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# Optimization of Process Parameters in Spray Drying of Cashew Apple Juice

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***ABSTRACT:*** *The present investigation tries to optimize different carriers in varying proportions and inlet temperature for spray drying of clarified cashew apple juice. 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 co-current 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 ($T_6$). Feedrate was varied so as to maintain the outlet temperature at 88 ± 2 °C at 4 bar atomization pressure and 2000 RPM blower capacity. Increment of 50°C, 40°C and 20°C from the lowest inlet temperature led to 153 per cent, 98 per cent and 45 per cent higher feed rate respectively. Higher concentration of maltodextrin par with subsequent lower concentration of resistant dextrin in recovery of powder at cyclone. Resistant dextrin, higher concentration of carrier and lower inlet temperature had marked effect in translocating more powder to cyclone. The variation in process parameters had higher influence in the cyclone recovery than powder from chamber. The optimized parameters were resistant dextrin in carrier types, juice solid and carrier ratio of 40:60 in concentration and 160°C inlet temperature which yielded 72.1 per cent of the total solids of the feed as powder with 40.56 per cent powder recovery in cyclone.*

***Key words:*** *Cashew apple, spray drying, inlet temperature, maltodextrin, resistant dextrin, optimization*

## INTRODUCTION

Nature has given plenty yet we suffer poverty. The state of cashew apple usage better explains this paradox. The cashew apple corresponds to the juicy and fleshy part of the cashew fruit. It has vitamin C contents ranging from 120 to 300 mg/100g, values considered high when compared to other fruits. Despite its great nutritional value, functional properties and potential as raw material for several products, it is completely discarded every year as the fruit is highly perishable and main thrust is for the marketing of cashew nuts. Since the nut weight is 10 per cent of the cashew apple mass, 6.7 million tons of cashew apples are produced and most of them are left to rot in the country and Kerala contribute 10.5 per cent of them. Apart from the cashew nut, the apple is fairly valued except in India and Brazil, especially in the form of juice as recorded by Cavalcante *et a*l. [1]. Goa is the only state in India where cashew apples are used to prepare "*feni*" a fermented cashew apple beverage. Some conventional products like jam, candy, syrup, vinegar and wine can be prepared from cashew apple but commercial production is limited. Like cashew apples of other producing countries cashew apples of India and Kerala are rich and deserves to be exploited and it require unique processing technologies.

Requirements of the consumers concerning convenience, food safety, health benefits and sensory quality has increased demand for fruit juices but most consumers do not have time to spend in preparing them, requiring ready-to-use or easy-to-prepare products. Instant juice powders can meet consumer requirements being cheap to transport and with prolonged shelf life as reported by Cano-Chauca *et al.* [2]. Moreover Shreshta et al. [3] enumerated benefits and economic potentials of fruit juice powders over their liquid counterparts as reduced volume or weight, reduced packaging, easier handling and transportation, and much longer shelf life. Besides, their physical state provides a stable, natural, and easily dosable ingredient, which

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generally finds usage in many foods and pharmaceutical products such as flavoring and coloring agents. As opinioned by Shahidi and Han [4] microencapsulation through spray drying effectively protect food ingredients against deterioration from adverse environmental conditions such as undesirable effects of light, moisture and oxygen which lead to extension of shelf life.

Murugesan and Orsat [5] described the major steps in spray drying as preparation of the dispersion, homogenization of the dispersion, atomization of the in feed dispersion and dehydration of the atomized particles. The atomization process refers to the dispersion of liquid in a gas as well as subsequent reduction in particle size. The increment in surface area of the particles due to dispersion helps to dry the feed in seconds. During atomization, the feed is exposed to the drying gas. The drying of feed droplets in a spray drying process is a result of simultaneous heat and mass transfer. The heat transfers from the drying medium to droplets by convection and then converted to latent heat during the evaporation of the droplets' moisture content. Following the drying process, the dried particles fall towards the bottom of the drying chamber or travel along with the outgoing air to cyclone. The dense particles are recovered at the base of the drying chamber while the finest ones from cyclone.

As per opinion of Desai and Park [6] almost all spray drying processes in the food industry are carried out from aqueous formulations and the typical shell materials include gum acacia, maltodextrin, hydro phobically modified starch and mixtures of them. Other polysaccharides such as alginate, carboxymethylcellulose, guar gum and proteins like whey proteins, soy proteins, sodium caseinate can also be used, though their usage becomes very complicated and expensive because of their low solubility in water, which implies an increase in the amount of water to be evaporated, a decrease in the dry matter content and in the amount of active ingredient.

Being faced with the multiple challenges like scanty information on cashew apple processing particularly on modern drying methods and complexities in generalization of information due to its contradictory nature, the present investigation tries to optimize different carriers in varying proportions and inlet temperature for spray drying of clarified cashew apple juice.

## 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 , Thavanur and Cashew Research Station, Madakkathara of Kerala Agricultural University during the period 2014-2015.

### Materials

Fully ripe, firm fruits of Cashew apple variety "*Dhana*" without bruises were obtained from farm of Cashew Research Station, Madakkathara. Fruits were washed in the running water after discarding immature, rotten and damaged fruits. The juice was extracted in screw press, strained through muslin cloth and clarified using powdered and cooked sago @ 5g and potassium metabisulphite (KMS) 2.5 g per litre of juice. Stirred juice was kept still for 12 hours to allow the tannin to settle and the upper layer of clear juice was decanted carefully without mixing the sediments. This clarified 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. Resistant dextrin was non sweet soluble off white to lightly yellowish powder of 5DE.

### Process parameters

Feed for spray drying were 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 is then fed to co-current 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 ($T_6$). Feedrate 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 on spray drying. At specified inlet air temperature, water was fed into the nozzle atomizer by peristaltic pump. The feed rate of the water was adjusted so as to maintain the outlet temperature of air 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, mixes thoroughly with the hot air in the drying chamber and instantly converts into powder. The feed rate of the mix was adjusted such 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 air into the cyclone separator. In the cyclone separator powder particles were separated from the air and were collected in a jar. Air was let out to the atmosphere. Loose powder remaining in the drying chamber also was collected by tapping with clean cloth. Powder from cyclone and loose powder from chamber was 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

### Feedrate

The 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

The data on Table 1 clearly depicted that the feed rate did not vary between the carriers. However, varying proportions of the carriers and inlet temperature positively influenced feed rate in a significant manner (Table 2 and 3). Increase in concentration of carrier materials in the feed mix realised higher feed rates as the combination with highest carrier content (40:60) recorded 42 per cent and 30 per cent elevation in feed rate than 70:30 and 60:40 respectively (Table 2). Quicker drying of the feed mix with higher carrier content might be due the lower content of water in it. This quicker drying elevated the outlet temperature and consequently led to higher feed rate since feed rate had to be raised for maintaining the outlet temperature at 88± 2°C.

**Table 1**
**Main effect of Carriers**

| *Carrier* | *Feedrate (g/min)* | *Recovery of powder (%)* | | |
|---|---|---|---|---|
| | | *Cyclone* | *Chamber* | *Total* |
| M | 5.94 | $3.08^b$ | $10^b$ | $13.08^b$ |
| D | 5.53 | $9.98^a$ | $14.1^a$ | $24.14^a$ |
| Pvalue | 0.967 | <0.005 | <0.005 | <0.005 |

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

Moreover, higher inlet temperature invariably led to higher feed rates (Table 3). A fifty degree increment from the lowest inlet temperature led to 153 per cent increase in feed rate. Similarly 40°Cand 20°C increment led to 98 per cent and 45 per cent higher feed rates respectively. However, the ten degree difference between 160 and 170 °C or 180 and 190°C could not produce significant change. Though both interaction effects that involve carrier were not significant (Table 4 and 5), the concentration with inlet temperature effect was clearly evident (Table 6). Two combinations (50:50 and 60:40) with 200°C more than tripled feed rates than the coolest combinations.

**Table 2**
**Main effect of Concentration**

| *Concentration* | *Feedrate (g/min)* | *Recovery of powder (%)* | | |
|---|---|---|---|---|
| | | *Cyclone* | *Chamber* | *Total* |
| $C_1$ | $4.89^d$ | $0.35^d$ | $1.37^d$ | $1.72^d$ |
| $C_2$ | $5.50^c$ | $2.39^c$ | $6.95^c$ | $9.36^c$ |
| $C_3$ | $6.40^b$ | $6.37^b$ | $13.38^b$ | $19.76^b$ |
| $C_4$ | $6.95^a$ | $17.02^a$ | $26.60^a$ | $43.62^a$ |
| P value | <0.005 | <0.005 | <0.005 | <0.005 |

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

The superior effect of inlet temperature for higher feed rate was in the limelight as the top three homogenous subsets involved 180°C, 190°C and 200°C with all concentration levels. As reviewed by Phisut [7] there is a greater temperature gradient between the atomized feed and drying air at higher inlet air temperatures, and it results in greater driving force for water evaporation. Due to quicker evaporation, the product temperature became higher which invariably raised the outlet temperature and feed rate.

**Table 3**
**Main effect of Inlet Temperature**

| *Inlet temperature* | *Feed rate (g/min)* | *Recovery of powder(%)* | | |
|---|---|---|---|---|
| | | *Cyclone* | *Chamber* | *Total* |
| $T_1$ | 3.52$^{d}$ | 6.42$^{b,c}$ | 12.91a$^{,b}$ | 19.33$^{b,c}$ |
| $T_2$ | 4.50$^{c}$ | 9.23$^{a}$ | 13.83$^{a}$ | 23.06$^{a}$ |
| $T_3$ | 5.09$^{c}$ | 7.84$^{a,b}$ | 12.97$^{a,b}$ | 20.81$^{b}$ |
| $T_4$ | 6.64$^{b}$ | 6.33$^{c}$ | 11.79 $^{b,c}$ | 18.12 $^{c,d}$ |
| $T_5$ | 6.98$^{b}$ | 5.58$^{c}$ | 10.86$^{c,d}$ | 16.43$^{d}$ |
| $T_6$ | 8.89$^{a}$ | 3.82$^{d}$ | 10.09$^{d}$ | 13.94$^{e}$ |
| P value | <0.005 | <0.005 | <0.005 | <0.005 |

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

## Product Recovery

Addition of carriers improved powder recovery (Figure 1,2,3). As discussed by Ameri and Maa [8] increasing total solid content of the feed solution is one way of increasing the powder recovery in spray-drying operations. The addition of carriers could increase the total solid content in the feed and thus, improved yield of the product.

Moreover, according to Bhandari *et al.* [9] sticky behaviour of sugar and acid rich materials can be attributed to low molecular weight sugars such as fructose, glucose, and sucrose and organic acids such as citric, malic and tartaric acid, which constitute more than 90% of the solids in fruit juices and purees. These materials have low glass transition temperature (sucrose: 62$^{0}$C, fructose:" 5$^{0}$C, glucose: 32$^{0}$C). The glass transition temperature (*Tg*), is the temperature at which the amorphous phase of the polymer is converted between rubbery and glassy states. Hence molecular mobility of polymer is high when the temperature of the spray-dried particle is sufficiently above the glass transition temperature.

They tend to stick to the walls of the dryer and finally give a paste like structure instead of powder when dried at temperatures normally prevailing in spray driers. As suggested by Quek *et al.*[10] carrier could alter the surface stickiness of low molecular weight sugars such as glucose, sucrose and fructose and organic acids, therefore, facilitated drying and reduced the stickiness of the spray dried product. Thus addition of carrier became an important step since the stickiness of particles during the spray drying could lead to formation of agglomerations inside the chamber and many other operational problems which might reduce product recovery as in conformity with Gianfrancesco *et al.*[11].

Within carriers, (Table 1) resistant dextrin yielded 41 per cent more powder in drying chamber than maltodextrin (Figure 1). However, more profound effect of resistant dextrin was observed in the quantity of powder obtained at cyclone (Figure 2) since the recovery tripled of maltodextrin. Thus use of resistant

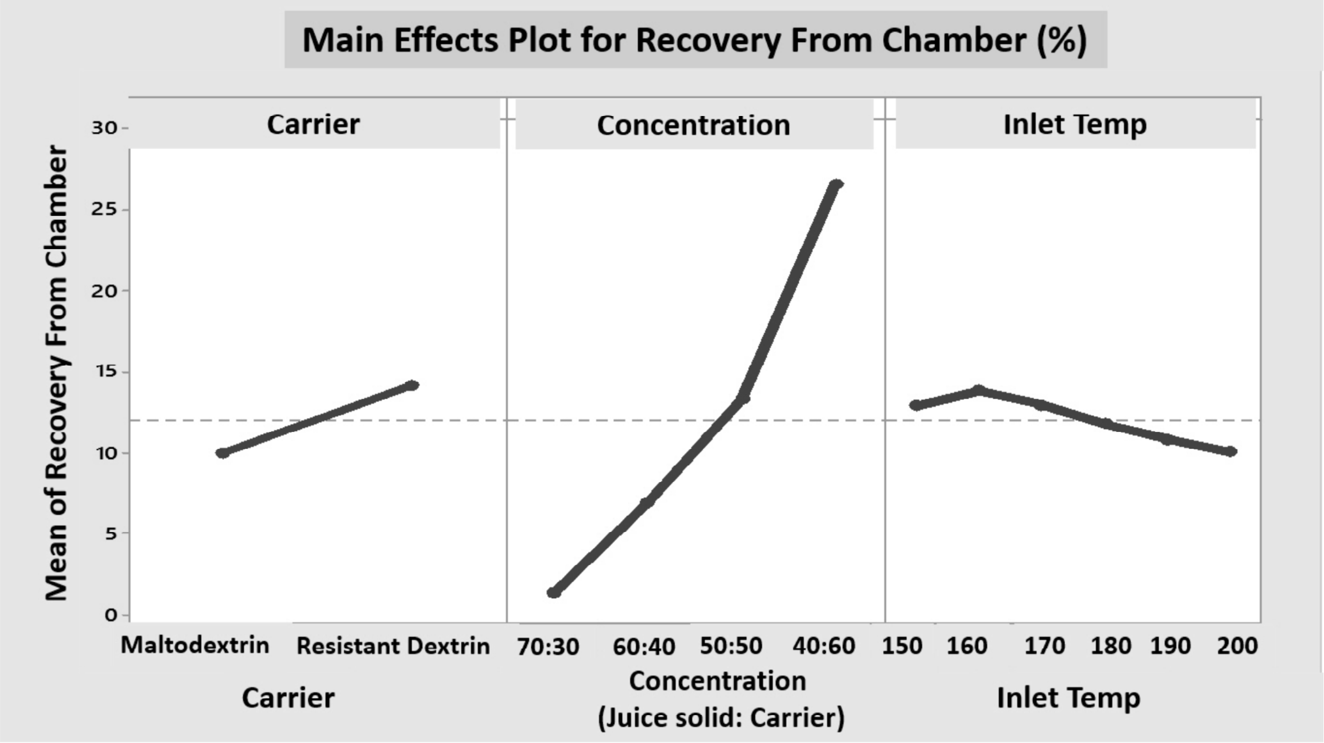

**Figure 1 : Main Effects Plot for recovery from chamber**

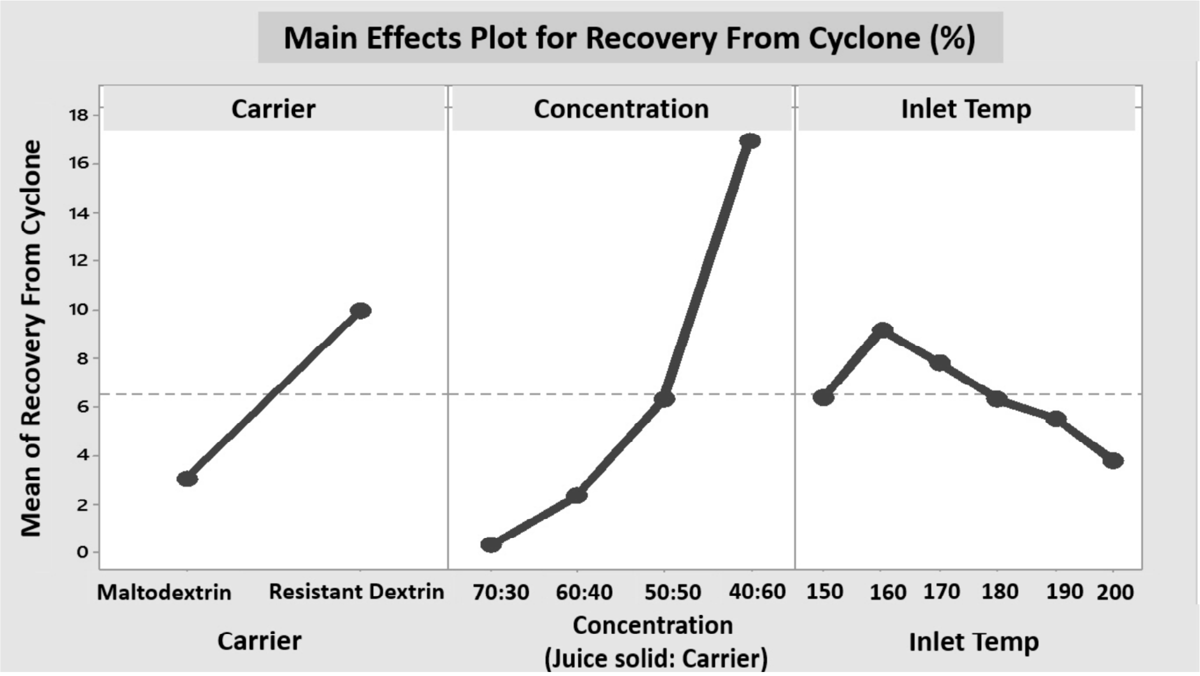

**Figure 2: Main Effect Plot for recovery from Cyclone**

dextrin as carrier resulted 85 per cent higher recovery than maltodextrin from bulked powder (Figure 3). Better recovery of powder with resistant dextrin can be attributed to the lower dextrose equivalence of resistant dextrin because the lower the carrier DE, the higher its glass transition temperature and, as a consequence, the higher the elevation of the Tg of the feedmix. Werner *et al*.[12] who tested level of stickiness of droplets reported that low DE carrier reach a state of non adhesion faster than high-DE carriers.

Moreover, increase in carrier ratio of the feed mix (Table 2) led to higher yield from chamber (Figure 1). The feed with juice solid to carrier ratio of 40:60 recorded 19 times higher recovery from feed of 70:30 ratio while the yield nearly quadrupled and doubled from 60:40 and 50:50 respectively.

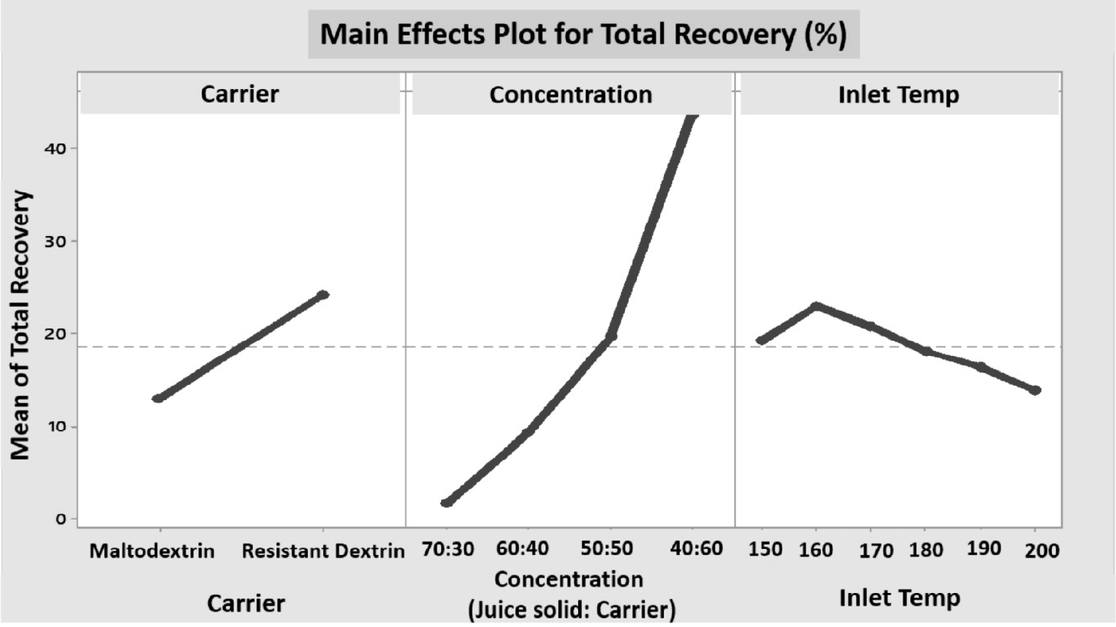

**Figure 3 : Main Effects Plot for Total recovery**

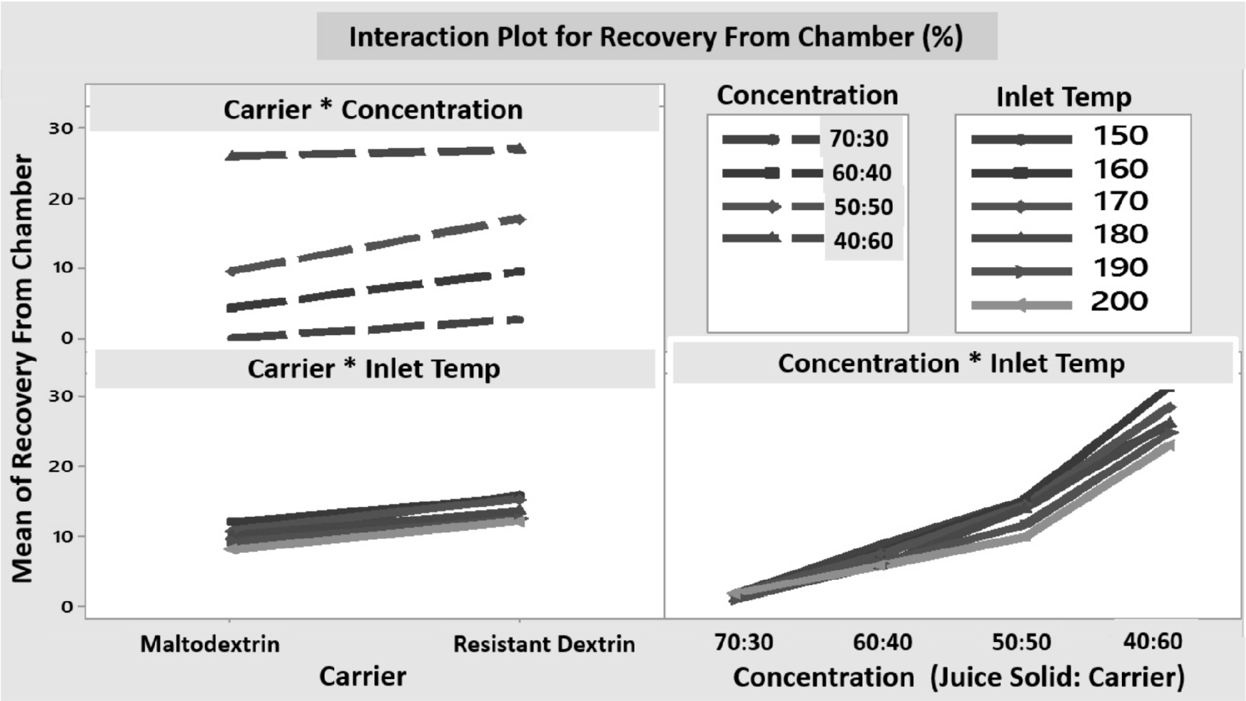

**Figure 4 : Interaction Plot for Recovery from Chamber**

The carrier concentration (Table 2) had a more marked effect in the powder recovery from cyclone (Figure 2). Higher concentration of carrier and lower juice solids multiplied the recovery as 49 times, 7 times and 2.7 times respectively when juice solid to carrier ratio is varied from 70:30, 60:40, 50:50 to 40:60. In the bulked powders (Figure 3) the powder recovery of 70:30 and 60:40 juice solid to carrier ratio of feed mix were very low and negligible in commercial point of view, while the highest content of carrier material in the feed mix (60:40) recorded 2.2 times recovery than the nearest lower concentration (Table 2)

The increment in yield corresponding to the increase in carrier concentration could be explained by the observations made by some authors [3,9,10] on the increased the *T*g values of the amorphous fractions in the mixtures that are rich in low *T*g components when carrier concentration was increased. As discussed elsewhere [13,14] increase in the carrier content results in an increase of the recovery of feed solids in the product. However Jittanit *et al.*[15] pointed that increase in carrier concentration beyond optimum reduced the yield.

The data on recovery of powder from chamber (Figure 4) exhibits marked interaction of concentration with carrier (Table 4) and reiterate the above findings. Maltodextrin failed to produce any recoverable powder at juice solid to carrier ratio of 70:30 as the entire material stuck to the chamber wall while resistant dextrin could yield significantly higher quantity. Interactive effect of carrier with the highest concentration was nearly 10 times higher than the lowest concentration in which powder was recoverable (Table 4). However, within highest concentration of 40:60, both carriers did not exhibit any significant deviation in the powder obtained from chamber.

**Table 4**
**Interaction Effect of Carrier with Concentration**

| *Carrier* Concentration* | *Feed rate (g/min)* | *Recovery of powder (%)* | | |
|---|---|---|---|---|
| | | *Cyclone* | *Chamber* | *Total* |
| MC$_1$ | 4.92 | 0.00$^d$ | 0.00$^e$ | 00.00$^f$ |
| MC$_2$ | 5.52 | 0.14$^d$ | 4.36$^d$ | 4.51$^e$ |
| MC$_3$ | 6.38 | 3.38$^c$ | 9.61$^c$ | 12.99$^d$ |
| MC$_4$ | 6.94 | 8.82$^b$ | 26.03$^a$ | 34.86$^b$ |
| DC$_1$ | 4.88 | 0.71$^d$ | 2.74$^d$ | 3.44$^e$ |
| DC$_2$ | 5.48 | 4.63$^c$ | 9.54$^c$ | 14.22$^d$ |
| DC$_3$ | 6.42 | 9.37$^b$ | 17.15$^b$ | 26.53$^c$ |
| DC$_4$ | 6.96 | 25.21$^a$ | 27.17$^a$ | 52.38$^a$ |
| P value | 0.995 | <0.005 | <0.005 | <0.0055 |

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

Recovery of powder from cyclone (Figure 5) exhibited a pattern. Higher concentration in maltodextrin yielded at par with subsequent lower concentration of resistant dextrin. Resistant dextrin at juice solid to carrier ratio of 40: 60 recorded highest recovery followed by the ratio of 50:50 of the same carrier in the powder obtained from cyclone (Table 4).This clearly reiterated superiority of resistant dextrin in improving powder recovery from cyclone. Within resistant dextrin, increasing carrier concentration from juice solid to carrier ratio of 50: 50 to 40:60 improved powder recovery by 168 per cent. From the data on total recovery (Figure 6) it could be summarized that within the carrier and concentration interaction, Resistant dextrin was superior to maltodextrin in equal concentration levels (Table 4). At the highest carrier concentration levels resistant dextrin was better than maltodextrin by 50 per cent due to the higher efficiency to translocate from chamber to cyclone which is very important in commercial point of view.

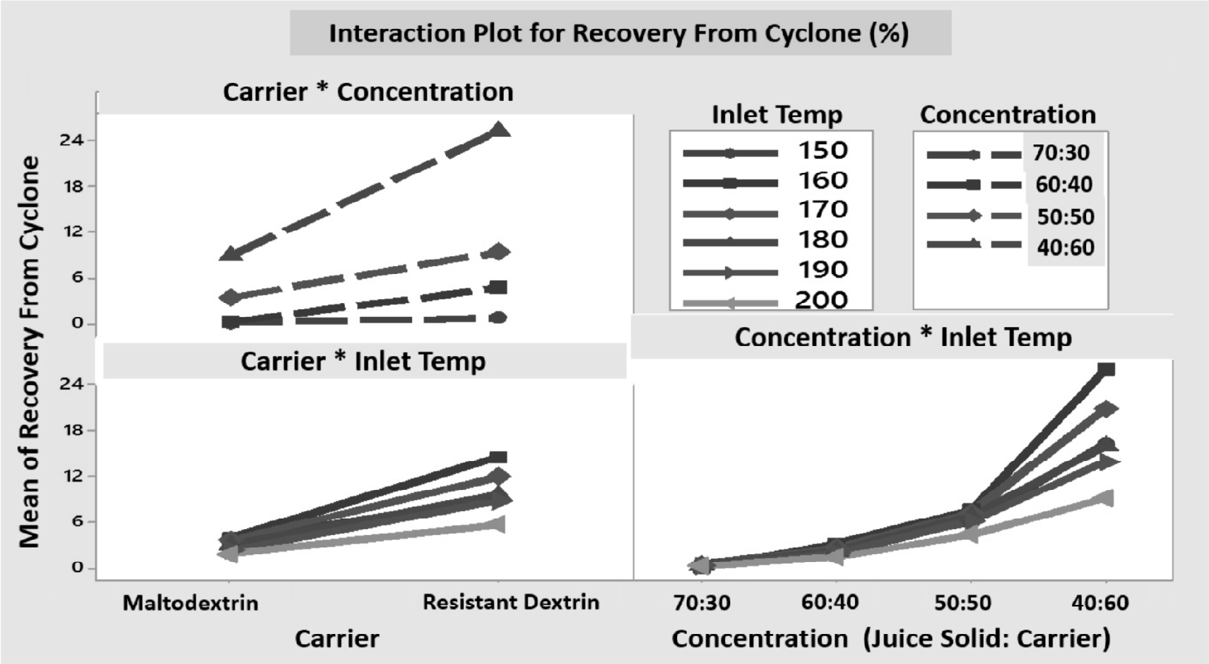

Figure 5 : Interaction Plot for Recovery from Cyclone

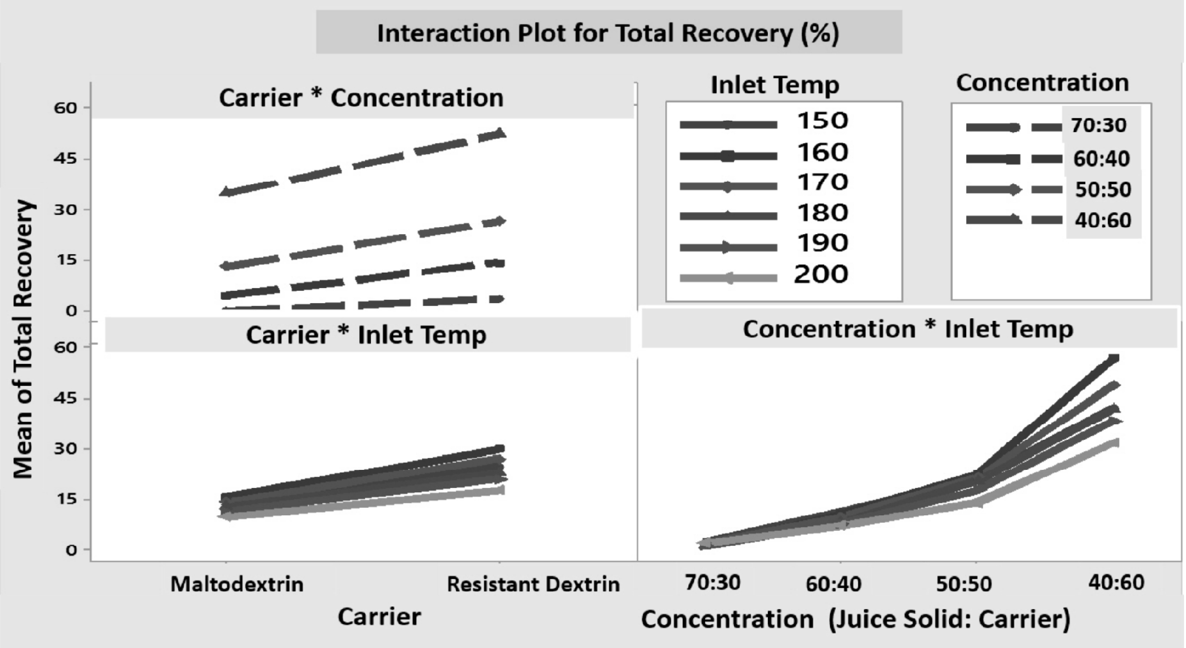

Figure 6 : Interaction Plot for Total Recovery

In contrast with the observation of the feed rates, the powder recovery in the drying chamber decreased with higher temperatures (Table 3). The temperature range from 150 to 170°C recorded 30 to 37per cent higher recoveries while 190 to 200°C yielded the lowest (Figure 1). Any 10 °C difference between the inlet temperatures could not make any significant deviation. Negative temperature difference of 20°C in the higher temperature range of 180-200°C and 30°C in temperature range of 150to 180°C could improve the yield significantly. However lower inlet temperature range of 160 to 170°Cexhibited a profound effect on recovery of powder in cyclone (Figure 2). Reduction of temperature from 200 to 160°C resulted 2.4 times increase in recovery. Even the ten degree increment between 170 and 180°C or 190 and 200°C reduced the recovery significantly. In contrast a ten degree increase from 150°C improved powder yield by 44 per cent. In bulked powders (Figure 3), the feed mix dried at 160°C had the best recovery followed by 170 or 150°C. A negative ten degree change in the temperature could positively influence the total recovery in the highest temperature range by 17.6 per cent while a positive 10 degree change could positively influence the recovery in the lowest temperature range by 21 per cent (Table 3).

Troung *et al.*[16 ]described stickiness as the phenomena of particle–particle cohesion and particle–wall adhesion in the spray drying process. Stickiness depends not only on the properties of materials but also on the inlet variables applied in a spray drying system. As discussed by Jittanit *et al.*]15]the increase of inlet air temperature has reduced the yield and it might be caused by higher cohesion of the powder to wall at higher temperature and therefore the amount of powder production and yield was reduced.

Another possibility for lower yields at high temperatures can be the higher feed rates employed to maintain outlet temperature. Higher flow rates at constant atomization imply in a shorter contact time between the feed and drying air and making the heat transfer less efficient and thus caused the lower water evaporation and lower yield. Toneli *et al.*[17] also noted an increase on mass production rate with increasing air temperatures and decreasing pump speeds in the spray drying of inulin. As observed by Chegini and Ghobadian [18] increasing the feed flow rate, at constant atomizer speed, more liquid was atomized into chamber, thus time of drying was reduced and finally the drying was incorrect.

However according to Tonon *et al.* [19]The increase of inlet temperatures has given the higher process yield due to the greater efficiency of heat and mass transfer processes occurring when higher inlet air temperatures were used. This might explain the higher recovery when the temperature is raised by ten degree from the lowest one.

**Table 5**
**Interaction Effect of Carrier with Inlet Temperature**

| *Carrier* Inlet Temp* | *Feed rate (g/min)* | *Recovery of powder (%)* | | |
|---|---|---|---|---|
| | | *Cyclone* | *Chamber* | *Total* |
| $MT_1$ | 3.55 | $3.56^{d,e}$ | 9.93 | $13.49^{f,g}$ |
| $MT_2$ | 4.52 | $3.99^{d,e}$ | 11.98 | $15.97^{e,f}$ |
| $MT_3$ | 5.07 | $3.71^{d,e}$ | 10.69 | $14.40^{f,g}$ |
| $MT_4$ | 6.68 | $3.03^{e}$ | 10.05 | $13.08^{f,g,h}$ |
| $MT_5$ | 6.94 | $2.35^{e}$ | 9.29 | $11.64^{g,h}$ |
| $MT_6$ | 8.89 | $1.88^{e}$ | 8.07 | $9.95^{h}$ |
| $DT_1$ | 3.5 | $14.47^{a}$ | 15.89 | $25.16^{b,c}$ |
| $DT_2$ | 4.48 | $11.96^{b}$ | 15.68 | $30.15^{a}$ |
| $DT_3$ | 5.12 | $9.62^{c}$ | 15.26 | $27.22^{a,b}$ |
| $DT_4$ | 6.6 | $9.27^{c}$ | 13.53 | $23.16^{c,d}$ |
| $DT_5$ | 7.12 | $8.81^{c}$ | 12.42 | $21.22^{d}$ |
| $DT_6$ | 8.9 | $5.76^{d}$ | 12.11 | $17.94^{e}$ |
| P value | 0.999 | <0.005 | 0.074 | <0.005 |

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

Interaction effect of carrier with inlet temperature was non significant in the powder obtained from chamber but was significant in cyclone and bulked powders (Table 5). Among the lower temperature range of 160 to 170°C, interaction with resistant dextrin (Table 5) led to the superiority of 160°C over 170°C while both temperature were on par with maltodextrin in the powder obtained from cyclone (Figure 5). Reduction of 40°C from 200 to 160°C improved cyclone powder yield by the magnitude of 151 per cent against 112 per cent in maltodextrin (Table 5). This clearly indicate that as the Resistant dextrin reduced stickiness, the recovery improved, and the effect of other operating parameters became more evident. The variation in process parameters had higher influence in the cyclone recovery than powder from chamber. Resistant dextrin had nearly double yields than maltodextrin at equal temperature levels in bulked powders (Figure 6)

Evident interaction between concentration and inlet temperature (Table 6) could be observed in the powder obtained from chamber(Figure 4) since highest concentration with lower temperature resulted 33 times higher recovery than the lowest concentration and higher temperature. Within the highest concentration of the carrier (40:60) 37 per cent increase in yield could be obtained by reducing temperature from 200 to 160°C. However, further reduction of ten degree celsius reduced the powder yield significantly. The temperature of 160$^{o}$C recorded 21 per cent higher yield than 150$^{o}$C in the highest concentration level of carrier. It is also interesting to note that in all other concentration levels this 10$^{o}$C difference between 150$^{o}$C and 160$^{o}$C failed to produce any significant deviation as observed in main effect analysis. The reduced recovery in the lowest temperature might be due to the inefficient drying at very low temperature at high concentration levels of carrier since the product appeared as moisture laden and agglomerated.

This negative effect of lowest temperature could be observed in the powder obtained from the cyclone too (Figure 5). Within the highest carrier concentration levels the reduction of temperature from 200 to 160$^{o}$C led to 182 per cent higher recovery and the increment from 150 to 160$^{o}$C saved 59 per cent powder as the moisture laden powder caked at the cyclone (Table 6). However as the concentration of carrier got lower, these interaction effects got lowered and then diminished.

After analyzing the data on the total recovery (Figure 6) of powder, it could be summarized that lower ranges of temperature exhibited higher yields in higher concentration levels. In the highest concentration levels 160$^{o}$C was the optimum temperature since it resulted in 16 per cent higher recovery from the nearest higher temperature and 35 per cent higher yield from the lower one (Table 6). However in the lower concentration levels these lower temperature ranges did not exhibit any marked deviation pattern.

**Table 6**
**Interaction Effect of Concentration with Inlet Temp**

| *Concen-tration *Inlet Temp* | *Feed rate (g/min)* | *Recovery of powder (%)* | | |
|---|---|---|---|---|
| | | *Cyclone* | *Chamber* | *Total* |
| $C_1T_1$ | $3.30^{i}$ | $0.68^{i}$ | $1.69^{h}$ | $2.36^{i,j}$ |
| $C_1T_2$ | $3.98^{h,i}$ | $0.09^{i}$ | $1.18^{h}$ | $1.26^{j}$ |
| $C_1T_3$ | $4.32^{g,h,i}$ | $0.51^{i}$ | $1.61^{h}$ | $2.11^{j}$ |
| $C_1T_4$ | $5.44^{f,g,h}$ | $0.34^{i}$ | $1.02^{h}$ | $1.35^{j}$ |
| $C_1T_5$ | $5.89^{e,f,g}$ | $0.26^{i}$ | $0.93^{h}$ | $1.18^{j}$ |
| $C_1T_6$ | $6.48^{d,e,f}$ | $0.26^{i}$ | $1.78^{h}$ | $2.03^{j}$ |
| $C_2T_1$ | $3.34^{i}$ | $2.71^{g,h,i}$ | $8.87^{e,f,g}$ | $11.58^{g,h}$ |
| $C_2T_2$ | $4.19^{g,h,i}$ | $3.22^{f,g,h,i}$ | $7.58^{fg}$ | $10.79^{g,h}$ |
| $C_2T_3$ | $4.89^{f,g,h,i}$ | $2.73^{g,h,i}$ | $7.40^{fg}$ | $10.13^{g,h}$ |
| $C_2T_4$ | $5.82^{e,f,g}$ | $2.26^{h,i}$ | $6.15^{fg}$ | $8.17^{h}$ |
| $C_2T_5$ | $6.33^{d,e,f}$ | $1.97^{h,i}$ | $5.92^{g}$ | $8.11^{h}$ |
| $C_2T_6$ | $8.44^{b,c}$ | $1.46^{h,i}$ | $5.77^{g}$ | $7.37^{hi}$ |
| $C_3T_1$ | $3.6^{i}$ | $5.96^{d,e,f,g}$ | $15.13^{d}$ | $21.08^{e}$ |
| $C_3T_2$ | $4.87^{f,g,h,i}$ | $7.63^{d,e}$ | $15.25^{d}$ | $22.88^{e}$ |
| $C_3T_3$ | $5.32^{f,g,h}$ | $7.28^{d,e}$ | $14.47^{d}$ | $21.75^{e}$ |
| $C_3T_4$ | $7.33^{c,d,e}$ | $6.80^{d,e,f}$ | $13.94^{d}$ | $20.73^{e}$ |
| $C_3T_5$ | $7.41^{c,d,e}$ | $6.21^{d,e,f,g}$ | $11.62d^{e}$ | $17.82^{ef}$ |
| $C_3T_6$ | $9.92^{a,b}$ | $4.37^{e,f,g,h}$ | $9.88^{e,f}$ | $14.25^{fg}$ |
| $C_4T_1$ | $3.90^{h,i}$ | $16.32^{c}$ | $25.95^{bc}$ | $42.27^{c}$ |
| $C_4T_2$ | $4.96^{f,g,h,i}$ | $25.97^{a}$ | $31.32^{a}$ | $57.28^{a}$ |
| $C_4T_3$ | $5.85^{e,f,g}$ | $20.82^{b}$ | $28.42^{a,b}$ | $49.24^{b}$ |
| $C_4T_4$ | $7.99^{c,d}$ | $15.92^{c}$ | $26.29^{b,c}$ | $42.21^{c}$ |
| $C_4T_5$ | $8.29^{b,c}$ | $13.87^{c}$ | $24.72^{b,c}$ | $38.58^{c}$ |
| $C_4T_6$ | $10.74^{a}$ | $9.19^{d}$ | $22.92^{c}$ | $32.10^{d}$ |
| P value | <0.005 | <0.005 | <0.005 | <0.005 |

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

When all the favorable factors as resistant dextrin, juice solid and carrier ratio of 40: 60 and optimum temperature of 160$^{o}$C effected together, powder recovery in cyclone was 40. 56 per cent of the total solid of the feed mix followed by 31.15 per cent at 170$^{o}$C (Table7). The three factor interaction analysis of bulked powder clearly pointed out the favorable levels as resistant dextrin in carrier, juice solid and carrier ratio of 40:60 in concentration and 160$^{o}$C in inlet temperatures as the optimum for higher recovery of solids from the feed. This combination yielded 72.1 per cent of the total solids of the feed as powder and the remaining were lost as entrainment or sticky losses. This combination recorded 19.6 per cent higher recovery than the nearest better combination which involved the same carrier and concentration but dried at 170$^{o}$C.

## CONCLUSION

The present work describes possibility of producing cashew apple juice powers by spray drying and tries to optimize different carriers in varying proportions and inlet temperature. The variation in process parameters had higher influence in the cyclone recovery than powder from chamber.Combined powder recovery from cyclone and chamber clearly point out the favorable levels as resistant dextrin in carrier, juice solid and carrier ratio of 40:60 in concentration and 160$^{0}$C in inlet temperatures as the optimum for higher recovery of solids from the feed. This combination yielded 72.1 per cent of the total solids of the feed as powder and the remaining was lost as entrainment or sticky losses. At these levels powder recovery in cyclone was 40. 56 per cent of the total solid of the feed mix.

## REFERENCES

Cavalcante, A.A.M., Rubensam, G., Picada, J.N., Silva, E.G., Moreira, J.C.F and Henriques, J.A.P. (2003), Mutagenicity, antioxidant potential and antimutagenic activity against hydrogen peroxide of cashew (*Anacardium occidentale*) apple juice and cajuina. *Environ. Mol. Mutagen.*, 41: 360–369.

**Table 7**
**Interaction Effect of Carrier*Concentration *Inlet**

| *Carrier* Concentration *Inlet Temp* | *Feed rate (g/min)* | | *Recovery of powder (%)* | |
|---|---|---|---|---|
| | | *Cyclone* | *Chamber* | *Total* |
| $MC_1T_1$ | 3.1 | $0^{m}$ | 0 | $0^{u}$ |
| $MC_1T_2$ | 3.4 | $0^{m}$ | 0 | $0^{u}$ |
| $MC_1T_3$ | 4.43 | $0^{m}$ | 0 | $0^{u}$ |
| $MC_1T_4$ | 5.46 | $0^{m}$ | 0 | $0^{u}$ |
| $MC_1T_5$ | 5.84 | $0^{m}$ | 0 | $0^{u}$ |
| $MC_1T_6$ | 6.74 | $0^{m}$ | 0 | $0^{u}$ |
| $MC_2T_1$ | 3.39 | $0.32^{m}$ | 5.52 | $5.84^{p,q,r,s,t,u}$ |
| $MC_2T_2$ | 4.34 | $0.32^{m}$ | 5.84 | $6.17^{o,p,,q,r,s,t,u}$ |
| $MC_2T_3$ | 4.78 | $0.22^{m}$ | 4.76 | $4.98,^{q,r,s,t,u}$ |
| $MC_2T_4$ | 6.00 | $0^{m}$ | 3.25 | $3.23^{t,u}$ |
| $MC_2T_5$ | 6.32 | $0^{m}$ | 3.57 | $3.57^{s,t,u}$ |
| $MC_2T_6$ | 8.26 | $0^{m}$ | 3.25 | $3.25^{t,u}$ |
| $MC_3T_1$ | 3.62 | $2.34^{k,l,m}$ | 11.71 | $14.05^{l,m,n}$ |
| $MC_3T_2$ | 4.71 | $4.23^{g,h,i,j,k,l,m}$ | 10.99 | $15.22^{l,m,n}$ |
| $MC_3T_3$ | 5.32 | $4.14^{g,h,I,j,k,l,m}$ | 10.27 | $14.41^{l,m,n}$ |
| $MC_3T_4$ | 7.28 | $3.78^{i,j,k,l,m}$ | 10.18 | $13.96^{l,m,n,o}$ |
| $MC_3T_5$ | 7.38 | $3.33^{j,k,l,m}$ | 7.84 | $11.17^{m,n,o,p,q,r,s}$ |
| $MC_3T_6$ | 9.97 | $2.43,^{k,l,m}$ | 6.67 | $9.1^{n,o,pq,r}$ |
| $MC_4T_1$ | 4.08 | $11.57^{d,e}$ | 22.5 | $34.07^{g,h,i}$ |
| $MC_4T_2$ | 5.09 | $11.39^{d,e}$ | 31.09 | $42.48^{d,e,f}$ |
| $MC_4T_3$ | 5.73 | $10.5^{d,e,f}$ | 27.73 | $38.22^{e,f,g}$ |
| $MC_4T_4$ | 7.96 | $8.35^{d,e,f,g,h,I,j}$ | 26.77 | $35.13^{f,g,h,i}$ |
| $MC_4T_5$ | 8.20 | $6.05^{efghijkl\ e,f,g,h,i,j,k,l}$ | 25.75 | $31.8^{g,h,I,j}$ |
| $MC_4T_6$ | 10.5 | $5.08^{fghijkl}$ ffghijkl$^{f,g,h,I,j,k,l,m}$ | 22.36 | 27.44i$^{,j}$ |
| $DC_1T_1$ | 3.49 | $1.35^{k,l,m}$ | 3.38 | $4.74^{r,s,t,u}$ |
| $DC_1T_2$ | 4.02 | $0.17^{m}$ | 2.37 | $2.54^{t,u}$ |
| $DC_1T_3$ | 4.19 | $1.02^{k,l,m}$ | 3.22 | $4.23^{r,s,t,u}$ |
| $DC_1T_4$ | 5.40 | $0.68^{k,l,m}$ | 2.03 | $2.71^{t,u}$ |
| $DC_1T_5$ | 5.93 | $0.51^{l,m}$ | 1.86 | $2.37^{t,u}$ |
| $DC_1T_6$ | 6.20 | $0.51^{l,m}$ | 3.55 | $4.06^{r,s,t,u}$ |
| $DC_2T_1$ | 3.28 | $5.1^{f,g,h,i,j,k,l,m}$ | 12.23 | $17.32^{k,l,m}$ |
| $DC_2T_2$ | 4.03 | $6.11^{e,f,g,h,I,j,k,l}$ | 9.32 | $15.43^{l,m,n}$ |
| $DC_2T_3$ | 5 | $5.24^{fg,h,i,j,k,l,m}$ | 10.04 | 15.28l$^{,m,n}$ |
| $DC_2T_4$ | 5.63 | $4.51^{g,h,I,j,k,l,m}$ | 8.59 | $13.1^{l,m,n,o,p}$ |
| $DC_2T_5$ | 6.33 | $3.93^{h,i,j,k,l,m}$ | 8.74 | $12.67^{l,m,n,o,p,q}$ |
| $DC_2T_6$ | 8.61 | $2.91^{j,k,l,m}$ | 8.3 | $11.51^{m,n,o,p,q,r}$ |
| $DC_3T_1$ | 3.5 | $9.58^{d,e,f,g,h}$ | 18.55 | $28.12^{i,j}$ |
| $DC_3T_2$ | 5.03 | $11.03^{d,e}$ | 19.52 | $30.55^{g,h,I,j}$ |
| $DC_3T_3$ | 5.32 | $10.42^{d,e,f}$ | 18.67 | $29.09^{h,I,j}$ |
| $DC_3T_4$ | 7.36 | $9.82^{d,e,f,g}$ | 17.7 | $27.52^{i,,j}$ |
| $DC_3T_5$ | 7.43 | $9.09^{d,e,f,g,h,i}$ | 15.4 | $24.49^{j,k}$ |
| $DC_3T_6$ | 9.86 | $6.3^{e,f,g,h,i,j,k}$ | 13.09 | $19.39^{k,l}$ |
| $DC_4T_1$ | 3.72 | $21.06^{c}$ | 29.41 | $50.47^{c}$ |
| $DC_4T_2$ | 4.82 | $40.56^{a}$ | 31.54 | $72.1^{a}$ |
| $DC_4T_3$ | 5.96 | $31.15^{b}$ | 29.11 | $60.26^{b}$ |
| $DC_4T_4$ | 7.99 | $23.48^{c}$ | 25.81 | $49.3^{c,d}$ |
| $DC_4T_5$ | 8.36 | $21.69^{c}$ | 23.68 | $45.37^{c,d,e}$ |
| $DC_4T_6$ | 10.9 | $13.29^{d}$ | 23.48 | $36.78^{f,g,h}$ |
| P value | 0.999 | <0.005 | 0.201 | <0.005 |

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

Cano-Chauca, M., Stringheta,P.C., Ramos, A.M. Cal-Vidal, J. (2005), Effect of the carriers on the microstructure of mango powder obtained by spray drying and its functional characterization. *Innov. Food Sci. Emerg. Technol.*,6: 420-428.

Shrestha, A.K., Ua-arak, T., Adhikari, B.R., Howes, T. Bhandari, B.R. (2007), Glass transition behavior of spray dried orange juice powder measures by differential scanning calorimetry (DSC) and thermal mechanical compression test (TMCT). *Int. J. Food Prop* 10: 661–673.

Shahidi, F and Han, X. Q. (1993), Encapsulation of food ingredients. *Crit Rev Food Sci Nutr* 33 : 501–547.

Murugesan, R. and Orsat, V. (2011), Spray Drying for the Production of Nutraceutical Ingredients-A Review. *Food Bioprocess Technol.*, 8: 1-12.

Desai, K. G. H., and Park, H. J. (2005), Recent developments in microencapsulation of food ingredients. *Dry Technol*,23, 1361-1394.

Phisut, N. (2012), Spray drying technique of fruit juice powder: some factors influencing the properties of product *IFRJ* 19(4): 1297-1306.

Ameri, M., and Maa, Y. F. (2006), Spray drying of biopharmaceuticals: stability and process considerations. *Dry Technol.*, 24, 763-768.

Bhandari, B.R., Datta, N., and Howes, T. (1997), Problem associated with spray drying of sugar-rich foods. *Dry Technol.*, 15 (2): 671–684.

Quek, Y.S., Chok, N.K. and Swedlund, P. (2007), The physicochemical properties of spray-dried watermelon powders. *Chem. Eng. Process*.. 46: 386-392.

Gianfrancesco, A., Turchiuli, C., Flick, D., and Dumoulin, E. (2010), CFD modeling and simulation of maltodextrin solutions spray drying to control stickiness. *Food Bioprocess Technol.*, 3: 946–955.

Werner, S. R. L., Jones, J. R., and Paterson, A. H. J. (2007), Stickiness of maltodextrins using probe tack test during in-situ drying. *J. Food Eng*, 80: 859-868.

Papadakis, S.E., Gardeli, C. and Tzia, C. (1998), Raisin extract powder: Production, physical and sensory properties. In: Proceedings of the 11th international drying symposium IDS '98, Halkidiki, Greece.

Roustapour, R.O.,Hosseinalipour,M., Ghobadian, B. Mohaghegh, F., Azad M.N. O.R. (2009), A proposed numerical–experimental method for drying kinetics in a spray dryer. *J. Food Eng* 90: 20–26.

Jittanit, W., Niti-Att, S. and Techanuntachikul, O. (2010), Study of spray drying of pineapple juice using maltodextrin as an adjunct. *Chiang Mai J.Sci.*, 37(3): 498-506.

Truong, V., Bhandari, B.R. and Howes, T. (2005), Moisture and glass optimization of co-current spray drying process of sugar rich foods: transition temperature profile during drying. *J. Food Eng* 71: 55–65.

Toneli, J., Park, K.J., Murr, F. and Negreiros, A. (2006), Spray drying optimization to obtain inulin powder. In: Proceedings of the 15*th* International Drying Symposium (IDS 2006), Budapest, Hungary.

Chegini, R.G. and Ghobadian, B. (2007), Spray dryer parameters for fruit juice drying. *World J. Agric. Sci.*,3: 230-236.

Tonon, V.R., Brabet, C. and Hubinger, M. (2008), Influence of process conditions on the physicochemical properties of acai powder produced by spray drying. *J. Food Eng.*, 88: 411-418.