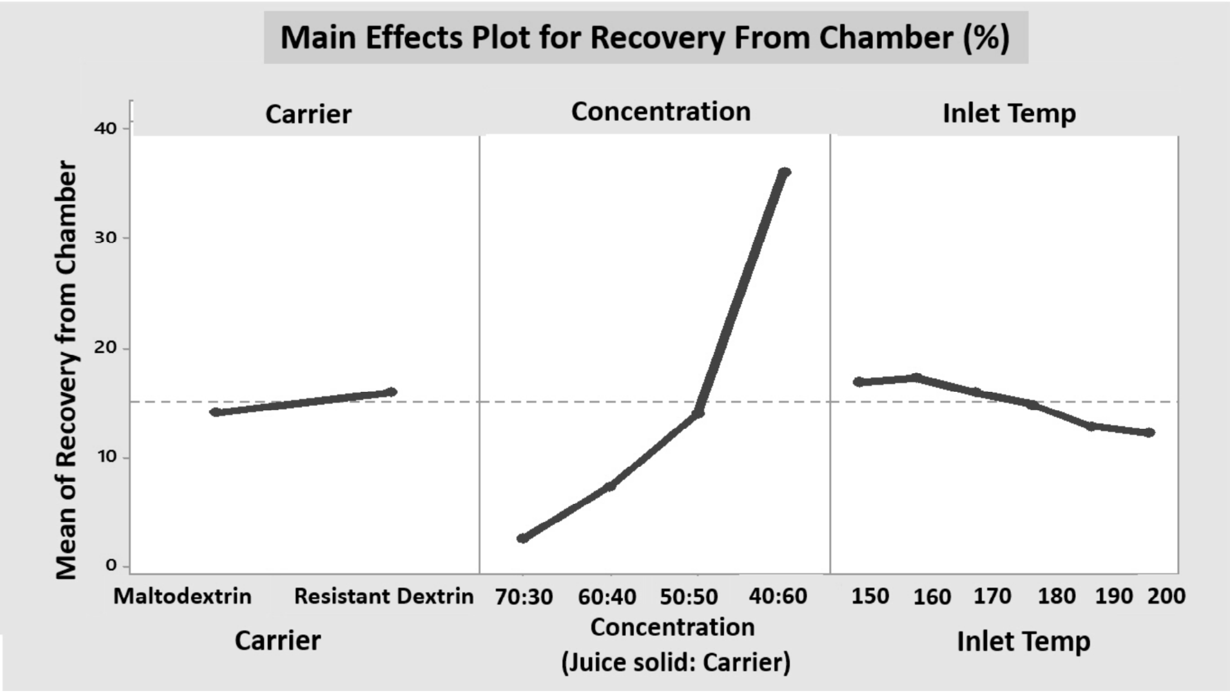

Figure 1 : Main Effects Plot for recovery from chamber

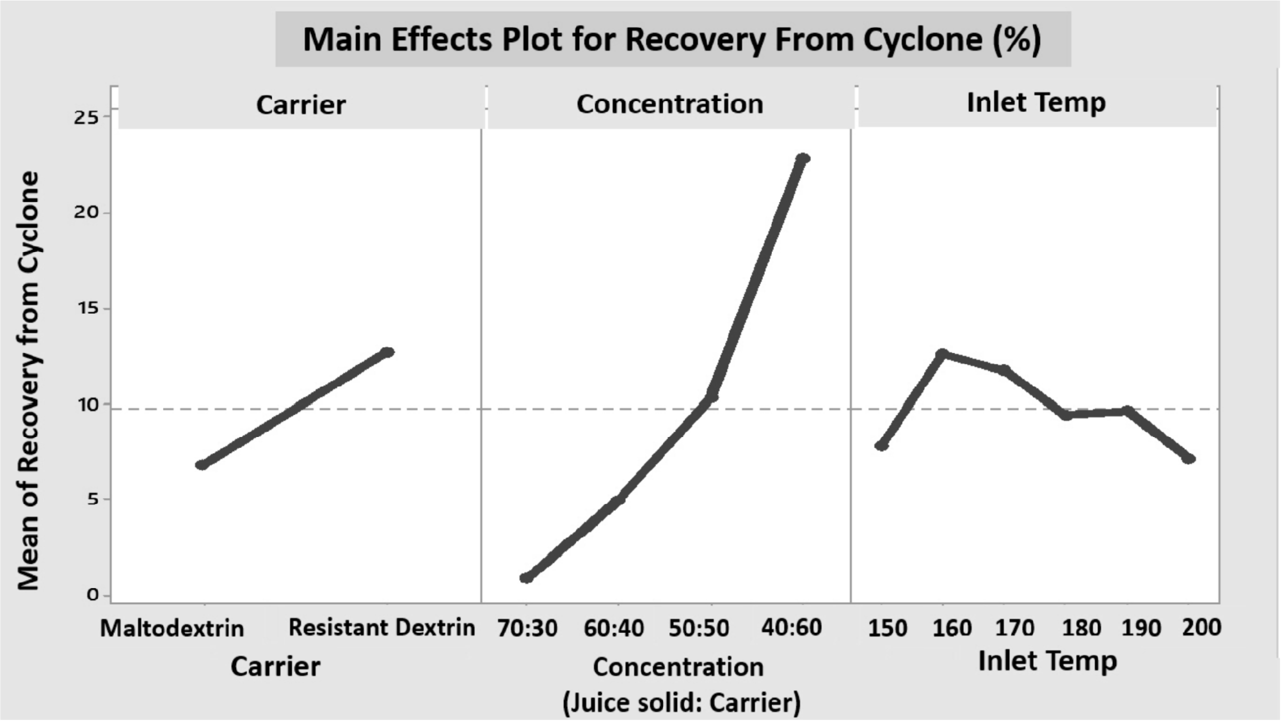

Figure 2: Main Effect Plot for recovery from Cyclone

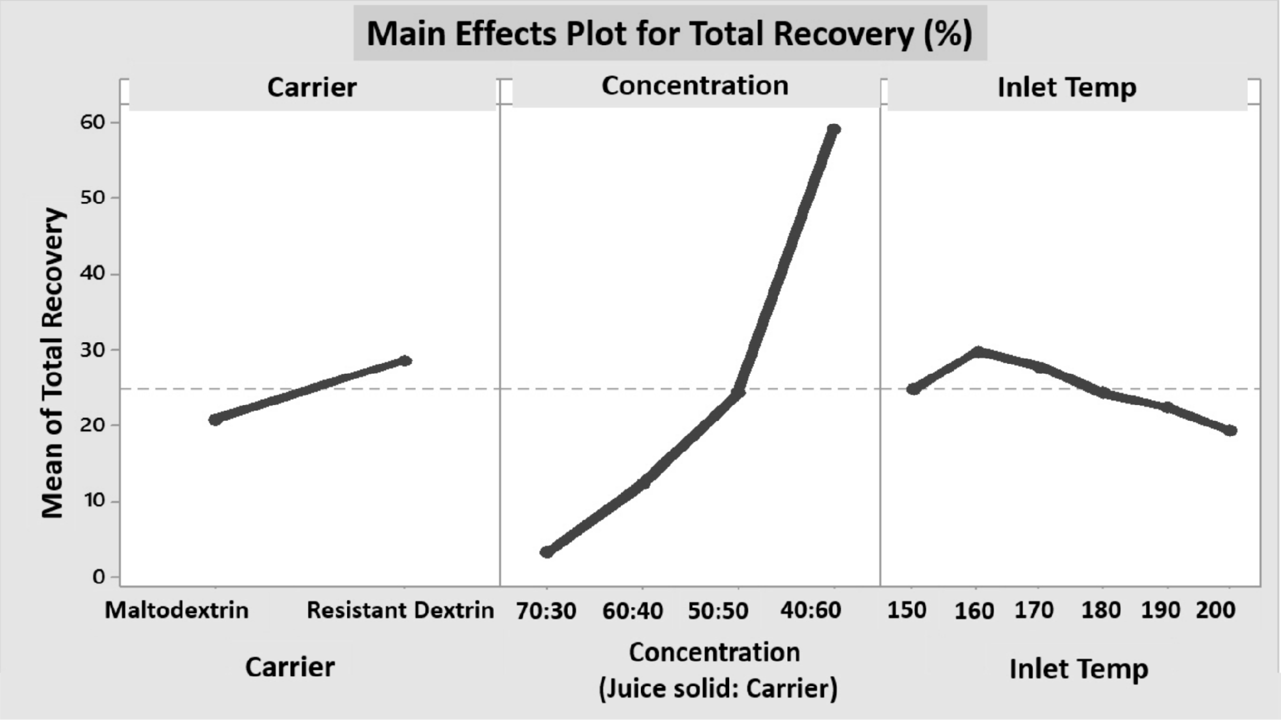

Figure 3 : Main Effects Plot for Total recovery

As discussed by Goula and Adomopoulose [14] product recovery is mainly determined by powder collection efficiency. Material loss in a spray drying system is due mostly to the attachment of sprayed droplets and dry powder to the wall of the dryer and some entrainment losses. Several authors [15,16] have found that the stickiness phenomenon is closely related to the glass transition phenomenon. Glass transition is a phase transition of amorphous materials during their gradual transition from a soft state with higher water mobility to a glassy and relatively hard state with low water mobility. The temperature during this transition is therefore called glass transition temperature (Tg). As explained by Troung *et al.* [15] stickiness in spray drying of sugar-rich foods is mainly caused by the thermoplastic behavior of low molecular weight sugars and organic acids which depresses the glass transition temperature (Tg) of the product. During the drying process, the temperature higher than the glass transition temperature of the product, leads to the viscoelastic state and thus have a high risk of stickiness as this liquid like state of the amorphous material, is responsible for inter particle cohesion or particle adhesion on the dryer surfaces. Since sticky problem is not encountered when starch derivatives are spray dried, addition of such high molecular weight substances could have increased the Tg of the product and thus reduced the risk of stickiness during spray drying.

Increase in concentration of carrier materials (Table 2) had a marked effect in the recovery of powder. The recovery tripled at chamber when juice solid and carrier concentration was changed from 50:50 to 40:60(Figure 1). Similarly the yield went up by 2.2 times and 2.4 times in cyclone (Figure 2) and bulked powder (Figure 3)recovery respectively. Though the recovery of powder at lower carrier concentration levels of 60:40 and 70:30 were negligible in commercial point of view the magnitude of the increase in recovery were 2.9, 5.6 and 3.6 times in chamber, cyclone and bulked powders at 60: 40 level. As discussed by Ameri and Maa[20] increasing the total solid content of the feed solution is one way of increasing the powder recovery in spray drying operations. The addition of more carriers could increase the total solid content in the feed and thus, improve yield of the product. Furthermore, the stickiness decreases with increasing carrier concentration. Higher the carrier contents higher the elevation of the glass transition temperature as suggested by Goula and Adomopoulose [14]. In general, an increase in the maltodextrin content results in an increase of the recovery of feed solids in the product.

Analysis of interaction effects between carrier and concentration (Table 4) revealed resistant dextrin as better translocator of powder from chamber to cyclone. Resistant dextrin had lower recovery by 19 per cent than maltodextrin at the highest carrier concentration level in the chamber (Figure 4). However in the cyclone powder, resistant dextrin exhibited 2.5 times yield than maltodextrin (Figure 5). Considering the quantity of bulked powder, resistant dextrin was better by 25 per cent than maltodextrin at the highest concentration level (Figure 6).

Table 4
Interaction Effect of Carrier with Concentration

Carrier Concentration*	*Feedrate (g/min)*	*Recovery of powder (%)*		
		Cyclone	*Chamber*	*Total*
MC_1	5.58	0^{e}	0^{g}	0^{f}
MC_2	6.33	3.97^{d}	4.14^{f}	8.11^{e}
MC_3	7.81	10.17^{c}	12.79^{d}	22.97^{c}
MC_4	7.83	13.17^{b}	39.24^{a}	52.40^{b}
DC_1	5.51	1.78^{e}	5.02^{f}	6.80^{e}
DC_2	6.27	5.96^{d}	10.62^{e}	16.57^{d}
DC_3	7.43	10.59^{c}	15.06^{c}	25.65^{c}
DC_4	7.98	32.52^{a}	33.0^{b}	65.51^{a}
P value	0.576	<0.005	<0.005	<0.005

Means with the different superscript within same column are significantly different ($P < 0.05$).

The results clearly indicated higher efficiency of resistant dextrin to aid translocation of powder from chamber to the cyclone at the carrier concentration level of 40:60. The higher recoveries at cyclone was always considered as the index of efficient spray drying since the dryer had to be shut down frequently to collect powder from chamber, which is not cost effective. Moreover, powder from the chamber might be of lesser quality as deposits can become scorched due to continuous exposure to heat and when dislodged, mix in and contaminate the entire product. Furthermore, deposits influence drying volume and heat transfer processes between the chamber walls and the moving fluids. Higher translocation of powder to the chamber by resistant dextrin could be attributed to the lower dextrose equivalence of it. As observed by Goula and Adamopoulos, [17] the residue yield in the drying chamber decreases with decreasing the carrier dextrose equivalent, since the lower the carrier DE, the higher its glass transition temperature and, as a consequence, the higher the elevation of glass transition temperature of the feed mix. Papadakis *et al.*[18] also found that by decreasing DE, the recovery of spray dried raisin juice powder was increased. Werner *et al.* [19] reported that low DE carriers reach a state of no adhesion faster than high DE carriers and hence such materials could be favored as wall deposit-reducing agents during drying. However, resistant dextrin could not sustain this effect at lower concentrations. It might be due to the low level of carrier contents which could not raise the glass transition temperature sufficiently to reduce the stickiness.

Positive and negative changes in inlet temperatures from 160^0C produced unfavorable response in the recovery of solids from the feed mix (Table 3).Drying at inlet temperature of 160^0C saved 41 per cent, 76 per cent and 54 per cent powder with respect to the quantity obtained at 200^oC in chamber (Figure 1), cyclone (Figure 2) and bulked powder (Figure 3) respectively. The results indicated that that lower temperatures are conducive for spray drying of fruit juices and higher drying temperatures worsen the problem of stickiness, The higher the difference between the product temperature and glass transition temperature, higher is the degree of stickiness [15].

Moreover, decreased yield at higher inlet air temperature was observed previously in case of spray-dried orange juice (Chegini and Ghobadian [12] and mountain tea extract (Sahin-Nadeem *et al*., [21]. Such decrease could be caused by sticking of the droplets on hot surface of the spraying cylinder, due to the high feed rate for fixing the outlet air temperature. As discussed by Tonon *et al.* [11] the increase on feed flow rate resulted in lower process yields, due to the slower heat and mass transfer. When higher feed rates were used atomization was poor resulting in a lower process yield. According to Leon-Martinez *et al*. [22] yield increases when feed flow rate decrease, as atomization rises.

However, 160^0C recorded 61 per cent and 21 per cent more powder in cyclone and bulked powder respectively in comparison to the next lower temperature though the effect was insignificant in the chamber powder(Table 3). According to Masters [23] there are semi-wet deposits caused by droplets, which are not sufficiently dry before hitting the wall apart from sticky deposits caused by the nature of the product. Inlet air temperature might haves shown a positive effect on process yield at a temperature lower than optimum, due to the higher degree of heat and mass transfer which probably avoided hitting of the inadequately dried particles to the drying chamber wall. Furthermore, this clearly denoted that the optimum conditions had more influence in powder recoveries at cyclone than chamber.

Table 5
Interaction Effect of Carrier with Inlet Temperature

Carrier Inlet Temp*	*Feed rate (g/min)*	*Recovery of powder (%)*		
		Cyclone	*Chamber*	*Total*
MT_1	3.89	3.56^{e}	$17.29^{a,b}$	$20.85^{e,f}$
MT_2	5.1	$8.45^{c,d}$	$16.07^{a,b,c,d}$	$24.52^{c,d,e}$
MT_3	5.78	$8.22^{c,d}$	$14.79^{b,c,d}$	$23.01^{d,e}$
MT_4	8.27	$7.26^{c,d}$	$13.84^{c,d,e}$	$21.10^{e,f}$
MT_5	7.93	$7.74^{c,d}$	$11.43^{e,f}$	$19.16^{f,g}$
MT_6	10.35	$5.74^{d,e}$	10.85^{f}	16.59^{g}
DT_1	3.73	12.14^{b}	$16.48^{a,b,c}$	28.62^{b}
DT_2	5.22	16.84^{a}	18.45^{a}	3.28^{a}
DT_3	6.08	15.36^{a}	$17.10^{a,b}$	32.47^{a}
DT_4	7.69	11.66^{b}	$15.74^{a,b,c,d}$	$27.40^{b,c}$
DT_5	8.15	11.62^{b}	$14.18^{c,d,e}$	$25.80^{b,c,d}$
DT_6	9.94	8.65^{c}	$13.56^{d,e,f}$	$22.23^{d,e,f}$
P value	0.327	<0.005	0.026	<0.005

Means with the different superscript within same column are significantly different ($P < 0.05$).

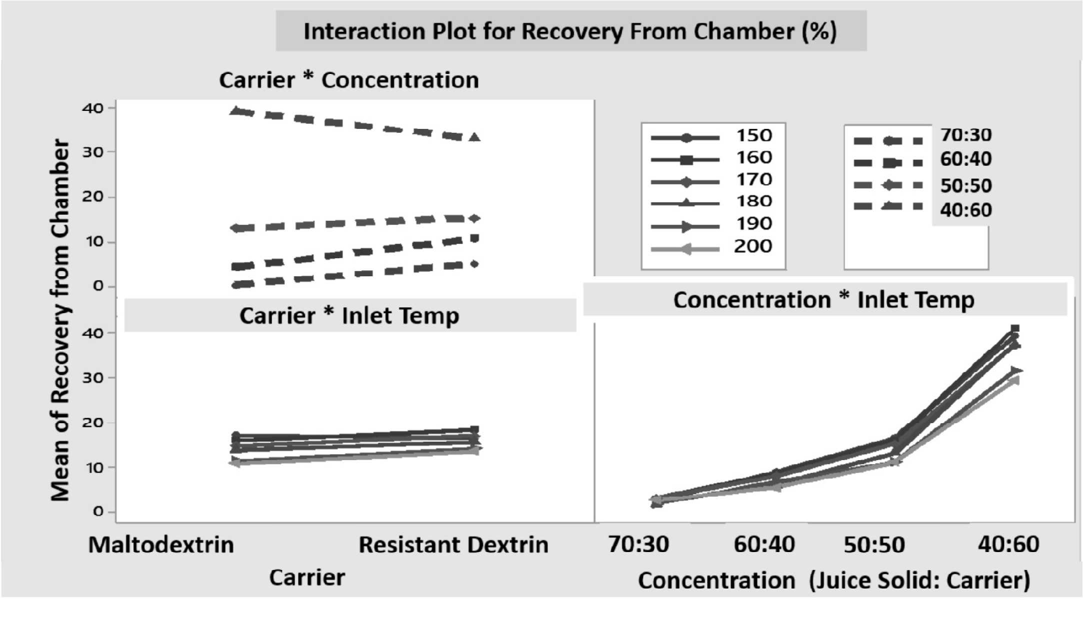

Figure 4 : Interaction Plot for Recovery from Chamber

Analysis of interaction effects of carrier with Inlet temperature (Table 5) confirmed lower temperature range of 160 and 170^{0}C as better yielder with respect to resistant dextrin in the powder obtained from cyclone while the range from 160 to 190^{0}C could not exhibit any significant deviation with maltodextrin (Figure 5). However, lower temperature of 160 and 170^{0}C with both carrier types exhibited same yield in the chamber (Figure 4). As far as the bulked powder is concerned highest yielding temperature range (150^{o}C,160^{0}C, 170^{0}C, and 180^{0}C) in maltodextrin were onpar with lowest yielding combination of resistant dextrin (200^{0}C) (Figure 6). The result pointed out the superiority of resistant dextrin over maltodextrin even at different temperature levels in the cyclone recovery and total powder recovery.

As per the interaction effects of concentration with inlet temperature (Table 6) in the cyclone (Figure 5) and bulked powders(Figure 6), lower temperature at same level of concentration yielded better but the range of temperature change needed for significant deviation depended on the concentration levels. Higher carrier concentration levels required lesser range. The highest concentration levels required 20^{0}C change while the concentration level of 50:50 required 40^{o}C change. Both concentration levels required 30^{0}C change in the powder recovered at chamber(Figure 4). At concentration levels of 60:40 and 70:30, temperature changes did not make any difference in all powder collection procedures. Higher contents of carrier material in the mix influenced the effect of inlet temperature favorably. Ás Goula and Adomopoulose [14] pointed out, the lower the proportion of carrier, the lower the effect of inlet temperature.

The interaction effects of the three factors (Table 7) led to the optimum process parameters of resistant dextrin in carrier types, juice solid to carrier ratio of 40:60 in concentration levels and 160^{0}C in inlet

Table 6
Interaction Effect of Concentration with Inlet Temp

*Concentration *Inlet Temp*	*Feed rate (g/min)*	*Recovery of powder (%)*		
		Cyclone	*Chamber*	*Total*
C_1T_1	3.28^{k}	1.47^{j,k,l}	2.60^{h,i}	4.07^{i,j}
C_1T_2	4.83^{g,h,I,j,k}	1.07^{k,l}	3.07^{h,i}	4.13^{i,j}
C_1T_3	5.07^{g,h,I,j}	0.87^{k,l}	3.07^{h,i}	3.93^{i,j}
C_1T_4	6.31^{e,f,g,h}	0.80^{k,l}	1.93^{i}	2.73^{j}
C_1T_5	6.54^{e,f,g}	0.73^{l}	1.8^{i}	2.53^{j}
C_1T_6	7.23^{d,e}	0.40^{l}	2.60^{h,i}	3.0^{j}
C_2T_1	3.9^{j,k}	4.3^{i,j,k,l}	8.94^{e,f,g}	13.23^{h}
C_2T_2	4.72^{h,I,j,k}	5.67^{h,I,j}	8.65^{f,g}	14.32^{g,h}
C_2T_3	5.13^{g,h,I,j}	6.19^{g,h,i}	8.13^{f,g}	14.32^{g,h}
C_2T_4	7.14^{e,f}	3.72^{i,j,k,l}	6.19^{g,h,i}	9.91^{h,i}
C_2T_5	7.33^{d,e}	5.15^{h,i,j,k}	6.82^{f,g,h}	11.97^{h}
C_2T_6	9.92^{b,c}	4.75^{h,i,j,k,l}	5.56^{g,h,i}	10.31^{h}
C_3T_1	3.75^{i,j,k}	7.81^{f,g,h,i}	16.57^{c}	24.38^{e,f}
C_3T_2	5.61^{e,f,g,h}	12.14^{e,f}	16.14^{c}	28.29^{e}
C_3T_3	6.53^{e,f,g}	10.43^{e,f,g}	15.29^{c,d}	25.72^{e,f}
C_3T_4	9.13^{c}	10.81^{e,f}	13.29^{c,d,e}	24.10^{e,f}
C_3T_5	8.96^{c,d}	12.10^{e,f}	11.10^{d,e,f}	23.19^{e,f}
C_3T_6	11.73^{a}	9.0^{f,g,h}	11.19^{d,e,f}	20.19^{f,g}
C_4T_1	4.62^{h,I,j,k}	17.83^{c,d}	39.43^{a}	52.26^{b,c}
C_4T_2	5.47^{f,g,h,i}	31.70^{a}	41.18^{a}	72.88^{a}
C_4T_3	7.0^{e,f}	29.68^{a}	37.30^{a}	66.97^{a}
C_4T_4	9.33^{c}	22.52^{b}	37.75^{a}	60.27^{b}
C_4T_5	9.35^{c}	20.72^{b,c}	31.50^{b}	52.23^{c}
C_4T_6	11.66ab	14.63^{c,d}	29.52^{b}	44.15^{d}
P value	<0.0005	<0.005	<0.005	<0.005

Means with the different superscript within same column are significantly different ($P < 0.05$).

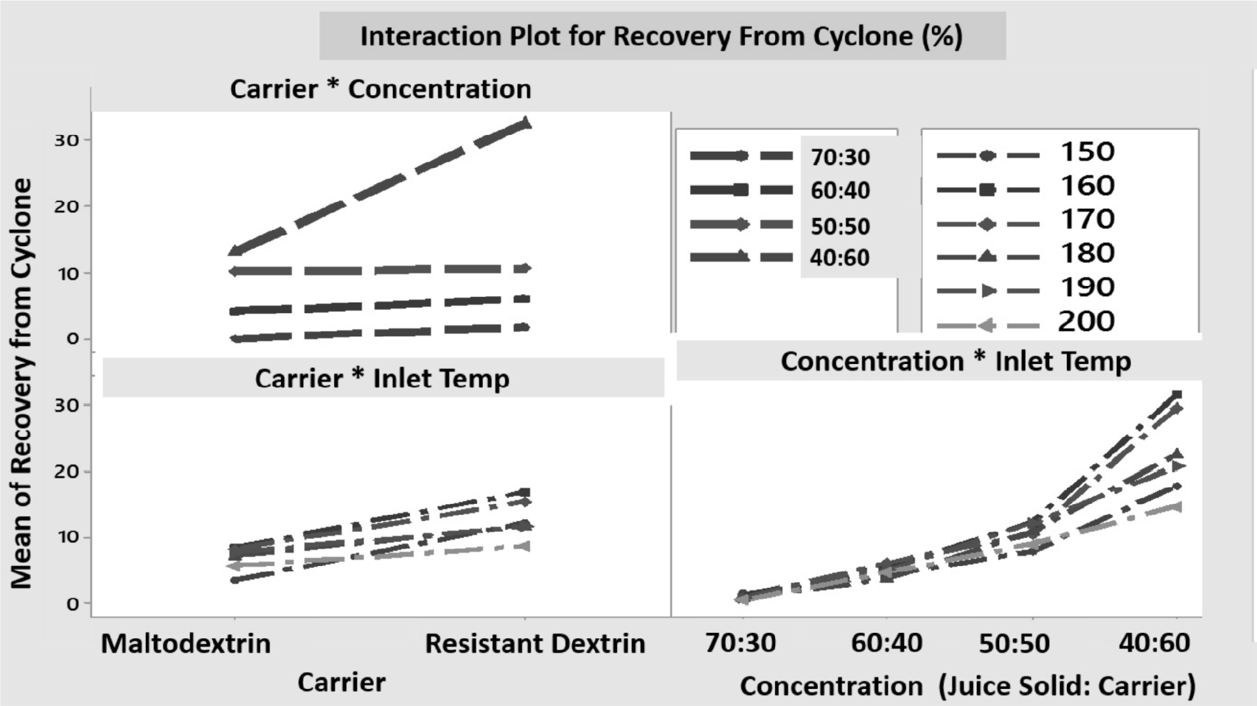

Figure 5 : Interaction Plot for Recovery from Cyclone

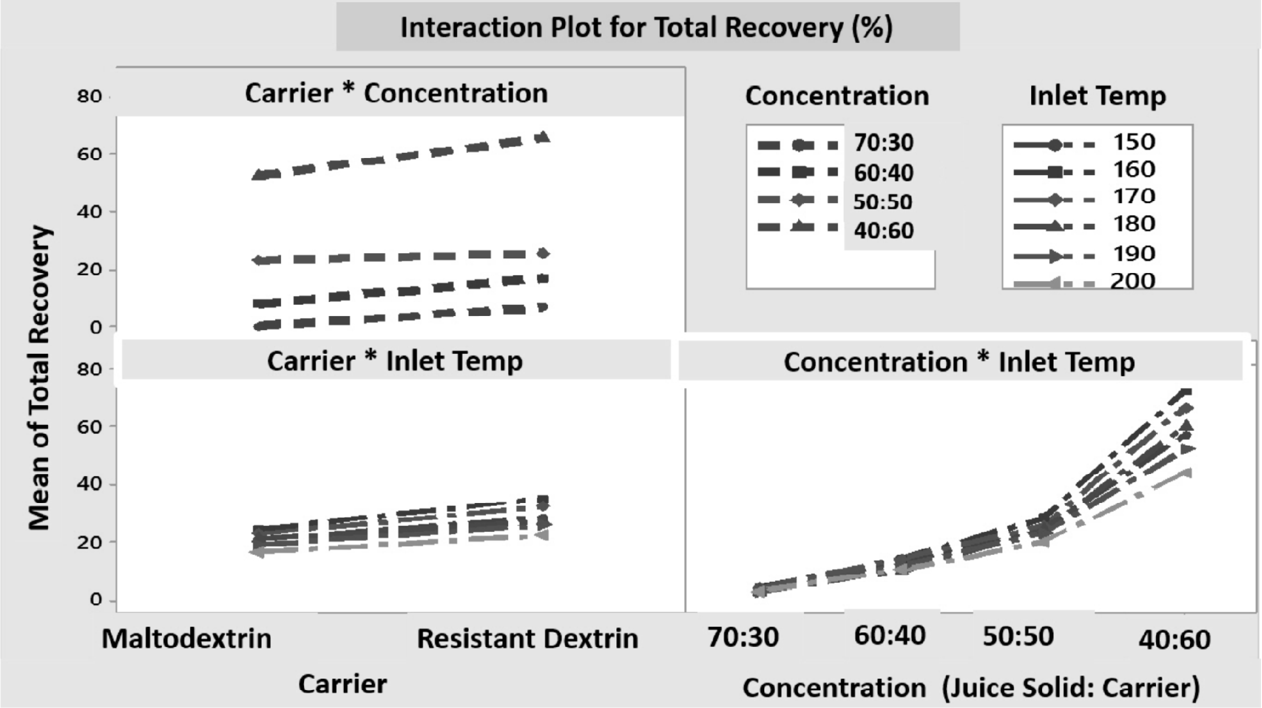

Figure 6 : Interaction Plot for Total Recovery

temperature for maximum recovery of powder from the cyclone. At these levels recovery was 47.09 per cent of the total solids of the feed which is 2.8 times of the recovery from highest yielding maltodextrin combination. The same combination recorded 38.55per cent of total solids of the feed in chamber which is 26.4 per cent less than the highest yielding maltodextrin combination. Highest recovery in chamber belonged to maltodextrin combination with 40:60 juice solid ratio and 150^{0}C inlet temperature.

Table 7
Interaction Effect of Carrier*Concentration *Inlet

Carrier Concentration *Inlet Temp*	*Feed rate (g/min)*	*Recovery of powder (%)*		
		Cyclone	*Chamber*	*Total*
MC_1T_1	3.26	0^{p}	0^{n}	0^{o}
MC_1T_2	4.69	0^{p}	0^{n}	0^{o}
MC_1T_3	4.87	0^{p}	0^{n}	0^{o}
MC_1T_4	6.42	0^{p}	0^{n}	0^{o}
MC_1T_5	6.75	0^{p}	0^{n}	0^{o}
MC_1T_6	7.51	0^{p}	0^{n}	0^{o}
MC_2T_1	3.7	$1.95^{o,p}$	$5.16^{m,n}$	$7.10^{m,n,o}$
MC_2T_2	4.64	$4.93^{h,I,j,k,l,m,n,o,p}$	$4.58^{m,n}$	$9.1^{l,m,n}$
MC_2T_3	5.11	$5.50^{g,h,I,j,k,l,m,n,o,p}$	$4.24^{m,n}$	$9.74^{k,l,m,n}$
MC_2T_4	7.24	$3.44^{l,m,n,o,p}$	$3.44^{m,n}$	$6.87^{m,n,o}$
MC_2T_5	7.01	$4.47^{i,j,k,l,m,n,o,p}$	$4.01^{m,n}$	$8.48^{m,n,o}$
MC_2T_6	10.27	$3.55^{k,l,m,n,o,p}$	$3.44^{m,n}$	$6.99^{m,n,o}$
MC_3T_1	3.8	$5.05^{g,h,i,j,k,l,m,n,o,p}$	$15.24^{g,h,i,j}$	$20.28^{g,h,I,j}$
MC_3T_2	5.45	$12.57^{c,d,e,f}$	$15.90^{g,h,i}$	28.47^{g}
MC_3T_3	6.35	$10.76^{d,e,f,g,h,i,j}$	$14.00^{g,h,i,j,k}$	$24.76^{g,h,i}$
MC_3T_4	9.97	$11.14^{d,e,f,g,h,i}$	$12.67^{g,h,i,j,k,l}$	$23.81^{g,h,i}$
MC_3T_5	8.88	$12.38^{c,d,e,f}$	$9.24^{i,j,k,l,m}$	$21.61^{g,h,I,j}$
MC_3T_6	12.39	$9.14^{e,f,g,h,i,j,k,l,m}$	$9.71^{h,i,j,k,l,m}$	$18.85^{h,I,j,k,l}$
MC_4T_1	4.8	$7.24^{f,g,h,i,j,k,l,m,n,o}$	48.76^{a}	$55.99^{c,d}$
MC_4T_2	5.61	$16.30^{c,d}$	$43.81^{a,b}$	$60.11^{b,c}$
MC_4T_3	6.8	$16.61^{c,d}$	$40.91^{b,c}$	$57.52^{b,c}$
MC_4T_4	9.47	$14.48^{c,d,e}$	$39.24^{b,c,d}$	$53.71^{c,d,e}$
MC_4T_5	9.07	$14.09^{c,d,e}$	$32.46^{d,e,f}$	$46.55^{e,f}$
MC_4T_6	11.21	$10.29^{d,e.f,g,h,ij,k,l}$	$30.24^{e,f}$	40.3^{f}
DC_1T_1	3.3	$2.93^{m,n,o,p}$	$5.2^{m,n}$	$8.13^{m,n,o}$
DC_1T_2	4.97	$2.13^{n,o,p}$	$6.13^{m,n}$	$8.27^{m,n,o}$
DC_1T_3	5.27	$1.73^{o,p}$	$6.13^{m,n}$	$7.87^{m,n,o}$
DC_1T_4	6.2	$1.60^{o,p}$	$3.87^{m,n}$	$5.47^{n,o}$
DC_1T_5	6.33	$1.47^{o,p}$	$3.6^{m,n}$	$5.06^{n,o}$
DC_1T_6	7.01	$0.80^{o,p}$	$5.2^{m,n}$	$6^{n,o}$
DC_2T_1	3.48	$6.64^{f,g,h,i,j,k,l,m,n,o,p}$	$12.72^{g,h,i,j,k,l}$	$19.36^{g,h,I,j}$
DC_2T_2	4.8	$6.41^{f,g,h,i,j,k.l,m,n,o,p}$	$12.03^{g,h,i,j,k,l}$	$19.13^{g,h,I,j,k}$
DC_2T_3	5.13	$6.87^{f,g,h,i,j,k,l,m,n,o}$	$12.72^{g,h,i,j,k,l}$	$18.90^{h,I,j,k,l}$
DC_2T_4	7.04	$4.01^{j,k,l,m,n,o,p}$	$8.94^{j,k,l.m}$	$12.95^{j,k,l,m,n}$
DC_2T_5	7.6	$5.84^{f,g,h,i,j,k,l,m,n,o,p}$	$9.62^{h,i,j,k,l,m}$	$15.46^{i,j,k,l,m}$
DC_2T_6	9.57	$5.95^{f,g,h,i,j,k,l,m,n,o,p}$	$7.67^{k,l,m}$	$13.63^{j,k,l,m,n}$
DC_3T_1	3.7	$10.57^{d,e,f,g,h,I,j}$	17.91^{g}	28.48^{g}
DC_3T_2	5.77	$11.71^{d,e,f,g,h}$	$16.38^{g,h}$	$28.09^{g,h}$
DC_3T_3	6.7	$10.10^{d,e,f,g,h,i,j,k,l}$	16.57^{g}	$26.67^{g,h}$
DC_3T_4	8.3	$10.48^{d,e,f,g,h,i,j}$	$13.90^{g,h,i,j,k}$	$24.38^{g,h,i}$
DC_3T_5	9.03	$11.81^{d,e,f,g}$	$12.95^{g,h,i,j,k}$	$24.76^{g,h,i}$
DC_3T_6	11.01	$8.86^{e,f,g,h,i,j,k,l,m,n}$	$12.67^{g,h,i,j,k,l}$	$21.52^{g,h,I,j}$
DC_4T_1	4.43	28.42^{b}	$30.09^{e,f}$	$58.51^{b,c}$
DC_4T_2	5.33	47.09^{a}	$38.55^{b,c,d}$	85.64^{a}
DC_4T_3	7.2	42.74^{a}	$33.68^{d,e,f}$	76.42^{a}
DC_4T_4	9.2	30.55^{b}	$36.27^{c,d,e}$	66.82^{b}
DC_4T_5	9.63	27.35^{b}	$30.55^{e,f}$	$57.90^{b,c}$
DC_4T_6	12.1	18.97^{c}	28.8^{f}	$47.77^{d,e,f}$
P value	0.812	<0.005	<0.005	<0.005

Means with the different superscript within same column are significantly different ($P < 0.05$).

Hence, resistant dextrin with juice solid to carrier ratio of 40:60 at 160^0C inlet temperature led to 85.64 per cent recovery from the feed solid content.

CONCLUSION

The present investigation was to find the effect of a set of variables in the recovery of pineapple powder through spray drying. Inlet temperature realised a linear increase in feed rates and highest temperature recorded 2.7 times higher feed rates than the lowest one. Resistant dextrin with juice solid and carrier ratio of 40:60 at 160^0C inlet temperature led to 85.64 per cent recovery from the feed solid content. Resistant dextrin led to better translocation of powder from chamber to cyclone since powder recovery in the cyclone was 47.09 per cent of the total solids of the feed at these levels which is 2.8 times of the recovery from highest yielding maltodextrin combination. Positive and negative changes in inlet temperatures from 160^0C produced unfavorable response in the recovery of solids from the feed mix. Highest yielding temperature range in maltodextrin were on par with lowest yielding combination of resistant dextrin. Increase in concentration of carrier materials had a marked effect in the recovery of powder since the yield went up by 2.2 times and 2.4 times in cyclone and combined powder recovery respectively.

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