INSTANT JUICE POWDERS OF CASHEW APPLE (*Anacardium occidentale* L.) AND PINEAPPLE (*Ananas comosus* (L.) Merr.)

by

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THESIS

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DECLARATION

I, hereby declare that this thesis entitled **"INSTANT JUICE POWDERS OF CASHEW APPLE (*Anacardium occidentale* L.) AND PINEAPPLE (*Ananas comosus* (L.) Merr.)"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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LIST OF ABBREVIATIONS

%	-	per cent
CD (0.05)	-	Critical difference at 5 % level
cm	-	centimeter
et al.	-	and co-workers/co-authors
ha	-	hectare
i.e.	-	that is
kg	-	kilogram
KAU	-	Kerala Agricultural University
Viz.	-	Namely
Tg	-	Glass transition Temperature
DE	-	Dextrose Equivalence
g	-	gram
mg	-	milli gram
µg	-	microgram
@	-	at the rate of
o	-	Degrees (Angle)
°C	-	Degree centigrade
oB	-	Degree brix
nm	-	nano meter
µm	-	micro meter
mPas	-	milli pascal seconds
KMS	-	Pottassium meta bisulphite
RPM	-	Rotation per minute
psi	-	Pounds per square inch
ERH	-	Equilibrium relative humidity
EMC	-	Equilibrium moisture content
SEM	-	Scanning electron microscopy
DSC	-	Differential scanning calorimetry
TSS	-	Total soluble solids
RTS	-	Ready to serve
ppm	-	Parts per million

Introduction

1. INTRODUCTION

Nature has given plenty yet we suffer from poverty. The state of postharvest losses better explains this paradox. The extent of postharvest losses in vegetables and fruits is quantified at 40% in India, depending upon the commodity. However, not even two per cent of vegetables and fruits are converted to products as against 65 per cent in the US, 70 per cent in Brazil, 78 per cent in the Philippines, 80 per cent in South Africa and 83 per cent in Malaysia. This is sheer wastage of labour, energy and inputs involved in production and loss of crores of rupees (Planning commission, 2007).

The situation of postharvest losses in Kerala is not different from its counterparts. Though the area under cashew in Kerala shows an increasing trend and contribute 8.1 per cent of the total area in our country and produced 71000 metric tonne of cashew nuts (NHB, 2011), cashew apple is completely thrown away every year as the fruit is extremely perishable and main thrust is for marketing of cashew nuts. Goa is the only state in India where cashew apples are utilised to prepare "*feni*" a fermented cashew apple beverage. Some conventional products like jam, candy, syrup, vinegar and wine can are standardised from cashew apple but commercial production is still limited, deserving exploitation of unique processing technologies.

Pineapple is one of the favorite fruits which is consumed either in raw or in processed forms as canned slices and juice. In Kerala, pineapple is cultivated in an area of 12500 with a productivity of 8.20t/ha, consistently stable over the last few years. Kerala is 4^{th} major pineapple cultivating state in India with 11per cent of area and have 8^{th} position with six per cent of the production (NHB, 2011). The congenial humid climate of kerala always favored farming of pineapple. The best quality "Mauritius Pineapple" which is unparalleled in aroma, flavor, sweetness and low acidity descends from Kerala. Gajanana *et al*. (2002) estimated the total postharvest loss in pineapple as 29.25 per cent, elucidating the scope of value addition and processing of pineapple in Kerala.

Planning commission (2007) stressed the importance of innovative product development using modern technologies to meet the requirements of fast expanding processing industries as well as national and international markets. The fast economic uprise and higher health consciousness have changed the trend of food consumption from calories assurance to diet nutrient enrichment.

Many drying methods such as spray drying, tray drying, freeze drying, vacuum drying, fluidised bed drying and microwave drying are considered as novel dehydration technologies that have better control of the process to improve quality. Among these techniques, spray drying is used in a broad spectrum of products in food industries to produce dry powders and microcapsules.

Microencapsulation through spray drying is reported to produce light weight final products with low water activity thus resulting in easy storage, transportation and marketing. These quality fruit powders can be instantly reconstituted to a fine product resembling the original. This quick single step drying method with scant contact time is considered as one of the finest dehydration techniques to convert liquid substances into hygienic solid particles for minimizing the process, maximizing the profit and conserving nutrients.

In order to reap benefits from the potential functional properties and health related advantages of cashew apple and pineapple it becomes imperative to add value in forms of powders that are stable over a longer storage time and with desired functionalities. Instant powders offer various advantages over a variety processed products like jams, candies and liquid beverages. Development instant juice powder may improve demand for natural beverages and open new market avenues.

However, complicated interactions of equipment, process, operating conditions and feed parameters occur in the process of spray drying which highly determine the end product characteristics and quality parameters (Chegini *et al.*, 2008). The physical, chemical and morphological properties of end products mainly depend on inlet temperature, drying air flow rate, feed flow rate, atomizer speed, types of drying aids and concentration levels.

Though there are a few investigations reported on the various parameters that influence spray drying efficiency, any generalization could not be obtained due to contradicting results and the optimal values differed for each material. These variations may be related to different feed compositions and process conditions during spray drying. Therefore, it is imperative to optimize operational parameters that pave way for economic and efficient production of powder. Different carriers and drying conditions produces different physical, chemical and morphological properties of powders. Knowledge of food properties is crucial for optimizing the processes, functionalities, and reduce costs.

Being faced with the multiple challenges like scanty information on cashew apple and pineapple processing particularly on modern drying methods and complexities in generalization of information on drying parameters, the present research tries to optimise the process parameters for micro encapsulation through spray drying of cashew apple and pineapple juices, to evaluate the effect of drying on physical chemical and nutritional quality parameters of fruit powders, to formulate blended fruit powder, and to assess organoleptic quality, storage stability, economics and consumer acceptability of the standardised formulations.

Review of Literature

2. REVIEW OF LITERATURE

This chapter provides background information relevant to the instant juice powder production by spray drying and storage. In order to carry systematic research work, a brief review of literature on dehydration, spray drying, drying parameters, powder charateristics, storage and reconstitution is done.

2.1 DEHYDRATION OF FRUITS

Though canning of vegetables and fruits or their products is the main processing method in India which constitute about 40 per cent of processed products, higher moisture content elevates cost of transportation and cause more spoilage. In India where the ambient temperature in summer month ranges between 32-45°C storage of fruit juices even after reduction of moisture through concentration is difficult. However, dehydration of food saves storage space and handling cost. Reduced cost of the container, lower labour requirement for production and packing and reduced distribution cost can improve affordability of processed products. Convenience, versatility and stability of storage are other advantages of dried fruit products.

Jayaraman and Gupta (1992) reiterated that when water contained in fruit or vegetable is limited to a level below its water activity, spoilage organisms do not grow and multiply in storage and thus preservation with reduced use of harmful additives is the main advantage in dried products. Over the past three decades, higher concerns have been developed for food quality degradation and nutrient destruction during thermal processing. Thermal processing for preserving food materials and microbiological safety, with limited regard for nutritional quality is gradually shifting (Goula *et al*. 2006).

Requirements of the consumers concerning convenience, safety of food, health benefits and sensory quality have increased demand for fruit juices but most consumers may not have time to process or prepare them, requiring ready-to-use or easy-to-prepare products. Juices and nectars require higher costs to transport, because of their higher weights and frozen pulps require costly cold chain. Powdered products can meet consumer requirements being cheap to transport and have prolonged shelf life (Cano-Chauca *et al*., 2005). Powders of fruit juices have many potentials and economic benefits than liquid products such as reduction in volume or weight, packaging cost, easier transportation, better handling and much higher shelf life. Besides, their better physical state provides a natural, stable and easy dosable ingredient, that is useful in many foods and as food additives meant for flavoring and coloring (Shrestha *et al.,* 2007).

The drying techniques commonly used in food industry, besides conventional hot air drying are freeze, spray and vacuum drying. Brown (1999) noted the difficulties in freeze drying of pineapples due to high content of sugar and problems in water vaporization. Fruits and vegetables with moisture content of 85-95 per cent had to be dried for 24-30 hours to a final water content of two per cent. Chopda and Barrett (2001) subjected clarified juice of guava to freeze-drying, spray-drying and tunnel-drying. Though the freeze-dried product had superior sensory quality, the spray-dried product provided better stability and economic feasibility. The driers like constant bed dryer and fluidized bed dryer use hot air for drying foods but require longer drying time than spray drier (Roustapour *et al.* 2009). Horszwald *et al.* (2013) also reported that conventional air drying which require extended application of high temperature is the most extensively used technique for dehydration of food materials which resulted in products with lesser porosity, high density and low quality. Spray drying, being the cheaper one step drying technique has least impact on the loss of bio active constituents due to a short residence time and comparatively soft conditions of the process.

2.2 MICRO ENCAPSULATION

Microencapsulation is a process in which droplets or tiny particles are encircled by a coating or confined in a homo or heterogeneous matrices to produce small capsules termed as micro capsules. The material within the microcapsule is called as the core, whereas the wall is often referred as shell, coating, wall material or membrane.

Microencapsulation create a forcible barrier between the core component and the other constituents of the product. Fluid droplets, solid particles or gas substances are entrapped into lean films of a food grade agent through micro encapsulation. The core may contain just one or many compounds and the wall may contain single or double layers. The chemical functionality, solubility, polarity and volatility govern retention capability of cores (Poshadri and Kuna, 2010).

Shahidi and Han (1993) highlighted six reasons for employing microencapsulation in food industry. The reactivity of core with factors can be reduced. Transfer rate of the embedded core substance to the outside surroundings can be decreased. Handling become easier. Release of the embedded substance can be controlled. Core taste can be masked and finally the core substance can be diluted when necessary to be used in very minute amounts. Hence microencapsulation is adopted in food industry to protect, isolate or control the release of a required substance which is important in many sections of food product manufacturing. Converting a fluid to a powder form allows diversified uses of constituents. Capsules produced by dissimilar encapsulation processes are grouped as per their size. Size of microcapsules ranges between 0.2 and 5,000 μm, while macrocapsules have more than 5,000 μm. Capsules smaller than 0.2 μm are nanocapsules (Murugesan and Orsat, 2012).

Gibbs *et al.* (1999) stressed on three precautions that has to be considered for developing microcapsules. A wall surrounding the material is to be formed ensuring no leakage and undesired materials. Therefore, the selection of process for microencapsulation depends on the physiochemical properties of core and coating materials and the intended use of food ingredients. Spray drying, lyophilization, spray chilling or spray cooling, fluidized-bed coating, extrusion coating, liposomal entrapment, coacervation, cocrystallization, centrifugal suspension separation and inclusion complexation are the main encapsulation techniques. Spray drying is an effective method in the microencapsulation of vitamins, minerals, flavor substances and antioxidants by utilizing a specific and proper carrier or encapsulating substance. With proper selection of the carrier aids or encapsulating materials, selective diffusion of the encapsulated core compound can be achieved (Chiou and Langrish, 2007).

Shahidi and Han (1993) opinioned that microencapsulation through spray-drying effectively protects food ingredients against deterioration from adverse effects of environmental conditions, such as light, gases, and moisture which lead to extension of shelf life. Microencapsulation by spray drying is advantageous than conventional encapsulation techniques since it produce microcapsules through a relatively simple and continuous process. It is widely employed for flavours due to higher efficiency in protecting materials and economical considerations. The spray drying apparatus used is same as used for obtaining dry milk powder (Poshadri and Kuna, 2010).

2.3 SPRAY DRYING

Preparation of the dispersion, homogenization of the dispersion, atomization of the fed dispersion and dehydration of the atomized particles are the main steps of spray drying. These four phases and their operational conditions have major effect upon efficiency of drying and properties of final product. The feed mix can be a suspension, an emulsion or a solution. The end product can be granules, powders and agglomerates, which depends on the physiochemical properties of the feed mix and process operating parameters (Murugesan and Orsat, 2012).

The atomization process points to the dispersion of liquid in a gas and subsequent decrease in particle size. Tiny droplets with similar size that formed in an effective atomization is subjected to uniform and effective heat and mass transfer at the process of drying. Surface area of the atomized particles increases exponentially due to the reduction in particle size and uniform dispersion in the hot drying gas. This increase in surface area dries the feed in seconds. Moisture removal occurs without disturbing the integrity of components due to even distribution of the liquid feed and small sized droplets. Atomization is done by different type of atomizers as rotary atomizers, pneumatic nozzles pressure nozzles and sonic nozzles (Cal and Sollohub, 2009).

During atomization, the feed is in contact with the drying gas. Generally, the drying gas refers to atmospheric air. Sometimes, nitrogen or inert gases are also used which depends upon the feed types and its sensitivity to oxygen. During the process of spray drying, the atmospheric air can be filtered through filtering mechanism and subsequently preheated according to the required operating parameters (Cal and Sollohub, 2009). The drying process of feed droplets in spray drying is due to simultaneous heat and mass transfer. The heat convect from the hot drying medium to droplets and then get converted to latent heat during the evaporation of the droplets' moisture content (Murugesan and Orsat, 2012).

Subsequent to the drying process, the dried feed falls to the bottom part of the hot drying chamber or travel forward with the blowing air. The separation happens in a cyclone or bag filter (Murugesan and Orsat, 2012). The dense particles can be recovered at the base of the hot drying chamber while the finest ones pass to the cyclone and get separated from the humid air. Apart from cyclones, spray dryers are commonly equipped with the filters, called ''bag houses'' which remove the finest powder from outgoing air. The obtained powder is composed of particles that originate from globose droplets after shrinking (Phisut, 2012).

2.3.1 Advantages and Disadvantages of Spray drying

The spray drying process is very quick with an intensive moisture evaporation from surface of droplets, which makes droplets cool till the dry stage. (Masters, 1991). The temperature of droplets is kept at comparatively low and thus the quality of product is not affected in negative way (Roustapour *et al.,* 2009). In consequence, certain properties of food, such as flavor, color, and nutrients are retained in high per centages (Leon- Martinez *et al.,* 2010).

Desobry *et al.* (1997) compared the freeze drying and spray drying techniques and reported that spray drying could be the most common and cheapest method to produce microcapsules of food materials since the equipment is easily available and production costs are lesser than most other methods. The cost of spray-drying method is 30–50 times cheaper than freeze drying. Spray drying is widely selected as the particle size apportioning can be controlled (Obón *et al.,* 2009). Spray drying processes produce comparatively free flowing powders with uniform spherical particles and distinct particle size spreading (Caparino *et al.,* 2012).

Spray drying was a highly appropriate drying method for heat sensitive constituents such as carotenoids since the powders exhibited good reconstitutional properties, low water activity, and therefore applied with success for obtaining stability of carotenoid in foods that made from carrots, tomato pulp, sweet potato and sea buckthorn (Kha *et al.*, 2010). Instant properties of spray dried foods, make them attractive to consumers (Nadeem *et al.*, 2011).

Tari and Singhal (2002) reported that microencapsulation by spray drying can protect the flavour from undesirable interactions with food, minimize loss against light-induced reactions and oxidation, increase the flavour shelf life, allow a controlled release and retain aroma in a food product during storage. Spray drying can be uninterrupted, comparatively cheap process for which the equipment required is promptly available (Fang and Bhandari, 2011). Spray drying provides wide range of output rates and extended tractability in dryer machine design (Aghbashlo *et al.*, 2012). Estenvinho *et al.* (2013) justified the preference of spray drying in industrial terms over other microencapsulation techniques for being reproducible, allowing easy scale-up, offering significant variation in microencapsulation matrix, is capable to adapt to common processing apparatus and bring forth quality powders.

On the other hand, Luck and Grothe (1973) obtained a hygroscopic powder which never had the quality characteristics of the original product on reconstitution through spray drying of fruit juice with milk. Caparino *et al.* (2012) also reported losses of sensory and quality attributes as vitamin C, ß - carotene, flavors and aroma.

One of the main limitations of the spray drying is the requirement of aqueous solubility of the encapsulating agent at satisfactory level (Desai and Park, 2005). Murugesan and Orsat (2012) communicated concern over limited availability and high cost of the carrier aids or encapsulating materials.

While Gharsallaoui *et al.* (2007) considered spray drying as an energy wasting process since it is difficult to use all the heat passed to the drying chamber, Yoshii *et al.* (2008) described spray drying as a harsh drying method due to the use of high temperature at initial stages of process. Under high temperatures, vitamins and enzymes and other thermo labile components may get destroyed or inactivated during the process of drying.

2.3.2 Spray Driers

Cocurrent spray dryers are most widely used and drying kinetics as well as particle behaviour in such systems are well known in comparison to countercurrent or mixed flow systems. (Zbicinski *et al.*, 2002). In cocurrent dryers, the feed droplets move in the same direction of the hot drying air flow while losing moisture content since the atomizer and the gas stream inlet are located in the top part of the drying chamber. In countercurrent dryers, the drying gas is provided from the lower most part of the chamber and the atomization happens in the top portion of the hot drying chamber. In mixed flow dryers, the air inlet is located in the top most part of the chamber while the feed mix is atomized upwards, towards the top of the chamber, thus, the drying air moves countercurrent compared to the atomized feed. This method produces fair-sized particles. This is the most economical method that is used to dry thermo stable products (Cal and Sollohub, 2009).

2.3.3 Factors Affecting Drying Process in Spray Driers

Siddappa and Ranganna (1961) encountered many problems when mango pulp was spray dried, the pulp did not dry well in the spray drier in spite of the slow feeding. Thick bands were developed on the sides and at the upper part of the chamber due to deposition of partly dried pulp. Further particle deposition on the vertical walls and in the cone, were higher since the powder particles were not carried properly to the receiver along with blowing air. Because of the heavy wall deposits resulting from hygroscopic and thermoplastic nature of the product, Brennan *et al.*(1971) could not spray dry concentrated orange juice without additives.

According to Bhandari *et al.* (1997) sticky behaviour of materials which is rich in sugar and acids is attributed to sugars of low molecular weight such as glucose, sucrose, fructose and organic acids as citric, malic and tartaric acid, which constitute above ninety per cent of the total solids in fruit juices, nectars and purees. These materials have very low glass transition temperature (sucrose: 62°C, fructose: -5°C, glucose: 32°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 such materials will be higher when the temperature of the spray dried particle is higher than 20°C above the glass transition temperature. Hence these particles stick to the surface of chamber walls in dryer and finally give a paste like structure instead of powder when dried at temperatures normally prevailing in spray driers. This sticky nature of particles at spray drying lead to formation of agglomerations inside the chamber as well as cause deposits on other parts which come in contact with powder and several other operational problems which may reduce product recovery (Gianfrancesco *et al.,* 2010).

Adhikari *et al.* (2004) classified foods into two liberal groups: non-sticky and sticky. Nonsticky materials are those dried by a simple dryer design and the final products remain free flowing. Materials such as skim milk, maltodextrins, gums and proteins belong to this group. In contrast, sticky materials exhibit problems while drying under normal spray drying conditions. Plant products rich in sugar and acid as honey and fruit and vegetable juices are part of this group.

Troung *et al.* (2005) described stickiness as the phenomena of particle to particle cohesion and particle to wall adhesion in the spray drying process. Stickiness reckons not only on the physico chemical properties of materials but also on the inlet parameters applied in a spray drying system. Powder deposition on walls relates to the stickiness as well as the design of the spray dryer. Theoretically, there should be no deposition at walls if the dryer chamber is large enough. Because of the economic factors, the chamber size of the dryer gets limited to a suitable range. Therefore, stickiness and deposition should be solved by other means than using a very big dryer chamber.

Cabral *et al.* (2009) advised to spray dry at temperature lower than glass transition temperature by 20◦C to avoid stickiness. When this approach is not economically feasible, drying aids with the high molecular weight is used to increase the glass transition temperature of the powder. Jayasundera *et al.* (2011) reiterated that stickiness could be lowered by maintaining the outlet temperature of the drier below 50^0C or dry at ambient temperature as process based modification. However, the powders produced at substantially low outlet temperature always had high aqueous content and water activity which negatively affected their subsequent storage. Otherwise large amounts of carrier materials are to be mixed with fruit juices as material based approach.

2.3.4 Carriers and Additives

Lee *et al.* (2003) considered selection of suitable carrier material as the most crucial step in spray drying. It should not only form uninterrupted lean films but also protect the core constituent from deterioration. The material should be of low cost, have mild taste and stable in storage. High solubility, effective emulsification, lower viscosity even at high concentration of solids, low hygroscopicity, easy release of core material and efficient drying properties are the desired functional properties of carriers. Encapsulating materials used in the food processing industry, are biomolecules. They are grouped into three broad categories, i.e. carbohydrate polymers, lipids and proteins. Carbohydrate polymers are the most widely used carrier materials in comparison to proteins and lipids. Carbohydrate polymers are again classified into five subcategories, i.e. starch derivatives, cellulose derivatives, marine extracts, botanical exudates or extracts, and microbial or animal polysaccharides. Common microencapsulating substances as maltodextrins and arabic gum are placed in polysaccharide category (Wandrey *et al.,* 2010).

Most spray drying operations in the food industry are executed from aqueous formulations and the typical shell materials include gum acacia, maltodextrins, hydrophobically modified starch and mixtures of them. Other polysaccharides as carboxymethylcellulose, alginate, guar gum and proteins like whey proteins, sodium caseinate and soy proteins can be used as carrier agents. However, their usage becomes very complicated and expensive due to their low aqueous solubility, which implies higher requirement of water evaporation, a reduction in the solid content and in the quantity of active ingredient (Desai and Park, 2005).

Carriers for specific purpose can be prepared by modifying carbohydrate polymers such as starches through chemical, biochemical and physical methods. Functional derivatives as acetylated, cross-linked, hydroxypropylated, oxidized and partially hydrolysed molecules of starch provide an array of varied techno functional properties. According to Mckernan (1973) maltodextrin was being increasingly used in microencapsulation studies as they had acceptable food grade qualities. They were found to be non- reactive with core materials with low viscosity at high solid content and were relatively inexpensive. Maltodextrins which are manufactured by starch hydrolysis could be the best example in this class. Hydrolysis can be done by chemical or biochemical method. The derivatives of starch are assigned a dextrose equivalent value (DE) based on the extent of hydrolysis. Higher Dextrose Equivalence with shorter glucose chain, exhibit higher sweetness and aqueous solubility (Murugesan and Orsat, 2012).

Kha *et al.* (2010) conducted a study on effects of spray drying conditions on the physicochemical and antioxidant properties of the Gac fruit aril powder. Spray drying of Gac fruit aril extract had not been successful without maltodextrin and the carrier preserved the colour and antioxidant properties. Moisture content, bulk density, colour characteristics, total carotenoid content, encapsulation efficiency and total antioxidant activity were significantly influenced by concentration of maltodextrin. For spray-drying, maltodextrin was one of the best choices as carrier material not only due to their cheap price, high water solubility, bland flavour, and lower viscosity and but also reduced stickiness and agglomeration issues during storage, hence improved product stability (Krishnaiah, 2015).

Cano-Chauca *et al.* (2005) pointed out the main advantage provided by maltodextrin in spray drying as better physical properties especially high aqueous solubility. While comparing carrier agents such as maltodextrin, arabic gum, waxy starch and microcrystalline cellulose on physico-chemical properties and morphology of the pomegranate juice powder, Yousefi *et al.* (2011) observed that starch was nearly insoluble in water but maltodextrin was more soluble. The lowest solubility of pomegranate juice powder was with waxy starch.

Tonon *et al.* (2011) reported that extent of polymerization in maltodextrin influenced powder properties. The powder particles gained with maltodextrin 10 DE as carrier exhibited the lowest water adsorption rate. Particles obtained with arabic gum and maltodextrin 20DE exhibited greater hygroscopicity and quick water adsorption. The powder with maltodextrin 10DE had higher mean diameter in comparison with the maltodextrin 20DE. Greater maltodextrin DE is resulted from higher degree of hydrolysis and hence, shorter chain.

Quek *et al.* (2007) noted that the concentration of the wall material affected properties of watermelon juice powder. There was no powder accumulated in cyclone if maltodextrin was not mixed to the feed. The particles were sticky which deposited to the wall surface of cyclone and hot drying chamber and recovery was impossible. The addition of maltodextrin at five per cent concentration to the feed mix gave better recovery than three per cent maltodextrin. The use of maltodextrin increased the solid content of feed mix and there by decreased the water content of powder. However, further addition to ten per cent level of maltodextrin reduced attractive red-orange colour of powder. In contrast Goula and Adomopoulose (2008) reported higher moisture content when dried with higher maltodextrin concentration.

According to Grabowski *et al.* (2006) water solubility index sweet potato powder was directly proportional to the maltodextrin concentration. Tonon *et al.* (2008) obtained lesser hygroscopic powder particles with greater maltodextrin concentration. Higher concentration of maltodextrin reduced bulk density in tomato and orange juice powders (Goula and Adomopoulos, 2010).

Gharsallaoui (2007) noted that maltodextrin samples had the highest retention of fruit flavor. Sucrose, glucose and starch did not facilitate spray drying of fruit flavor due to higher caramelisation, adherence to the spray dryer surface and heterogeneous form that clogged nozzle.

The microstructural analysis of the microcapsules obtained with maltodextrin exhibited more homogeneous particles, which is preferred in a drying process (Silva *et al.,* 2013).

Dextrins are produced by partial hydrolysis of starches by applying heat in the presence of little amounts of food grade acid. Dextrinization reduced molecular weight in drastic manner and introduced new glucoside linkages. In contrast to starches and maltodextrins with "digestible" a-(1,4) and a-(1,6) glucosidic linkages, dextrins are constituted with "indigestible" (1,2) and (1,3) - glucosidic linkages too. These indigestible linkages do not get hydrolyzed in human body by digestive enzymes. Therefore, a part of dextrin does not get subjected to digestion in the upper portion of the gastro intestinal tract and hence not directly available for energy production and utilization. However, a part of the indigested material is hydrolyzed later by bacterial flora in the colon resulting free fatty acids that can be utilized for energy production. Hence, resistant dextrin is proposed for using in food as bulking agent or as dietary fiber as suggested by Vermorel *et al.* (2004) in baked goods, liquid beverages, cereal bars, condiments, dressings, confections, frozen desserts, sauces, gravies, pasta, soups, snacks and can potentially be used for production of dry beverage powder.

2.3.5 Operational Parameters

Complicated interactions of machine process, operating conditions and feed parameters occur in the process of spray drying which determine the final product characteristics and quality (Chegini *et al.,* 2008). The final powder properties counted upon feed flow rate, viscosity, inlet and outlet temperatures, pressure and type of atomizer (Tonon *et al.,* 2008). Operational parameters in phases like atomization of feed, drying gas and dispersed particle contact, drying process of feed mix and product separation had strong influence on the efficiency of drying and the characteristics of final product (Cal and Sollohub, 2009). The spray drying conditions as air flow rate, atomizer speed, types of drying aid and their concentration influenced bulk density, particle diameter, yield moisture content and hygroscopicity of powder in spray dried foods (Phisut, 2012).

The air inlet temperature is usually determined by two factors. The temperature should be in a safe range to avoid damage of the product, should not create operational hazards and cost of heat source needed to be affordable. The low air inlet temperature leads to low evaporation rate, microcapsules with high density membranes, high water content, poor fluidity and agglomerated particles. In contrast, high inlet temperature causes excessive evaporation which leads to cracks in the membrane with premature release of volatiles and degradation of encapsulated ingredient (Zakarian and King, 1982). Inlet temperature influenced yield, powder properties as particle size, moisture content, hygroscopicity, bulk density, morphology and stability of pigments of powders in spray drying (Tonon *et al.*, 2008). Humidity and inlet air temperature affect performance and efficacy of the spray drying process. Inlet temperature can be a controlled variable in the process of spray drying (Murugesan and Orsat, 2012). Inlet air temperature should be optimum for the process and the product. (Medina- Torres *et al.*,2013).

The temperature at the terminal point of the drying zone which is referred as outlet temperature or exhaust temperature is considered as the control index of the spray dryer. Since outlet temperature is influenced by the dehydration characteristics of the material, prediction of it is difficult. In contrast to the inlet temperature, outlet temperature cannot be directly controlled since it depends on the several operational parameters like inlet temperature and feed flow rate (Gharsallaoui 2007). At constant inlet temperature, outlet temperature got reduced when the feed flow rate increased (Jittanit *et al.,* 2010). By decreasing compressed air flow rate or inlet temperature, the outlet temperature is decreased and moisture content of powder is increased (Fazaeli *et al.,* 2012).

Papadakis *et al.* (1998) reported that air flow rate influenced powder solubility through its effect on moisture content of powder, as low moisture content was associated with the quick dissolution. The increase in air flow rate led to the greater powder moisture and less powder solubility. Phisut (2012) correlated air flow rate with energy accessible for evaporation of moisture. The movement of air induces the transfer of dispersed particles along the drying zone, the concentration of product in the dryer wall region and extent the semi dried droplets that re enter the moving hot air and thus decide the drying rate. Higher drying air flow rate, decrease the residence time of the dispersed particles in the hot drying chamber which lead to increased moisture content, stickiness and lesser bulk density.

Zbicinski *et al.* (2002) reported that the feed rate to the atomizer is adjusted to ensure the desired drying level of each droplet, before it contacts surface of the drying chamber. Chegini and Ghobadian (2007) reported higher wall deposit and reduced yield with increasing the feed flow rate. At constant atomization, more liquid was atomized to the chamber by elevated feed rate which led to improper drying. In addition the greater atomizer speed led to higher the bulk density.

Tonon *et al.* (2008) noted negative influence of the feed flow rate on aqueous content of the acai juice powder. Shorter time of contact between feed and hot drying air due to elevated flow rates led to less efficient heat transfer and lower evaporation. The higher feed flow rate lowered heat transfer and lowered process yield. In addition, elevated feed rates and lower atomisation gave rise to dripping in the drying chamber. Murugesan and Orsat (2012) observed that the feed spray and air contact time decided the rate and degree of drying. The overly rapid travel of the dispersed particle reduces contact time with the hot air which limit the escape of moisture into the drying air and ultimately cause wall deposits. The residence time of stay of each particle inside the hot chamber is decided by the spray's flow rate and drying chamber size.

Chegini and Ghobadian (2005) observed the effect of atomizer speed (10,000-25,000 rpm) on the characteristics of orange juice powder. At greater atomizer speed, small droplets were produced, contact surface were increased, more moisture was evaporated and residual moisture were reduced.

Keogh *et al.* (2003) observed a direct enlargement of the particle size with fluid viscosity on spray drying of ultra filtered concentrated whole milk in a two fluided nozzle atomizer. According to Chegini and Ghobadian (2007) efficiency in spray drying can be enhanced by concentrating feed before introducing into the spray dryer. The concentrated juice had more solid contents and lower liquids that needed to be drawn of in the form of vapour in the spray dryer. The feed mix is normally concentrated to 50 to 60 per cent in conventional large scale driers before introduction to feed pump. However, small scale spray driers used in laboratory require more diluted feed mix since it will be easily clogged by high viscosity feeds.

2.3.6 Process optimisation

Wang *et al.* (2012) used three types of maltodextrin, i.e. DE 5, DE 10 and DE 15 at concentration levels of 20 per cent and 40 per cent (w/v) respectively, as a carrier to produce soy sauce powders. The powders from the feed mix containing greater maltodextrin concentration of 40 per cent had bigger particle size, less hygroscopicity, high glass transition temperatures and lower cohesive index.

Maltodextrin of a lesser DE value resulted in soy sauce powders with alleviated cohesion, more glass transition temperature and decreased hygroscopicity.

Fazaeli *et al.* (2012) obtained best drying yield (82%) and aqueous solubility (87%) with mixture of maltodextrin 6DE and arabic gum in black mulberry. The powders with least moisture content (1.5%) was produced with compressed air flow rate of 800 L/h. Bulk density was negatively influenced by inlet air temperature due to elevated porosity of powder. Lower the bulk density, higher was the powder solubility. Morphological analysis of powder revealed smallest sized particles in the powder resulted by maltodextrin and gum arabic mixture.

Moreira *et al.* (2009) optimized spray drying process of acerola pomace as inlet temperature of 194°C, carrier/acerola solid ratio of 4:1 in which replacement of maltodextrin by cashew tree gum, was at minimum of 80per cent. Elevated inlet temperatures resulted the desired characteristics of the powder, by decreasing water content and hygroscopicity and improving flowability. The carrier especially cashew tree gum decreased hygroscopicity of powder, but enhanced product flowability.

Solval *et al.* (2012) developed cantaloupe fruit juice powder at inlet temperature of 170°C with 10% maltodextrin which had higher ß-carotene and vitamin C.

Nadeem *et al.* (2013) reported that reconstituted product of instant soluble sage powder showed the better physical and chemical properties and quality attributes, especially for aqueous solubility and solution turbidity when produced at 145°C after adding of ß-cyclodextrin at the concentration of 3g/100 g. The inlet air temperature of 145 and 155°C resulted in similar and improved stability of 1,8-cineole.

Abadio *et al.* (2004) spray dried pineapple in a pilot scale spray drier with added maltodextrin at inlet temperature of 190°C and outlet temperature of 90°C. The blower velocity and feed rate were 25,000 rpm and 0.18 kg/min respectively. 25000 rpm atomization speed and 10% maltodextrin were sufficient to obtain free-flowing products with superior solubility.

Shu *et al.* (2006) prepared lycopene microcapsules through spray drying using carrier system composed of gelatin and sucrose. Gelatin/sucrose ratio of 3/7 and core and wall ratio of 1/4, feed temperature of 55°C, inlet temperature of 190°C, homogenization pressure at 40 MPa, lycopene purity of not less than 52 per cent were adjudged as optimal conditions.

Obon *et al.* (2009) produced a red purple food colorant powder from *Opuntia stricta* fruit juice with dry glucose syrup as carrier. Optimum conditions were identified as 20 per cent juice content at 1.2°B, 10 per cent glucose fed at 0.72 l/h, spray air flow-rate of 0.47 m^3/h, drying air flow-rate of 36 m^3/h, and inlet drying air temperature 160°C for spray drying. More than 98 per cent color got retained during spray drying process and powder yield was 58 per cent.

Kha *et al.* (2010) prepared Gac powder which had good quality parameters such as colour, carotenoid content and total antioxidant activity through spray drying using ten per cent maltodextrin as carrier at inlet temperature of 120°C.

Silva *et al.* (2013) used 30 per cent maltodextrin as drying aid combined with inlet temperature of 180°C to maximize anthocyanin retention and minimize responses of overall color deviation, moisture and hygroscopicity when jaboticaba (*Myrciaria jaboticaba)* peel extracts were spray dried.

Fang and Bhandari (2011) successfully spray dried bay berry juice with maltodextrin of 10 Dextrose Equivalence as the carrier, at equal ratio with inlet and outlet temperatures of 150°C and 80°C, respectively.

Caliskan and Dirim (2013) increased total solid content of sumac extract from 3.5 to 10 per cent through adding maltodextrin and spray dried at 160°C inlet and 80◦C outlet temperature successfully. The pressure for atomization and the air flow rate were held constant as 392 kPa and 1.54 m^3/min respectively.

Mishra *et al.* (2014) reported that amla juice powder dried at 125°C temperature with five per cent maltodextrin concentration showed better phenolic content retention as well as free radical scavenging activity but powder was very sticky. However, drying at 175°C with seven per cent could produce powder with less hygroscopcity, acceptable color in terms of $L*$, $a*$ and $b*$ and potent free radical scavenging activity.

Phongpipatpong *et al.* (2008) optimised spray drying condition that provided high longan powder yield and solubility with maltodextrin (0.6 g/g soluble solids), medium inlet temperature (175°C) and medium air flow (1.62 m^3 min^{-1}).

Brennan *et al.* (1971) spray dried concentrated orange juice. Use of liquid glucose (39-43 dextrose equivalent) as carrier reduced wall residue and yielded a product with acceptable flavour and free flowing properties.

Bhandari *et al.* (1993) tried different maltodextrins as carriers to find optimum juice to maltodextrin (DE 6) ratio of 65:35 for black currant, 60:40 for apricot and 55:45 for raspberry with inlet temperature of 60-90^{0}C.

Borges *et al.* (2002) spray dried passion fruit and pineapple juices with maltodextrin (20-30%) additive at outlet temperature of 85-95°C. The powder yield and bulk density increased with higher maltodextrin concentration.

Rao and Gupta (2002) tried vitamin C enrichment of milk through spray drying after incorporation of orange juice. The resulted powder from the blend comprising 15:85 orange juice to skim milk possessed the best sensory properties.

Mani *et al.* (2002) recorded optimal ratio of fruit solids and maltodextrin for spray drying of mango juice as 55:45 with air inlet temperature of 167°C and outlet temperature of 89°C.

Maya (2004) spray dried the beverage mix containing 1:1 ratio of sapota pulp and milk solids at an inlet temperature of 185°C and outlet temperature of 90°C to obtain best quality sapota milk beverage powder.

Cooke *et al.* (1976) found that less viscous mango puree obtained by enzyme treatment could be spray dried in a co-current laboratory spray drier at atomizer speed of 14,000 rpm after diluting with water (2:1 v/v). The feed rate was 250 ml per minute and inlet and outlet temperatures were 154°C and 88°C respectively.

Dacosta and Cal-Vidal (1988) homogenized coconut milk after adding the anticaking agents, surface acting agents and 15-20 per cent corn starch and successfully spray dried using disc atomizer (10000 rpm) at inlet and outlet air temperature of 200 ± 100°C and 85 ± 10°C respectively.

Ganeshan (1996) centrifuged and concentrated coconut milk in vacuum evaporator to 40 per cent total solids and spray dried at atomizer speed of 22,000 rpm with feed rate of $3Lh^{-1}$ and feed temperature of 35°C. The inlet and outlet temperature were 120°C and 80°C respectively.

Rao and Gupta (2000) spray dried mixture of orange juice concentrate of 60 per cent total solids with condensed skim milk of 30-35 per cent total solids in the ratio of 15:85. This blend with total solids content between 25-30 per cent was homogenized and subjected to spray drying at an inlet and outlet temperature of 180°C and 80-85°C respectively using two fluid nozzle spray drier provided with compressed air pressure of 124-137 kPa to obtain powder with 75 per cent moisture, 0.51 bulk density, 3.1 per cent acidity and solubility index of 25.

Mani *et al.* (2002) observed that spray drying of fruit juices was possible after addition of high molecular weight materials or by drier chamber modification with an air broom system that rotated to alleviate stickiness. Fruit solids and Maltodextrin in ratio of 55:45 with air inlet temperature of 167°C and outlet of 89°C could produce powder with five per cent moisture content.

Oliveira *et al.* (2009) encapsulated cashew apple juice using maltodextrin (DE 10) and cashew apple tree gum through spray drying. Inlet and outlet temperatures were kept at 185°C and 90°C respectively. The rate of feed flow and air flow was 840 mL/h and 3.75×104 L/h, respectively. Drying carrier and juice ratio of 5:1 with cashew apple tree gum level of more than fifty per cent in carrier resulted in powder with good flowing properties and aqueous solubility.

Mishra *et al.* (2014) conducted spray drying of amla with maltodextrin at 175°C inlet temperature to obtain less hygroscopic powder with satisfactory color and potent free radical scavenging activity.

The physico chemical powder properties, except for the pH and colour of the spray dried sumac extract powders, were influenced by both the inlet/outlet temperature. As a result, the extracts with 10% TSS and 160/80°C inlet/outlet temperature were rated as best conditions for sumac extract powder (Caliskan and Dirim, 2013).

2.3.7 Characteristics of Spray Dried Powder

According to Papadakis and King (1988) when drying air temperature increased, air took more moisture from the spray thereby resulting in lower moisture content in the powder and the spray drier temperature largely controlled the moisture content of the final powder. The high inlet temperature and low temperature difference between inlet and outlet air led to very fast drying and also produced slightly larger particles than slow drying (Masters, 1991). Cai and Corke (2000) observed faster drying and higher powder productivity with higher drying air temperature. The bulk density of pigment powders decreased with the increase of spray drying air temperature. The lower the bulk density, the more occluded air lead to higher oxidative degradation of the pigments and lower storage stability. Fazaeli *et al.* (2012) revealed that inlet air temperature negatively influenced the bulk density due to the increase in powder's porosity. The solubility of the powder increased with decrease in bulk density.

Rosenberg *et al.* (1985) reported that the presence of surface dents on powder particles adversely affects powder flowability and reconstitution properties. Rosenberg and Lee (1993) reported that factors like wall composition and properties, flavour to wall ratio, atomization and drying parameters, uneven shrinkage at early stages of drying, surface tension-driven viscous flow and storage conditions influenced microstructure of powder particles. Analysis of microstructure of orange oil powder using maltodextrin showed relatively spherical and smooth particles (Kim and Morr, 1996).

Mishra *et al.* (2014) observed that maltodextrin concentration (5-9%) and drying temperature (125-200^{0}C) significantly affected moisture content, bulk density, hygroscopicity and color attributes in amla juice powder dried at 175^{o}C and seven per cent maltodextrin was adequately effective to produce powder with less hygroscopicity, acceptable color in terms of L*, a* and b* values and potent free radical scavenging activity.

2.3.8 Nutrient Retention in Spray Dried Powders

Most food nutrients like vitamins and minerals gets damaged or denatured during produce handling and subsequent processing. Stability of vitamin C in food depends on the components of the matrix, process of production and storage conditions. The vitamin C gets degraded and degree of loss depended on many parameters such as temperature, light, time, pH, oxygen, presence of enzymes, and metallic catalyzers. Moreover, vitamin C is regarded as an index of nutrient quality when foods are processed and stored, since, if vitamin C is retained successfully, then the other nutrients will also be retained (Santos and Silva, 2008).

Uddin *et al.* (2001) analyzed encapsulation process of ascorbic acid with different methods like melt dispersion, thermal phase separation, solvent extraction and spray drying. The reduction of ascorbic acid at microencapsulation process was the lowest in spray drying with inlet and outlet temperatures of 200-300°C and 70-95°C respectively. Addition of starch and β-cyclodextrin as carrier components in the process of spray drying delayed the reduction of vitamin C over unencapsulated product. Oliveira *et al.* (2009) observed successful retention of Vitamin C while cashew apple juice was spray dried. The extent of retention was 95% when maltodextrin (DE 10) and cashew apple tree gum were used as carrier. Kurozawa *et al.* (2014) recommended lower temperatures of 40 to 50°C to obtain hot air dried papaya cubes with retention of 50 per cent of vitamin C content. The rate of loss in nutrient might depend upon the deviation between the drying temperature and glass transition temperature where greater the difference, higher the degradation.

Rodríguez-Hernández *et al.* (2005) observed lower vitamin C degradation of cactus pear (*Opuntia streptacantha*) juice with 10 DE maltodextrin through spray drying at pressure and temperature limits of 0.1 MPa and 205°C. Use of starch and β-cyclodextrin as carrier components while spray drying reduced the vitamin C loss on storage and exhibited better results over unencapsulated vitamin C. No color change was observed in encapsulated vitamin C even after exposing the powder to air for one month (Uddin *et al.,* 2001).

Desobry *et al.* (1997) studied the influence of three dissimilar processes in terms of retentivity of β-carotene (Vitamin A). Pure β-carotene was microencapsulated by spray drying, drum drying and freeze drying with maltodextrin (25 dextrose equivalent) as carrier. The lowest degradation of β-carotene was noted in freeze drying (around 8%), followed by spray drying (11%) and drum drying (14%). Quek *et al.* (2007) reported that elevation in inlet temperature decreased the lycopene and β-carotene contents when watermelon juice is spray dried with maltodextrin. β-carotene was more labile to the temperature than lycopene. The β-carotene degradation was nearly 27 per cent compared to 24 per cent loss for lycopene with same inlet temperature.

Ersus and Yurdagel (2007) studied microencapsulation of black carrot anthocyanin using spray drying and reported that maltodextrin had low flavour and were non reactive with the core component (anthocyanin) used for microencapsulation. A core to maltodextrin ratio of 1:3 was adjudged as optimum. It was revealed that storage at 4°C increased the half-life of spray dried anthocyanin pigments three times when compared to 25°C storage temperature.

Obón *et al.* (2009) retained higher than 98 per cent of β-cyanin pigments through co-current spray drying of *Opuntia stricta* fruit juice. Juice content (20% v/v; 1.2°Brix), glucose syrup content (10% w/v), fluid feed rate (0.72 l/h), spray air flow-rate (0.47 m^3/h), drying air flow-rate (36 m^3/h), and inlet temperature 160°C were recorded as optimum conditions for spray drying.

Bastos *et al.* (2012) spray dried cashew apple juice with encapsulating agent ratio of 1:1, 1:1.5 and 1:2 and could not find any significant difference in yield and vitamin C content among treatments. The encapsulating agent in this study was a mixture of chitosan (1.5% w/w) and commercial bovine whey protein isolate (12 % w/w).

Solval *et al.* (2012) reported that *Cucumis melo* powder produced at inlet temperature of 170°C had higher β-carotene content and vitamin C than those at 180 and 190°C.

Fang and Bhandari (2011) suggested spray drying as a satisfactory technique for drying heat sensible polyphenols since retention of total poly phenols and anthocyanin were quite high as 96 and 94 per cent in spray drying process of bayberry juice.

Lezama *et al.* (2012) microencapsulated non-aqueous extracts from chilli (*Capsicum annuum L.*) by spray drying. They reported that approximately 80 per cent of the antioxidant activity of the non-aqueous extracts was preserved in microencapsulates. The microcapsules did not contain fractures, and this finding may have contributed to the protective action against oxidation.

Nadeem *et al.* (2013) reported that starch derivatives retained better color values for spray drying of sage tea. Instant sage powder produced at 145°C with three per cent β- cyclodextrin retained the highest quantity of 1,8-cineole, the main volatile constituent of the *Salvia fruticosa.*

2.3.9 Packing and Storage

Reduction in shelf life of the product upon storage is due to physiochemical and microbial changes causing deterioration. Factors as temperature of storage, relative humidity, type of packaging substance and the composition of the product contribute to the extent of deterioration. Hence, packaging of dehydrated fruit must protect the product against moisture, light, dust, microflora, foreign odour, insects and rodents. It should provide strength and stability to maintain size, shape and appearance of original product.

Loesecke (1998) reported that non-enzymatic browning in dehydrated foods was due to the interaction of the nitrogenous constituents with the reducing sugars and organic acids which is referred as Maillard reaction. The factors influencing browning were the pH, moisture, storage temperature and packaging atmosphere. Aruna *et al.* (1998) reported that cereal based papaya powder when stored for nine months, non-enzymatic browning expressed as optical density increased from 0.06 to 0.140 while moisture increased from 1.05 per cent to 11.9 per cent. The microbial counts such as viable bacteria, yeast and mould counts were found to increase slightly only after six months of storage. Babu and Gupta (2002) developed ready-to-reconstitute toned milk and lassi powder containing pineapple juice using concentrated milk as well as curd as carriers in spray drying. The powder packed in poly propylene pouches remained acceptable upto six months at both 37°C and room temperature. Kanakdande *et al.* (2006) conducted experiments on microencapsulation of cumin oleoresin powder and packed in polyethylene pouches for storage studies. Flavour components were found to be safe against oxidation as well as volatilization for six weeks. Chin *et al.* (2010) observed that the stability of volatiles in spray dried durian powder was notably influenced by relative humidity as greater degradation was observed at elevated RH. The structure of the encapsulated matrix was constrained by the absorption of vapour under high humidity which destructed the crust, caused molecular permeation of volatile analyte to the headspace under accelerated storage conditions. Bastos *et al.* (2012) reported that encapsulated cashew apple juice with a mixture of chitosan (1.5% w/w) and commercial bovine whey protein isolate (12 % w/w) remained stable even after five months of room temperature storage.

Pineapple powder was prepared using foam mat drying process and the dehydrated product was packaged in 300gauge high-density polyethylene packages and aluminium foil and the samples were kept at room temperature. The dried product was shelf stable for six months and the foam mat dried pineapple powder was better in colour, flavour, flowability, solubility and overall acceptability than the spray dried powder (Hassan and Ahmed, 1998).

Desobry *et al.* (1997) observed that relative humidity had no effect on encapsulated β-carotene during storage. Uddin *et al.* (2001) did not observe any colour variation in encapsulated Vitamin C even after exposing to air for 1 month. Starch and β-cyclodextrin when used as carrier materials retained vitamin C during storage. Obón *et al.* (2009) observed high stablility of powder colorant obtained by spray drying of *Opuntia stricta* after storage for one month at room temperature. Foods with this colorant exhibited a vivid red purple tone which was retained even after one month of storage under refrigeration at 4°C.

Kjaergaard (1974) quoted that lower amount of occluded or entrapped air and highest density of the dry matter content of the powder particles contributed positively towards better shelf-life. Tsami *et al.* (1998) observed that high sugar fruit powders exhibited crystallization and caking during storage when incorrectly dried. Addition of maltodextrins and starches to β-cyanin extracts from amaranthus markedly reduced hygroscopicity and enhanced storage stability (Cai and Corke, 2000).

Khurdia and Roy (1974) observed that guava powder packed in 200 guage polyethylene coupled with aluminium foil was the best even after six months.

George (1983) observed that that whole milk powder could be stored for about 30 days in metallised PE pouches. Delamination of metallised polyester and breakage of outer seal were also observed during storage. Whole milk powder became brown, insoluble and unacceptable for consumption above 32 per cent RH with equilibrium moisture content of 5.3 per cent. Malhotra and Mann (1989) reported that ready-to-reconstitute coffee powder could be kept for three months in metallised polyester LDPE laminate at 30 ± 10^0C. Moisture content increased from 2.28 to 2.29 per cent and pH decreased from 6.45 to 6.37 in storage. Shah *et al.* (2000) reported that polymeric films with aluminium foil are most suitable for packaging freeze dehydrated fruits due to adequate barrier protection against oxygen, water and light ingress.

Talley *et al.* (1966) reported that drum dried pumpkin powder could be kept in store for one year using nitrogen without flavour changes. Addition of 25 ppm Butylated Hydroxyanisole and 25 ppm Butylated Hydroxytoluene reduced oxidation in nitrogen packing. But with atmospheric air hay like off flavour developed. Nitrogen packing improved shelf-life of cooked lima bean powder. Addition of three ppm Butylated Hydroxytoluene proved beneficial in both air and nitrogen packs. Flavour changes started in powder packed under nitrogen with four per cent moisture after 7.5 months at 38°C (Burr *et al.*, 1969). Spray dried srikhand powder when packed in containers with nitrogen gas showed good flavour and reconstitution for about 45 days at room temperature (Mahajan *et al.,* 1979). Loesecke (1998) reported lower fading and off flavour development when dehydrated sweet potatoes were packed with nitrogen. Residual oxygen of less than two per cent is ideal for packing of dehydrated products. Sagar *et al.* (1999) observed that 260 gauge aluminium laminated polyethylene bags with nitrogen were most suitable for retaining the quality and colour of dehydrated ripe mango slices. Nitrogen packaging inhibited lipid oxidation (Lagunes *et al.,* 1999).

Kumar and Sreenarayanan (2000) reported lower non enzymatic browning (NEB) of onion flakes when vacuum packed in 300 gauge polyethylene. Gvozdenovic *et al.* (2000) reported that colour change of product depended largely on the barrier properties of the packaging material and its permeability to water

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vapour and oxygen, not on permeability of light. Vacuum packed orange powder retained their bright orange colour throughout the storage period. Thankitsunthorn *et al.* (2009) compared changes in water activity values of spray dried gooseberry under different packaging condition. The vacuumpacked samples did not show any change in water activity compared to the control samples in which water activity increased.

One important parameter characterizing the temperature stability of fruit powders was the glass transition temperature (Tg) since fruit sugars and acids were low molecular weight entities having low Tg values. The glass transition refers to physical change from the glassy to the liquid state in amorphous solids when they are heated. Due to low Tg value, fruit pulps gave sticky products on drying. In order to improve the Tg effectively, high molecular additives like starch, maltodextrin were mixed to fruit pulp (Lloyd *et al.,* 1996). Wauters *et al.* (2002) reported that storage of fruit powders at a lower temperature than Tg prevented caking and lumping. Moreira *et al.* (2009) considered moisture level as the most crucial factor regarding powder stability since small amount of water can depress the Tg to elevate the mobility of microcapsule matrix in storage. Sagar *et al.* (2000) reported that ripe mango powder could be stored for six months at 7°C and for four months at ambient temperature in 400gauge low density polyethylene pouches without loss of colour, flavour and texture. Low storage temperature recorded higher retention of vitamin C and total carotenoids. For storage of osmotically dehydrated onion powder with 3.85 per cent moisture content, the optimal relative humidity (RH) was 47.5 per cent. The critical and danger points as 9.14 per cent and 6.75 per cent moisture respectively. The product could be stored upto six months in 200gauge high density polyethylene pouches at 7°C compared to four months at ambient condition (Sagar, 2001). Fang and Bhandari (2011) observed that under an aw of 0.11–0.44 and storage temperature of 5°C, total poly phenols and anthocyanin in bayberry powders reduced by about 6–8% and 7–27%, respectively after 6 month storage. At 25°C storage temperature the degradation was 6-9% and 9-37%, and at 40°C they decreased by 7-37% and 9-94%, respectively. The anthocyanin was more readily degraded than other phenolic compounds. Reduction in antioxidant capacity was associated with the decreases in total phenolic content and total anthocyanin in the bayberry powders in storage. Spray dried bayberry powder had to be stored at a temperature lower than 25 ^{O}C and aw of 0.33 on account of the polyphenol stability.

2.3.10 Reconstitution

Food powders, must exhibit good solubility to be functional and useful on usage as ingredients. Dissolution of powdered components is of basal importance to manufacturers as well as consumers as an index of functionality. The solubility being the final step of powder dissolution was always considered as the key factor of the general reconstitution quality (Jayasundera *et al.* 2011).

Ready-to-reconstitute tea powder was reconstituted into tea by dissolving about 15 g powder in 20 ml warm water followed by the addition of makeup water to fill a cup of 140 ml (Jha and Mann, 1995).

Quek *et al.* (2007) have reported that the time required for the spray dried watermelon juice powders for a full aqueous reconstitution were comparatively shorter at lesser inlet temperatures, due to the greater agglomeration which improved the reconstitution character of the powders.

Nadeem *et al.* (2013) obtained reconstituted product of sage tea with better quality characteristics particularly for aqueous solubility and solution turbidity by spray drying at 145^{O}C with three per cent β- cyclodextrin.

Materials and Methods

3. MATERIALS AND METHODS

The present investigation on" Instant juice powders of cashew apple (*Anacardium occidentale* L.) and pineapple (*Ananas comosus* (L.) Merr.) 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 2013-2016.

The objectives of study were to

1. Optimise the process parameters for micro encapsulation through spray drying of cashew apple, pineapple juices and their equal blend.

2. Evaluate the effect of drying on physical, chemical and nutritional quality parameters of fruit powders.

3. Assess organoleptic quality, storage stability, economics and consumer acceptability of the standardised formulations.

For achieving the desired results, the whole programme was divided into three major parts.

Part- 1: In order to optimise process parameters like type of carrier (two carriers) carrier concentration (five levels) and inlet temperature (six temperatures) for production of instant fruit powders, micro encapsulation through spray drying was done independently for cashew apple, pineapple and their equal blended juices. Based on higher recovery, five best treatment combinations was selected from each carrier (Ten powders from each juice) independently for cashew apple, pineapple and their equal blended juices. Details on materials and methods used are described in section 3.1 of this chapter.

Part- 2: In order to assess the quality, selected powders from part one were subjected to quality analysis. The best powder with good quality parameters was selected from each carrier (two powders from each juice) for cashew apple pineapple and their equal blended juices. Three parameters viz. sorption behaviour, glass transition temperature and microstructure were investigated on this selected six powders. Details on materials and methods used are described in section 3.2 of this chapter.

Part- 3: In order to assess storage stability and nutrient retention of the powders the selected powders from part-2 were subjected to four packaging atmospheres for a period of six months with bimonthly observations. One powder with best storage stability and nutrient retention was selected from each carrier (two powder from each juice) independently for cashew apple pineapple and their equal blended juices. Further, cost of production and consumer acceptability of these six powders were investigated. Details on materials and methods used are described in section 3.3 of this chapter.

3.1 OPTIMISATION OF PROCESS PARAMETERS FOR INSTANT FRUIT POWDER PRODUCTION BY MICRO ENCAPSULATION THROUGH SPRAY DRYING

3.1.1 Preparation and Analysis of Juice

3.1.1.1 Preparation of Juice

3.1.1.1.1 Cashew Apple Juice

Fully ripe firm fruits of cashew apple variety "*Dhana*" without bruises were collected from farm of Cashew Research Station, Madakkathara. Fruits were washed in running water after discarding immature, rotten and damaged fruits. Juice was extracted in screw press, strained through muslin cloth, clarified using powdered and cooked sago @ 5g and preserved by adding 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 with the sediments. This clarified juice was stored in well sterilized air tight food grade plastic barrels and used for product preparation.

3.1.1.1.2 Pineapple Juice

Fully ripe good quality firm and uniform fruits of pineapple variety "*Mauritius*" were collected from farm of Pineapple Research Station, Mannuthy, Kerala Agricultural University. Fruits were washed in running water, peeled, removed the inedible portions and cut in to small pieces 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 food grade plastic barrels and used for product preparation.

3.1.1.1.3 Blended Juice

Equal quantities of cashew apple and pineapple juices were mixed on wet weight basis thoroughly before spray drying and used for product preparation.

3.1.1.2 Analysis of Chemical Parameters of Juice

Chemical analyses of both juices and their blend were done.

3.1.1.2.1 pH

The pH of juices were determined using a digital pH meter (M/s. Systronics; Model MK VI). Before determining the pH of the juice, the pH meter was standardized with double distilled water of pH 7.0 and standards of pH 4.0, and 9.0.

3.1.1.2.2 Total Soluble Solids

The Total Soluble Solids (°B) of the juices was determined by using a hand refractometer (M/s. Erma, Japan) with a range of 0 - 32°B.

3.1.1.2.3 Titrable Acidity

The method described by Ranganna (1986) was adopted to measure titratable acidity which was expressed in terms of per cent citric acid equivalent.

3.1.1.2.4 Total, Reducing, Non-Reducing sugars

The titrimetric method of Lane and Eynon as described by Ranganna (1986) was adopted for the estimation of reducing sugar, total sugar and non reducing sugar in percentage.

3.1.1.2.5 β-carotene

As described by Ranganna (1986) five grams of juice sample was mixed with 15 ml acetone along with few crystals of anhydrous sodium sulphate. The supernatant was decanted and the process was repeated twice. The combined supernatant was transferred to a separating funnel and 10 ml petroleum ether was added. On standing the lower transparent layer was discarded and the upper colourful layer was collected in a 100 ml volumetric flask and volume made up with petroleum ether. Optical density was recorded at 452nm in a spectrophotometer (Plate 7) using petroleum ether as control and β-carotene was calculated from calibration curve. β-carotene was expressed as μg/100g.

3.1.1.2.6 Vitamin C

The titrimetric method described by Ranganna (1986) was adopted and vitamin C was expressed as mg/ 100g.

3.1.2 Carriers

The carrier materials used for microencapsulation were maltodextrin obtained from M/s Himedia Laboratories Ltd, India and resistant dextrin (Nutriose®FM06) from M/s Roquette India Private Ltd. Malodextrin is a non-sweet, soluble, white to off white, slightly hygroscopic powder having 20 Dextrose Equivalence. Resistant dextrin is a non-sweet, soluble, off white to light yellow powder of 5 DE (Dextrose Equivalence).

3.1.3 Process parameters

Process parameters for spray drying viz., juice carrier combination and inlet temperature were standardized using the co-current spray drier established at the Department of Food and Agricultural Process Engineering, KCAET, Tavanur, Kerala Agricultural University (Plate 1).

3.1.3.1 Juice Carrier Combination

The juice carrier combinations were tried in five different ratios.

3.1.3.1.1 Juice solid (J) :Maltodextrin(M)

M_1- 80(J):20(M)

M_2 - 70(J):30(M)

M_3- 60(J):40(M)

M_4- 50(J):50(M)

M_5 - 40(J):60(M)

3.1.3.1.2 Juice solid (J) : Resistant Dextrin (R)

R_1- 80(J):20(R)

R_2 - 70(J):30(R)

R_3- 60(J):40(R)

R_4- 50(J):50(R)

R_5 - 40(J):60(R)

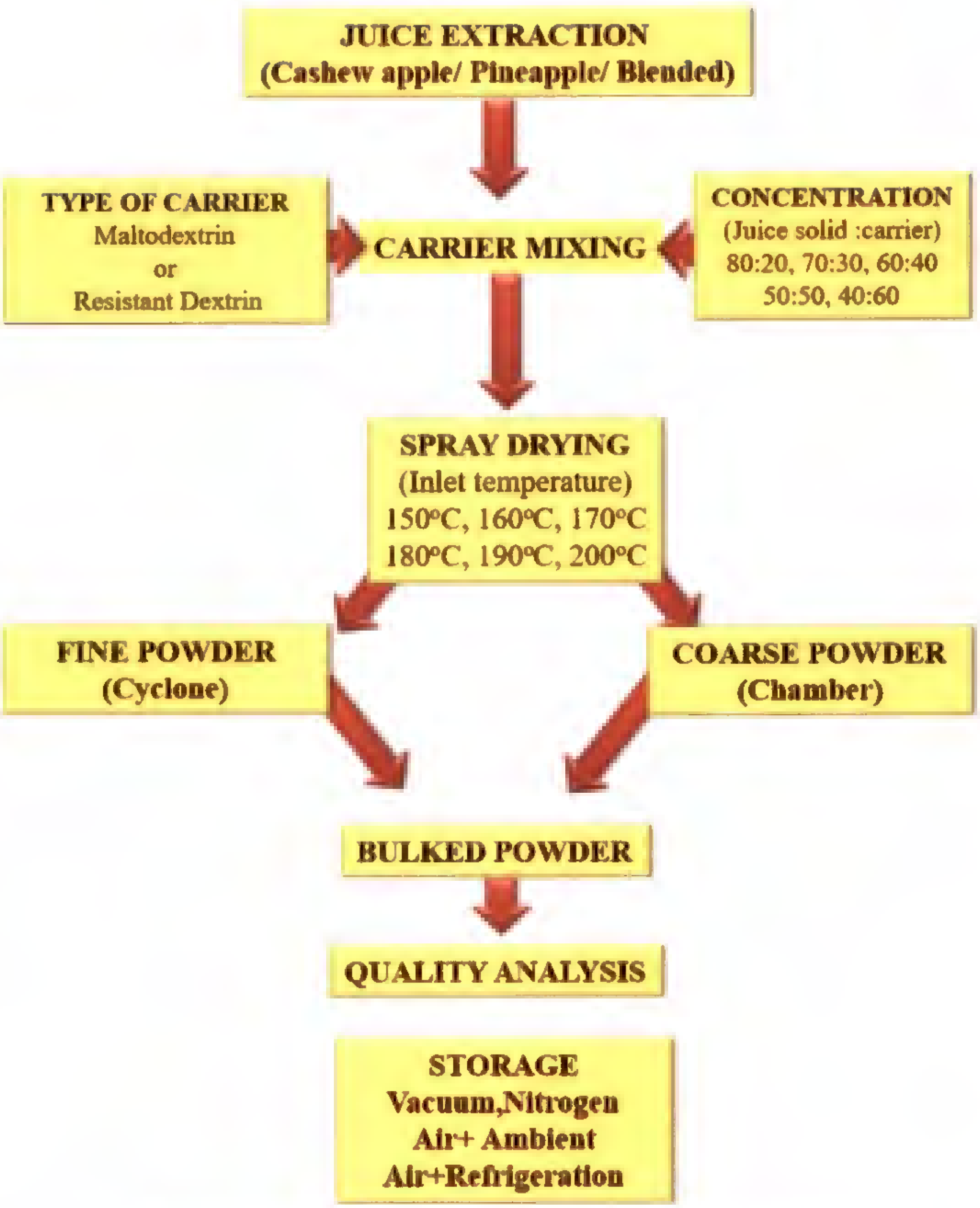

Plate 1: Process flowchart of instant juice powder production

Feed for spray drying was prepared by mixing 125 ml juice and carrier materials [Maltodextrin (M) or Resistant dextrin (R)] in varying proportions based on the total soluble solids.

3.1.3.2. *Inlet Temperature*

Properly mixed feed was fed by a peristaltic pump for drying at six different inlet temperatures (T).

T_1- 150^{0}C

T_2-160^{0}C

T_3- 170^{0}C

T_4- 180^{0}C

T_5- 190^{0}C

T_6- 200^{0}C

3.1.3.3. Treatment Combination Sets

Treatment combination sets of solid ratios and inlet temperature formulated for the study were as follows.

3.1.3.3.1 Treatment Combination Set with Maltodextrin

Carrier- Maltodextrin

Ratios-5

Inlet temperatures – 6

Treatment combinations- 30

3.1.3.3.2 Treatment Combination Set with Resistant Dextrin

Carrier- Resistant Dextrin

Ratios-5

Inlet Temperatures – 6

Treatment combinations – 30

3.1.3.4 Other Parameters

Feed rate was varied so as to maintain the outlet temperature as 88 ± 2^{o}C. Other operating parameters viz., atomization pressure and blower capacity were maintained constant as 4 bar and 2000 RPM respectively.

3.1.4 Spray Drying

Spray dryer used for the study was a co current, two fluid nozzle drier (Plate 2) having a water evaporation capacity of one litre per hour (M/s S.M. Scientech, Kolkata). Major components of the spray drier used for the production of juice powder were air supply system, feed supply system, atomizer, drying chamber, powder recovery system and control panel.

3.1.4.1 Air Supply System

Air supply system consists of compressor, air filter and air heater. The air is compressed by a compressor and this compressed air is introduced into twin fluid pressure nozzle atomizer through an air filter and heater. The compressed air converts the feed mixture into a fine mist. The air filter limits the entry of microorganism and the air is heated through electric heating coils to get a maximum temperature upto 350°C.

3.1.4.2 Feed Supply System

A peristaltic pump and a feed source constitute the feed supply system. The feed kept in a feed bowl is pumped into the atomizer situated at the top of the drying chamber of the spray drier by a peristaltic pump. Peristaltic pump consists of five rollers, which press and squeeze the hypalon natural rubber tube (6 mm diameter) against the walls of the pump, thereby impart forward thrust on the feed solution inside the tube. Thus, the feed gets pumped forward in the pumping direction due to the vacuum created which sucks the feed solution from the feed bowl. The motor of the peristaltic pump is DC operated with variable speed arrangement and its rpm is controlled by a rotary knob in control panel which helps to regulate feed flow.

3.1.4.3 Atomizer

Within the drying chamber, the feed mix is fed along with compressed air in downward direction in the form of fine spray by means of a two fluid nozzle situated at the ceiling of the chamber. The kinetic energy of compressed air causes dispersion of the feed solution as fine mist in a cone shaped spray pattern. The pressure of the compressed air for the fine mist was maintained at 4 kg/cm^2. The feed pumped by the peristaltic pump is thus brought into contact with the heated

Feed bowl **Control panel**

Plate 2: The spray drier

air after atomization for the evaporation of moisture to take place uniformly from the surface of all droplets.

3.1.4.4 Drying Chamber

The drying chamber of the spray drier is made up of SS304 stainless steel with cylindrical shaped upper part and conical shaped bottom part for effective drying and easy flow of dried powder. Inspection window glass is provided to observe the operation inside the drying chamber which is illuminated by a 60 W incandescent light. A 1000 ml collection jar is flanged at the bottom with teflon gaskets at the conical portion of the drying chamber for collecting the dried powder.

3.1.4.5 Powder Recovery System

The blower fitted at the back of the spray drier sucks away hot air along with fine powder particles from the drying chamber to the cyclone separator where they are separated. Air along with particles swirl down in a spiral direction inside cyclone and then air leaves the cyclone through a duct pipe since it is less dense than the particles. The fine powder gets collected in glass bottle attached at the bottom of the cyclone through threaded flange with a teflon gasket. The air escapes to the atmosphere through the exhaust pipe which may cause entrainment losses of extremely fine particles. The blower speed can be varied up to 2500 RPM with higher cyclone separation and higher entrainment losses at higher speeds.

3.1.4.6 Control Panel

The blower speed, feed rate and inlet or outlet temperature were controlled with regulator knobs, ON/OFF push buttons and indicators arranged in the electrical control panel. An automatic and manual de-blocking knob is also provided to remove clogged particles from atomizer.

3.1.5. Production of Juice Powder.

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 throughout the drying process. 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 was mixed thoroughly with the hot air in the drying chamber and instantly converted into powder. 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 got 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.

3.1.9 Observations.

The rate of feed supply and recovery of spray dried powder were recorded.

3.1.9.1 Powder Recovery

Powder recovered from cyclone and chamber were weighed separately, bulked and total recovery was expressed in percentage fraction of the total solids content of feed mixture.

3.1.9.2 Feed Rate

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

3.1.10 Statistical Analysis and Selection of Powders

Statistical analysis was done based on three factor Completely Randomised Design and ten best treatments with higher powder recovery were selected from each juice (five powders from each carrier) independently for cashew apple, pineapple and their equal blend (thirty powders in total).

3.2 QUALITY EVALUATION OF MICROENCAPSULATED FRUIT POWDERS

Ten micro encapsulated fruit powders (five from each carrier) selected from part 1 of the experiment, independently from cashew apple juice, pineapple juice and their equal blend, were evaluated of the following physical, chemical, nutritional and sensory quality parameters.

3.2.1 Physical Parameters

3.2.1.1 Moisture

Moisture content of juice powder was determined as described by Ranganna (1986) and expressed in percentage.

3.2.1.2. Bulk density

Bulk density of the juice powder was determined by tapping method (Bhandari *et al.*, 1992). Two grams of juice powder was loosely weighed into a 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. The result was expressed in gram/cm^3

3.2.1.3 Average Particle Density and Percentage Volume Occupied

Average particle density and percentage volume occupied were calculated using the method described by Beckett *et al.* (1962). In a 100ml graduated cylinder, 50ml hexane was taken and covered with aluminium foil. Volume (V_1) and total weight (W_1) of hexane were recorded. Sample powder was added slowly through a funnel into the cylinder to increase the volume by about 40ml. The cylinder was placed on a leveled and vibration free surface after covering with aluminium foil. The volume of powder (V_3), hexane (V_2) and the total weight (W_2) were recorded after one hour. The calculation was done as given below.

$$\text{Average Particle Density (g/cm}^3) = \frac{W2-W1}{V2-V1}$$

$$\text{Volume occupied by powder particles (\%)} = \frac{V2-V1}{V3}$$

3.2.1.4 Total Soluble Solids

The powder sample was reconstituted to 30, 35 and 32.5 per cent solution in cashew apple, pineapple and blended juice respectively based on the potential yield of the feed mix as suggested by Jittanit *et al*. (2010). The Total Soluble Solids (°B) of the juice powder was determined by using a hand refractometer (M/s. Erma, Japan) with a range of 0 - 32° and 27 - 68° Brix.

3.2.1.5 Soluble and Dispersible Solids

The powder sample was reconstituted to 30, 35 and 32.5 per cent solution in cashew apple, pineapple and blended juice respectively and 10 ml aliquot of the reconstituted juice was taken and filtered through a pre-weighed filter paper. The filtrate was collected, dried and weighed separately. Solids remaining on the filter

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paper gave the per cent dispersed solids and the dried filtrate gave per cent soluble solids.

3.2.1.6 Sinkability

Distilled water (3.5 ml) at 25°C was taken in a cuvette and 10 mg juice powder sample was dusted on the surface of water. The percentage transmission was continuously recorded for 6 minutes at 760 nm in spectrophotometer at 2nd, 4th and 6th minute.

3.2.1.7 Hunter Colour Value

Each color has its own distinct appearance based on three elements: hue (tonality), chroma (intensity) and value (lightness). A particular color can be accurately distinguished from any other if described using these three attributes. The colour of the juice powder was measured using a Hunter lab colourmeter (Hunter Association laboratory, Inc., Reston, Virgina, USA; model: HunterLab's ColourFlex EZ) as depicted in Plate 3. Colorimeters are tristimulus(three-filtered) devices that make use of red, green, and blue filters that emulate the response of the human eye to light and color. The Hunter lab's colour flex spectro colourmeter consists of measurement (sample) port, opaque cover and display unit. This colour flex meter works on the principle of focusing the light and measuring energy reflected from the sample across the entire visible spectrum. For matching a series of colour across the visible spectrum, primary lights are required and describes the colour by mathematical model called as Hunter model. It reads the colour of sample in terms of L*, a* and b* values where, luminance (L) forms the vertical axis, which indicates whiteness to darkness and ranges from black (L* = 0) to white (L* = 100). Chromatic portion of the solids is defined by: a* (+) redness, a* (-) greenness, b* (+) yellowness, and b* (-) blueness. Thus L* value is the degree of lightness to darkness, a* value is the degree of redness to greenness and b* value is degree of yellowness to blueness.

Hue is how we perceive an object's color (tonality) red, orange, green, blue, etc. A color wheel subtends 360°, with red-purple traditionally placed at the far right (or at an angle of (0°); yellow, bluish-green, and blue follow counter clockwise at 90°, 180°, and 270°, respectively. For the purposes of data analysis

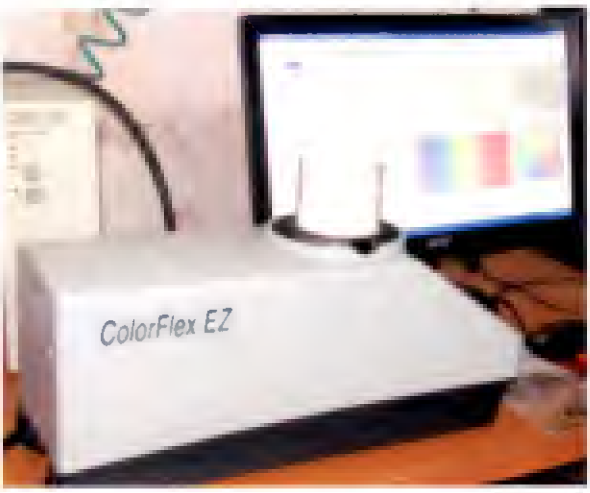

Plate 3: Hunter colour Lab

Plate 4: Water activity meter

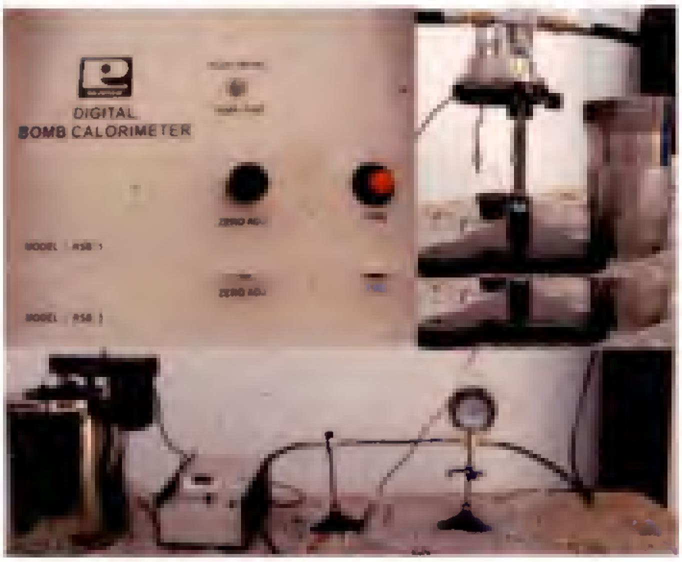

Plate 5: Bomb calorie meter

Plate 6: Brookefield viscometer

Plate 7: Spectrophotometer

and data interpretation, in order to achieve uniform representation of hue derived from the Hunter L*,a*,b* color space positive signed results are generated for the first quadrant [+a, +b] only using the standard calculation($\tan^{-1}(b/a)$. The other quadrants are also handled so that a 360° representation is accommodated and results are expressed as positive signed numbers. Second quadrant [-a,+b] and third quadrant [-a,-b] calculations are as: hue = 180+($\tan^{-1}(b/a)$. Fourth quadrant [+a,-b] calculations are as: hue = 360 + ($\tan^{-1}(b/a)$ as suggested by McLellan *et al.*(1995).

Chroma describes the vividness or dullness of a color (intensity of color) or in other words, how close the color is to either gray or the pure hue. The chroma scale begins at zero for neutral colors, but has no arbitrary end. Chroma is calculated as per following equation.

$$\text{Chroma} = (a^2+b^2)^{1/2}$$

In order to measure L*,a*,b* values a transparent glass cup filled with sample was placed over the port of the instrument and an opaque cover which act as a light trap to exclude the interference of external light was placed over the cup. Colour was calibrated by fixing the definite colours like white and black tiles. After calibration, the sample was placed over the port and values of L*, a* and b* were recorded in triplicates. Chroma and hue angle were also calculated.

3.2.1.8 Relative viscosity

The viscosity of the prepared emulsion was determined using a rotational viscometer (Brook field DV-E Viscometer, USA) (Plate 6). The instrument was first calibrated by an auto test without spindle from 0 to 100 rpm. The principle of the viscometer is based on the torque necessary to overcome the resistance offered by viscosity of solution during the rotation of the cylinder or a submerged disc in the solution. After preliminary calibration, the spindle was fitted and submerged in 500 ml solution taken in 600 ml beaker with due care to avoid spindle friction with beaker walls. When spindle rotation become nearly steady state, viscosity values were recorded in milli pascal seconds (mPas).

3.2.1.9 Flowability (Angle of Repose)

The angle of repose provides a quick and simple method to measure the flowability of different powders. Lower angles of repose correspond to freely flowing powders, whereas higher angles indicate a cohesive or poor flowing material. This technique can be utilized for quantifying the cohesiveness of the bulk material (Cain, 2002). Goula *et al* (2004) defined the angle of repose as "the angle formed between the horizontal plane and a sloped line extending along the face of a heap formed by pouring material onto the horizontal surface". This angle is also known as the static angle of repose.

The static angle of repose was measured to characterize the relative flowability of spray dried powder through fixed funnel method. The material was poured through a funnel to form a cone. The tip of the funnel was held close to the growing cone and slowly raised as the pile grows, to minimize the impact of falling particles and pouring of the material was stopped when the pile reached a predetermined base width. Angle of the resulting cone was calculated through inverse tangent of ratio between height of cone by half the width of the base of the cone.

3.2.1.10 Water Activity

The water activity of juice powder was determined using Aqua Lab water activity meter (M/s. Aqua Lab, U.S.A; model: Series 3TE) as presented in plate4). For determining the water activity, juice powder was filled in the disposable cup of the water activity meter and the sample drawer knob was turned to OPEN position. After opening the drawer, the disposable cup with juice powder was then placed in the drawer and closed. The sample drawer knob was then turned to the READ position and the water activity of juice powder was noted from the LCD display of the water activity meter.

3.2.1.11 Sorption Behaviour

Sorption behavior of the best quality powders selected from each carrier were assessed by wink's weight equilibrium method as suggested by Ranganna (1986) for cashew apple, pineapple and blended juice independently. Moisture sorption studies were conducted by exposing instant juice powder (two grams) to different relative humidities ranging from 5 to 90 per cent created using sulphuric acid of various normalities. These atmospheric conditions were prepared by placing sulphuric acid of various normalities in the bottom part of the dessicators.

Table 1: Normality of sulphuric acid required for specific relative humidities.

SL No	Relative Humidity (%)	Normality of sulphuric acid
1	5	22.0
2	15	18.0
3	25	15.8
4	35	13.9
5	45	12.3
6	65	9.2
7	85	5.2
8	95	2.3

The critical and danger points were assessed and equilibrium moisture curves (sorption isotherms) were plotted to find the equilibrium moisture content as described by Ranganna (1986).

3.2.1.12 Glass Transition Temperature

Glass transition temperature of the best quality powders selected from each carrier were assessed for cashew apple, pineapple and blended juice independently. Glass transition temperature (Tg) was measured by a Differential Scanning Calorimeter (Mettler-Toledo DSC822e, Switzerland) equipped with liquid nitrogen cooling accessories (Plate 7) at Sophisticated Test and Instrumentation Centre of Cochin University of Science and Technology, Kalamasseri Ernakulam. Around 5-10 mg of juice powder was weighed into a 40µl aluminium standard crucible and hermetically sealed with an aluminium standard lid A sealed empty crucible was used as reference. The heating ramp rate was set to 10 °C/min and heat scanned from an equilibrium starting temperature of -50^{0}C to 200^{0}C. The midpoint values for glass transition temperature of the samples were calculated using DSC STARe evaluation software. The experiments were carried out at a heating rate of 100°C/min under nitrogen. Glass transition temperature was analysed by STARe software (Version 8.01, Mettler-Toledo, Switzerland), and taken at the mid point of phase transition.

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Plate 7a: Differential scanning calorimetry

Plate 8: Scanning electron microscopy

3.2.1.13 Microstructure of Best Powders

Microstructure of the best quality powders selected from each carrier were assessed for cashew apple, pineapple and blended juice independently. Scanning electron microscopy (SEM) was used to investigate the microstructural characteristics of the instant juice powders. SEM creates magnified images of powders and determines the particle size of a powder by scanning their surfaces with electrons, rather than light waves. Scanning Electron Microscopy analysis of the samples was carried out at Sophisticated Test and Instrumentation Centre of Cochin University of Science and Technology, Kalamasseri, Ernakulam using a JSM-6400 scanning electron microscope (JEOL, Tokyo, Japan) as depicted in plate 8. Prior to examination, a double adhesive carbon tape was stuck to the sample holding side of the stub the samples were uniformly spread on the tape. Since the SEM illuminates samples with electrons, it was coated with a very thin layer of gold by using HUMMLE VII Sputter Coating Device (Anatech Electronics, Garfield, N.J., USA) to conduct electricity. The sample was then placed inside the vacuum column of the microscope through an air-tight door. After the air was pumped out of the column an electron gun from the top emittted a beam of high energy electrons which travels downward through a series of magnetic lenses designed to focus the electrons on a very small spot. Near the bottom, a set of scanning coils moves the focused beam back and forth across the specimen, row by row. As the electron beam hits each spot on the sample, secondary electrons are loosened from its surface. A detector counts these electrons and sends the signals to an amplifier. The final image was built up from the number of electrons emitted from each spot on the sample (Oatley, 1972). The sputter coated samples were examined at a SEM voltage of 15 kV to obtain micrographs.

3.2.2 Chemical Parameters

3.2.2.1 Vitamin C

The titrimetric method described by Ranganna (1986) was adopted for 5g sample of juice powder and the result was expressed in mg/100g.

3.2.2.2 β-carotene

Juice powder (5g sample) was subjected to extraction and estimation as described in 3.1.1.2.5 and the result was expressed in μg/100g.

3.2.2.3 Crude Fibre

Crude fibre was estimated by acid digestion method (Ranganna,1986). Two grams of juice powder was extracted with ether. The residue was digested with 200ml of 0.255N sulphuric acid solution. The residue from acid digestion was boiled with 200 ml of 0.313N NaOH solution and filtered. Then the residue was washed with boiling water and alcohol and dried at 110°C to constant weight. The resultant residue was ignited in muffle furnace to find the crude fibre in percentage.

3.2.2.4 Total Ash

Total ash was estimated by igniting five grams of juice powder in a silica dish on a muffle furnace (Ranganna,1986).

3.2.2.5 Sugars (Total Reducing and Non Reducing Sugar)

The titrimetric method of Lane and Eynon as described by Ranganna (1986) was adopted for the estimation of reducing sugars in instant juice powder and the result was expressed in percentage.

3.2.2.6 pH

The pH of reconstituted juice was determined using a digital pH meter (M/s. Systronics; Model MK VI).

3.2.2.7 Titrable Acidity

The method described by Ranganna (1986) was adopted to measure titratable acidity and expressed the result in percentage.

3.2.2.8 Energy Value

Gross energy value of the juice powder was estimated using Bomb calorie meter (M/s, Rajadhani S) as depicted in plate 5. The oxygen bomb calorimeter consists of puff insulated outer jacket with calorimeter vessel support, bomb valve assembly, firing and control unit. The juice powder was converted to small pellets of one gram using the pellet press. The pellet placed in the crucible was put into the crucible ring adjacent to the electrodes. An ignition wire of 6 cm length was tied tightly across electrodes. A cotton thread knot with 10 cm length was tied at the centre of the ignition wire in such a way that the other end of the thread touches the pellet. Two drops of water were added to the bomb and the crucible assembly was placed inside the bomb and its lid was tightened. The bomb was charged with oxygen upto 25 kg/cm2 pressure. The bomb was placed in the supporting column of calorimeter vessel using the hook provided. Distilled water was filled in the calorimeter vessel up to the marking on the bomb ring. Electrical connections were made properly with electronic firing unit. A stirrer and a temperature sensor were placed in the water through the holes in the cover and connected them to the main firing unit. The glowing green LED light indicated proper continuity of electrical connections. The temperature in the digital display unit indicated the initial temperature of the water inside since the temperature switch is in the initial mode. The stirrer was turned on and waited for few seconds for a stable initial reading. The temperature switch was shifted to rise mode and the temperature display was calibrated to zero by using the zero adjusting knob. The fire button was pressed to ignite the powder pellet present inside the bomb assembly. The dimmed green light and glowing red light indicated successful ignition of the bomb. The temperature reading in the display rose gradually and stabilized after few minutes. This stabilized reading is taken as the final rise in temperature and applied to below formula to assess the energy value.

$$\text{Calorific value of the powder} = \frac{(T \times W) - (Cv_T + Cv_W)}{M}$$

Where

T is the final rise in temperature of the given sample in °C

W is the water equivalent of the apparatus (2406.81cal/°C)

Cv_T is the calorific value of the thread (2.1cal/cm)

Cv_W is the calorific value of the wire (2.33 cal/cm)

M is the mass of the powder pellet in grams

3.2.3 Sensory Parameters

Sensory evaluation of the reconstituted juice powders were organoleptically scored by a 26 member semi trained panel. The powder samples were reconstituted to 30, 35 and 32.5 per cent solution in cashew apple, pineapple and blended juice respectively. The panel were asked to score the appearance, colour, flavour, texture, taste of the sample using a nine-point hedonic scale in the order of preference as shown below for cashew apple, pineapple and blended juice independently.

Like extremely - 9

Like very much - 8

Like moderately - 7

Like slightly - 6

Neither like nor dislike- 5

Dislike slightly - 4

Dislike moderately - 3

Dislike very much - 2

Dislike extremely - 1

3.2.4 Statistical Analysis and Selection of Powders

The data on physical and chemical parameters were subjected to statistical analysis in two factor Completely Randomized Design and the data on sensory parameters were analysed with Kruskal Wallis test computing mean ranks and multiple pair wise comparison were made by Dunn's multiple comparison procedure (Dunn, 1964).

Based on physical, chemical and sensory quality parameters, two powders from each juice (one from each carrier) for cashew apple, pineapple and their blended juices independently (six powders in total) were selected and three physical parameters viz. sorption behavior, glass transition temperature and microstructure were instigated on these selected six powders. Then these six powders were subjected to storage study under part three of the experiment as detailed below.

3.3 STORAGE STABILITY OF PURE AND BLENDED FRUIT JUICE POWDERS.

The six encapsulated fruit juice powders selected from part two of the experiment were subjected to the following four packaging and storage conditions in metallised polyester pouches of 10 cm x 17.5cm size.

1. Modified atmospheric packaging with vacuum (V) and storage in ambient temperature.

2.Modified atmospheric packaging with nitrogen (N) and storage in ambient temperature.

3. Air packaging and storage under refrigeration (L).

4. Air packaging and storage in ambient temperature (A).

Modified atmospheric packaging was done with a laboratory model vacuum and nitrogen packaging machine (M/s Sevana – QS 400 MG (MC).

Vacuum packaging machine consists of a programmable pump that creates desired percentage of vacuum inside the product chamber. The product chamber has a thermal film sealer as well as a gas flushing nozzle which can fill the product chamber with selected gas inside the product package if desired.

3.3.1Modified atmospheric packaging with vacuum (V)

Mode 4 of the machine was selected for modified atmospheric packaging with vacuum at -680mm Hg pressure with sealing and cooling time of 2.5 and 9 seconds respectively. Twenty five grams of powder were filled into metallised polyester pouches and kept inside the product chamber of the machine in such a way that sealing bars could seal the pouches properly. When the acrylic lid was closed and gently pressed vacuum pump evacuated air inside the chamber. The pouch opening was hermetically sealed by a heat impulse transmitted by the bar resistance and cooled. When the lid of product chamber was automatically opened the packaged product was taken out. The packaged product was stored at ambient temperature.

3.3.2 Modified atmospheric packaging with nitrogen (N)

Modified atmospheric packaging with nitrogen was done using mode 1 of the machine where packet was vacuumed at -680 mmHg pressure and then flushed with nitrogen till -200 mmHg pressure. Sealing time, cooling time and other operational procedures were similar to vacuum packaging. The packaged product was stored at ambient temperature.

3.3.3 Air packaging and storage under refrigeration (R)

Twenty five grams of powder were filled into metallised polyester pouches and sealed with hand sealing machine (M/s Sevana) and stored under refrigeration at 4°C

3.3.4 Air packaging and storage in ambient temperature (A)

Metallised polyester pouches with twenty five grams powder were sealed with hand sealing machine (M/s Sevana) and stored under ambient temperature.

3.3.5 Storage period

Changes in quality parameters of packaged powder were assessed at bimonthly interval for a period of six months.

1. S_1 – 2nd Month
2. S_2 – 4th Month
3. S_3 – 6th Month

3.3.6 Observations

3.3.6.1 Moisture

As described as in 3.

3.3.6.2 Total Phenol

Foline Ciocalteu method was used to determine the Total Phenolic Content of the samples and the result was expressed as gallic acid equivalents (GAE) in percentage as described by Ranganna (1986).

3.3.6.3 pH

As described as in 3.

3.3.6.4 Titrable acidity

As described as in 3.

3.3.6.5 Microbial Count

The quantitative assay of the micro flora in powder samples was carried out by serial dilution and pour plate technique. Nutrient agar and potato dextrose agar medium were used for the enumeration of bacterial and fungal population at dilution of 10^{-3} and without dilution.

3.3.6.6 β-carotene

As described as in 3.

3.3.6.7 Vitamin C

As described as in 3.

3.3.6.8 Sensory Evaluation

As described in 3.

3.3.6.9 Statistical Analysis and Selection of Powders

The data of three replications were subjected to statistical analysis in three factor completely randomized design with storage period as a split plot for each fruit juice separately to select best packaging atmosphere which provide maximum storage stability and nutrition retention. Data on sensory parameters were subjected to Kruskal wallis test and multiple pair wise comparison with Dunn's procedure (Dunn, 1964). Two best powders (one from each carrier) with better storage stability and nutrient retention was selected independently for cashew apple, pineapple and blended juice. These six powders were subjected to investigation on consumer acceptability and computation of cost of production.

3.3.7 Cost of production

The cost of production of selected six instant juice powders was estimated by considering the cost of spray drier, raw material, processing, labour, electricity and other related costs as suggested by Marouli and Maroulis (2004). The fixed and variable costs were taken into account for determining the cost of production.

Fixed cost was calculated by using the following assumptions and relationships

Fixed cost of the drier / year = Fixed cost × Capital Recovery Factor

Where,

Capital Recovery Factor (CRF) was derived by using the equation.

$$CRF = \frac{Ri\,(1+Ri)^n}{(1+Ri)^n - 1}$$

where,

Ri = Existing rate of interest for long term bank loans (11%),

n = life period of the spray drier (15 year)

The variable costs which are incurred on wages, electricity charges, repairs and maintenance, raw materials *etc*., were calculated by collecting data during the operation of equipment and assuming certain data reasonably wherever necessary. The yield of powder from the spray dryer was calculated based on the recovery percentage of the particular treatment combination and cost of production per kilogram of the product was worked out.

3.3.8 Consumer acceptability (Organoleptic scoring)

Consumer acceptability of six selected instant juice powder was assessed from a panel consisting 26 consumers through non parametric evaluation of their preference, price fairness, payment intention in 5 point scale. As described by Jeong and Kim (2014) price fairness refers to perception of consumer with respect to rationality of price in relation to the value possessed by product. Payment intention refers to positive attitude of the consumer to pay money willingly to purchase the product. The data was analysed with Kruskal Wallis test computing mean ranks and multiple pair wise comparisons were made by Dunn's multiple comparison procedure (Dunn,1964). Mean of perceived value of the product was also computed.

3.4 BEST INSTANT JUICE POWDER

Based on the results from the entire three parts of investigation, the most economical treatment combination with optimum yield, quality, storage stability and consumer acceptance was selected from each juice for cashew apple, pineapple and blended juice. Hence, the present investigation led to formulation of three instant juice powders, one each from cashew apple, pineapple and blended juice.

Results

4. RESULTS

The data generated from the spray drying, subsequent quality analysis, storage study, computation of cost of production and investigation on consumer acceptability were statistically analysed and the results are presented in detail in this chapter as three parts.

4.1 OPTIMISATION OF PROCESS PARAMETERS FOR INSTANT FRUIT POWDER PRODUCTION BY MICRO ENCAPSULATION THROUGH SPRAY DRYING

In order to optimize process parameters spray drying of three juices were conducted independently by adding carriers in different proportion and drying at different inlet temperatures. The data received on observations like chemical parameters of juice, recovery of powder either fine (from cyclone), coarse (from chamber) and bulked powders (total powder) and feed rate employed were assessed, The thrice replicated data were analysed in three factor completely randomized design with carrier, concentration and inlet temperature as factors and the result is presented in this section.

4.1.1 Chemical Parameters of the Juice

Chemical parameters such as pH, titrable acidity, total, reducing and non-reducing sugars, β carotene and vitamin C were assessed and depicted in table 2. Cashew apple juice did not contain any β carotene but had the highest content of vitamin C (209.2 mg/100g). Pineapple juice had the highest content of total soluble solids (13.4°B) and cashew apple juice contained 10.8°B. Cashew apple juice was clear while pineapple juice was medium yellow colour due to presence of β carotene (11.3 ug/100g).

4.1.2 Recovery of Powders.

In order to assess the proper conditions for maximum efficiency in spray drying recovery of powders from cyclone (fine powder), from drying chamber (coarse powder) were collected separately and then bulked. The recovery was assessed as percentage of the total solid content of the feedmix used for dying. The results indicated that the factors like carrier, concentration, inlet temperature and their interactions influenced powder recovery and effects of each factors and their interactions are described below;

4.1.2.1 Effect of Carrier on Recovery of Fine, Coarse and Bulked Powders

The different carriers used in the study has significantly influenced recovery of powders and the effect is depicted in Table 3. Effect of resistant dextrin was highly superior in obtaining higher recovery in fine, coarse and bulked powders. Effect of resistant dextrin was more profound in the yield of fine powder in the cyclone where the yield was increased from 2.28 to 7.82 per cent in comparison to maltodextrin. The increase in yield from 7.6 to 12.48 per cent and 9.6 to 20.30 per cent were observed in the coarse and bulked powders respectively.

The superiority of resistant dextrin was also evident in pineapple powder recovery. Resistant dextrin recorded 10.19 per cent 14.27 per cent and 24.51 per cent recovery in fine, coarse and bulked powers respectively. The yield of maltodextrin formulation was 5.5, 10 and 15.32 per cent in fine, coarse and bulked powders respectively.

The use of resistant dextrin as carrier yielded 9.67, 11.55 and 21.54 per cent recovery of total solids in the feed in the form of fine, coarse and bulked powders respectively while maltodextrin could only yielded 3.59, 8.84 and 12.20 per cent in blended juice powders.

4.1.2.2 Effect of Concentration on Recovery of Fine, Coarse and Bulked Powders

The different concentration of carrier material as a ratio of the solid content of the pure juice significantly influened the recovery of fine, coarse and total powder as described in table 4.

Table 2 : Chemical Parameters of juices

SLNo	Parameter	Cashew apple	Pineapple	Blended
1	pH	4.01	3.85	4.19
2	Total Soluble solids (^{O}B)	10.8	14.4	12.6
3	Titrable Acidity (%)	0.33	0.69	0.42
4	Total sugar (%)	10.82	13.4	11.9
5	Reducing sugar (%)	8.17	10.7	9.3
6	Non reducing sugar (%)	2.65	2.7	2.6
7	β -carotene ((µg/100g)	0	11.3	5.5
8	Vitamin C (mg/100g)	209.2	13.1	102.3

The juice solid and carrier combination in the ratio of 80:20 could not yield any cashew apple juice powder since juice droplets sticked to the chamber wall and got converted to rubbery deposits (Plate 9). The increase in concentration of carrier material from 30:70 ratio to 40:60 ratio improved powder recovery markedly (Table 4). The juice solid to carrier ratio of 40:60 yielded highest recovery of 15.57, 26.47 and 42.78 per cent in fine coarse and bulked powder respectively. The next lower carrier ratio of 50:50 ratio could only record 5.92, 13.04 and 19.04 per cent improvement in fine coarse and bulked powder yield.

The lowest carrier ratio of 80:20 could not produce any pineapple juice powder. As carrier concentration increased, powder recovery improved. The recovery of powder at juice solid to carrier ratio of 70: 30 was meagre and the ratio of 40:60 recorded higher recovery (Table 4) of 21.34, 35.84 and 58.35 per cent of the total solids in the feed mixture.

The highest carrier concentration (40:60) recorded highest recovery of 19.68, 26.11and 46.83 per cent in fine, coarse and bulked powder recovery in the spray drying process of blended juice. The lower carrier concentration of 50:50 yielded lower with 9, 13.43 and 22.58 per cent respectively (Table4).

4.1.2.3 Effect of Inlet Temperature on Recovery of Fine, Coarse and Bulked Powders

Inlet temperature significantly influenced powder recovery in the spray drying process. As depicted in table 5. In general, lower temperature yielded significantly higher recovery of fine coarse and bulked powders. The optimum temperature was 160°C for highest recovery of the three type of powders where the temperature of 170°C was at par in fine and coarse powders of cashew apple juice.

CM_1T_1 CM_1T_6

CM_4T_1 CM_4T_6

Plate 9 : Stickiness and burning in treatment combinations

Chamber Cyclone Cyclone – inside view

Plate 10: Higher recovery of powder in R_5T_2

C- Cashew apple juice, M_1 – Maltodextrin@80:20 (Juice: Carrier). M_4 – Maltodextrin@50:50 (Juice: Carrier), R_5 -Resistant dextrin@40:60 (Juice: Carrier), T_1-150°C, T_2- 160°C. T_6- 200°C

Table: 3 Effect of carrier on recovery of fine, coarse and bulked powders

Carrier	Recovery (%)								
	Cashew apple juice powder (C)			Pineapple juice powder (P)			Blended juice powder (B)		
	Fine	Coarse	Bulked	Fine	Coarse	Bulked	Fine	Coarse	Bulked
Maltodextrin (M)	2.28 (1.81)	7.6 (2.93)	9.6 (3.26)	5.5 (2.55)	10.0 (3.32)	15.32 (4.04)	3.59 (2.14)	8.84 (3.13)	12.20 (3.63)
Resistant dextrin (R)	7.82 (2.97)	12.48 (3.67)	20.30 (4.62)	10.19 (3.34)	14.27 (3.91)	24.51 (5.05)	9.67 (3.27)	11.55 (3.54)	21.54 (4.75)
CD (0.05)	0.09	0.07	0.08	0.11	0.08	0.11	0.09	0.09	0.09

The data in parenthesis is the square root transformed values

Table: 4 Effect of concentration on recovery of fine, coarse and bulked powders

Concentration levels (Juice Solid : Carrier)	Recovery (%)								
	Cashew apple juice powder (C)			Pineapple juice powder (P)			Blended juice powder (B)		
	Fine	Coarse	Bulked	Fine	Coarse	Bulked	Fine	Coarse	Bulked
70:30	0.31 (1.15)	1.11 (1.45)	1.37 (1.54)	0.75 (1.32)	1.93 (1.71)	2.55 (1.89)	0.28 (1.13)	2.1 (1.76)	2.32 (1.82)
60:40	1.93 (1.7)	6.66 (2.77)	8.67 (3.11)	4.73 (2.39)	6.96 (2.82)	11.84 (3.58)	2.92 (1.98)	5.73 (2.6)	9.03 (3.17)
50:50	5.92 (2.63)	13.04 (3.75)	19.04 (4.48)	10.18 (3.34)	13.77 (3.84)	24.12 (5.01)	9 (3.16)	13.43 (3.80)	22.58 (4.86)
40:60	15.57 (4.07)	26.47 (5.24)	42.78 (6.61)	21.34 (4.72)	35.84 (6.07)	58.35 (7.70)	19.68 (4.55)	26.11 (5.2)	46.83 (6.92)
CD (0.05)	0.12	0.10	0.11	0.15	0.12	0.15	0.13	0.13	0.13

The data in parenthesis is the square root transformed values

Table: 5 Effect of inlet temperature on recovery of fine, coarse and bulked powders

Inlet temperature (°C)	Recovery (%)								
	Cashew apple juice powder (C)			Pineapple juice powder (P)			Blended juice powder (B)		
	Fine	Coarse	Bulked	Fine	Coarse	Bulked	Fine	Coarse	Bulked
150 (T_1)	4.90 (2.43)	10.90 (3.45)	15.65 (4.08)	6.27 (2.7)	13.58 (3.82)	19.92 (4.57)	6.01 (2.65)	10.33 (3.37)	16.56 (4.19)
160 (T_2)	6.27 (2.7)	11.24 (3.50)	17.45 (4.30)	9.72 (3.27)	13.98 (3.87)	23.61 (4.96)	7.86 (2.98)	12.24 (3.64)	20.12 (4.60)
170 (T_3)	5.65 (2.57)	10.68 (3.42)	16.23 (4.15)	9.18 (3.19)	13.02 (3.74)	22.11 (4.80)	7.72 (2.95)	10.88 (3.45)	18.65 (4.43)
180 (T_4)	4.66 (2.38)	9.55 (3.25)	14.04 (3.88)	7.49 (2.91)	11.64 (3.56)	18.91 (4.46)	6.40 (2.72)	10.43 (3.38)	16.99 (4.24)
190 (T_5)	4.10 (2.26)	8.83 (3.14)	12.79 (3.71)	7.86 (2.98)	10.35 (3.37)	18.09 (4.37)	5.70 (2.59)	9.33 (3.21)	15.06 (4.01)
200 (T_6)	2.96 (1.99)	8.36 (3.06)	11.22 (3.50)	5.91 (2.63)	9.98 (3.31)	15.81 (4.1)	4.48 (2.34)	7.98 (2.98)	12.49 (3.67)
CD (0.05)	0.15	0.13	0.14	0.19	0.15	0.19	0.15	0.16	0.16

The data in parenthesis is the square root transformed values

The highest temperature of 200°C recorded lowest powder recovery irrespective of the fineness and coarseness. The optimum temperature recorded 6.27, 11.24 and 17.45 per cent recovery of solids from the feed. Drying at 150°C recorded yield of4.9, 10.9 and 15.65 per cent in fine, coarse and bulked powders respectively (Table 5).

The optimum temperature for highest pineapple juice powder recovery was 160 and 170°C irrespective of powder recovery point (Plate 10). The recovery ranged from 5.91 to 9.72 per cent, 9.98 per cent to 13.98 per cent and 15.81 per cent to 23.61 per cent in fine, coarse and bulked powders respectively from highest (200°C) to the optimum temperature (160°C). The recovery in the lowest temperature were 6.27 and 19.92 per cent in fine and bulked powders which were significantly lower than the recovery at optimum temperature.

The optimum temperature for maximum recovery was 160°C in coarse and bulked powders and it performed at par with 170°C with respect to fine powder from the cyclone. The lowest and highest recovery percentages ranged from 4.48 to 7.86, 7.98 to 12.24 and 12.49 to 20.12 when temperature varied from 200°C to 160°C in fine, coarse and bulked powders respectively. Further reduction of temperature reduced recovery significantly since the recovery of powder from cyclone and chamber were 6.01 and 10.33 per cent which led to 16.56 per cent bulked powder recovery at 150°C.

4.1.2.4 Interaction Effects on Recovery of Fine, Coarse and Bulked Powders

4.1.2.4.1 Interaction Effect of Carrier with Concentration on Recovery of Fine, Coarse and Bulked Powders

Interaction effects of carrier with concentration were significant in fine, coarse and bulked powder recovery of cashew apple juice as described in table 6. Maltodextrin at juice solid to carrier ratio of 70: 30 could not yield any powder but resistant dextrin at the same concentration could yield powder though in low quantities. The resistant dextrin at juice solid to carrier ratio of 40:60 recorded the highest yield of 24.46 per cent in the fine powder obtained from the cyclone whereas maltodextrin yielded 8.59 per cent with the same concentration. However, both the combination recorded at par yield in coarse powder production at chamber. When the powder was bulked, resistant dextrin at the concentration of 40:60 yielded significantly higher in comparison to all other carrier – concentration combinations by converting 51.74 per cent of total solids in the feed to powder. Maltodextrin at the same concentration level could only transform 34.65 per cent of total solid to cashew apple juice powder (Table 6).

The recovery of fine pineapple juice powder from the cyclone, coarse powder chamber and the bulked powder was significantly influenced by the interaction effect of carrier and concentration. Resistant dextrin at the juice solid to carrier ratio of 40:60 was significantly superior to all other combinations in powder recovery from cyclone (31.81) and the bulked one (64.92). Resistant dextrin at lower concentration level of 30:70 could yield small quantity of pineapple juice powder but maltodextrin could not yield any powder at the same concentration. The recovery of fine powder from cyclone got lowered from 31.81to 12.89 per cent when carrier was changed from resistant dextrin to maltodextrin at the same concentration level. The yield of bulked powder also got lowered from 64.92 to 52.12 per cent. However, recovery of pineapple juice powder from the chamber increased from 32.87 per cent to 38.94 per cent (Table 6).

Interaction effects between carrier and concentration of carrier were significantly varied among the combinations in spray drying of blended juice. Maltodextrin combinations were significantly inferior to resistant dextrin concentration irrespective of the recovery point in spray drier. Resistant dextrin at concentration of 40:60 recorded highest recovery of 31.72, 27.32 and 56.76 per cent of total solid in the feed as fine, coarse and bulked blended juice powders (Table 6).

Table: 6 Interaction effect of carrier with concentration on recovery of fine, coarse and bulked powders

Carrier	Concentration levels (Juice Solid : Carrier)	Recovery (%)								
		Cashew apple juice powder (C)			Pineapple juice powder (P)			Blended juice powder (B)		
		Fine	Coarse	Bulked	Fine	Coarse	Bulked	Fine	Coarse	Bulked
Maltodextrin (M)	70:30 (M_2)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)
	60:40 (M_3)	0.13 (1.07)	4.29 (2.30)	4.41 (2.33)	3.70 (2.16)	4.08 (2.25)	7.97 (3)	0.32 (1.15)	5.23 (2.50)	5.55 (2.56)
	50:50 (M_4)	3.33 (2.08)	9.52 (3.24)	12.88 (3.72)	9.91 (3.30)	12.61 (3.69)	22.77 (4.88)	8.28 (3.05)	5.35 (2.52)	21.44 (4.74)
	40:60 (M_5)	8.59 (3.1)	25.90 (5.2)	34.65 (5.97)	12.89 (3.72)	38.94 (6.32)	52.12 (7.29)	10.38 (3.37)	6.25 (2.69)	37.85 (6.23)
Resistant Dextrin (R)	70:30 (R_2)	0.66 (1.29)	2.63 (1.90)	3.32 (2.08)	1.70 (1.64)	4.88 (2.43)	6.65 (2.77)	0.59(1.26)	12.91 (3.73)	5.98 (2.64)
	60:40 (R_3)	4.56 (2.36)	9.47 (3.24)	14.13 (3.89)	5.87 (2.62)	10.47 (3.39)	16.41 (4.18)	6.90 (2.81)	13.97 (3.87)	13.25 (3.78)
	50:50 (R_4)	9.13 (3.18)	17.06 (4.25)	26.33 (5.23)	10.47 (3.39)	14.97 (4)	25.51 (5.15)	9.74 (3.28)	24.94 (5.09)	23.75 (4.98)
	40:60 (R_5)	24.46 (5.05)	27.03 (5.29)	51.74 (7.26)	31.81 (5.73)	32.87 (5.82)	64.92 (8.12)	31.72 (5.72)	27.32 (5.32)	56.76 (7.60)
CD (0.05)		0.17	0.15	0.16	0.22	0.17	0.22	0.18	0.18	0.18

The data in parenthesis is the square root transformed values. The concentration level 80:20 (M_1) did not yield any powder

4.1.2.4.2 Interaction Effect of Carrier with Inlet Temperature on Recovery of Fine, Coarse and Bulked Powders

Interaction effect between carrier and inlet temperature significantly influenced the recovery of fine powder from the cyclone alone (Table7). Resistant dextrin recorded highest recovery of fine powder (10.62 and 9.39 per cent) at 160°C and 170°C respectively (Table7).

Significant interaction effects were observed in the fine and bulked pineapple juice powder recovery (Table 7). Resistant dextrin at the temperature of 160 °C (12.99 per cent) and 170 °C (11.92 per cent) yielded maximum fine pineapple juice powder which in turn led to highest quantity of powder when bulked (29.81 and 27.8 per cent respectively).

The fine powder recovery of blended juice was significantly influenced by the interaction effect between carrier and inlet temperature as depicted in table 7. Resistant dextrin at the temperature of 160 °C (11.96 per cent) and 170°C (11.39 per cent) recorded highest recovery followed by same carrier at 150 °C (10.41 per cent). The best maltodextrin combination was at 160 °C which recorded far lower yield of fine powder (4.69 per cent).

4.1.2.4.3 Interaction Effect of Concentration with Inlet Temperature on Recovery of Fine, Coarse and Bulked Powders

Interaction effect of concentration and inlet temperature significantly altered powder recovery irrespective of whether fine, coarse or bulked it was, as depicted in table 8. Highest ratio of carrier (40:60) at inlet temperature of 160 °C recorded highest recovery of 23.77, 31.25 and 56.29 per cent in fine, coarse and bulked powder respectively followed by same concentration at 170 °C. The least yield recorded among different temperature levels in 40: 60 concentration was 8.7, 22.82 and 31.86 per cent by the highest inlet temperature of 200 °C in fine, coarse and bulked powders respectively and this combination was significantly superior than all combinations of lower concentration levels with same temperature. The yield at 70:30 carrier ratio was similar among the temperature levels.

Interaction effect between concentration and inlet temperature significantly influenced recovery of fine, coarse and bulked pineapple juice powders as depicted in table 8. In fine powder recovery, the optimum combinations were 40: 60 juice solid to carrier ratio and inlet temperature of 160°C and 170 °C which transformed 29.68 and 28.15 per cent of total solids into fine powder. When the powder was bulked these combinations exhibited highest recovery of 72.29 per cent and 66.58 per cent of solids. The concentration of 40:60 and 160°C was adjudged as optimum to improve powder recovery from chamber (41.09 per cent) followed by 150°C at same concentration (38.81 per cent). The yield data did not differ significantly among various temperature levels within same concentration when juice solid to carrier ratio of 70: 30 was used for drying, irrespective of place of collection of powder as depicted in table 8. But at the concentration of 40: 60, the significant difference between temperature levels were more evident (Table 8).

The concentration of 40:60 at inlet temperature of 160°C and 170°C transformed maximum blended juice solids into powders collected in chamber as well as in cyclone. When the powders were bulked the recovery percentage of 160°C at 40:60 concentration level was significantly superior to 170°C at same concentration level. Similarly to pineapple juice powders effect of temperature levels within a concentration was more evident at higher carrier concentration levels in contrast to at par values seen at the lower concentration levels of 70:30 and 60:40 which denoted that at concentration levels of 50:50 and 40:60 different temperature levels varied the yield markedly (Table 8).

Table: 7 Interaction effect of carrier with inlet temperature on recovery of fine, coarse and bulked powders

Carrier	Inlet temperature (°C)	Recovery (%)								
		Cashew apple juice powder (C)			Pineapple juice powder (P)			Blended juice powder (B)		
		Fine	Coarse	Bulked	Fine	Coarse	Bulked	Fine	Coarse	Bulked
Maltodextrin (M)	150 (T_1)	2.52 (1.88)	7.92 (2.99)	10.22 (3.35)	3.02 (2.01)	12.17 (3.63)	14.97 (4)	2.68 (1.92)	6.66 (2.77)	11.76 (3.57)
	160 (T_2)	2.94 (1.98)	9.14 (3.18)	11.76 (3.57)	6.89 (2.81)	11.52 (3.54)	18.10 (4.37)	4.53 (2.35)	7.79 (2.96)	15.02 (4.00)
	170 (T_3)	2.74 (1.94)	8.16 (3.03)	10.61 (3.41)	6.75 (2.79)	10.59 (3.41)	17.04 (4.25)	4.69 (2.39)	9.28 (3.21)	13.72 (3.84)
	180 (T_4)	2.27 (1.81)	7.50 (2.92)	9.43 (3.23)	5.89 (2.62)	9.79 (3.29)	15.34 (4.04)	3.53 (2.13)	9.36 (3.22)	12.64 (3.69)
	190 (T_5)	1.82 (1.68)	6.94 (2.82)	8.53 (3.09)	6.27 (2.70)	8.31 (3.05)	14.43 (3.93)	3.53 (2.13)	9.37 (3.22)	11.17 (3.49)
	200 (T_6)	1.49 (1.58)	6.09 (2.66)	7.35 (2.89)	4.64 (2.37)	7.92 (2.99)	12.37 (3.66)	2.78 (1.94)	9.39 (3.22)	9.25 (3.20)
Resistant Dextrin (R)	150 (T_1)	7.89 (2.98)	14.32 (3.9)	22.13 (4.81)	10.48 (3.39)	15.07 (4.01)	25.55 (5.15)	10.41 (3.38)	10.86 (3.45)	22.14 (4.81)
	160 (T_2)	10.62 (3.41)	13.55 (3.81)	24.18 (5.02)	12.99 (3.74)	16.66 (4.20)	29.81 (5.55)	11.96 (3.6)	10.99 (3.46)	25.93 (5.19)
	170 (T_3)	9.39 (3.22)	13.50 (3.81)	22.95 (4.89)	11.92 (3.60)	15.66 (4.08)	27.80 (5.37)	11.39 (3.52)	11.34 (3.51)	24.29 (5.03)
	180 (T_4)	7.73 (2.95)	11.82 (3.58)	19.48 (4.53)	9.27 (3.20)	13.63 (3.83)	22.84 (4.88)	10 (3.32)	11.54 (3.54)	21.93 (4.79)

Table: 7 Interaction effect of carrier with inlet temperature on recovery of fine, coarse and bulked powders (continued)

Carrier	Inlet temperature (°C)	Recovery (%)								
		Cashew apple juice powder (C)			Pineapple juice powder (P)			Blended juice powder (B)		
		Fine	Coarse	Bulked	Fine	Coarse	Bulked	Fine	Coarse	Bulked
Resistant Dextrin (R)	190 (T_5)	7.06 (2.84)	10.92 (3.45)	17.84 (4.34)	9.61 (3.26)	12.59 (3.69)	22.13 (4.81)	8.30 (3.05)	12.60 (3.69)	19.48 (4.53)
	200 (T_6)	4.78 (2.41)	10.95 (3.46)	15.82 (4.10)	7.31 (2.88)	12.26 (3.64)	19.64 (4.54)	6.50 (2.74)	13.67 (3.83)	16.16 (4.14)
CD (0.05)		0.21	NS	NS	0.27	NS	0.27	0.22	NS	NS

The data in parenthesis is the square root transformed values

Table:8 Interaction effect of concentration with inlet temperature on recovery of fine, coarse and bulked powders

Concentration levels (Juice Solid : Carrier)	Inlet temperature (°C)	Recovery (%)								
		Cashew apple juice powder (C)			Pineapple juice powder (P)			Blended juice powder (B)		
		Fine	Coarse	Bulked	Fine	Coarse	Bulked	Fine	Coarse	Bulked
70:30	150 (T_1)	0.6 (1.27)	1.39 (1.55)	1.88 (1.7)	1.22 (1.49)	1.93 (1.71)	2.94 (1.99)	0.34 (1.16)	2.067 (1.75)	2.33 (1.82)
	160 (T_2)	0.08 (1.04)	0.99 (1.41)	1.04 (1.43)	0.89 (1.37)	2.36 (1.83)	3.05 (2.01)	0.47 (1.21)	2.12 (1.77)	2.49 (1.87)
	170 (T_3)	0.45 (1.21)	1.26 (1.50)	1.64 (1.63)	0.74 (1.319)	2.32 (1.82)	2.9 (1.98)	0.27 (1.13)	2.12 (1.77)	2.32 (1.82)

Table:8 Interaction effect of concentration with inlet temperature on recovery of fine, coarse and bulked powders (continued)

Concentration levels (Juice Solid : Carrier)	Inlet temperature (°C)	Recovery (%)								
		Cashew apple juice powder (C)			Pineapple juice powder (P)			Blended juice powder (B)		
		Fine	Coarse	Bulked	Fine	Coarse	Bulked	Fine	Coarse	Bulked
70:30	180 (T_4)	0.30 (1.14)	0.86 (1.37)	1.14 (1.46)	0.69 (1.3)	1.55 (1.60)	2.14 (1.77)	0.26 (1.12)	2.16 (1.78)	2.37 (1.84)
	190 (T_5)	0.23 (1.11)	0.80 (1.34)	0.98 (1.41)	0.64 (1.28)	1.47 (1.57)	1.992 (1.73)	0.27 (1.13)	2.10 (1.76)	2.32 (1.82)
	200 (T_6)	0.23 (1.11)	1.40 (1.55)	1.61 (1.62)	0.36 (1.16)	2.02 (1.74)	2.31 (1.82)	0.07 (1.03)	2.02 (1.74)	2.07 (1.75)
60:40	150 (T_1)	2.27 (1.81)	8.54 (3.09)	10.85 (3.44)	3.99 (2.23)	8.45 (3.07)	12.46 (3.67)	3.67 (2.16)	6.33 (2.71)	10.50 (3.39)
	160 (T_2)	2.61 (1.90)	7.47 (2.91)	10.30 (3.36)	5.56 (2.56)	8.13 (3.02)	13.89 (3.86)	3.49 (2.12)	6.12 (2.67)	10.08 (3.33)
	170 (T_3)	2.23 (1.80)	7.15 (2.85)	9.47 (3.24)	6.09 (2.66)	7.66 (2.94)	13.93 (3.87)	3.21 (2.05)	5.82 (2.61)	9.48 (3.24)
	180 (T_4)	1.80 (1.97)	5.63 (2.58)	7.43 (2.9)	3.63 (2.15)	5.89 (2.63)	9.62 (3.26)	3.02 (2.01)	5.36 (2.52)	8.79 (3.13)
	190 (T_5)	1.57 (1.60)	5.90 (2.63)	7.49 (2.91)	4.97 (2.44)	6.52 (2.74)	11.66 (3.56)	2.45 (1.86)	5.36 (2.52)	8.08 (3.01)
	200 (T_6)	1.21 (1.49)	5.50 (2.55)	6.81 (2.80)	4.35 (2.31)	5.35 (2.52)	9.82 (3.29)	1.84 (1.69)	5.42 (2.53)	7.42 (2.90)
50:50	150 (T_1)	5.43 (2.54)	14.92 (3.99)	20.50 (4.64)	7.54 (2.92)	16.48 (4.18)	24.13 (5.01)	6.78 (2.79)	15.48 (4.06)	22.51 (4.85)
	160 (T_2)	7.25 (2.87)	14.97 (4)	22.25 (4.82)	12.1 (3.62)	16.13 (4.13)	28.26 (5.41)	10.23 (3.35)	17.07 (4.25)	27.33 (5.32)
	170 (T_3)	6.78 (2.79)	14.17 (3.9)	21.09 (4.7)	10.42 (3.38)	15.23 (4.03)	25.67 (5.17)	11.83 (3.58)	13.56 (3.82)	25.49 (5.15)

Table: 8 Interaction effect of concentration with inlet temperature on recovery of fine, coarse and bulked powders (continued)

Concentration levels (Juice Solid : Carrier)	Inlet temperature (°C)	Recovery (%)								
		Cashew apple juice powder (C)			Pineapple juice powder (P)			Blended juice powder (B)		
		Fine	Coarse	Bulked	Fine	Coarse	Bulked	Fine	Coarse	Bulked
50:50	180 (T_4)	6.36 (2.71)	13.67 (3.8)	20.11 (4.60)	10.78 (3.4)	13.26 (3.78)	24.06 (5.01)	9.47 (3.24)	14.08 (3.88)	23.64 (4.96)
	190 (T_5)	5.91 (2.63)	11.32 (3.51)	17.22 (4.27)	11.82 (3.58)	10.97 (3.46)	23.01 (4.90)	9.55 (3.25)	11.43 (3.53)	21.05 (4.70)
	200 (T_6)	4.06 (2.25)	9.63 (3.26)	13.74 (3.84)	8.81 (3.13)	11.07 (3.48)	19.97 (4.58)	6.62 (2.76)	9.6 (3.26)	16.29 (4.16)
40:60	150 (T_1)	15.89 (4.11)	25.79 (5.18)	41.80 (6.54)	16.18 (4.14)	38.81 (6.31)	57.20 (7.63)	19.11 (4.49)	23.46 (4.95)	43.90 (6.70)
	160 (T_2)	23.77 (4.98)	31.25 (5.68)	56.29 (7.57)	29.68 (5.54)	41.09 (6.49)	72.29 (8.56)	26.26 (5.22)	33.38 (5.86)	60.82 (7.86)
	170 (T_3)	19.48 (4.53)	28.35 (5.42)	48.59 (7.04)	28.15 (5.4)	37.19 (6.18)	66.58 (8.22)	24.52 (5.05)	30.30 (5.60)	55.59 (7.52)
	180 (T_4)	14.96 (3.99)	26.28 (5.22)	41.88 (6.55)	21.79 (4.77)	37.71 (6.22)	60.05 (7.81)	19.41 (4.52)	27.48 (5.34)	48.50 (7.04)
	190 (T_5)	12.66 (3.70)	24.66 (5.07)	38.28 (6.27)	20.19 (4.60)	31.47 (5.70)	52.07 (7.29)	16.02 (4.13)	24.45 (5.05)	41.22 (6.50)
	200 (T_6)	8.73 (3.12)	22.82 (4.88)	31.86 (5.73)	14.22 (3.90)	29.49 (5.52)	44.05 (6.71)	14.06 (3.88)	18.86 (4.46)	33.55 (5.88)
CD (0.05)		0.3	0.26	0.27	0.37	0.29	0.37	0.31	0.32	0.32

The data in parenthesis is the square root transformed values. The concentration level 80:20 did not yield any powder

Table: 9 Interaction effect of carrier and concentration with inlet temperature on recovery of fine, coarse and bulked powders

Carrier	Concentration levels (Juice Solid : Carrier)	Inlet temperature (°C)	Recovery (%)								
			Cashew apple juice powder (C)			Pineapple juice powder (P)			Blended juice powder (B)		
			Fine	Coarse	Bulked	Fine	Coarse	Bulked	Fine	Coarse	Bulked
Maltodextrin (M)	70:30 (M_2)	150 (T_1)	0(1)	0(1)	0(1)	0(1)	0(1)	0(1)	0(1)	0(1)	0(1)
		160 (T_2)	0(1)	0(1)	0(1)	0(1)	0(1)	0(1)	0(1)	0(1)	0(1)
		170 (T_3)	0(1)	0(1)	0(1)	0(1)	0(1)	0(1)	0(1)	0(1)	0(1)
		180 (T_4)	0(1)	0(1)	0(1)	0(1)	0(1)	0(1)	0(1)	0(1)	0(1)
		190 (T_5)	0(1)	0(1)	0(1)	0(1)	0(1)	0(1)	0(1)	0(1)	0(1)
		200 (T_6)	0(1)	0(1)	0(1)	0(1)	0(1)	0(1)	0(1)	0(1)	0(1)
	60:40 (M_3)	150 (T_1)	0.32 (1.15)	5.48 (2.55)	5.80 (2.61)	1.90 (1.70)	5.04 (2.46)	7.05 (2.84)	0.38 (1.18)	4.35 (2.31)	6.27 (2.70)
		160 (T_2)	0.31 (1.14)	5.84 (2.62)	6.15 (2.67)	4.82 (2.41)	4.52 (2.35)	9.4 (3.24)	0.47 (1.21)	4.73 (2.39)	6.34 (2.71)
		170 (T_3)	0.2 (1.10)	4.74 (2.40)	4.96 (2.44)	5.37 (2.52)	4.20 (2.28)	9.69 (3.27)	0.36 (1.17)	5 (2.45)	6 (2.65)
		180 (T_4)	0 (1)	3.21 (2.05)	3.21 (2.05)	3.33 (2.08)	3.43 (2.11)	6.80 (2.79)	0.36 (1.17)	5.12 (2.47)	5.38 (2.53)
		190 (T_5)	0 (1)	3.55 (2.1)	3.55 (2.13)	4.22 (2.28)	3.97 (2.23)	8.42 (3.07)	0.23 (1.11)	5.27 (2.50)	4.97 (2.44)
		200 (T_6)	0 (1)	3.21 (2.05)	3.21 (2.05)	3.01 (2.00)	3.41 (2.10)	6.64 (2.76)	0.12 (1.06)	5.37 (2.52)	4.48 (2.34)

Table: 9 Interaction effect of carrier and concentration with inlet temperature on recovery of fine, coarse and bulked powders (continued)

Carrier	Concentration levels (Juice Solid : Carrier)	Inlet temperature (°C)	Recovery (%)								
			Cashew apple juice powder (C)			Pineapple juice powder (P)			Blended juice powder (B)		
			Fine	Coarse	Bulked	Fine	Coarse	Bulked	Fine	Coarse	Bulked
Maltodextrin (M)	50:50 (M_4)	150 (T_1)	2.32 (1.82)	11.69 (3.56)	14.03 (3.88)	5.02 (2.45)	15.11 (4.01)	20.16 (4.60)	4.17 (2.27)	5.41 (2.53)	19.30 (4.51)
		160 (T_2)	4.22 (2.28)	10.99 (3.46)	15.22 (4.03)	12.52 (3.68)	15.90 (4.11)	28.46 (5.43)	9.94 (3.31)	5.41 (2.53)	26.81 (5.27)
		170 (T_3)	4.11 (2.26)	10.27 (3.36)	14.41 (3.93)	10.75 (3.43)	13.97 (3.87)	24.73 (5.07)	11.73 (3.57)	5.55 (2.56)	25.06 (5.11)
		180 (T_4)	3.76 (2.18)	10.15 (3.34)	13.92 (3.86)	11.11 (3.48)	12.66 (3.70)	23.80 (4.98)	9.13 (3.18)	5.63 (2.57)	22.53 (4.85)
		190 (T_5)	3.33 (2.08)	7.83 (2.97)	11.17 (3.49)	12.10 (3.62)	9.18 (3.19)	21.55 (4.75)	9.49 (3.24)	5.74 (2.6)	20.69 (4.66)
		200 (T_6)	2.41 (1.85)	6.66 (2.77)	9.08 (3.18)	8.95 (3.15)	9.61 (3.26)	18.56 (4.42)	6.33 (2.71)	5.86 (2.62)	15.25 (4.03)
	40:60 (M_5)	150 (T_1)	11.50 (3.54)	22.42 (4.84)	33.98 (5.91)	7.23 (2.87)	48.64 (7.05)	55.91 (7.54)	9.39 (3.22)	5.89 (2.63)	36.05 (6.09)
		160 (T_2)	11.31 (3.51)	31.02 (5.66)	42.41 (6.59)	16.18 (4.15)	43.80 (6.70)	60.05 (7.81)	14.10 (3.89)	6.02 (2.65)	48.36 (7.03)
		170 (T_3)	10.46 (3.39)	27.71 (5.36)	38.21 (6.26)	16.51 (4.19)	40.88 (6.47)	57.43 (7.64)	13.47 (3.80)	6.02 (2.65)	42.54 (6.60)
		180 (T_4)	8.27 (3.04)	26.76 (5.27)	35.06 (6)	14.47 (3.93)	39.17 (6.34)	53.67 (7.39)	8.92 (3.16)	6.39 (2.72)	39.89 (6.40)
		190 (T_5)	5.95 (2.64)	25.70 (5.17)	31.79 (5.73)	14.06 (3.88)	32.45 (5.78)	46.54 (6.90)	9.04 (3.17)	6.58 (2.75)	33.30 (5.86)
		200 (T_6)	5.07 (2.46)	22.34 (4.83)	27.43 (5.33)	10.15 (3.34)	30.21 (5.59)	40.48 (6.4)	8.07 (3.01)	6.80 (2.79)	28.55 (5.44)

Table: 9 Interaction effect of carrier and concentration with inlet temperature on recovery of fine, coarse and bulked powders (continued)

Carrier	Concentration levels (Juice Solid : Carrier)	Inlet temperature (°C)	Recovery (%)								
			Cashew apple juice powder (C)			Pineapple juice powder (P)			Blended juice powder (B)		
			Fine	Coarse	Bulked	Fine	Coarse	Bulked	Fine	Coarse	Bulked
Resistant Dextrin (R)	70:30 (R_2)	150 (T_1)	1.35 (1.53)	3.38 (2.09)	4.74 (2.4)	2.92 (1.98)	4.88 (2.42)	7.83 (2.97)	0.73 (1.32)	8.78 (3.13)	6.01 (2.65)
		160 (T_2)	0.16 (1.08)	2.31 (1.82)	2.46 (1.86)	2.05 (1.74)	6.10 (2.66)	8.16 (3.03)	1.03 (1.43)	10.44 (3.38)	6.47 (2.73)
		170 (T_3)	1 (1.41)	3.03 (2)	4.06 (2.25)	1.69 (1.64)	6.00 (2.65)	7.72 (2.95)	0.57 (1.25)	11.10 (3.48)	6.0 (2.65)
		180 (T_4)	0.64 (1.28)	1.99 (1.73)	2.71 (1.93)	1.56 (1.60)	3.82 (2.20)	5.46 (2.54)	0.57 (1.25)	11.78 (3.58)	6.13 (2.67)
		190 (T_5)	0.48 (1.22)	1.83 (1.68)	2.29 (1.81)	1.44 (1.56)	3.60 (2.15)	5.056 (2.46)	0.57 (1.25)	13.23 (3.77)	6.00 (2.65)
		200 (T_6)	0.48 (1.22)	3.39 (2.1)	3.98 (2.23)	0.78 (1.34)	5.13 (2.48)	5.96 (2.64)	0.14 (1.07)	13.28 (3.77)	5.28 (2.51)
	60:40 (R_3)	150 (T_1)	5.09 (2.47)	12.19 (3.63)	17.29 (4.28)	6.63 (2.76)	12.61 (3.69)	19.25 (4.5)	8.90 (3.15)	13.90 (3.86)	15.70 (4.09)
		160 (T_2)	6.06 (2.66)	9.28 (3.2)	15.38 (4.05)	6.36 (2.71)	12.64 (3.69)	19.07 (4.48)	8.14 (3.02)	14.91 (3.99)	14.59 (3.95)
		170 (T_3)	5.24 (2.50)	9.97 (3.31)	15.24 (4.03)	6.84 (2.8)	11.98 (3.60)	18.90 (4.46)	7.6 (2.93)	14.94 (4)	13.67 (3.83)
		180 (T_4)	4.51 (2.35)	8.59 (3.10)	13.10 (3.76)	3.94 (2.22)	8.88 (3.14)	12.87 (3.73)	7.07 (2.84)	16.03 (4.13)	12.93 (3.73)
		190 (T_5)	3.88 (2.21)	8.73 (3.12)	12.64 (3.69)	5.78 (2.6)	9.60 (3.26)	15.40 (4.05)	5.79 (2.61)	16.86 (4.23)	11.85 (3.59)
		200 (T_6)	2.91 (1.98)	8.28 (3.05)	11.50 (3.54)	5.89 (2.62)	7.65 (2.94)	13.55 (3.82)	4.36 (2.32)	17.30 (4.28)	10.99 (3.46)

Table: 9 Interaction effect of carrier and concentration with inlet temperature on recovery of fine, coarse and bulked powders (continued)

Carrier	Concentration levels (Juice Solid : Carrier)	Inlet temp (°C)	Recovery (%)								
			Cashew apple juice powder (C)			Pineapple juice powder (P)			Blended juice powder (B)		
			Fine	Coarse	Bulked	Fine	Coarse	Bulked	Fine	Coarse	Bulked
Resistant Dextrin (R)	50:50 (R_4)	150 (T_1)	9.54 (3.25)	18.52 (4.42)	28.12 (5.40)	10.51 (3.39)	17.89 (4.35)	28.43 (5.43)	9.93 (3.31)	17.34 (4.28)	25.95 (5.19)
		160 (T_2)	10.99 (3.46)	19.50 (4.53)	30.54 (5.62)	11.69 (3.56)	16.36 (4.17)	28.07 (5.39)	10.53 (3.40)	20.45 (4.63)	27.86 (5.37)
		170 (T_3)	10 (3.32)	18.65 (4.43)	28.98 (5.48)	10.07 (3.33)	16.54 (4.19)	26.63 (5.26)	11.94 (3.6)	20.50 (4.64)	25.92 (5.19)
		180 (T_4)	9.52 (3)	17.65 (4.32)	27.39 (5.33)	10.43 (3.38)	13.86 (3.86)	24.31 (5.03)	9.82 (3.29)	23.85 (4.99)	24.77 (5.07)
		190 (T_5)	9.08 (3.18)	15.39 (4.05)	24.48 (5.05)	11.52 (3.54)	12.92 (3.73)	24.53 (5.05)	9.61 (3.26)	24.24 (5.02)	21.41 (4.73)
		200 (T_6)	6.05 (2.66)	13.09 (3.75)	19.29 (4.5)	8.67 (3.11)	12.63 (3.70)	21.42 (4.74)	6.92 (2.81)	25.06 (5.11)	17.36 (4.29)
	40:60 (R_5)	150 (T_1)	20.94 (4.68)	29.39 (5.51)	50.41 (7.17)	28.37 (5.42)	30.06 (5.57)	58.50 (7.71)	32.00 (5.75)	26.61 (5.26)	52.50 (7.32)
		160 (T_2)	40.55 (6.45)	31.45 (5.7)	72.09 (8.55)	47.06 (6.93)	38.46 (6.28)	85.62 (9.31)	42.02 (6.56)	28.99 (5.48)	74.70 (8.70)
		170 (T_3)	31.13 (5.67)	29.01 (5.48)	60.17 (7.82)	42.73 (6.61)	33.65 (5.89)	76.40 (8.80)	38.69 (6.38)	30.93 (5.65)	70.35 (8.45)
		180 (T_4)	23.46 (4.95)	25.81 (5.18)	49.28 (7.09)	30.50 (5.61)	36.27 (6.11)	66.80 (8.23)	33.64 (5.89)	31.65 (5.71)	57.93 (7.68)
		190 (T_5)	21.62 (4.76)	23.65 (4.97)	45.35 (6.81)	27.34 (5.32)	30.52 (5.62)	57.89 (7.67)	24.84 (5.08)	32.59 (5.80)	49.96 (7.14)
		200 (T_6)	13.24 (3.77)	23.31 (4.93)	36.6 (6.13)	18.92 (4.46)	28.76 (5.46)	47.76 (6.98)	21.60 (4.75)	34.19 (5.93)	38.94 (6.32)
CD (0.05)			0.42	NS	NS	NS	0.42	NS	NS	NS	NS

The data in parenthesis is the square root transformed values. The concentration level 80:20 did not yield any powder

4.1.2.4.4 Interaction Effect of Carrier and Concentration with Inlet Temperature on Recovery of Fine, Coarse and Bulked Powders

All treatment combinations with 80:20 juice solid to carrier ratio and maltodextrin combinations with 70:30 ratio failed to produce powders in all fruit juices. The interaction of carrier and concentration with inlet temperature was not alike in all juices.

Significant interaction effect of carrier, concentration and inlet temperature was observed in fine cashew apple juice powder recovery alone as depicted in table 9. The highest fine powder recovery (40.55 per cent) was obtained with the combination of resistant dextrin at a concentration of 40: 60 juice solid to carrier ratio dried at 160°C (Table 9).

Significant interaction effect of carrier, concentration and inlet temperature was observed in coarse pineapple juice powder obtained from chamber. Highest coarse powder recovery was noted in the treatment combination involving juice solid to maltodextrin carrier in 40:60 ratio dried at 150°C and 160°C. These combinations transformed 48.64 and 43.8 per cent of total solid to coarse powder which remained in the chamber as depicted in table 9.

Interaction effect of carrier concentration and inlet temperature were non-significant in fine coarse and bulked powders of blended juice.

As a combination, carrier resistant dextrin, juice solid to carrier ratio of 40:60 and 160°C inlet temperature resulted in high recovery of fine, coarse and bulked fruit powders. This combination recovered 72.09, 85.62 and 74.70 per cent of total solid content from juice carrier mix of cashew apple, pineapple and their equal blend respectively of which 40.55, 47.06 and 42.02 per cent were from cyclone.

4.1.3 Feed Rate

Feed rate is one of the most important parameters in the spray drying process as it influence the atomization of particles inside the drier. As the feed rate increases more liquid is fed into the system which lead to less atomization causing incorrect drying. But very lower feed rate causes outlet temperature to rise and over dry the product. Hence an optimum feed rate is needed for better efficient drying which is also dependent on other parameters. Parameters like carriers, concentration and inlet temperature may influence the feed rate. In the present investigation feed rate was varied to maintain the outlet temperature at 88 ± 2°C and these rates were recorded and analysed.

4.1.3.1 Effect of Carrier on Feed Rate

Different carriers did not influence the feed rate applied for drying of cashew apple and pineapple juice whereas resistant dextrin recorded higher feed rate (6.11 g/min) in comparison to maltodextrin (5.74 g/min) in production of blended juice powder (Table 10).

4.1.3.2 Effect of Concentration on Feed Rate

As the ratio of carrier content of the cashew apple juice mixture increased from 20 to 60, the feed rate increased from 4.9 g/min to 6.95g/ min as depicted in table 11. As carrier concentration ratio increased from 50 to 60 in the pineapple juice mixture feed rate enhanced from 7.62 g/min to 7.86g/min. In blended juice feed rate was increased from 5.23 to 7.28 when ratio of carrier concentration in the juice carrier mixture was enhanced from 30 to 60 (Table 11).

4.1.3.3 Effect of Inlet Temperature on Feed Rate

As inlet temperature of drier increased from 150°C to 200 °C, feed rate increased from 3.43 to 8.19 g/min in case of cashew apple juice, 3.69 to 9.36 g/min in case of pineapple juice and 3.7 to 8.21g/min with blended juice (Table 12).

4.1.3.4 Interaction Effects on Feed rate

Interaction effect of carrier with concentration, carrier with inlet temperature and carrier, concentration with inlet temperature were non significant in all juices (Table 13, Table 14, Table 16).

4.1.3.4.1 Interaction Effect of Concentration with Inlet Temperature on Feed Rate

Effect of carrier concentration levels in increasing feed rate was influenced by inlet temperatures and vice versa as depicted in table 15. At higher carrier concentration levels of 50: 50 and 40:60 the feed rate required were at par with 9.92 and 10.738 g/min respectively at highest drying temperature of 200°C. Further reduction in the carrier particles reduced the required feed rate even at same inlet temperature. Maximum feed rate required was 10.74g/min for juice solid carrier ratio 40:60 dried at 200°C which was on par with juice solid ratio of 50:50 dried at 200°C (9.92 g/min) as depicted in table 15.

Interaction effect of concentration with inlet temperature significantly influenced feed rate in case of pineapple juice powders. Treatment combinations involving higher carrier content when dried at higher temperature required highest feed rates since the concentration of 40:60 dried at 200°C required highest feed rate of 11.66g/min and the concentration of 70:30 dried at 150°C required very lower feed rate of 3.22g/min. The feed rates of 50:50 and 60:40 concentration at 200°C were 11.73 g/min and 11.66g/min respectively which were at par. Similarly, the feed rate of 80:20 and 70:30 concentration at 200°C were 6.24 g/min and 7.6g/min respectively which were also at par (Table 15). Interaction effect of concentration and inlet temperature also altered feed rate in production of powder from blended juice. Highest concentration of 40:60 dried at a temperature of 200°C required highest feed rate of 10.65g/min (Table 15).

Table: 10 Effect of carrier on feed rate

Carrier	Feed rate (g/min)		
	Cashew apple juice	Pineapple juice	Blended juice
Maltodextrin (M)	5.6	6.51	5.74
Resistant dextrin (R)	5.58	6.41	6.11
CD (0.05)	NS	NS	0.22

Table: 11 Effect of concentration on feed rate

Concentration levels (Juice solid: carrier)	Feed rate (g/min)		
	Cashew apple juice	Pineapple juice	Blended juice
80:20			
70:30	4.90	5.55	5.23
60:40	5.50	6.30	5.80
50:50	6.40	7.62	6.76
40:60	6.95	7.86	7.28
CD (0.05)	0.36	0.37	0.34

Table: 12 Effect of inlet temperature on feed rate

Inlet temperature	Feed rate (g/min)		
	Cashew apple juice	Pineapple juice	Blended juice
150 (T_1)	3.43	3.69	3.70
160 (T_2)	4.28	4.94	4.78
170(T_3)	4.85	5.67	5.24
180(T_4)	6.22	7.53	6.53
190(T_5)	6.56	7.55	7.11
200 (T_6)	8.19	9.36	8.21
CD (0.05)	0.39	0.41	0.37

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Table: 13 Interaction effect of carrier with concentration on feed rate

Carrier	Concentration levels (Juice Solid: Carrier	Feed rate (g/min)		
		Cashew apple juice	Pineapple juice	Blended juice
Maltodextrin (M)	80:20 (M_1)	4.22	4.98	4.55
	70:30 (M_2)	4.92	5.58	5.12
	60:40 (M_3)	5.52	6.33	5.52
	50:50 (M_4)	6.38	7.81	6.52
	40:60 (M_5)	6.94	7.83	7.00
Resistant Dextrin (R)	80:20 (R_1)	4.16	4.93	4.56
	70:30 (R_2)	4.88	5.51	5.33
	60:40 (R_3)	5.48	6.27	6.08
	50:50 (R_4)	6.42	7.43	7.01
	40:60 (R_5)	6.96	7.89	7.57
CD (0.05)		NS	NS	NS

Table: 14 Interaction effect of carrier with inlet temperature on feed rate

Carrier	Inlet temperature (°C)	Feed rate (g/min)		
		Cashew apple juice	Pineapple juice	Blended juice
Maltodextrin (M)	150 (T_1)	3.44	3.76	3.56
	160 (T_2)	4.31	4.91	4.56
	170 (T_3)	4.84	5.56	4.98
	180 (T_4)	6.26	7.77	6.58
	190 (T_5)	6.53	7.49	6.76
	200 (T_6)	8.20	9.54	8.03
Resistant Dextrin (R)	150 (T_1)	3.43	3.62	3.84
	160 (T_2)	4.26	4.98	5.00
	170 (T_3)	4.86	5.77	5.51
	180 (T_4)	6.18	7.28	6.48
	190 (T_5)	6.59	7.60	7.45
	200 (T_6)	8.17	9.18	8.39
CD (0.05)		NS	NS	NS

100

Table: 15 Interaction effect of concentration with inlet temperature on feed rate

Concentration (Juice Solid : Carrier)	Inlet temperature (°C)	Feed rate (g/min)		
		Cashew apple juice	Pineapple juice	Blended juice
80:20	150 (T_1)	3.07	3.22	3.18
	160 (T_2)	3.42	4.08	4.05
	170 (T_3)	3.86	4.63	3.95
	180 (T_4)	4.55	5.70	4.91
	190 (T_5)	4.88	5.85	5.49
	200 (T_6)	5.36	6.24	5.78
70:30	150 (T_1)	3.30	3.28	3.37
	160 (T_2)	3.98	4.83	4.68
	170 (T_3)	4.32	5.07	4.74
	180 (T_4)	5.44	6.31	5.56
	190 (T_5)	5.89	6.54	6.53
	200 (T_6)	6.48	7.26	6.48
60:40	150 (T_1)	3.34	3.59	3.61
	160 (T_2)	4.19	4.72	4.64
	170 (T_3)	4.89	5.12	5.08
	180 (T_4)	5.82	7.14	6.15
	190 (T_5)	6.33	7.31	6.62
	200 (T_6)	8.44	9.92	8.70
50:50	150 (T_1)	3.56	3.75	3.96
	160 (T_2)	4.87	5.61	4.94
	170 (T_3)	5.32	6.53	6.04
	180 (T_4)	7.33	9.15	8.13
	190 (T_5)	7.41	8.96	8.08
	200 (T_6)	9.92	11.73	9.44

Table: 15 Interaction effect of concentration with inlet temperature on feed rate (continued)

Concentration levels (Juice Solid: Carrier)	Inlet temperature (°C)	Feed rate (g/min)		
		Cashew apple juice	Pineapple juice	Blended juice
40:60	150 (T_1)	3.91	4.62	4.37
	160 (T_2)	4.96	5.47	5.58
	170 (T_3)	5.85	7.00	6.41
	180 (T_4)	7.98	9.33	7.89
	190 (T_5)	8.29	9.07	8.81
	200 (T_6)	10.74	11.66	10.65
CD(0.05)		0.88	0.91	0.83

Table: 16 Interaction effect of carrier and concentration with inlet temperature on feed rate

Carrier	Concentration levels (Juice Solid : Carrier)	Inlet temperature (°C)	Feed rate (g/min)		
			Cashew	Pineapple	Blend
Maltodextrin (M)	80:20 (M_1)	150 (T_1)	3	3.26	3.12
		160 (T_2)	3.45	4.15	3.99
		170 (T_3)	3.90	4.69	3.95
		180 (T_4)	4.6	5.73	5.023
		190 (T_5)	4.9	5.74	5.377
		200 (T_6)	5.46	6.32	5.87
	70:30 (M_2)	150 (T_1)	3.1	3.26	3.24
		160 (T_2)	3.94	4.69	4.49
		170 (T_3)	4.44	4.87	4.56
		180 (T_4)	5.47	6.42	5.88
		190 (T_5)	5.84	6.75	6.38
		200 (T_6)	6.75	7.51	6.16
	60:40 (M_3)	150 (T_1)	3.39	3.7	3.45
		160 (T_2)	4.34	4.64	4.34
		170 (T_3)	4.79	5.11	4.72
		180 (T_4)	6.00	7.24	6.21
		190 (T_5)	6.32	7.01	6.17
		200 (T_6)	8.26	10.27	8.21
	50:50 (M_4)	150 (T_1)	3.6	3.8	3.8
		160 (T_2)	4.7	5.5	4.8
		170 (T_3)	5.3	6.4	5.6
		180 (T_4)	7.3	10.0	7.9
		190 (T_5)	7.4	8.9	7.6
		200 (T_6)	10.0	12.4	9.4

Table: 16 Interaction effect of concentration with inlet temperature on feed rate (continued)

Carrier	Concentration levels (Juice Solid : Carrier)	Inlet temperature (°C)	Feed rate (g/min)		
			Cashew	Pineapple	Blend
Maltodextrin (M)	40:60 (M_5)	150 (T_1)	4.083	4.8	4.21
		160 (T_2)	5.09	5.61	5.183
		170 (T_3)	5.73	6.8	6.043
		180 (T_4)	7.963	9.47	7.85
		190 (T_5)	8.207	9.07	8.253
		200 (T_6)	10.577	11.21	10.467
Resistant Dextrin (R)	80:20 (R_1)	150 (T_1)	3.133	3.18	3.233
		160 (T_2)	3.39	4.01	4.1
		170 (T_3)	3.807	4.57	3.95
		180 (T_4)	4.49	5.67	4.8
		190 (T_5)	4.867	5.97	5.6
		200 (T_6)	5.257	6.15	5.7
	70:30 (R_2)	150 (T_1)	3.49	3.3	3.5
		160 (T_2)	4.02	4.97	4.867
		170 (T_3)	4.197	5.27	4.92
		180 (T_4)	5.403	6.2	5.233
		190 (T_5)	5.933	6.33	6.667
		200 (T_6)	6.207	7.01	6.8
	60:40 (R_3)	150 (T_1)	3.283	3.48	3.767
		160 (T_2)	4.033	4.8	4.933
		170 (T_3)	5	5.13	5.433
		180 (T_4)	5.637	7.04	6.1
		190 (T_5)	6.333	7.6	7.067
		200 (T_6)	8.613	9.57	9.2

Table: 16 Interaction effect of concentration with inlet temperature on feed rate (continued)

Carrier	Concentration levels (Juice Solid : Carrier)	Inlet temperature (°C)	Feed rate (g/min)		
			Cashew	Pineapple	Blend
Resistant Dextrin (R)	50:50 (R_4)	150 (T_1)	3.50	3.70	4.17
		160 (T_2)	5.03	5.77	5.13
		170 (T_3)	5.32	6.70	6.47
		180 (T_4)	7.37	8.30	8.33
		190 (T_5)	7.43	9.03	8.53
		200 (T_6)	9.87	11.07	9.43
	40:60 (R_5)	150 (T_1)	3.73	4.43	4.53
		160 (T_2)	4.83	5.33	5.97
		170 (T_3)	5.97	7.20	6.77
		180 (T_4)	7.99	9.20	7.93
		190 (T_5)	8.37	9.07	9.37
		200 (T_6)	10.90	12.10	10.83
CD (0.05)			NS	NS	NS

4.1.4 **Selection of Powders from Part 1**

Hence, based on higher recovery percentages ten treatment combinations from each juice (five from each carrier) at juice solid to carrier ratio of 40:60 dried at temperature levels of 150°C, 160°C, 170°C, 180°C, and 190 °C were selected for cashew apple pineapple and blended juices independently. The selected treatment combinations are given in table 17 and presented in six plates (Plate 11 to Plate 16).

4.2 QUALITY EVALUATION OF MICROENCAPSULATED FRUIT POWDERS

The thirty treatment combinations from part one of the investigation selected as ten treatments from each juice (five from each carrier within a juice) were subjected to quality analysis juice wise ie. cashew apple, pineapple and blended juice independently. The thrice replicated data were analyzed in two factor completely randomized design with carrier and inlet temperature as factors and the result is presented in this section. This section has seven sub sections viz. physical parameters, chemical parameters, sensory parameters, selection of treatment combinations and study of three physical parameters viz. sorption behavior, glass transition temperature and microstructure on these selected powders.

4.2.1 Physical Parameters

4.2.1.1 Moisture Content

4.2.1.1.1 Effect of Carrier on Moisture

The powder produced from cashew apple juice by using resistant dextrin as carrier had lower moisture content (4.28 per cent) than maltodextrin (4.808). In pineapple and blended juice, resistant dextrin produced powders with significantly lower moisture content of 4.76 and 4.48 per cent as depicted in table 18.

Table 17. The selected treatments from Part-1

Sl No	Carrier	Concentration	Inlet Temperature (°C	Symbols
Cashew apple juice powders (C)				
1	Maltodextrin (M)	40:60	150°C (T_1)	CM_5T_1
2			160°C (T_2)	CM_5T_2
3			170°C (T_3)	CM_5T_3
4			180°C (T_4)	CM_5T_4
5			190°C (T_5)	CM_5T_5
6	Resistant Dextrin (R)		150°C (T_1)	CR_5T_1
7			160°C (T_2)	CR_5T_2
8			170°C (T_3)	CR_5T_3
9			180°C (T_4)	CR_5T_4
10			190°C (T_5)	CR_5T_5
Pineapple juice powders (P)				
1	Maltodextrin (M)	40:60	150°C (T_1)	PM_5T_1
2			160°C (T_2)	PM_5T_2
3			170°C (T_3)	PM_5T_3
4			180°C (T_4)	PM_5T_4
5			190°C (T_5)	PM_5T_5
6	Resistant Dextrin (R)		150°C (T_1)	PR_5T_1
7			160°C (T_2)	PR_5T_2
8			170°C (T_3)	PR_5T_3
9			180°C (T_4)	PR_5T_4
10			190°C (T_5)	PR_5T_5
Blended juice powders (B)				
1	Maltodextrin (M)	40:60	150°C (T_1)	BM_5T_1
2			160°C (T_2)	BM_5T_2
3			170°C (T_3)	BM_5T_3
4			180°C (T_4)	BM_5T_4
5			190°C (T_5)	BM_5T_5
6	Resistant Dextrin (R)		150°C (T_1)	BR_5T_1
7			160°C (T_2)	BR_5T_2
8			170°C (T_3)	BR_5T_3
9			180°C (T_4)	BR_5T_4
10			190°C (T_5)	BR_5T_5

Pure Maltodextrin

CM_5T_1

CM_5T_2

CM_5T_3

CM_5T_4

CM_5T_5

Plate 11: Cashew apple juice powders formulated with maltodextrin

C- Cashew apple juice, M_5 – Maltodextrin@40:60 (Juice: Carrier) T_1-150°C, T_2- 160°C. T_3- 170°C. T_4- 180°C, T_5- 190°C

Pure Resistant Dextrin

CR_5T_1

CR_5T_2

CR_5T_3

CR_5T_4

CR_5T_5

Plate 12: Cashew apple juice powders formulated with Resistant Dextrin

C- Cashew apple juice, R_5 -Resistant dextrin@40:60 (Juice: Carrier), T_1-150°C , T_2- 160°C. T_3- 170°C T_4- 180°C, T_5- 190°C

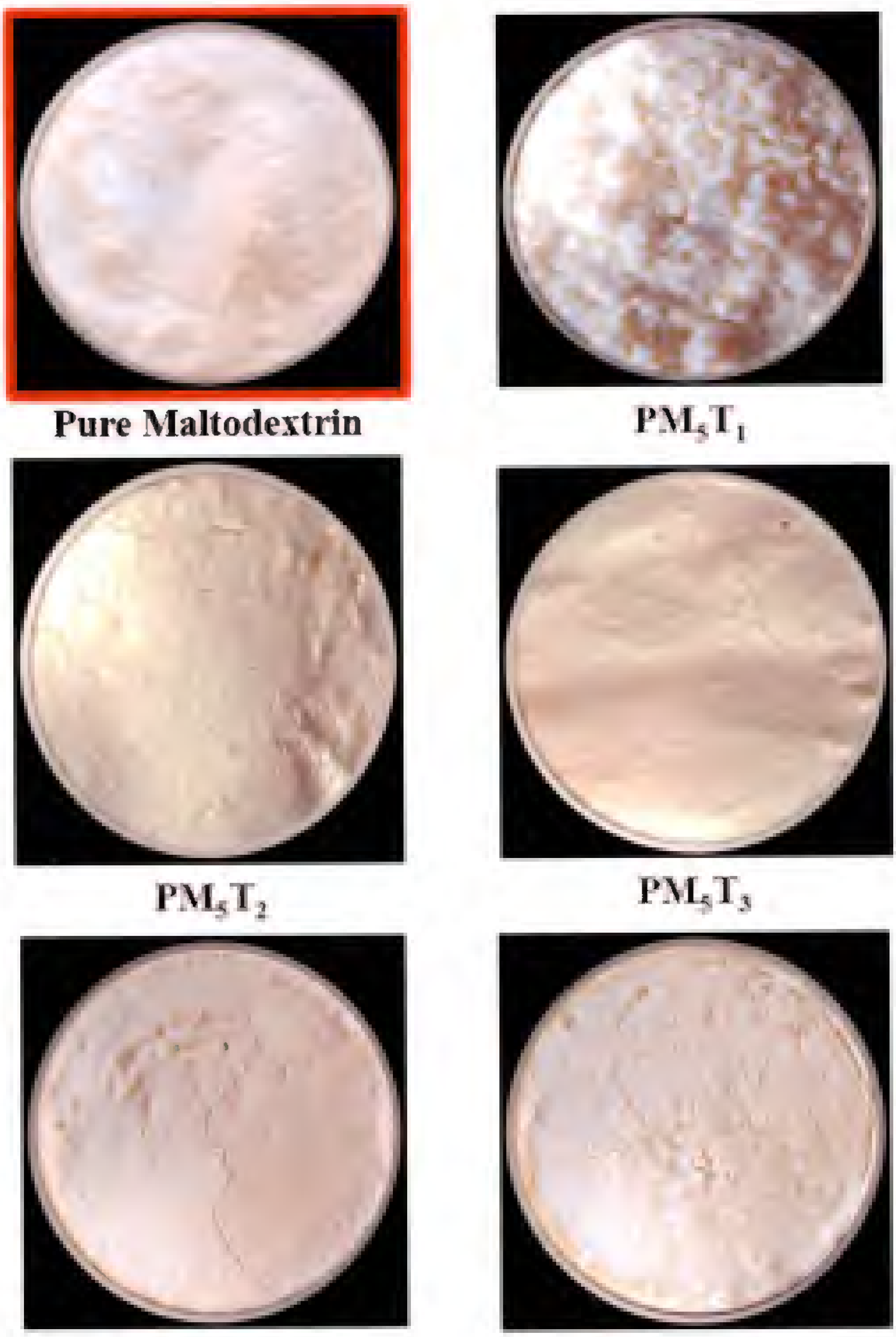

Plate 13: Pineapple juice powders formulated with maltodextrin

P- Pineapple juice, M_5 – Maltodextrin@40:60 (Juice: Carrier) T_1-150°C, T_2- 160°C. T_3- 170°C. T_4- 180°C, T_5- 190°C

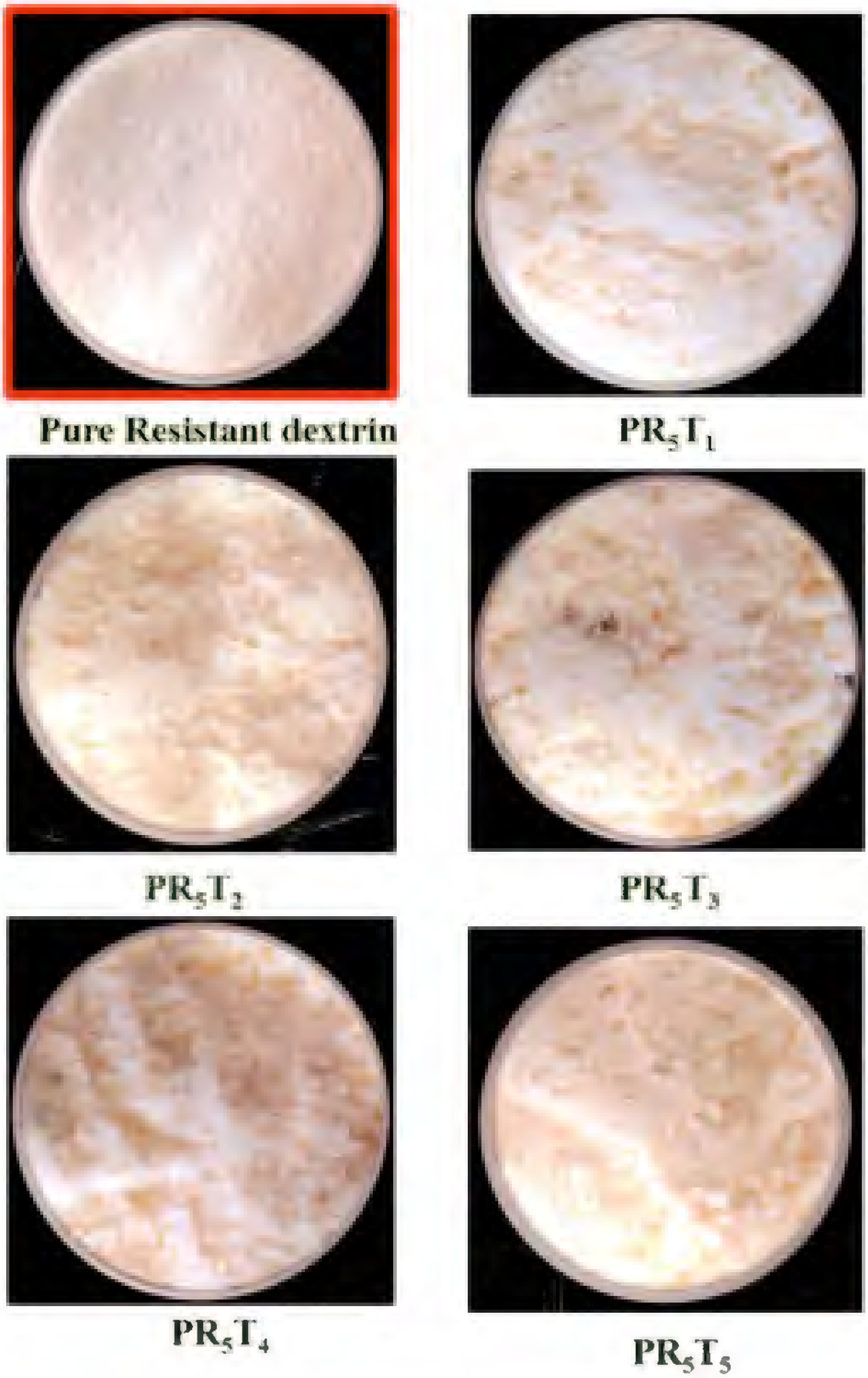

Plate 14: Pineapple juice powders formulated with resistant dextrin

P- Pineapple juice, R_5 -Resistant dextrin@40:60 (Juice: Carrier), T_1-150°C, T_2- 160°C. T_3- 170°C. T_4- 180°C, T_5- 190°C

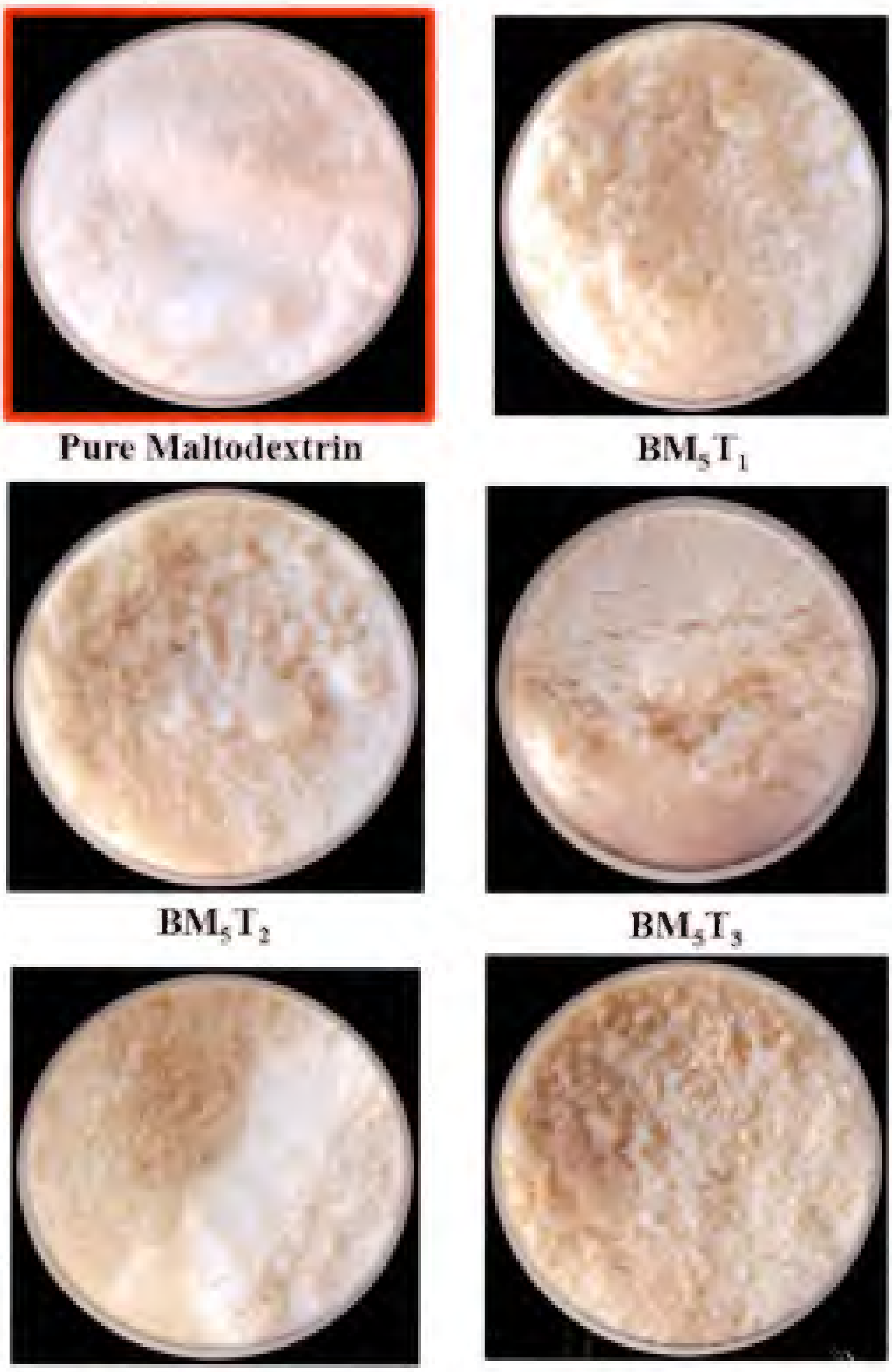

Plate 15: Blended juice powders formulated with maltodextrin

B-Blended juice, M_5 – Maltodextrin@40:60 (Juice: Carrier), T_1-150°C, T_2- 160°C. T_3- 170°C. T_4- 180°C T_5- 190°C

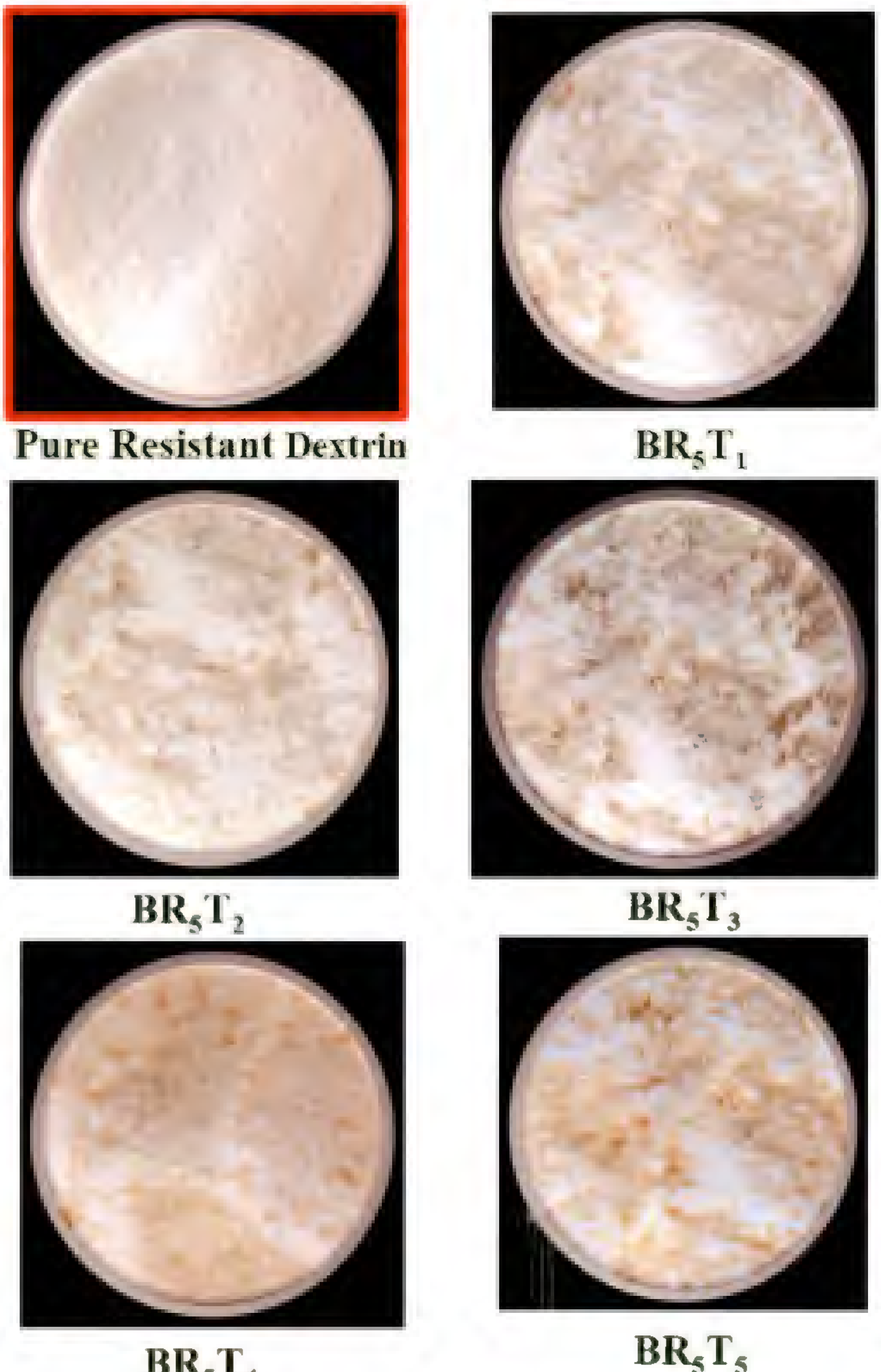

Plate 16: Blended juice powders formulated with resistant dextrin

B- Blended juice, R_5 -Resistant dextrin@40:60 (Juice: Carrier), T_1-150°C, T_2- 160°C . T_3- 170°C. T_4- 180°C, T_5- 190°C

Table:18 Effect of carrier on moisture

Carrier	Moisture (%)		
	Cashew apple juice powder	Pineapple juice powder	Blended juice powder
Maltodextrin (M)	4.81	5.58	5.13
Resistant dextrin (R)	4.28	4.76	4.48
CD(0.05)	0.28	0.42	0.45

Table: 19 Effect of inlet temperature on moisture

Inlet temperature	Moisture (%)		
	Cashew apple juice powder	Pineapple juice powder	Blended juice powder
150 (T_1)	6.11	6.26	5.77
160 (T_2)	4.61	5.21	4.99
170(T_3)	4.24	4.88	5.05
180(T_4)	4.38	5.39	4.32
190(T_5)	3.37	4.12	3.90
CD (0.05)	0.44	0.66	0.72

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Table: 20 Effect of interaction of carrier with inlet temperature on moisture

Carrier	Inlet temperature (°C)	Moisture (%)		
		C	P	B
Maltodextrin (M)	150 (T_1)	6.23	6.67	6.28
	160 (T_2)	4.79	5.83	5.34
	170 (T_3)	4.52	5.48	5.25
	180 (T_4)	4.64	5.36	4.98
	190 (T_5)	3.86	4.58	3.80
Resistant Dextrin (R)	150 (T_1)	5.99	5.85	5.26
	160 (T_2)	4.43	4.59	4.64
	170 (T_3)	3.97	4.28	4.86
	180 (T_4)	4.13	5.42	3.66
	190 (T_5)	2.88	3.67	4.00
CD(0.05)		NS	NS	NS

C- Cashew apple juice powder, P – Pineapple juice powder, B – Blended juice powder

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4.2.1.1.2 Effect of Inlet Temperature on Moisture

Drying at a temperature of 190°C caused significant moisture reduction in powders than all other temperatures. The moisture content at this temperature was 3. 37 against 6.11 per cent recorded by the lowest temperature under study (150°C). The temperature range between 160°C to 180 °C did not significantly vary the moisture content of fruit powder (Table 19).

The moisture content of powders produced at temperature from 150°C to 190°C ranged from 6.26 to 4.12 per cent and exhibited significant variation. However, the temperature range of 160 to 180°C could not produce significant difference in moisture content of powders as depicted in table 19.

As the temperature of drying increased from 150°C to 190°C, the moisture content of powders decreased from 5.77 to 3.90 per cent. The higher temperature levels of 180°C and 190°C were equally effective in reducing the moisture content (Table 19).

4.2.1.1.3 Interaction Effects on Moisture

Interactive effect on carriers and inlet temperature were non-significant in moisture content of all the three fruit juices under study (Table 20).

4.2.1.2 Bulk Density

4.2.1.2.1 Effect of Carrier on Bulk Density

Instant juice powder of cashew apple produced by adding maltodextrin as carrier yielded powder with higher bulk density (0.54) than maltodextrin (0.49) as depicted in table 21. Both carriers did not exhibit any significant influence in bulk density of pineapple juice powders. In blended juice powders also maltodextrin produced powder particles with higher bulk density (0.556) than resistant dextrin (0.498).

Table:21 Effect of carrier on bulk density, particle density and volume occupied by particles

Carrier	Bulk density			Particle density			Volume occupied by particles (%)		
	C	P	B	C	P	B	C	P	B
Maltodextrin (M)	0.54	0.60	0.56	1.37	1.42	1.40	39.82	41.98	39.66
Resistant dextrin (R)	0.49	0.56	0.50	1.35	1.46	1.41	36.17	38.52	35.29
CD (0.05)	0.03	NS	0.04	NS	NS	NS	1.58	1.37	1.35

C- Cashew apple juice powder, P – Pineapple juice powder, B – Blended juice powder.

Table: 22 Effect of inlet temperature on bulk density, particle density and volume occupied by particles

Inlet temperature (°C)	Bulk density			Particle density			Volume occupied by particles (%)		
	C	P	B	C	P	B	C	P	B
150 (T_1)	0.59	0.64	0.60	1.39	1.53	1.54	42.60	41.98	38.63
160 (T_2)	0.55	0.60	0.56	1.37	1.45	1.46	40.02	41.71	38.37
170 (T_3)	0.51	0.59	0.53	1.36	1.46	1.37	37.49	40.38	38.91
180 (T_4)	0.48	0.56	0.49	1.36	1.44	1.35	35.02	39.21	36.17
190 (T_5)	0.46	0.51	0.46	1.31	1.33	1.31	34.86	37.97	35.29
CD (0.05)	0.05	0.08	0.07	NS	NS	0.16	2.50	2.16	2.13

C- Cashew apple juice powder, P – Pineapple juice powder, B – Blended juice powder.

Table: 23 Effect of interaction of carrier with inlet temperature on bulk density, particle density and volume occupied by particles

Carrier	Inlet temperature (°C)	Bulk density			Particle density			Volume occupied by particles (%)		
		C	P	B	C	P	B	C	P	B
Maltodextrin (M)	150 (T_1)	0.62	0.66	0.64	1.39	1.32	1.55	33.82	36.16	40.77
	160 (T_2)	0.58	0.62	0.60	1.37	1.34	1.44	34.00	37.32	41.67
	170 (T_3)	0.55	0.60	0.57	1.35	1.39	1.36	34.67	38.26	41.79
	180 (T_4)	0.50	0.57	0.50	1.37	1.42	1.33	35.90	39.75	37.23
	190 (T_5)	0.48	0.53	0.48	1.33	1.43	1.30	36.04	39.79	36.85
Resistant Dextrin (R)	150 (T_1)	0.57	0.62	0.56	1.39	1.48	1.53	37.83	41.11	36.50
	160 (T_2)	0.51	0.59	0.52	1.27	1.48	1.47	40.31	41.11	35.08
	170 (T_3)	0.48	0.57	0.50	1.34	1.50	1.38	40.56	42.50	36.04
	180 (T_4)	0.45	0.55	0.48	1.40	1.52	1.37	42.20	42.86	35.11
	190 (T_5)	0.43	0.48	0.44	1.36	1.54	1.31	44.65	43.66	33.73
CD (0.05)		NS	NS	NS	NS	NS	NS	NS	NS	NS

C- Cashew apple juice powder, P – Pineapple juice powder, B – Blended juice powder.

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4.2.1.2.2 Effect of Inlet Temperature on Bulk Density

Effect of inlet temperature on bulk density of juice powders is presented in table 21. Higher temperature decreased bulk density of cashew apple juice powders. Drying at temperature of 150 and 160°C produced powder with higher bulk density of 0.593 and 0.547 g/cm^3 respectively. The higher temperature of 180 and 190°C produced powders with similar bulk density of 0.475 and 0.455 g/cm^3 respectively (Table 22).

Drying temperature of 150 to 170°C were at par in producing pineapple juice powders with higher bulk density. Bulk density at 150,160°C and 170°Cwere 0.64, 0.60 and 0.59 g/cm^3 respectively. The higher temperature range of 180 and 190°C were also at par to produce powders with lower bulk densities of 0.56 and 0.51 respectively as shown in table 22.

Bulk density of blended juice powders increased as the inlet temperature is reduced from190 to 150°C. Bulk densities observed at 150 and 160°C were 0.60 and 0.56 respectively. The higher temperature range of 180 and 190°C produced powder with bulk densities of 0.49 g/cm^3 and 0.46g/cm^3 (Table 22).

4.2.1.2.3 Interaction Effects on Bulk Density

Interactive effect of carriers and inlet temperature on bulk density of powder were non- significant in all three fruit juices under study (Table 23).

4.2.1.3 Particle Density

4.2.1.3.1 Effect of Carrier on Particle Density

Different carriers did not significantly influence the particle density of three fruit juices under study (Table 21).

4.2.1.3.2 Effect of Inlet Temperature on Particle Density

Inlet temperature did not influence the particle density in cashew apple and pineapple juice powders whereas the lower inlet temperatures of 150 to 160°C produced blended juice powder particle with higher and similar particle density of 1.54 and 1.46 (Table 22).

4.2.1.3.3 Interaction Effects on Particle Density

Interactive effects of carrier and inlet temperature were non - significant in all three fruit juices under study (Table23).

4.2.1.4 Volume Occupied By Particles

4.2.1.4.1 Effect of Carrier on Volume Occupied By Particles

Effect of carrier in the percentage volume occupied by the particles is shown in the table 21. Cashew apple juice powder particles formed by using carrier maltodextrin occupied more volume (39.82 per cent) compared to those produced using resistant dextrin (36.17 per cent). Carrier maltodextrin also led to pineapple juice powder particles that occupied more volume (41.98 per cent) than resistant dextrin (38.52 per cent). Addition of carrier maltodextrin produced powder particles with lesser porosity and powder particles occupied more volume (39.66 per cent) in comparison to resistant dextrin (35.29 per cent) in blended juice powder too (Table 21).

4.2.1.4.2 Effect of Inlet Temperature on Volume Occupied by Particles

Effect of carrier in the percentage volume occupied by the particles is shown in the table 22. The cashew apple juice powder particles formed by drying at lower temperature of 150°C occupied more volume (42.60 per cent) followed by particles dried at 160°C (40.02 per cent).

The lower temperature ranges of 150 to 170°C were equally effective in yielding pineapple juice powders which had higher volume occupancy than higher temperature. The volume occupied by the pineapple juice powder particles ranged from 41.98 to 37.97 per cent between the lowest and highest temperature under study (Table 22).

The lower range of 150-170°C differed significantly from the higher range of 180-190°C by occupying more volume in blended juice powders. The volume occupied by the particles ranged from 38.63 to 35.29 per cent between the lowest (150°C) and highest temperature (190°C) under study (Table 22).

4.2.1.4.3 Interaction Effects on Volume Occupied by Particles

Interaction effect of carriers and inlet temperature were on volume occupied by particles were non-significant in all three fruit juices under study (Table 23).

4.2.1.5 Total Soluble Solids

4.2.1.5.1 Effect of Carrier on Total Soluble Solids

Effect of carriers on total soluble solids of instant juice powders is expressed in table 24. Cashew apple juice powders produced using maltodextrin as carrier had significantly higher total soluble solids (26.47°B) compared to those produced using resistant dextrin (23.36°B). Addition of maltodextrin also increased total soluble solids content of pineapple juice powder (28.27°B) in comparison to powders formulated with resistant dextrin (24.49°B). Maltodextrin had similar effect in blended juice powder in which total soluble solid content of 26.793°B was observed in maltodextrin related powders and 24.18°B in resistant dextrin related powders as depicted in table 24.

4.2.1.5.2 Effect of Inlet Temperature on Total Soluble Solids

Inlet temperature did not significantly influence total soluble solid content of pineapple and blend powder whereas drying at temperature of 170°C produced cashew apple juice powder with highest total soluble solids (26.32°B) which was at par with 160°C (25.52°B) as depicted in table 25. The highest (190°C) and the lowest temperature (150°C) produced powder with lowest total soluble solids of 23.72°B and 23.95°B respectively.

4.2.1.5.3 Interaction Effects on Total Soluble Solids

Interaction effect of carrier and inlet temperature was not significant on total soluble solids of instant juice powders as expressed in table 26.

4.2.1.6 Percent Soluble Solids

4.2.1.6.1 Effect of Carrier on Percent Soluble Solids

Effect of carriers on percent soluble solids of instant juice powders is expressed in table 24. Cashew apple juice powders produced with resistant dextrin as carrier expressed significantly higher percentage of soluble solids (95.51 per cent) compared to those formulated with maltodextrin (93.71 per cent). Addition of resistant dextrin exhibited higher percentage of soluble solids in pineapple fruit powder (93.49 per cent) and blended juice powder (93.17 per cent) in comparison to those produced using maltodextrin (91.85 and 91.33 per cent respectively).

4.2.1.6.2 Effect of Inlet Temperature on Percent Soluble Solids

Inlet temperature did not significantly influence the percentage soluble solid content in all the three fruit juice powders (Table 25).

Table: 24 Effect of carrier on total soluble solids, percent soluble solids and dispersible solids

Carrier	Total soluble solids (°B)			Percent soluble solids (%)			Dispersible Solids (%)		
	C	P	B	C	P	B	C	P	B
Maltodextrin (M)	26.47	28.27	26.79	93.71	91.85	91.33	6.29	8.15	8.67
Resistant dextrin (R)	23.37	24.49	24.18	95.51	93.49	93.17	4.49	6.51	6.83
CD (0.05)	0.75	1.35	0.99	1.47	1.61	0.86	1.47	1.61	0.86

C- Cashew apple juice powder, P – Pineapple juice powder, B – Blended juice powder.

Table: 25 Effect of inlet temperature on total soluble solids, percent soluble solids and dispersible solids.

Inlet temperature (°C)	Total soluble solids (°B)			Percent soluble solids (%)			Dispersible Solids (%)		
	C	P	B	C	P	B	C	P	B
150 (T_1)	24.0	25.1	24.5	94.2	92.5	91.5	5.8	7.5	8.5
160 (T_2)	25.5	27.4	26.4	95.2	93.2	92.6	4.8	6.8	7.4
170 (T_3)	26.3	27.3	26.2	94.7	92.5	92.2	5.3	7.5	7.8
180 (T_4)	25.1	25.9	25.8	94.8	92.8	92.2	5.2	7.3	7.8
190 (T_5)	23.7	26.2	24.6	94.1	92.4	92.8	5.9	7.6	7.2
CD (0.05)	1.18	NS	NS	NS	NS	NS	NS	NS	NS

C- Cashew apple juice powder, P – Pineapple juice powder, B – Blended juice powder.

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Table: 26 Effect of interaction of carrier with inlet temperature on total soluble solids, percent soluble solids and dispersible solids.

Carrier	Inlet temperature (°C)	Total soluble solids (%)			Percent soluble solids (%)			Dispersibile Solids (%)		
		C	P	B	C	P	B	C	P	B
Maltodextrin (M)	150 (T_1)	25.27	26.70	25.47	93.37	91.47	90.03	6.63	8.53	9.97
	160 (T_2)	27.37	29.57	28.13	94.07	91.87	90.77	5.93	8.13	7.60
	170 (T_3)	27.17	29.43	27.23	93.37	92.17	91.63	6.63	7.83	9.23
	180 (T_4)	26.97	27.33	27.60	94.30	92.63	91.80	5.70	7.37	8.37
	190 (T_5)	25.60	28.33	25.53	93.47	91.10	92.40	6.53	8.90	8.20
Resistant Dextrin (R)	150 (T_1)	22.63	23.47	23.60	95.03	93.53	92.73	4.97	6.47	7.00
	160 (T_2)	23.67	25.27	24.60	96.40	94.57	92.80	3.60	5.43	7.20
	170 (T_3)	25.47	25.10	25.07	96.03	92.77	93.00	3.97	7.23	6.43
	180 (T_4)	23.27	24.53	23.90	95.30	92.87	93.57	4.70	7.13	7.27
	190 (T_5)	21.83	24.07	23.73	94.80	93.73	93.77	5.20	6.27	6.23
CD (0.05)		NS	NS	NS	NS	NS	NS	NS	NS	NS

C- Cashew apple juice powder, P – Pineapple juice powder, B – Blended juice powder.

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4.2.1.6.3 Interaction Effects on Percent Soluble Solids

Interaction effect of carrier and inlet temperature did not influence percent soluble solids of instant juice powders as expressed in table 26.

4.2.1.7 Dispersible Solids

4.2.1.7.1 Effect of Carrier on Dispersible Solids

Effect of carriers on dispersible solids of instant juice powders is expressed in table 24. Resistant dextrin recorded lower dispersible solids (4.49 per cent) in cashew apple juice powder than those produced using maltodextrin. Dispersible solid content in pineapple powder in which resistant dextrin was added as carrier was lower (6.51 per cent) compared to powder produced using maltodextrin (8.15 per cent). Resistant dextrin was highly efficient in producing blended juice powders with lower dispersible solids (6.83 per cent) in comparison to those produced with maltodextrin (8.67 per cent).

4.2.1.7.2 Effect of Inlet Temperature on Dispersible Solids

Inlet temperature did not significantly influence dispersible solid content all three fruit juice powders (Table 25).

4.2.1.7.3 Interaction Effects on Dispersible Solids

No significant difference was observed in interaction effects in all the three fruit juice powders (Table 26).

4.2.1.8 Sinkability

Sinkability was measured by observing the optical density readings when 2 mg powder was dusted on distilled water in spectro photometer. The optical density readings did not differ significantly in all the fruit juices as shown in the table 27, 28

Table 27 Effect of carrier on sinkability of powder

Carrier	Cashew apple juice powder			Pineapple juice powder			Blended juice powder		
	2^{nd}*	4^{th} *	6^{th} *	2^{nd}*	4^{th} *	6^{th} *	2^{nd}*	4^{th} *	6^{th} *
Maltodextrin (M)	0.95	0.88	0.84	0.94	0.86	0.83	0.93	0.87	0.84
Resistant dextrin (R)	0.95	0.88	0.85	0.94	0.86	0.83	0.94	0.87	0.81
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

The data represents factor mean values of optical density readings. * represents time of observation in minutes

Table 28 Effect of inlet temperature on sinkability of powder

Inlet temperature (°C)	Cashew apple juice powder			Pineapple juice powder			Blended juice powder		
	2^{nd}*	4^{th} *	6^{th} *	2^{nd}*	4^{th} *	6^{th} *	2^{nd}*	4^{th} *	6^{th} *
150 (T_1)	0.95	0.90	0.84	0.94	0.85	0.83	0.93	0.87	0.84
160 (T_2)	0.95	0.88	0.85	0.95	0.85	0.83	0.95	0.89	0.84
170 (T_3)	0.94	0.86	0.84	0.94	0.87	0.82	0.94	0.85	0.84
180 (T_4)	0.95	0.88	0.85	0.94	0.86	0.83	0.93	0.84	0.83
190 (T_5)	0.96	0.89	0.84	0.95	0.86	0.84	0.93	0.87	0.79
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

The data represents factor mean values of optical density readings. * represents time of observation in minutes

Table: 29 Effect of interaction of carrier with inlet temperature on on sinkability of powder

Carrier	Inlet temperature (°C)	Cashew apple juice powder			Pineapple juice powder			Blended juice powder		
		2nd*	4th *	6th *	2nd*	4th *	6th *	2nd*	4th *	6th *
Maltodextrin (M)	150 (T_1)	0.95	0.85	0.82	0.94	0.86	0.83	0.93	0.87	0.84
	160 (T_2)	0.95	0.91	0.84	0.95	0.85	0.83	0.94	0.89	0.84
	170 (T_3)	0.96	0.88	0.84	0.94	0.86	0.82	0.93	0.85	0.84
	180 (T_4)	0.94	0.88	0.84	0.94	0.86	0.83	0.93	0.84	0.83
	190 (T_5)	0.95	0.90	0.84	0.94	0.87	0.83	0.94	0.87	0.84
Resistant Dextrin (R)	150 (T_1)	0.95	0.89	0.85	0.93	0.85	0.83	0.94	0.87	0.83
	160 (T_2)	0.95	0.89	0.86	0.95	0.85	0.83	0.96	0.85	0.84
	170 (T_3)	0.92	0.87	0.84	0.95	0.87	0.82	0.94	0.89	0.84
	180 (T_4)	0.95	0.88	0.85	0.95	0.86	0.84	0.93	0.84	0.83
	190 (T_5)	0.96	0.89	0.84	0.95	0.85	0.84	0.93	0.87	0.73
CD (0.05)		NS	NS	NS	NS	NS	NS	NS	NS	NS

The data represents factor mean values of optical density readings. * represents time of observation in minutes and 29. In general the optical readings got lower as the time of observation advanced from 2 minute to six minutes as depicted in table 29.

The range of optical density readings was 0.96-0.92, 0.91-0.85 and 0.86 to 0.82 in cashew apple juice powders at 2nd 4th and 6th minute respectively. The range of optical density readings was 0.93-0.95, 0.87-0.85 and 0.84 to 0.82 in cashew apple juice powders at 2nd 4th and sixth minute respectively (Table 29).

Similar trend was observed in pineapple and blended juice powder also. In pineapple powders, optical density values ranged from 0.95-0.93, 0.87-0.85 and 0.84-0.82 at 2nd 4th and 6th minute respectively. With respect to blended juice powders the optical density range was 0.96-0.93, 0.89-0.84 and 0.84-0.73 at 2nd 4th and 6th minute respectively (Table29).

4.2.1.9 Hunter Colour Value

Hunter color values are expressed in L*a*b* scale as well as hue angle and chroma were computed in order to have a better understanding on the values obtained (Table 30, 31 and 32. The L* value represents lightness, hue represents tonality and chroma represents intensity of colour.

4.2.1.9.1 L Value*

4.2.1.9.1.1 Effect of Carrier on L Value*

Effect of carriers on L* value of instant juice powders is expressed in table 30 and resistant dextrin was consistently superior in producing powders with higher L* value. Resistant dextrin yielded cashew apple juice powder with higher lightness (91.12) compared to those with maltodextrin (90.61). The pineapple powder recorded higher L* value when resistant dextrin was added as carrier (93.21) compared powder with maltodextrin (91.99). Addition of resistant dextrin as carrier produced blended juice powders with significantly higher L* value of 92.77 in comparison to maltodextrin (90.45).

4.2.1.9.1.2 Effect of Inlet Temperature on L Value*

Effect of inlet temperature on L* value of instant juice powders is expressed in table 31. L* value of powders was inversely proportional to inlet temperature. The highest L* value was observed at a temperature of 150°C (92.33) and the lowest at 190°C (90.16). The lightness of pineapple powders also got reduced when drying temperature increased. Lighter powder was observed at 150°C (94.49) than at 190°C (90.98). Powder from blended juice too had lighter colour (higher L* value) when dried at a temperature of 150°C (92.45) than at 190°C (89.25).

4.2.1.9.1.3 Interaction Effects on L Value*

Interaction effects of carrier and inlet temperature were non-significant in cashew apple and pineapple powders whereas powder with resistant dextrin dried at a temperature of 160°C had the highest L* value (94.29) and maltodextrin at 190°C had lowest L* value (87.75) in blended juice powders as depicted in table 32.

4.2.1.9.2 a and b* values.*

a* values and b* value of the powders and their factor wise means are represented in the tables 30, 31 and 32. These values were subjected to descriptive analysis only as suggested by McGuire (1992).

The a* value of resistant dextrin formulated powders were high negative values than those produced with maltodextrin as given in table 30. As inlet temperature increased a* values shifted towards lower negative or positive values as given in table 31. The a* value ranged -0.41 to -2.47, -0.03 to -1.15 and -0.03 to -2.94 in cashew apple, pineapple and blended juice powders respectively as expressed in table 32.

The b* value of resistant dextrin formulated powders were higher than those produced with maltodextrin in case of cashew apple juice powders but were lower in case of pineapple and blended juice powders as given in the table 30. b* values were inversely proportional to the inlet temperature (Table 31). The b* value ranged 7.87 to -19.44, 9.84 to 16.42 and 11.78 to 19.72 in cashew apple, pineapple and blended juice powders respectively as expressed in table 32.

4.2.1.9.3 Hue Angle

4.2.1.9.3.1 Effect of Carrier on Hue Angle

Effect of carriers on hue angle of instant juice powders is expressed in table 30. Resistant dextrin elevated hue angle of cashew apple juice powder (94.79°), pineapple juice powder (92.67°) and blended juice powder (96.01°) than those produced with maltodextrin (93.29°, 90.57° and 90.52 ° in cashew apple pineapple and blended juice respectively.)

4.2.1.9.3.2 Effect of Inlet Temperature on Hue Angle

Effect of carriers on hue angle of instant juice powders is expressed in table 31. Hue angle was inversely proportional to the rising inlet temperature. The highest hue angle was noted at 150°C (97.90 °) and the lowest at 190°C (92.37 °). In pineapple powder also 150°C increased hue angle (95.53 °). The temperature range of 180°C and 190°C produced powders with lowest hue value (89.80 ° and 88.65 °). But in case of blended juice powder highest hue angle was observed at temperature of 160 and 170°C (95.92° and 95.08°) and the lowest at 190°C (88.80°).

4.2.1.9.3.3 Interaction Effects on Hue Angle

Interaction effect of carriers and inlet temperature on hue angle of instant juice powders is expressed in table 32. Resistant dextrin combination with 150°C recorded high hue angle (100.13°) in cashew apple juice powder whereas the lowest hue angle was recorded when maltodextrin is used and dried at 190°C (91.85°). Interaction effects did not influence pineapple juice powders. However, interaction effect of resistant dextrin with the inlet temperature of 170°C elevated the hue angle

Table: 30 Effect of carrier on colour of fruit powders

Carrier	L value			a*value#			b* value#			Hue(°)			Chroma		
	C	P	B	C	P	B	C	P	B	C	P	B	C	P	B
Maltodextrin (M)	90.61	91.99	90.45	-0.63	-0.05	-0.04	11.58	13.02	15.44	93.30	90.57	90.52	11.60	13.03	15.45
Resistant dextrin (R)	91.12	93.21	92.77	-1.36	-0.52	-1.44	17.12	12.68	14.6	94.79	92.67	96.01	17.19	12.71	14.702
CD (0.05)	0.23	0.19	0.244	-	-	-	-	-	-	0.589	1.153	0.659	0.222	0.173	0.428

C- Cashew apple juice powder, P – Pineapple juice powder, B – Blended juice powder. # Subjected to descriptive analysis as suggested by Maguire (1992)

Table: 31 Effect of inlet temperature on colour

Inlet Temperature (°C)	L value			a*value#			b*value#			Hue(°)			Chroma		
	C	P	B	C	P	B	C	P	B	C	P	B	C	P	B
150 (T_1)	92.33	94.49	92.45	-1.63	-0.97	-1.05	10.8	9.91	13.24	97.90	95.53	94.61	10.93	9.97	13.29
160 (T_2)	90.92	92.90	93.39	-1.02	-0.48	-1.05	14.92	12.89	11.84	93.89	92.24	95.08	14.960	12.91	11.91
170 (T_3)	89.92	92.85	92.05	-0.87	-0.41	-1.48	16.2	12.34	15.38	92.96	91.88	95.92	16.22	12.35	15.53
180 (T_4)	90.99	91.79	90.90	-0.78	0.05	-0.54	14.21	13.73	15.89	93.1	89.80	91.93	14.23	13.73	15.90
190 (T_5)	90.16	90.98	89.25	-0.67	0.38	0.43	15.62	15.38	18.73	92.37	88.65	88.80	15.64	15.38	18.75
CD (0.05)	0.369	0.307	0.387	-	-	-	-	-	-	0.931	1.823	1.043	0.351	0.275	0.678

C- Cashew apple juice powder, P – Pineapple juice powder, B – Blended juice powder. # Subjected to descriptive analysis as suggested by McGuire (1992)

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Table: 32 Effect of interaction of carrier with inlet temperature on colour.

Carrier	Inlet temp (°C)	L value			a*value#			b*value#			Hue(°)			Chroma		
		C	P	B	C	P	B	C	P	B	C	P	B	C	P	B
M	150 (T_1)	91.91	94.16	91.46	-0.78	-0.78	-0.61	7.87	9.84	13.69	95.66	94.55	92.55	7.91	9.87	13.71
	160 (T_2)	90.76	92.15	92.49	-0.79	-0.03	-0.45	12.12	13.55	11.9	93.74	90.11	92.19	12.15	13.55	11.91
	170 (T_3)	89.72	92.17	90.44	-0.53	-0.19	-0.03	12.96	12.01	16.55	92.36	90.91	90.10	12.97	12.01	16.55
	180 (T_4)	90.77	91.19	90.08	-0.61	0.17	-0.26	12.17	13.25	15.33	92.85	89.26	91.05	12.19	13.26	15.34
	190 (T_5)	89.90	90.27	87.75	-0.41	0.57	1.14	12.79	16.42	19.72	91.85	88.00	86.71	12.80	16.43	19.75
R	150 (T_1)	92.75	94.82	93.43	-2.47	-1.15	-1.5	13.73	9.99	12.79	100.13	96.51	96.67	13.96	10.07	12.88
	160 (T_2)	91.08	93.64	94.29	-1.25	-0.93	-1.65	17.72	12.22	11.78	94.05	94.37	97.97	17.77	12.26	11.90
	170 (T_3)	90.13	93.52	93.66	-1.21	-0.63	-2.94	19.44	12.67	14.2	93.55	92.85	101.73	19.47	12.69	14.51
	180 (T_4)	91.20	92.39	91.73	-0.95	-0.08	-0.81	16.24	14.2	16.45	93.34	90.33	92.81	16.26	14.20	16.47
	190 (T_5)	90.42	91.68	90.76	-0.93	0.18	-0.27	18.45	14.33	17.75	92.88	89.29	90.88	18.48	14.33	17.75
CD (0.05)		NS	NS	0.547	-	-	-	-	-	-	1.317	NS	1.475	0.497	0.388	0.959

M- Maltodextrin, R- Resistant Dextrin, C- Cashew apple juice powder, P – Pineapple juice powder, B – Blended juice powder. # Subjected to descriptive analysis as suggested by McGuire (1992) of blended juice powders to 101.73° and the lowest hue angle was noted when maltodextrin was used with 190°C (86.71°).

4.2.1.9.4 Chroma

4.2.1.9.4.1 Effect of Carrier on Chroma

Effect of carriers on chroma of instant juice powders is expressed in table 30. Maltodextrin resulted in cashew apple powders with lower chroma value (11.60) compared to powders with resistant dextrin (17.19) whereas resistant dextrin yielded powder with lower chroma in pineapple juice powders (12.71) and blended juice powders (14.70) than those produced with maltodextrin (13.03 and 15.45 respectively).

4.2.1.9.4.2 Effect of Inlet Temperature on Chroma

Effect of inlet temperature on chroma of instant juice powders is expressed in table 31. The lowest chroma value of 10.93 was obtained for cashew apple juice powders at temperature of 150°C and the highest chroma value was obtained at a temperature of 190°C (15.64). The chroma value of pineapple juice powder was also lower with 150°C drying temperature (9.97) and highest chroma value was obtained by drying at 190°C (15.38). However, the lowest chroma value was obtained at the temperature of 160°C (11.91) and the highest at 190°C (18.78) in blended juice powders.

4.2.1.9.4.3 Interaction Effects on Chroma

Interaction effect of carriers and inlet temperature on chroma of instant juice powders is expressed in table 32. The lowest chromaticity of cashew apple juice powders was noted at the combination of maltodextrin with 150°C inlet temperature (7.9) and the highest with resistant dextrin dried at 170°C (19.47). But the lowest (9.87) and the highest (16.43) chromaticity of pineapple juice powders were noted at 150°C and 190°C respectively with maltodextrin. In blended juice powders, lowest chromaticity was observed at the combination of 160°C with both carriers and highest at the combination at 190°C with maltodextrin.

4.2.1.10 Relative Viscosity

Relative viscosity of an instant juice is an important parameter of an instant juice which may depend upon the properties of particles embedded in the solution. Relative viscosity of the reconstituted juice at 30, 35 and 32.5 per cent solution (reconstitution percentages were computed based on the potential yield of total solids from the feed as discussed earlier) was measured by brookefield viscometer and the result is presented in the table 33, 34 and 35

4.2.1.10.1 Effect of Carrier on Relative Viscosity

Effect of carriers on relative viscosity of instant juice powders is expressed in table 33. Reconstituted fruit powders exhibited significantly lower viscosity when resistant dextrin was used and the relative viscosity were 7.40, 8.30 and 8 mPas in cashew apple, pineapple and blended juice powders respectively. The powders formulated with maltodextrin recorded 8.16, 8.73 and 8.21 mPas relative viscosity in cashew apple, pineapple and blended juice powders respectively.

4.2.1.10.2 Effect of Inlet Temperature on Relative Viscosity

Inlet temperature did not express any significant effect on relative viscosity of all reconstituted fruit juices as shown in the table 34.

4.2.1.10.3 Interaction Effects on Relative Viscosity

Interaction effects of carrier and inlet temperature did not significantly influenced relative viscosity of reconstituted fruit powders as shown in the table 35.

4.2.1.11 Flowability (Angle of Repose)

Angle of repose was measured to assess the flowability of the powder since powder need to be cohesive while handling. The angle formed between the horizontal plane and the sloped line extending along the face of the heap was computed by pouring material onto the horizontal as discussed earlier. The effect of carriers, inlet temperature and their interaction is presented in tables 33, 34 and 35 respectively.

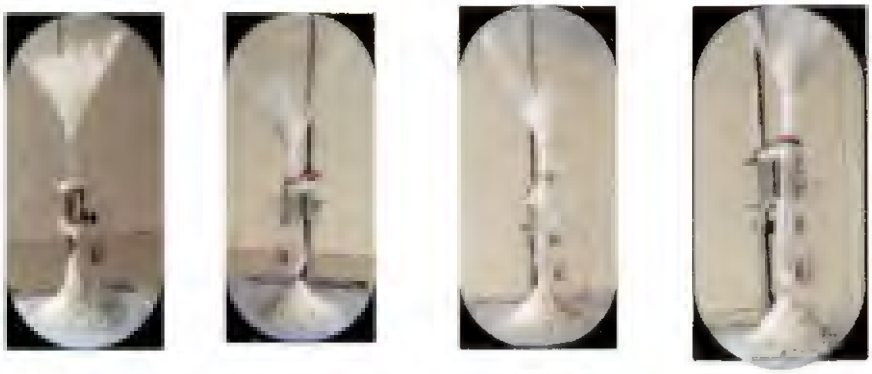
4.2.1.11.1 Effect of Carrier on Flowability (Angle of Repose)

Effect of carriers on angle of repose of instant juice powders is expressed in table 33. Addition of resistant dextrin as carrier led to development of cashew apple juice powders with lower angle of repose (34.05°) than maltodextrin (35.76°). Resistant dextrin recorded lower angle of repose of 38.93° while maltodextrin recorded higher angle of repose of 41.03° in pineapple powders. Resistant dextrin as carrier was beneficial in producing blended juice powders with lower angle of repose (33.57°) in comparison to maltodextrin (38.78 °) as depicted in plate 17.

4.2.1.11.2 Effect of Inlet Temperature on Flowability (Angle of Repose)

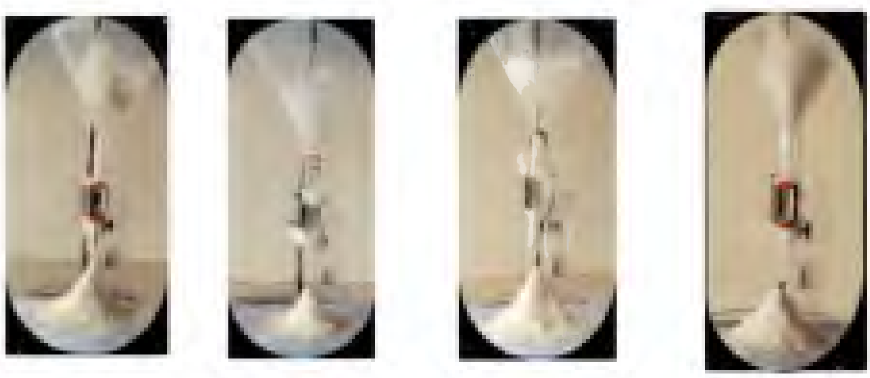
Effect of inlet temperature on angle of repose of instant juice powders is expressed in table 34. Angle of repose of the cashew apple juice powder that dried at 190°C was 31.85° which was significantly lower in comparison to all other temperature range. Highest angle of repose of 38.18 ° was exhibited by the lowest temperature of 150°C. The temperature range of 160 to 180°C did not differ significantly among them.

The highest drying temperature of 190°C recorded the lowest angle of repose (37.47°) of pineapple juice powders followed by 180°C (38.21°). The lower temperature of 150 °C and 160 recorded higher angle of repose of 42.46 ° and 41.64° respectively.



CM_5T_1 CM_5T_5 CR_5T_1 CR_5T_5

Cashew apple juice powders



PM_5T PM_5T_5 PR_5T_1 PR_5T_5

Pineapple juice powders

BM_5T_1 BM_5T_5 BR_5T_1 BR_5T_5

Blended juice powders

Plate 17: Angle of Repose measurement of powders

M_5 – Maltodextrin@40:60 (Juice: Carrier, R_5 -Resistant dextrin@40:60 (Juice: Carrier), T_1-150°C, T_2- 160°C. T_3- 170°C. T_4- 180°C, T_5- 190°C

Table: 33 Effect of carrier on relative viscosity, flowability (angle of repose) and water activity

Carrier	Relative viscosity (mPas)			Angle of repose (°)			Water activity (aw)		
	C	P	B	C	P	B	C	P	B
Maltodextrin (M)	8.16	8.73	8.21	35.76	41.03	38.78	0.26	0.28	0.27
Resistant dextrin (R)	7.40	8.30	8.00	34.05	38.93	33.57	0.25	0.27	0.26
CD (0.05)	0.18	0.40	0.20	1.12	1.84	1.89	NS	0.01	NS

C- Cashew apple juice powder, P – Pineapple juice powder, B – Blended juice powder.

Table: 34 Effect of inlet temperature on relative viscosity, flowability (angle of repose) and water activity

Inlet temperature (°C)	Relative viscosity (mPas)			Angle of repose (°)			Water activity (aw)		
	C	P	B	C	P	B	C	P	B
150 (T_1)	7.76	8.58	8.07	38.18	42.46	39.30	0.29	0.29	0.30
160 (T_2)	7.76	8.53	8.11	35.41	41.64	36.24	0.26	0.28	0.26
170 (T_3)	7.86	8.43	8.10	34.68	40.11	35.21	0.25	0.29	0.27
180 (T_4)	7.68	8.54	8.06	34.42	38.21	35.77	0.25	0.27	0.26
190 (T_5)	7.86	8.50	8.19	31.85	37.47	34.36	0.24	0.26	0.25
CD (0.05)	NS	NS	NS	1.77	2.90	2.99	0.02	0.01	0.02

C- Cashew apple juice powder, P – Pineapple juice powder, B – Blended juice powder.

Table: 35 Effect of interaction of carrier with inlet temperature on relative viscosity, flowability (angle of repose) and water activity

Carrier	Inlet temperature (°C)	Relative viscosity (mPas)			Angle of repose (°)			Water activity (aw)		
		C	P	B	C	P	B	C	P	B
Maltodextrin (M)	150 (T_1)	8.12	8.82	8.23	40.22	43.49	37.55	0.30	0.31	0.29
	160 (T_2)	8.17	8.74	8.21	36.14	43.07	38.02	0.26	0.29	0.27
	170 (T_3)	8.18	8.67	8.08	34.68	41.31	38.88	0.25	0.29	0.27
	180 (T_4)	8.10	8.57	8.24	35.67	38.91	39.36	0.26	0.28	0.27
	190 (T_5)	8.25	8.83	8.29	32.11	38.39	41.04	0.24	0.27	0.26
Resistant Dextrin (R)	150 (T_1)	7.39	8.34	7.92	36.14	41.43	32.11	0.28	0.28	0.30
	160 (T_2)	7.35	8.31	8.01	34.68	40.22	32.40	0.26	0.28	0.26
	170 (T_3)	7.54	8.18	8.11	34.68	38.91	32.66	0.25	0.29	0.26
	180 (T_4)	7.27	8.51	7.88	33.16	37.52	33.11	0.24	0.26	0.25
	190 (T_5)	7.47	8.16	8.08	31.59	36.54	36.61	0.24	0.26	0.24
CD (0.05)		NS	NS	NS	NS	NS	NS	NS	NS	NS

C- Cashew apple juice powder, P – Pineapple juice powder, B – Blended juice powder.

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The temperature range from 160 to 190°C had similar angle of repose in blended juice powders and temperature of 190°C exhibited angle of repose of 34.36°. The temperature of 150°C produced powder with higher angle of repose of 39.30°.

4.2.1.11.3 Interaction Effects on Flowability (Angle of Repose)

Effect of interaction of carrier with inlet temperature on angle of repose of the powder was non-significant as presented in table 35.

4.2.1.12 Water Activity

Water in food which is not bound to food molecules can support the growth of bacteria, yeasts and molds (fungi). The term water activity (aw) refers to this unbound water. Moist foods may have greater water activity than dry foods, but variety of foods may have exactly the same moisture content and yet have quite different water activities. The water activity (aw) represents the ratio of the water vapor pressure of the food to the water vapor pressure of pure water under the same conditions and it is expressed as a fraction in a scale that extends from 0 (bone dry) to 1.0 (pure water). Since water activity (aw) can help in predicting the growth of bacteria, yeasts and molds, it was measured using water activity meter and the result is presented in the tables 33.34 and 35.

4.2.1.12.1 Effect of Carrier on Water Activity

Effect of carriers on water activity of instant juice powders is expressed in table 33. Carriers did not significantly influence the water activity of cashew apple and blended juice powders. But resistant dextrin yielded pineapple powder with lower water activity value (0.27) compared to maltodextrin (0.28).

4.2.1.12.2 Effect of Inlet Temperature on Water Activity

Effect of inlet temperature on water activity of instant juice powders is expressed in table 34. Temperature range from 160 to 190°C produced cashew apple juice powders with at par water activity values and water activity at 190°C was 0.24. The inlet temperature of 150°C produced powder with water activity of 0.29.

Pineapple juice powder produced at temperature of 180°C and 190°C recorded lower water activity of 0.27 and 0.26 respectively. The temperature range from150 to 170°C were at par and the water activity of powder at 150°C was 0.29.

Temperature range from 160 to 190°C produced blended juice powders with at par water activity values and water activity at 190°C was 0.25. Inlet temperature of 150°C produced powder with highest water activity of 0.297 (Table 34).

4.2.1.12.3 Interaction Effects on Water Activity

Effect of interaction of carrier with inlet temperature on water activity of instant juice powders were non-significant in the powders produced from all fruit juices as presented in the table 35.

4.2.2 Chemical Parameters

4.2.2.1 Vitamin C

4.2.2.1.1 Effect of Carrier on Vitamin C

Effect of carriers on vitamin C of instant juice powders is expressed in table 36. The carriers did not express any significant effect on vitamin C content of pineapple and blended juice powder while resistant dextrin was more efficient in retaining vitamin C of cashew apple juice powder since the powder formulated with resistant dextrin had vitamin C content of 667.29 mg/100g in comparison to maltodextrin (661.68 mg/100g).

4.2.2.1.2 Effect of Inlet Temperature on Vitamin C

Effect of inlet temperature on vitamin C of instant juice powders is expressed in table 37. Powder obtained by drying at temperature of 150°C and 160°C were at par on retaining vitamin C since the vitamin C content of powders were 676.64 and 674.77 mg/100g respectively. Powder dried at 190°C had the lowest vitamin C content of 653.27 mg/100g.

Drying at temperature of 150°C and 160°C yielded powders with high vitamin C of 31.87 and 31.31 mg/100g respectively which were on par. Powder dried at the temperature range of 170 to 190°C had the lower vitamin C content and 190 °C yielded powder with least vitamin C (29.813mg/100g).

Powder obtained by drying at temperature of 150°C and 160°C exhibited vitamin C content of 292.523 and 289.72 mg/100g respectively which were on par. Powder dried at the temperature range of 170 to 190°C had the lower vitamin C content and 190°C produced powder with least vitamin C (269.159 mg/100g).

4.2.2.1.2 Interaction Effects on Vitamin C

Effect of interaction of carrier with inlet temperature on vitamin C content was non-significant in the powder produced from all fruit juices as depicted in table 38.

4.2.2.2 β-carotene

The powder from cashew apple juice did not contain any β-carotene. The carriers and its interaction with inlet temperature did not significantly influence the β-carotene content in all the fruit juices as presented in table 36 and 38.

4.2.2.2.1 Effect of Inlet Temperature on β-carotene

Effect of inlet temperature on β-carotene of instant juice powders is expressed in table 37. Lowest temperature of 150°C recorded highest β-carotene of 14.97μg/100g which was on par with 160 °C in pineapple powder. The temperature of 180 to 190°C effected higher loss of β-carotene.

Table: 36 Effect of carrier on vitamin C, β-carotene, crude fiber and total ash

Carrier	Vitamin C (mg/100g)			*β-carotene (µg/100g)		Crude fibre (%)			Total ash (%)		
	C	P	B	P	B	C	P	B	C	P	B
Maltodextrin (M)	661.68	30.80	277.01	13.83	6.45	0.58	0.58	0.61	1.47	1.51	1.45
Resistant dextrin (R)	667.29	30.54	281.87	13.78	6.47	0.61	0.61	0.63	1.44	1.51	1.44
CD (0.05)	4.81	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

C- Cashew apple juice powder, P – Pineapple juice powder, B – Blended juice powder. * Cashew apple juice powder did not contain β-carotene

Table:37 Effect of inlet temperature on vitamin C, β-carotene, crude fiber and total ash

Inlet temperature (°C)	Vitamin C (mg/100g)			β-carotene (µg/100g)		Crude fibre (%)			Total ash (%)		
	C	P	B	P	B	C	P	B	C	P	B
150 (T_1)	676.64	31.87	292.52	14.97	6.78	0.55	0.55	0.59	1.43	1.48	1.43
160 (T_2)	674.77	31.31	289.72	14.57	6.87	0.61	0.61	0.63	1.47	1.52	1.38
170 (T_3)	661.68	30.14	274.77	13.25	6.24	0.62	0.62	0.60	1.44	1.57	1.47
180 (T_4)	656.08	30.23	271.03	13.38	6.39	0.65	0.65	0.65	1.45	1.42	1.47
190 (T_5)	653.27	29.81	269.16	12.85	6.05	0.56	0.56	0.63	1.50	1.55	1.48
CD (0.05)	7.6	0.93	9.63	0.87	0.38	NS	NS	NS	NS	NS	NS

C- Cashew apple juice powder, P – Pineapple juice powder, B – Blended juice powder. * Cashew apple juice powder did not contain β-carotene

Table: 38 Effect of interaction of carrier with inlet temperature on vitamin C, β-carotene crude fibre and total ash

Carrier	Inlet temperature (°C)	Vitamin C (mg/100g)			β-carotene (µg/100g)		Crude fibre (%)			Total ash (%)		
		C	P	B	P	B	C	P	B	C	P	B
Maltodextrin (M)	150 (T_1)	672.90	31.96	265.42	15.30	6.82	0.52	0.60	0.59	1.36	1.47	1.42
	160 (T_2)	671.03	31.40	267.29	14.87	6.90	0.62	0.58	0.65	1.46	1.48	1.40
	170 (T_3)	657.94	30.47	272.90	13.30	6.22	0.57	0.63	0.55	1.53	1.64	1.47
	180 (T_4)	654.21	30.37	272.90	13.40	6.23	0.65	0.60	0.65	1.51	1.45	1.46
	190 (T_5)	652.34	29.81	274.77	12.27	6.11	0.55	0.63	0.62	1.49	1.50	1.49
Resistant Dextrin (R)	150 (T_1)	680.37	31.78	276.64	14.63	6.73	0.58	0.62	0.58	1.49	1.48	1.43
	160 (T_2)	678.51	31.22	287.85	14.27	6.26	0.60	0.63	0.62	1.47	1.55	1.35
	170 (T_3)	665.42	29.81	291.59	13.20	6.83	0.67	0.65	0.65	1.35	1.51	1.46
	180 (T_4)	657.94	30.09	291.59	13.37	6.55	0.65	0.58	0.66	1.40	1.39	1.48
	190 (T_5)	654.21	29.81	293.46	13.43	5.99	0.57	0.63	0.65	1.52	1.60	1.46
CD (0.05)		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

C- Cashew apple juice powder, P – Pineapple juice powder, B – Blended juice powder. * Cashew apple juice powder did not contain β-carotene

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Lower temperature range of 150 to 160°C were effective in higher retention of β-carotene which led to 6.78 μg/ and 6.87 μg/of β-carotene per 100g of blended juice powder. The temperature of 180 to 190°C caused higher loss of β-carotene.

4.2.2.3 Crude Fibre

Carriers, inlet temperature and their interaction did not exhibit any significant differences in crude fibre content of powders produced from all three fruit juices as presented in table 36, 37 and 38.

4.2.2.4 Total Ash

The treatments could not cause any significant difference in ash content of fruit powders as depicted in table 36,37 and 38.

4.2.2.5 Total Sugars

4.2.2.5.1 Effect of Carrier on Total Sugars

Effect of carriers on total sugar of instant juice powders is expressed in table 39 Instant cashew apple juice powders with maltodextrin had higher total sugar content (34.39 per cent) than those with resistant dextrin (29.48 per cent). Maltodextrin yielded pineapple powder with significantly higher (36.32 per cent) total sugar content than powder with resistant dextrin (31 per cent). Maltodextrin based blended juice powder had higher total sugar content (35.79 per cent) than those produced with resistant dextrin (31.51 per cent).

4.2.2.5.2 Effect of Inlet Temperature on Total Sugars

Inlet temperature range of 160 to 180°C yielded cashew apple juice powder with highest total sugar content (32.83 per cent) followed by 150°C (30.73 per cent) and 190°C (30.60 per cent) as presented in table 40. However, inlet temperature did not cause significant differences in total sugar content of pineapple and blended juice powders.

4.2.2.5.3 Interaction Effects on Total Sugars

Interaction effect of carriers and inlet temperature were non-significant in all three fruit juices under study as presented in table 41.

4.2.2.6 Reducing Sugars

4.2.2.6.1 Effect of Carrier on Reducing Sugars

Effect of carriers on reducing sugars of instant juice powders is expressed in table 39. Reducing sugar content of cashew apple juice powder was higher (26.72 per cent) when maltodextrin was used as carrier in comparison to the powder produced with resistant dextrin (24.51 per cent). Addition of carrier maltodextrin yielded pineapple powder with higher reducing sugars (28.26 per cent) than resistant dextrin (26.33 per cent). Maltodextrin as carrier yielded blended juice powders with 28.273 per cent reducing sugar content which was significantly higher than resistant dextrin (26.88 per cent).

4.2.2.6.2 Effect of Inlet Temperature on Reducing Sugars

Effect of inlet temperature on reducing sugars of instant juice powders is expressed in table 40. As the temperature increased, the reducing sugar increased up to 180°C where the content was 26.97 per cent. The lowest reducing sugar content of 23.69 and 24.90 per cent were recorded at 150 and 190°C respectively. The medium temperature of 160 and 170°C yielded powders with 26.10 and 26.41 per cent reducing sugars which did not differ significantly from each other.

Optimum temperature levels for higher reducing sugar content in pineapple juice powders were 160 and 170°C which had 28.97 and 28.81 per cent reducing sugars respectively. Drying powders at lower (150°C) or higher temperatures (180°C and190°C) significantly reduced the reducing sugar content of powders (Table 40).

Table: 39 Effect of carrier on total sugar, reducing sugar and non reducing sugar

Carrier	Total sugar (%)			Reducing sugar (%)			Non reducing sugar (%)		
	C	P	B	C	P	B	C	P	B
Maltodextrin (M)	34.39	36.32	35.79	26.72	28.26	28.27	7.67	8.06	7.51
Resistant dextrin (R)	29.48	31.00	31.51	24.51	26.33	26.88	4.98	4.66	4.63
CD (0.05)	1.21	1.03	1.81	1.06	1.60	1.11	1.15	2.13	1.95

C- Cashew apple juice powder, P – Pineapple juice powder, B – Blended juice powder.

Table: 40 Effect of inlet temperature on total sugar, reducing sugar and non reducing sugar

Inlet temperature (°C)	Total sugar (%)			Reducing sugar (%)			Non reducing sugar (%)		
	C	P	B	C	P	B	C	P	B
150 (T_1)	30.73	33.01	32.30	23.69	26.52	26.42	7.05	6.49	5.89
160 (T_2)	32.83	34.33	34.16	26.10	28.97	28.57	6.73	5.37	5.59
170 (T_3)	33.02	34.47	34.83	26.41	28.81	29.00	6.62	5.66	5.83
180 (T_4)	32.51	33.62	34.93	26.97	26.66	27.30	5.54	6.97	7.63
190 (T_5)	30.59	32.84	32.01	24.90	25.53	26.60	5.70	7.32	5.41
CD (0.05)	1.91	NS	NS	1.67	2.53	1.75	NS	NS	NS

C- Cashew apple juice powder, P – Pineapple juice powder, B – Blended juice powder.

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Table: 41 Effect of interaction of carrier with inlet temperature on total sugar, reducing sugar and non reducing sugar

Carrier	Inlet temperature (oC)	Total sugar (%)			Reducing sugar (%)			Non reducing sugar (%)		
		C	P	B	C	P	B	C	P	B
Maltodextrin (M)	150 (T1)	32.89	35.49	33.69	24.41	28.01	27.12	8.48	7.47	6.57
	160 (T2)	35.49	37.03	36.99	27.51	29.67	29.55	7.98	7.36	7.44
	170 (T3)	35.49	37.61	36.50	27.12	30.53	30.06	8.37	7.08	6.45
	180 (T4)	35.15	35.97	35.97	28.83	26.72	27.48	6.32	9.25	8.50
	190 (T5)	32.94	35.49	35.78	25.72	26.36	27.17	7.22	9.13	8.61
Resistant Dextrin (R)	150 (T1)	28.58	30.53	30.92	22.97	25.03	25.72	5.61	5.51	5.20
	160 (T2)	30.17	31.64	31.33	24.69	28.26	27.60	5.48	3.38	3.73
	170 (T3)	30.56	31.33	33.16	25.69	27.08	27.94	4.86	4.25	5.22
	180 (T4)	29.86	31.28	33.88	25.10	26.60	27.12	4.76	4.68	6.76
	190 (T5)	28.25	30.20	28.25	24.07	24.69	26.03	4.17	5.51	2.22
CD (0.05)		NS	NS	NS	NS	NS	NS	NS	NS	NS

C- Cashew apple juice powder, P – Pineapple juice powder, B – Blended juice powder.

The temperature range of 160-170°C produced powders with maximum reducing sugar content (28.57 and 29 per cent respectively). Higher or lower temperatures than this range reduced the reducing sugar content (Table 40).

4.2.2.6.3 Interaction Effects on Reducing Sugars

Interaction effect of carriers and inlet temperature were non-significant in all three fruit juices under study as presented in table 41.

4.2.2.7Non Reducing Sugars

4.2.2.6.1 Effect of Carrier on Non Reducing Sugars

Effect of carriers on reducing sugars of instant juice powders is expressed in table 39. The instant cashew apple juice powder produced with maltodextrin had highest non reducing sugar content (7.67 per cent) than with resistant dextrin (4.98 per cent). Pineapple powder with maltodextrin recorded higher non reducing sugar content (8.06 per cent) than resistant dextrin (4.66 per cent). Non reducing sugar content of blended juice powder produced by using maltodextrin as carrier was higher (7.51 per cent) than powders produced with resistant dextrin (4.63 per cent).

4.2.2.7.2 Effect of Inlet Temperature on Non Reducing Sugars

Inlet temperature did not influence the non reducing sugar content of powder produced from all three fruit juices as depicted in table 40.

4.2.2.7.3 Interaction Effects on Non Reducing Sugars

Interaction effect of carriers and inlet temperature on non reducing sugar was non-significant in all three fruit juices under study as presented in table 41.

4.2.2.8 ***pH***

Carriers, inlet temperature and their interaction did not exhibit any significant differences in pH of powders produced from all three fruit juices as presented in table 42, 43 and 44.

4.2.2.9 Titrable Acidity

Carriers, inlet temperature and their interaction did not exhibit any significant differences in titrable acidity of powders produced from all three fruit juices as presented in table 42, 43 and 44.

4.2.2.10 ***Energy Value***

4.2.2.10.1 Effect of Carrier on Energy Value

Effect of carriers on energy value of instant juice powders is expressed in table 42 and different carriers did not significantly influence the energy value of powders in all three fruit juices.

4.2.2.10.2 Effect of Inlet Temperature on Energy Value

Effect of inlet temperature on energy value of instant juice powders is expressed in table 43 and cashew apple juice powders produced under higher temperature range of 180°C and 190°C had the highest energy value (3595.06cal/g). Powder dried under 150°C exhibited lowest energy value (3388.89cal/g). Medium temperature range of 160°C and 170°C did not differ significantly between them and recorded energy value of 3439.53 and 3459.9 cal/g.

The highest temperature of 190°C recorded highest energy value of 3654.4 cal/g which was on par with 180°C (3592.97 cal/g) in pineapple juice powders. Lowest energy values were recorded by 150°C and 160°C.

In blended juice powders, the powder dried at 190°C recorded highest energy value (3646.29 cal/g) which was at par with 180°C (3586.75 cal/g). The lowest energy value was recorded by 150°C (3408.5 cal/g) which was at par with 160°C (3465 cal/g).

Table: 42 Effect of carrier on pH, titrable acidity and energy value

Carrier	pH			Titrable acidity (%)			Energy value (cal/g)		
	C	P	B	C	P	B	C	P	B
Maltodextrin (M)	4.21	4.24	4.19	0.95	1.43	1.07	3498.72	3557.14	3536.29
Resistant dextrin (R)	4.21	4.20	4.23	0.93	1.43	1.10	3467.45	3544.00	3514.42
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

C- Cashew apple juice powder, P – Pineapple juice powder, B – Blended juice powder.

Table: 43 Effect of inlet temperature on pH, titrable acidity and energy value

Inlet temperature (°C)	pH			Titrable acidity (%)			Energy value (cal/g)		
	C	P	B	C	P	B	C	P	B
150 (T_1)	4.18	4.22	4.19	0.95	1.44	1.08	3388.89	3446.73	3408.51
160 (T_2)	4.23	4.22	4.21	0.95	1.43	1.04	3439.53	3495.91	3465.28
170(T_3)	4.20	4.20	4.19	0.93	1.44	1.08	3459.91	3562.85	3519.92
180(T_4)	4.23	4.23	4.23	0.88	1.45	1.11	3532.02	3592.97	3586.75
190(T_5)	4.21	4.23	4.25	0.99	1.40	1.10	3595.06	3654.40	3646.30
CD (0.05)	NS	NS	NS	NS	NS	NS	96.94	100.80	90.92

C- Cashew apple juice powder, P – Pineapple juice powder, B – Blended juice powder

Table: 44 Effect of interaction of carrier with inlet temperature on pH, titrable acidity and energy value

Carrier	Inlet temperature (oC)	pH			Titrable acidity (%)			Energy value (cal/g)		
		C	P	B	C	P	B	C	P	B
Maltodextrin (M)	150 (T1)	4.18	4.20	4.18	0.92	1.43	1.07	3408.24	3495.41	3415.31
	160 (T2)	4.22	4.25	4.15	0.90	1.43	1.02	3439.79	3519.56	3467.78
	170 (T3)	4.21	4.29	4.21	1.06	1.45	1.05	3495.94	3527.69	3534.94
	180 (T4)	4.24	4.25	4.19	0.87	1.45	1.11	3553.82	3576.07	3595.46
	190 (T5)	4.21	4.24	4.23	0.98	1.41	1.09	3595.78	3666.99	3401.70
Resistant Dextrin (R)	150 (T1)	4.18	4.25	4.20	0.98	1.44	1.09	3369.53	3398.05	3667.92
	160 (T2)	4.23	4.19	4.26	1.00	1.43	1.06	3439.28	3472.25	3462.78
	170 (T3)	4.19	4.12	4.17	0.80	1.44	1.11	3423.87	3598.01	3504.90
	180 (T4)	4.22	4.22	4.26	0.89	1.44	1.12	3510.22	3609.87	3578.04
	190 (T5)	4.21	4.23	4.26	1.00	1.39	1.12	3594.34	3641.81	3624.67
CD (0.05)		NS	NS	NS	NS	NS	NS	NS	NS	NS

C- Cashew apple juice powder, P – Pineapple juice powder, B – Blended juice powder

4.2.2.10.3 Interaction Effects on Energy Value

Interaction effect of carriers and inlet temperature on energy was non-significant in all three fruit juices under study as presented in table 44.

4.2.3 Sensory parameters

Sensory evaluation of organoleptic properties of products especially instant juice powders are very important to assess the probable usage as a food material. Parameters like appearance (miscibility), colour, texture (juicy or foamy), flavor, taste and any abnormalities if present were assessed and the result is given in table 45.

4.2.3.1 Appearance

The cashew apple juice powders produced with resistant dextrin at temperature range from 150°C to 190°C had maximum score in appearance. The mean rank were in the range of 145.83 to 186.46 in these combinations.

The treatment combination of resistant dextrin in the temperature range of 160 to 190°C received the best scores in appearance in pineapple juice powders. The mean rank scores ranged from 141.42 to 182.46 in these treatment combinations.

All resistant dextrin combinations and two maltodextrin combinations (at 180 and 190°C) received best scores for appearance in blended juice powders. The mean rank scores ranged from 141.96 to 162.23 among these combinations (Table 45).

4.2.3.2 Colour

The organoleptic assessment of colour is presented in the table 45. Maltodextrin combinations in the temperature range of 150 to 170°C received maximum scores for colour in cashew apple juice powders. The mean rank scores were 198.08 to 147.79 in these combinations. Resistant dextrin combination with 180°C and

190°C had the lowest score for colour. The mean ranks were 176.12 and 186.46 respectively.

Combination of 180°C and 190°C with both carriers had produced pineapple powders with the highest mean rank score in colour and the scores were at par. Maltodextrin combination with the above temperature had mean rank scores of 155.29 and 179.29 respectively. Resistant dextrin combinations with 180°C and 190°C had the mean rank score of 181.12 and 192.75 respectively. Combination of lower temperature with both carriers received lower scores.

Resistant dextrin combination with 190°C had the highest mean score of 197.46 for colour of blended juice powders though it was at per with all resistant dextrin combinations. Maltodextrin combination with 150°C received the lowest score.

4.2.3.3 Texture

The organoleptic assessment of texture is presented in the table 45. Combination of resistant dextrin with all temperatures were at par in obtaining higher scores on texture of cashew apple powder. The score ranged from 151.58 to 206.6 among these treatment combinations as the temperature increased. Maltodextrin combinations with temperature range of 150 to 180°C had lowest mean ranks.

Texture scores of pineapple juice powder did not differ significantly by the combinations of carrier and inlet temperature as presented in table 45. Resistant dextrin combination with 190°C received the highest score of 163.19 which were at par with all other combination of resistant dextrin and combination of maltodextrin with 160 to 190°C temperature range in blended juice powders. The treatment combination of maltodextrin with the lowest temperature of 150°C received the lowest score.

4.2.3.4 Flavour

Effect of combinations of carrier and inlet temperature on flavor of instant juice powders is depicted in the table 45. Treatment combination of both carriers with 150°C and 160°C scored highest in flavor of cashew apple juice powder. Treatment combination of both carriers at 170 to 190°C scored lower in flavor.

Treatment combination of both carriers with 150 and 160°C scored highest in flavor of pineapple juice powder. The powder dried at higher temperature of 180 and 190°C had lower score for flavor in both carriers.

Treatment combinations of both carriers at lower temperature of 150 and 160°C received higher score for flavor of blended juice powders. Powder obtained at 170 to 190°C obtained lowest score.

4.2.3.5 Taste

The scores on the taste of instant juice powders obtained in sensory evaluation is given in the table 45. Combination of maltodextrin with 150 and 160°C and combination of resistant dextrin with 150 to 170°C received the highest score of mean ranks in taste of cashew apple juice powder. Resistant dextrin combination with 190°C and maltodextrin combinations with 180°C and 190°C scored lower in taste.

Combination of maltodextrin with inlet temperature of 150 to 160°C and resistant dextrin combination of 150 to 170°C received higher mean ranks in taste of pineapple juice powders. Resistant dextrin and maltodextrin combinations with 180°C and 190°C scored lower in taste.

Treatment combination of 150 and 160°C with both carriers received highest mean rank score in taste. Resistant dextrin combination with 190°C and maltodextrin combinations with 180°C and 190°C scored lower in taste.

Table: 45 Sensory parameters.

Carrier	Inlet temperature (°C)	Appearance			Colour			Texture		
		C	P	B	C	P	B	C	P	B
Maltodextrin (M)	150 (T_1)	6.08 (86.52)	6.12 (90.31)	6.35 (72.90)	8.23 (198.08)	6.92 (84.44)	5.46 (72.42)	4.85 (50.38)	7.73 (147.54)	7.31 (98.00)
	160 (T_2)	6.27 (88.37)	6.42(98.02)	6.12 (56.54)	7.92 (175.65)	6.92 (80.06)	5.92 (94.27)	5.15 (58.85)	7.46 (127.77)	7.42 (104.77)
	170 (T_3)	6.35 (92.92)	6.42 (98.02)	6.92 (98.58)	7.54 (147.79)	7.19 (96.58)	6.23 (106.46)	5.62 (81.44)	7.42 (119.12)	7.54 (113.37)
	180 (T_4)	6.31 (93.00)	6.85 (119.56)	7.46 (141.96)	7.00 (109.31)	8.00 (155.52)	6.77 (110.08)	6.31 (115.17)	7.50 (125.77)	7.81 (130.15)
	190 (T_5)	6.62 (108.17)	6.69 (110.37)	7.62 (153.02)	6.85 (98.75)	8.31 (179.29)	7.38 (114.37)	6.50 (124.69)	7.65 (139.44)	7.85 (131.71)
Resistant Dextrin (R)	150 (T_1)	7.23 (145.83)	6.77 (113.17)	7.81 (164.29)	7.96 (180.25)	7.23 (102.29)	6.04 (138.77)	6.96 (151.58)	7.58 (134.79)	8.00 (144.98)
	160 (T_2)	7.50 (162.29)	7.19 (141.42)	7.73 (157.67)	7.58 (152.38)	7.35 (108.46)	6.27 (139.44)	6.96 (151.58)	7.46 (124.92)	7.81 (128.60)
	170 (T_3)	7.46 (165.33)	7.50 (158.29)	7.58 (147.21)	7.00 (106.48)	7.58 (124.50)	6.77 (160.21)	7.35 (174.56)	7.62 (133.81)	7.96 (140.31)
	180 (T_4)	7.81 (176.12)	8.00 (193.38)	7.54 (150.60)	6.54 (72.79)	8.35 (181.12)	7.19 (171.52)	7.65 (190.15)	7.62 (132.88)	8.08 (149.92)
	190 (T_5)	7.65 (186.46)	7.81 (182.46)	7.65 (162.23)	6.35 (63.52)	8.50 (192.75)	7.92 (197.46)	8.00 (206.60)	7.46 (118.96)	8.23 (163.19)
K value		72.87	59.4270	70.14	99.03	82.45	62.74	126.67	3.77	19.29
CV		16.92	16.92	16.92	16.92	16.92	16.92	16.92	16.92	16.92
CD (0.05)		65.49	65.79	65.18	65.06	65.39	66.73	66.58	NS	64.45

C- Cashew apple juice powder, P – Pineapple juice powder, B – Blended juice powder. Data represents mean scores. Data in the parenthesis represents mean ranks.

Table: 45 Sensory parameters (continued).

Carrier	Inlet temperature (°C)	Flavour			Taste		
		C	P	B	C	P	B
Maltodextrin (M)	150 (T_1)	8.04 (207.04)	8.42 (197.37)	8.23 (200.94)	7.08 (180.35)	8.38 (188.31)	8.19 (206.25)
	160 (T_2)	7.50 (173.65)	8.23 (183.77)	7.58 (161.17)	6.50 (149.10)	8.12 (169.25)	7.58 (167.81)
	170 (T_3)	6.77 (119.83)	7.31 (121.40)	7.04 (124.12)	5.65 (112.19)	7.46 (126.58)	6.85 (122.85)
	180 (T_4)	6.38 (91.33)	6.96 (96.60)	6.31 (75.17)	5.12 (89.38)	6.69 (79.19)	5.92 (74.92)
	190 (T_5)	6.23 (82.88)	6.58 (77.73)	6.15 (73.88)	4.88 (79.17)	6.12 (53.00)	5.27 (44.60)
Resistant Dextrin (R)	150 (T_1)	7.54 (178.08)	8.38 (194.17)	8.08 (192.33)	7.42 (199.37)	8.54 (198.44)	8.27 (209.79)
	160 (T_2)	7.19 (152.65)	8.08 (173.08)	7.58 (160.48)	6.88 (171.92)	8.42 (190.31)	7.69 (174.85)
	170 (T_3)	6.69 (114.37)	7.35 (118.83)	7.12 (128.67)	6.12 (134.19)	7.85 (150.21)	6.88 (127.17)
	180 (T_4)	6.58 (106.15)	6.73 (79.63)	6.65 (101.87)	5.42 (101.65)	7.04 (98.23)	6.46 (103.73)
	190 (T_5)	6.23 (79.02)	6.35 (62.42)	6.38 (86.37)	5.08 (87.67)	6.12 (51.48)	5.77 (73.04)
K value		89.71	121.749	96.988	79.325	143.67	144.574
CV		16.92	16.92	16.92	16.92	16.92	16.92
CD (0.05)		65.13	65.48	65.726	66.77	65.93	66.36

C- Cashew apple juice powder, P – Pineapple juice powder, B – Blended juice powder. Data represents mean scores. Data in the parenthesis represents mean ranks.

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4.2.4 Selection of powders from part 2

The data clearly indicated that the treatment combination involving inlet temperature of 160°C possessed optimum quality in maximum parameters under investigation. Hence, the treatment combination of 160°C inlet temperature from both carriers were selected for further study for cashew apple (CM_5T_2 and CR_5T_2), pineapple (PM_5T_2 and PR_5T_2), and blended juice (BM_5T_2 and BR_5T_2), independently.

4.2.5 Sorption Behavior

Sorption behavior is a very important parameter the point towards the hygrioscopicity of powders consequently shelf life. Moreover it helps to identify the necessary packing conditions for the safe keep of the ptroduct. The sorption behavior of the selected six powders were assessed by wink's equilibrium weight method and the result is presented in tables 46, 47 and 48.

Sorption studies revealed the high hygroscopicity of cashew apple juice powders as depicted in table 46 and figure 1. The ERH and EMC at the danger point of the cashew apple juice powder produced by the combination of maltodextrin at juice solid and carrier ratio of 40: 60 dried at 160°C were 22.55 and 4.91 per cent respectively. The ERH and EMC at the critical point were 27.55 and 6.18 per cent respectively. Powder gradually changed to slightly brownish viscous fluid under higher humidity. The cashew apple juice powder produced by adding resistant dextrin at concentration of 40: 60 ratio and dried at 160°C expressed danger point at 24.7 per cent ERH and 4.6 per cent EMC. The powder reached its critical point at 29.7 per cent ERH and 6.17 per cent EMC. The powder turned to viscous fluid when exposed to humidity above 65 per cent.

The pineapple juice powders were also very hygroscopic as per the data presented in the table 47 and figure 2. The ERH and EMC at the danger point of the pineapple juice powder produced by the combination of maltodextrin at juice solid and

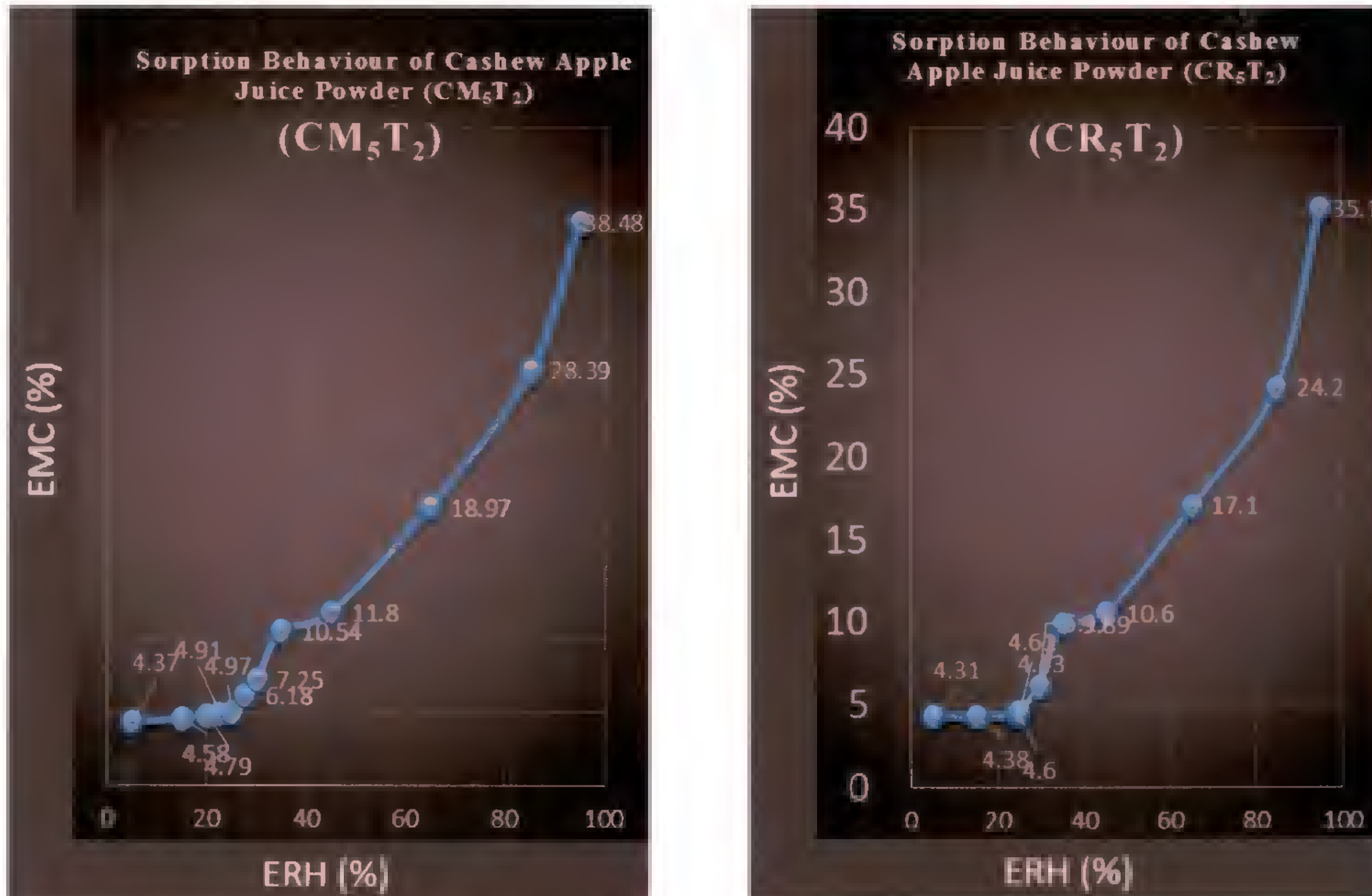


Figure 1: Sorption behavior of cashew apple juice powders

C- Cashew apple juice, M_5 – Maltodextrin@40:60 (Juice: Carrier), , R_5-Resistant dextrin@40:60 (Juice: Carrier), T_2- 160°C

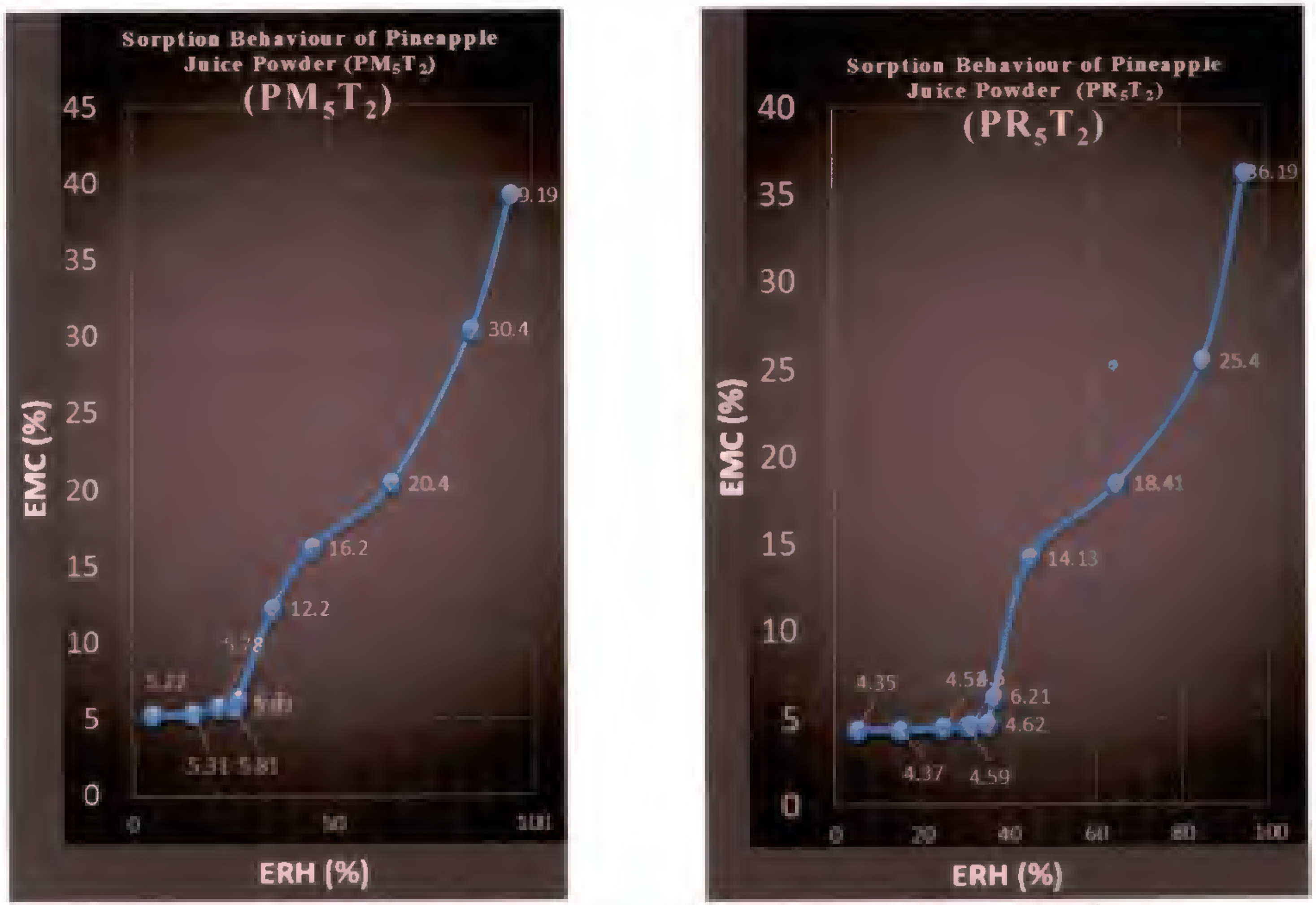
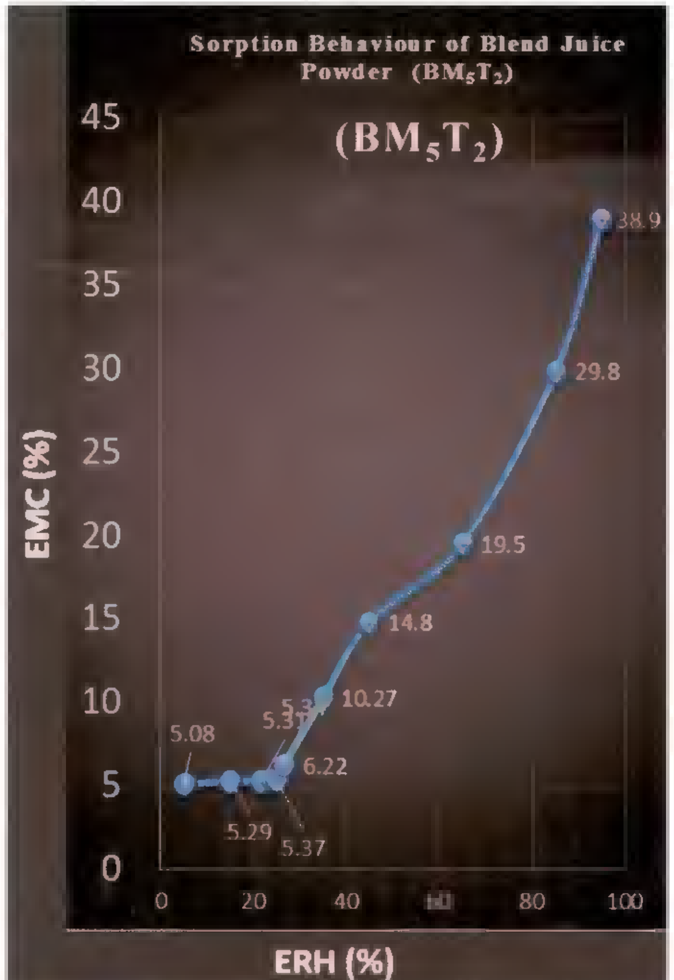


Figure 2: Sorption behavior of pineapple juice powders

P- Pineapple juice, M_5 – Maltodextrin@40:60 (Juice: Carrier), , R_5-Resistant dextrin@40:60 (Juice: Carrier), T_2- 160°C



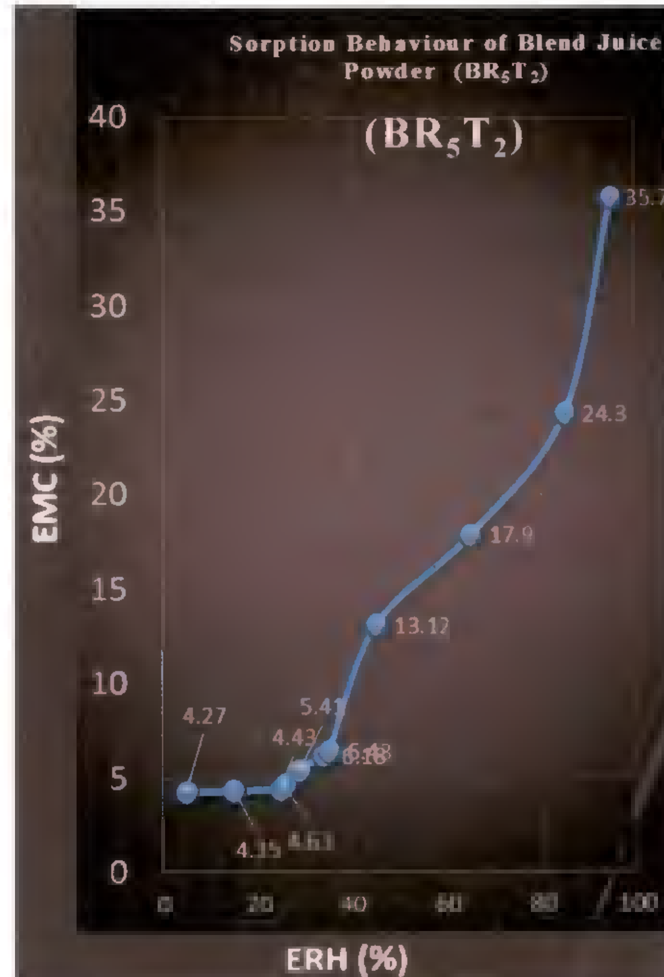


Figure 3: Sorption behavior of blended juice powders

B- Blended juice, M_5 – Maltodextrin@40:60 (Juice: Carrier), , R_5 -Resistant dextrin@40:60 (Juice: Carrier), T_2- 160°C carrier ratio of 40: 60 dried at 160°C were 21.3 and 5.78 per cent respectively. The ERH and EMC at the critical point were 26.3 and 6.3 per cent respectively.The pineapple juice powder produced by adding resistant dextrin at concentration of 40: 60 ratio and dried at 160°C expressed danger point at 31.5 per cent ERH and 4.6 per cent EMC. The powder reached its critical point at 36.5 per cent ERH and 6.21 per cent EMC.

The blended juice powders too were very hygroscopic as per the data described in table 48 and figure 3. The ERH and EMC at the danger point of the blended juice powder produced by the combination of maltodextrin at juice solid and carrier ratio of 40: 60 dried at 160°C were 21.68 and 5.31 per cent respectively. The ERH and EMC at the critical point were 26.68 and 6.22 per cent respectively.The blended juice powder produced by adding resistant dextrin at concentration of 40: 60 ratio and dried at 160°C expressed danger point at 25.81 per cent ERH and 4.63 per cent EMC. The powder reached its critical point at 33.8 per cent ERH and 6.18 per cent EMC.

4.2.6 Glass Transition Temperature

Glass transition temperature is one of the most important parameters of a dried product especially spray dried product. Above the glass transition temperature, the product is in the rubbery state (capable of flow in real time) and below glass transition temperature, the system is in the glassy state. Hence many physical properties of a powder is dependent on glass transition temperature. One of the most used methods for detection is differential scanning calorimetry which is based on the measurement of the increase in specific heat of the material as it passes from the glassy to the rubbery state. The glass transition temperature of the selected six powders were analysed by differential scanning calorimetry and the results are presented as figure 4 to figure 6.

Table: 46 Sorption behaviour of cashew apple juice powder

CM_5T_2			CR_5T_2		
ERH (%)	EMC (%)	Remarks	ERH (%)	EMC (%)	Remarks
5	4.37	Free flowing powder	5	4.31	Free flowing powder
15	4.58	Free flowing powder	15	4.38	Free flowing powder
20.13	4.79	Initial point	24.5	4.43	Initial point
22.55	4.91	Danger point	24.7	4.6	Danger point
25	4.97	Free flowing powder	25	4.61	Free flowing powder
27.55	6.18	Critical point	29.7	6.17	Critical point
35	10.54	Caked, Sticky, Slight brown	35	9.89	Caked, Sticky, Slightly brown
45	11.8	Watery lumps, Slight brown	45	10.6	Watery lumps, Slight brown
65	18.97	Slightly viscous, Slight brown	65	17.1	Slightly viscous, Slightly brown
85	28.39	Viscous paste, Slight brown	85	24.2	Viscous paste, Slight brown
95	38.48	Viscous fluid, Slight brown	95	35.1	Viscous fluid, Slight brown

C- Cashew apple juice, M_5- Maltodextrin at 40: 60 juice solid to carrier ratio, T_2- 160°C Inlet temperature, R_5- Resistant dextrin at 40: 60 juice solid to carrier ratio,

Table: 47 Sorption behaviour of pineapple juice powder

PM_5T_2			PR_5T_2		
ERH (%)	EMC (%)	Remarks	ERH (%)	EMC (%)	Remarks
5	5.22	Free flowing Powder	5	4.35	Free flowing powder
15	5.31	Free flowing powder	15	4.37	Free flowing powder
21.3	5.78	Danger point	25	4.52	Free flowing powder
25	5.81	Free flowing powder	30.3	4.59	Initial point
25.8	5.82	Initial point	31.5	4.6	Danger point
26.3	6.3	Critical point	35	4.62	Free flowing powder
35	12.2	Caked, Sticky, Slight brown	36.5	6.21	Critical point
45	16.2	Watery lumps, Slight brown	45	14.13	Caked Slight Brown
65	20.4	Slightly viscous, Slight brown	65	18.41	Slightly viscous, Slight brown
85	30.4	Viscous paste, Slight brown	85	25.4	Viscous paste, Slight brown
95	39.19	Viscous fluid, Slight brown	95	36.19	Viscous fluid, Slight brown

P- Pineapple juice, M_5- Maltodextrin at 40: 60 juice solid to carrier ratio, T_2- 160°C Inlet temperature R_5- Resistant dextrin at 40: 60 juice solid to carrier ratio,

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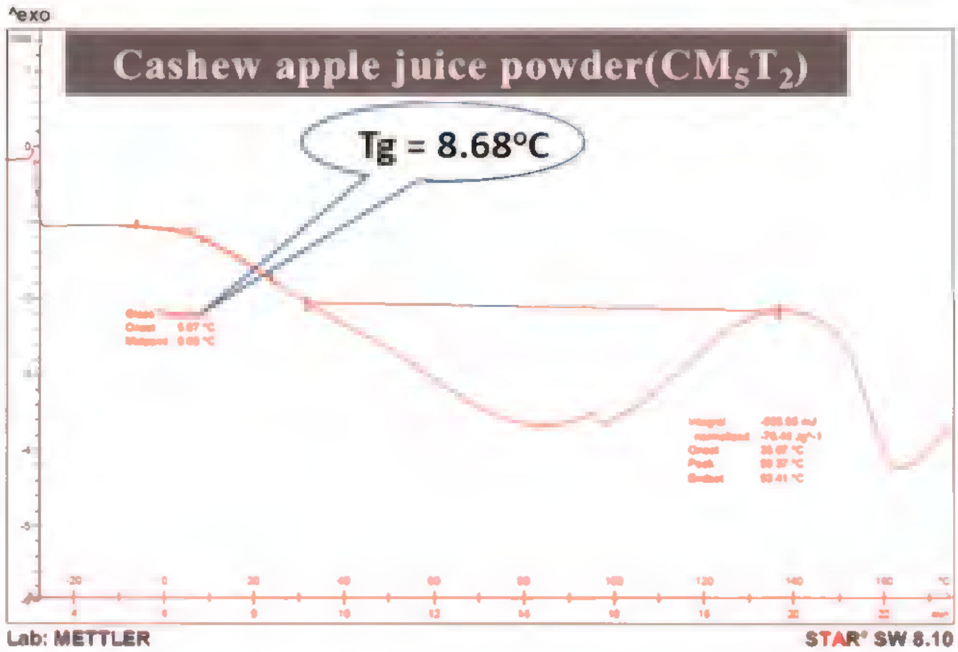
Table: 48 Sorption behaviour of blended juice powder

BM_5T_2			BR_5T_2		
ERH (%)	EMC (%)	Remarks	ERH (%)	EMC (%)	Remarks
5	5.08	Free flowing powder	5	4.27	Free flowing powder
15	5.29	Free flowing powder	15	4.35	Free flowing powder
21.68	5.31	Danger point	25	4.43	Free flowing powder
24.1	5.34	Initial point	25.81	4.63	Initial point
25	5.37	Free flowing powder	28.8	5.41	Danger point
26.68	6.22	Critical point	33.8	6.18	Critical point
35	10.27	Caked Sticky, Slightly brown	35	6.43	Caked, sticky slight brown
45	14.8	Lumps, Slight brown	45	13.12	Lumps, Slight brown
65	19.5	Slightly viscous, Slight brown	65	17.9	Slightly viscous Slightly brown
85	29.8	Viscous paste., Slight brown	85	24.3	Viscous paste, Slight brown
95	38.9	Viscous fluid, Slight brown	95	35.7	Viscous fluid, Slight brown

B- Blended juice, M_5- Maltodextrin at 40: 60 juice solid to carrier ratio, T_2- 160°C Inlet temperature, R_5- Resistant dextrin at 40: 60 juice solid to carrier ratio,



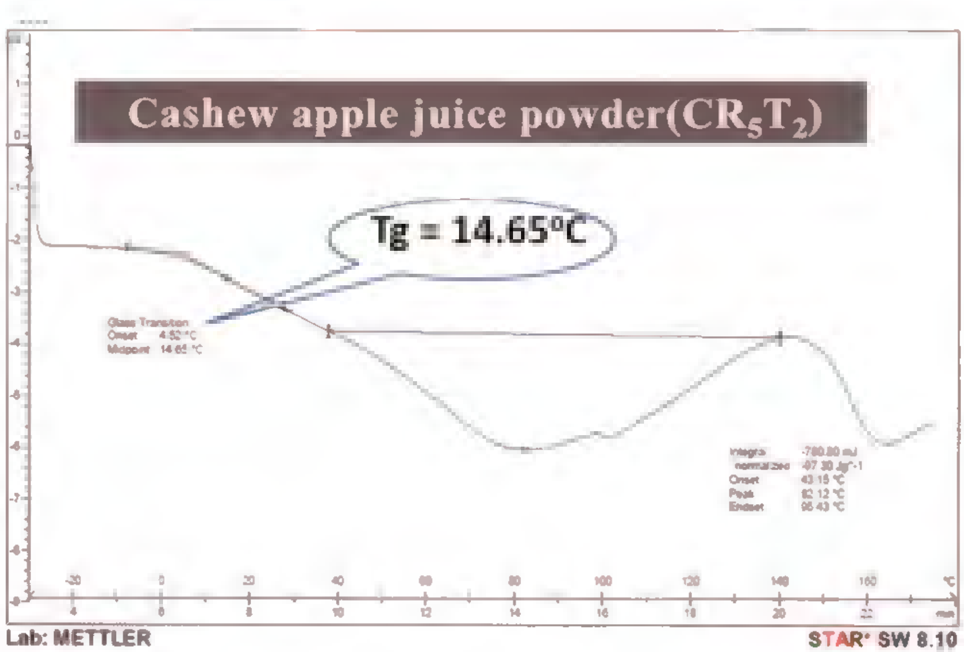
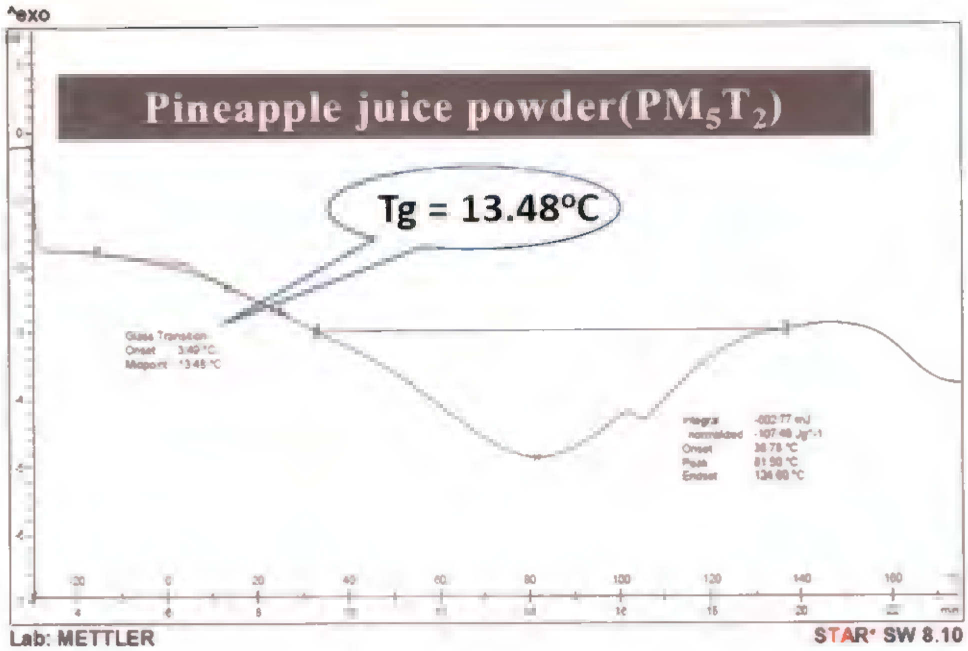


Figure 4: Glass transition temperature of cashew apple juice powders

C- Cashew apple juice, M_5 – Maltodextrin@40:60 (Juice: Carrier),, R_5-Resistant dextrin@40:60 (Juice: Carrier), T_2- 160°C



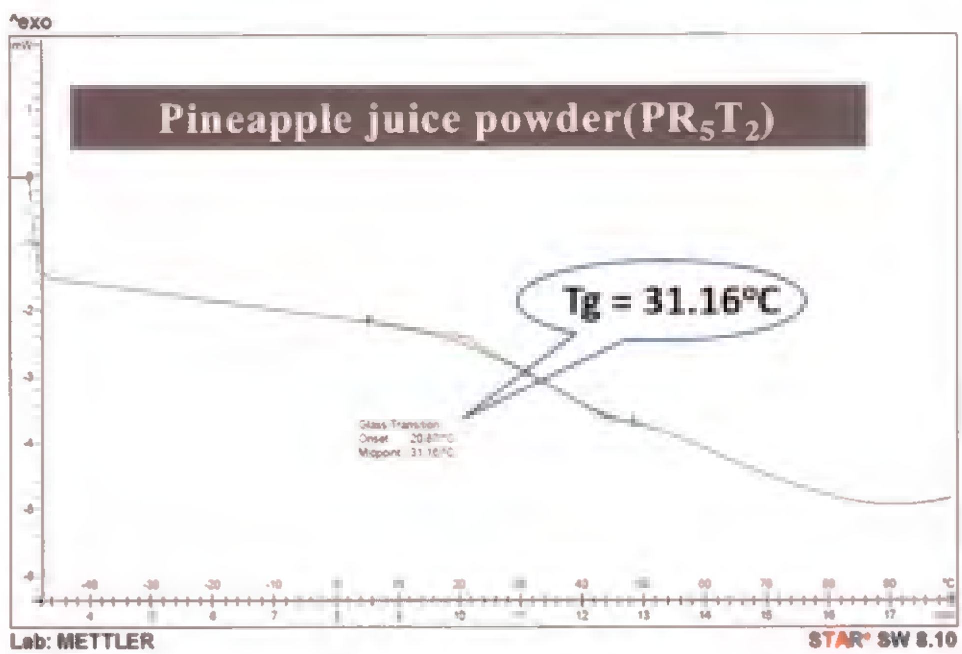
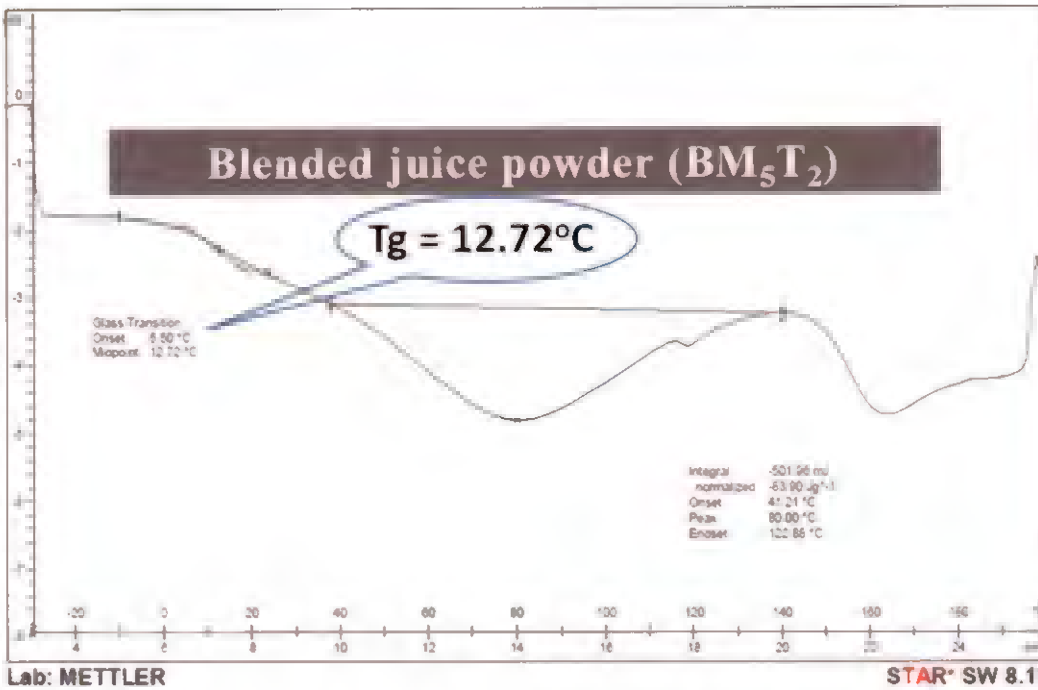


Figure 5: Glass transition temperature of pineapple juice powders

P- Pineapple juice, M_5 – Maltodextrin@40:60 (Juice: Carrier), ,
R_5 -Resistant dextrin@40:60 (Juice: Carrier), T_2- 160°C



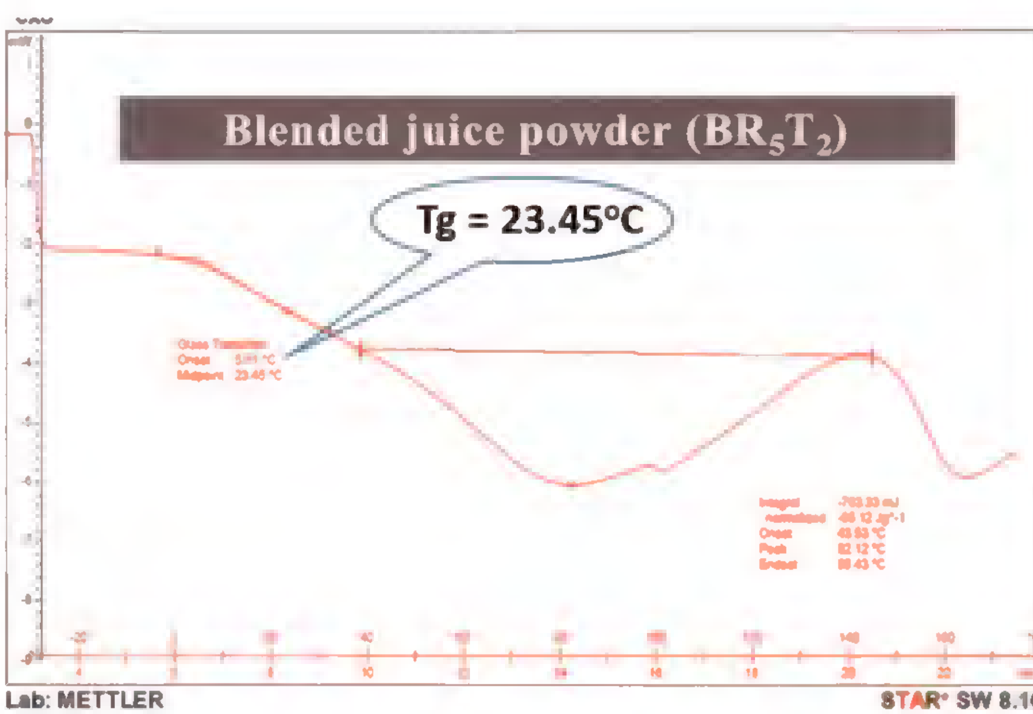


Figure 6: Glass transition temperature of blended juice powders

B- Blended juice, M_5 – Maltodextrin@40:60 (Juice: Carrier), R_5 -Resistant dextrin@40:60 (Juice: Carrier), T_2- 160°C

The glass transition of the cashew apple juice powder (Figure 4) produced by the combination of maltodextrin at juice solid and carrier ratio of 40: 60 dried at 160°C is presented as figure 7. This powder exhibited glass transition and the midpoint temperature was 8.68°C. The cashew apple juice powder from the same treatment combination with resistant dextrin exhibited glass transition temperature of 14.65 °C as presented in figure 8.

The glass transition of pineapple powder (Figure5) produced by the combination of maltodextrin at juice solid and carrier ratio of 40: 60 dried at 160°C is presented in figure 9. This powder exhibited glass transition with midpoint temperature of 13.48°C. The pineapple juice powder from the same treatment combination with resistant dextrin exhibited glass transition temperature of 31.16°C as presented in figure 10.

The glass transition of the blended juice powder (Figure 6)produced by the combination of maltodextrin at juice solid and carrier ratio of 40: 60 dried at 160°C is presented in figure 11, This powder exhibited glass transition with midpoint temperature of 12.72°C. The blended juice powder from the same treatment combination with resistant dextrin exhibited glass transition temperature of 23.45°C as depicted in figure 12.

4.2.7 Microstructure

The micro structural characteristics such as morphology of powder is a very important parameter that governs physical properties of powders. The morphology of the six selected powders were assessed by scanning electron miscoscopy and presented in six plates (Plate 18 to Plate 23).

The powder particles showed a spherical shape and various sizes with no apparent cracks, puffing pores or fissures. The average particle size of powders ranges from 3 to 30 µm. The powder produced with maltodextrin had smaller but

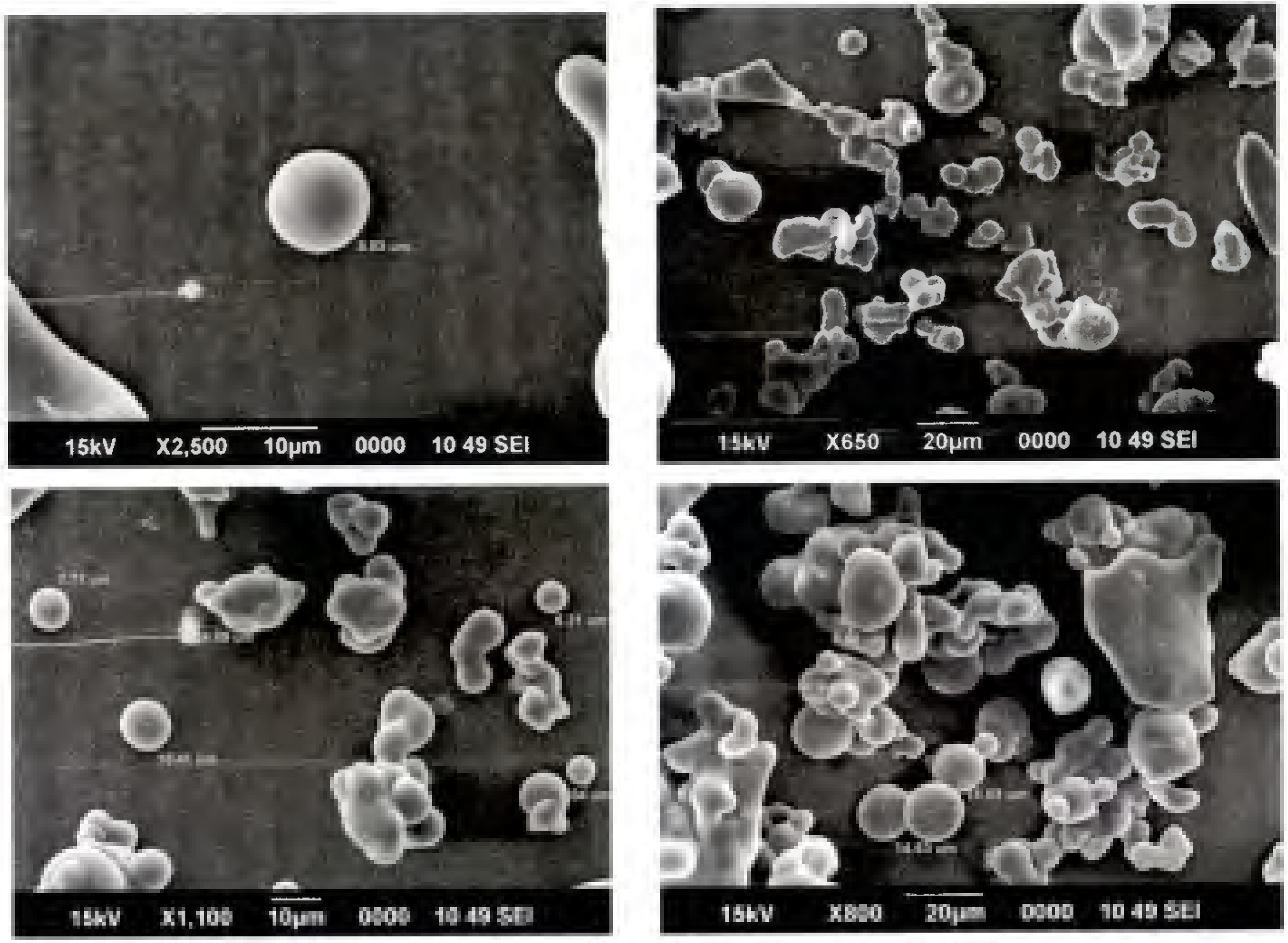


Plate: 18 Microstructure of cashew apple juice powder formulated with maltodextrin (CM_5T_2)

C- Cashew apple juice, M_5 – Maltodextrin@40:60 (Juice: Carrier), T_2- 160ºC.

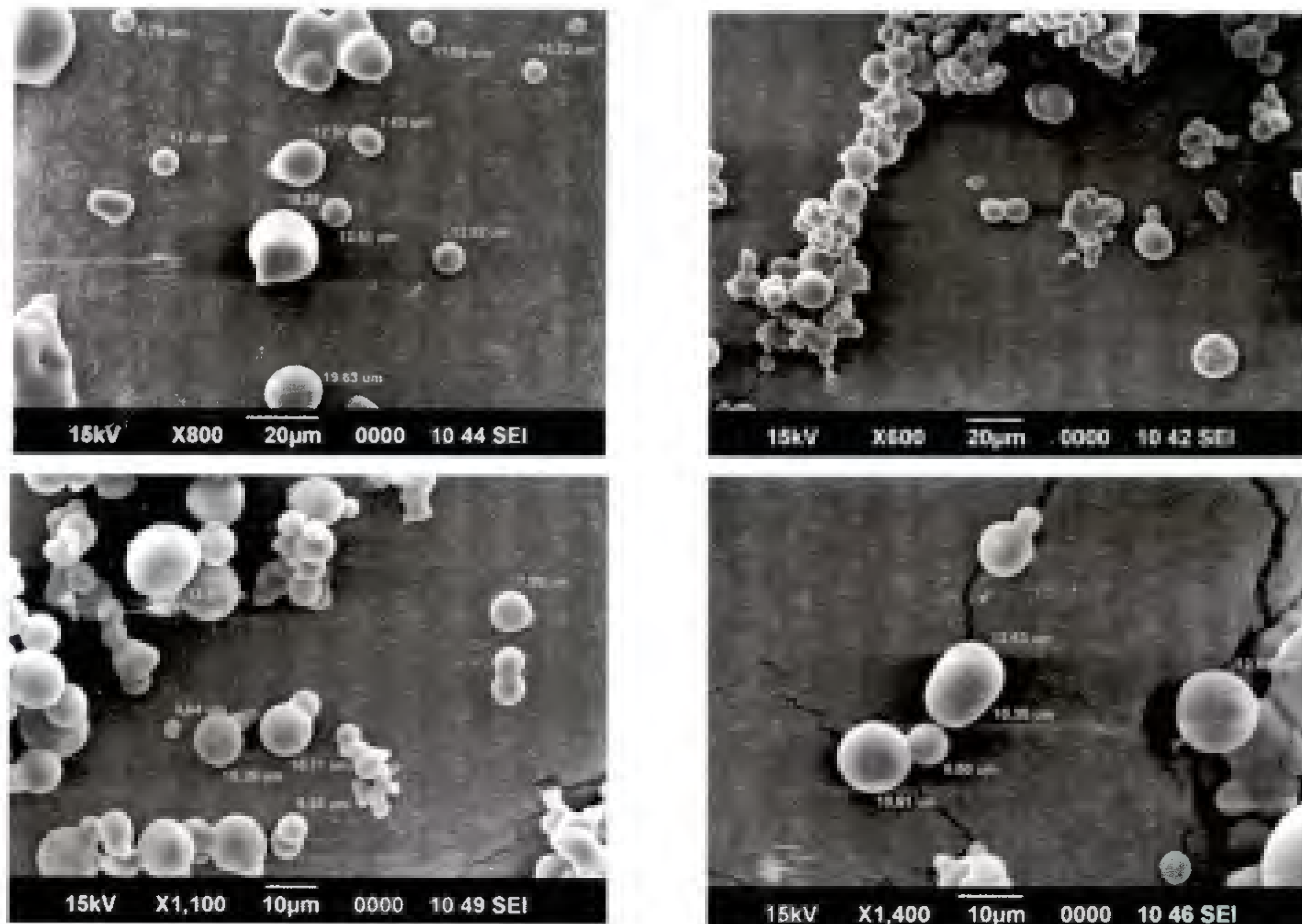


Plate: 19 Microstructure of cashew apple juice powder formulated with resistant dextrin (CR_5T_2)

C- Cashew apple juice, R_5 -Resistant dextrin@40:60 (Juice: Carrier), T_2- 160°C

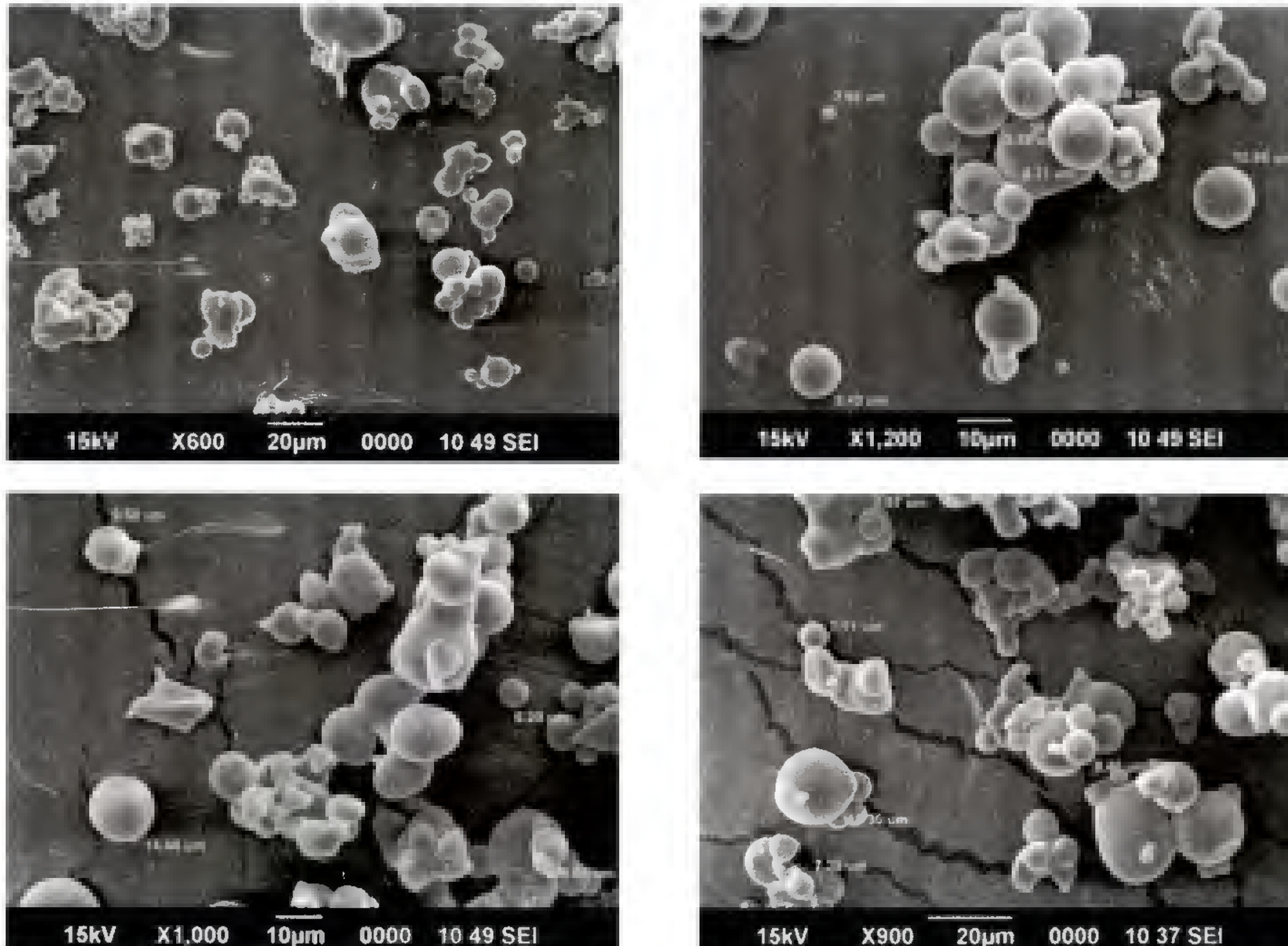


Plate 20: Microstructure of pineapple juice powder formulated with maltodextrin (PM_5T_2)

P- Pineapple juice, M_5 – Maltodextrin@40:60 (Juice: Carrier), T_2- 160°C.

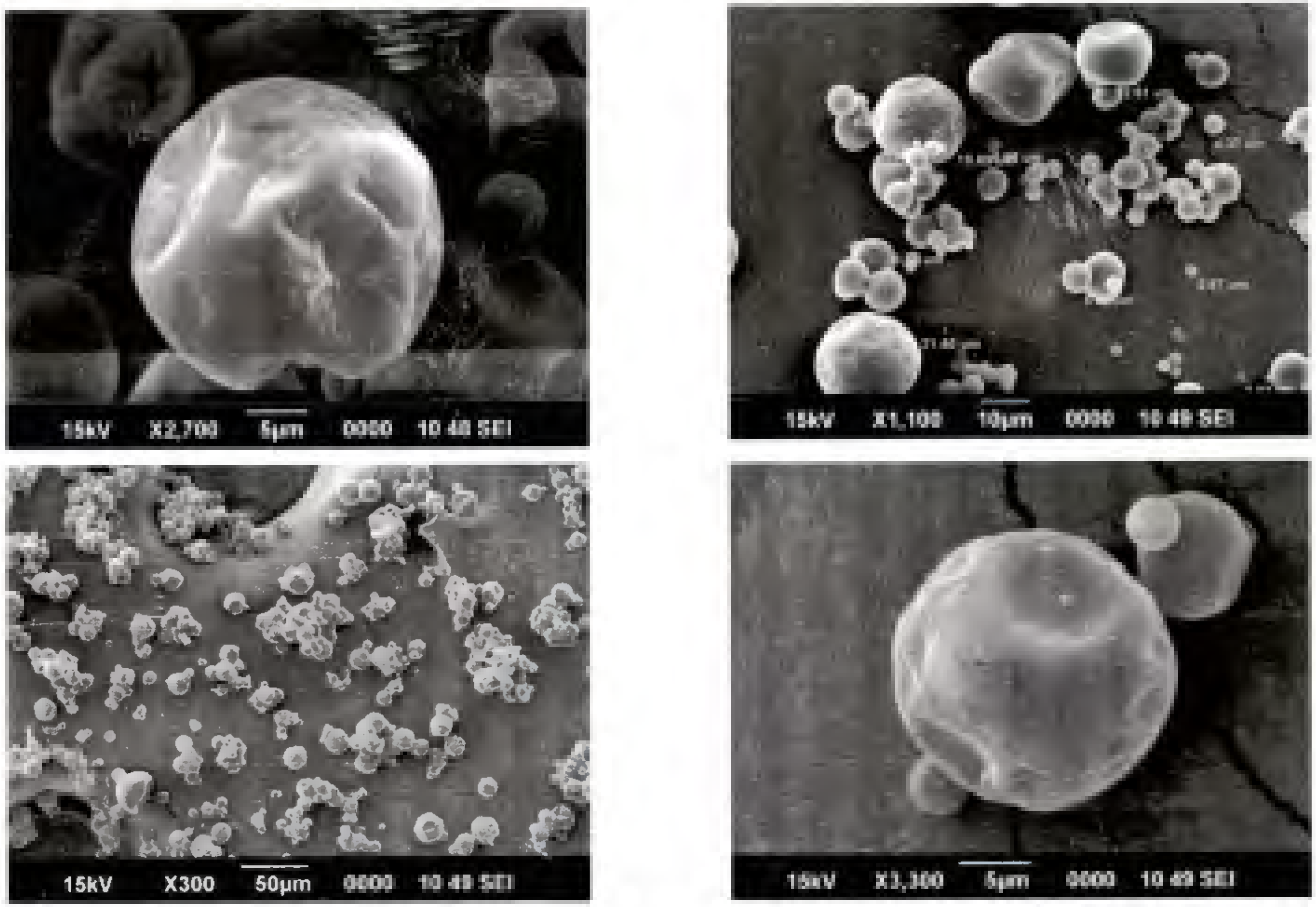


Plate 21: Microstructure of pineapple juice powder formulated with resistant dextrin (PR_5T_2)

P- Pineapple juice, R_5 -Resistant dextrin@40:60 (Juice: Carrier), T_2- 160°C

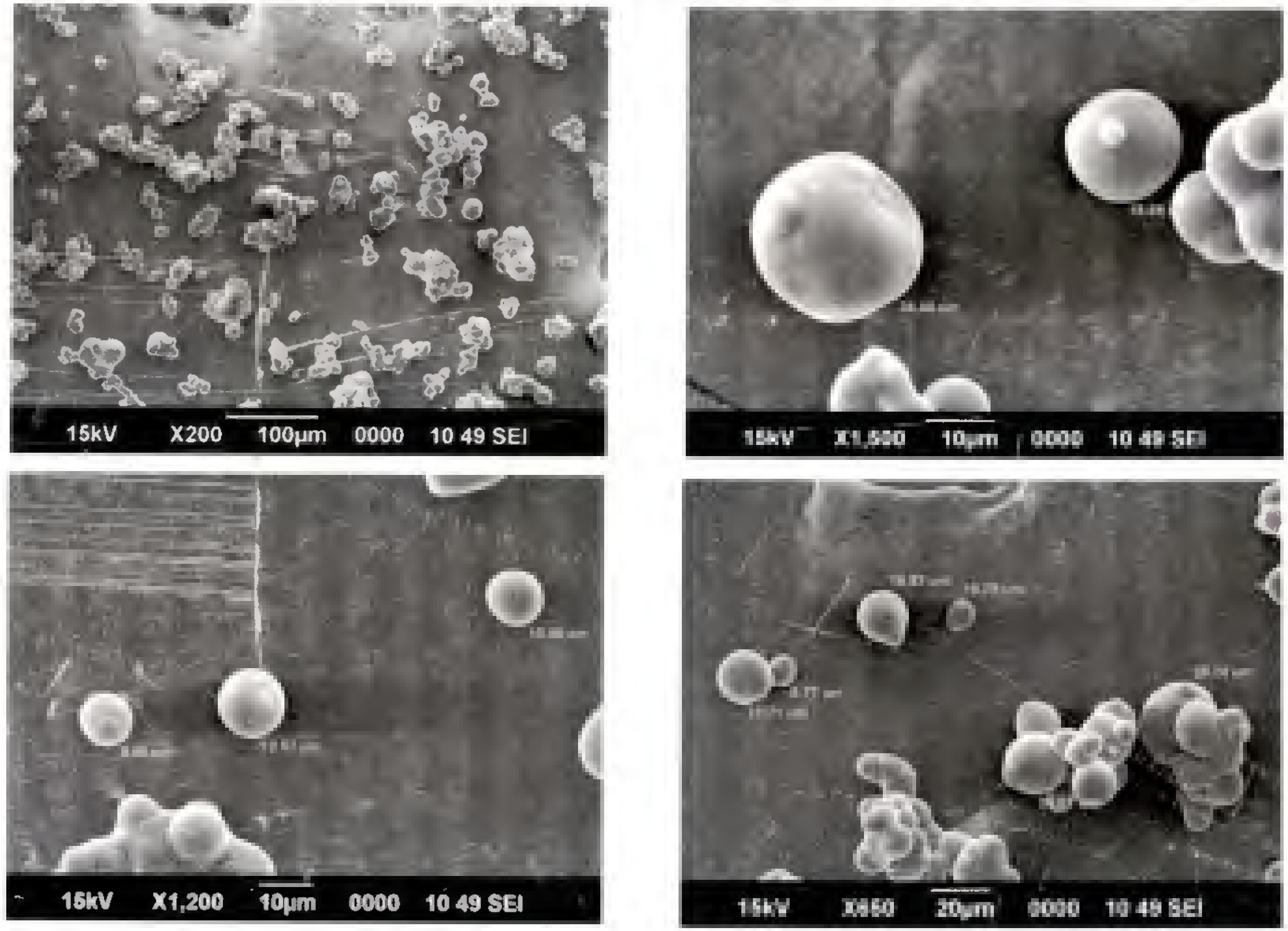


Plate 22: Microstructure of blended juice powder formulated with maltodextrin (BM_5T_2)

B- Blended juice, M_5 – Maltodextrin@40:60 (Juice: Carrier), T_2- 160°C

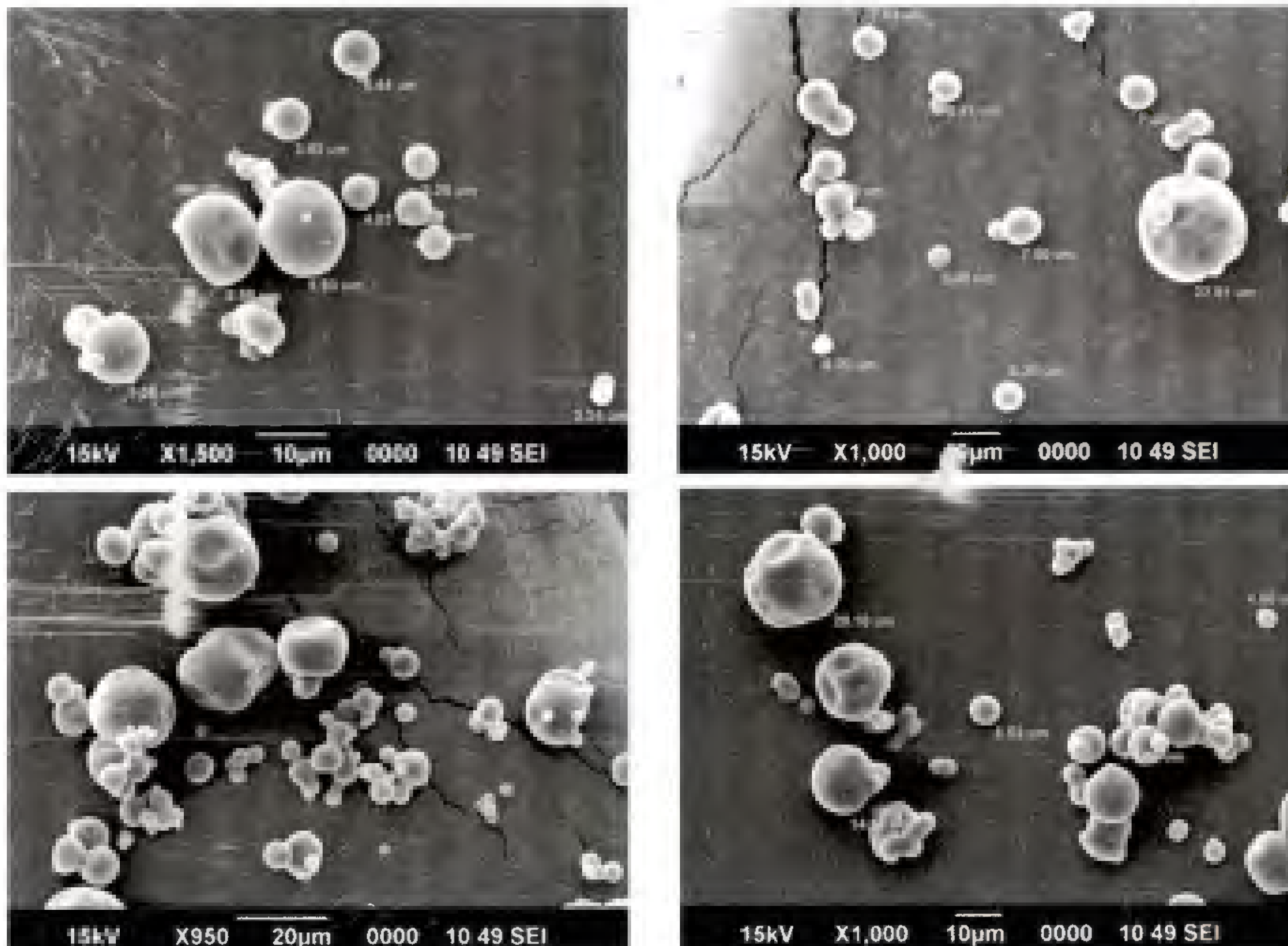


Plate 23: Microstructure of blended juice powder formulated with resistant dextrin (BR_5T_2)

B- Blended juice, R_5 -Resistant dextrin@40:60 (Juice: Carrier), T_2- 160°C smoother regular spherical particle without much surface dents or collapsed walls. However, the powder appeared more agglomerated. Powder particles that formed by the addition of resistant dextrin contained more number of discrete larger ones with irregular spherical shape and occasional surface dents and shrinkages. Surface dents were more prevalent in larger particles.

4.3 STORAGE STABILITY OF PURE AND BLENDED FRUIT JUICE POWDERS.

The six instant juice powders selected from part two of the experiment were subjected to the following four packaging and storage conditions with bimonthly observations for six months. The four packaging atmospheres under investigation were modified atmospheric packaging under vacuum, modified atmospheric packaging with nitrogen, conventional (Air) packing and conventional packing with refrigerated storage. The thrice replicated data were analysed in three factor completely randomized design with storage period (2nd month, 4th month and 6th month) as a split plot on two main plots ie. carrier and packaging atmospheres for cashew apple, pineapple and blended juice independently and the result is presented in this section. Based on the result. six powders with best storage stability and nutrient retention were selected and subjected to computation of cost of production and assessment of consumer acceptability.

4.3.1 Moisture

Carriers, and all interaction involving carriers were non-significant in influencing the moisture content all instant juice powders during storage as presented in table 49, 52, 53 and 55.

4.3.1.1Effect of Packaging Atmospheres on Moisture

The effect of storage atmosphere on moisture content of cashew apple powders during storage is presented in the table 50. The powder under refrigerated storage had least moisture content (5.15 per cent) followed by vacuum packed powder (6.77 per cent). Highest moisture content had been noted for powder packed ordinary with air and kept in ambient temperature (8.01 per cent).

The pineapple juice powder under refrigerated storage had least moisture content (5.88 per cent) followed by powder packed under vacuum (7.78 per cent). Highest moisture content has been noted in the ordinary packed pouch kept in ambient temperature (8.64 per cent) and powder packed under nitrogen (8.42per cent).

The blended juice powder under refrigerated storage had least moisture content (5.54 per cent) followed by powder packed under vacuum (7.23 per cent). Highest moisture content has been noted for powder packed ordinary with air and kept in ambient temperature (8.33 per cent) and powder packed under nitrogen (8.28 per cent).

4.3.1.2 Effect of Storage Period on Moisture

The effect of storage period on moisture content of powders during storage is presented in the table 51.The moisture content of cashew apple juice powder increased as the storage period advanced. The moisture content was 6.50 per cent at second month of storage which elevated to 7.45 per cent till sixth month. The moisture content of pineapple juice powder also increased as the storage period advanced The moisture content was 7.20 per cent at second month of storage which elevated to 7.98 per cent till sixth month. The moisture content of blended juice powder increased as the storage period. The moisture content was 6.8 per cent at second month of storage which again increased to 7.8 per cent by the end of sixth month.

4.3.1.3 Interaction effect of Packaging Atmospheres with Storage Period on Moisture

Interaction effect of packaging atmospheres with storage period is presented in the table 54. Cashew apple juice powder under refrigerated storage had lower moisture content during all the storage period in comparison to other packaging atmospheres.

Table : 49 Effect of carriers on the moisture, total phenol content and pH under storage

Carrier	Moisture (%)			Total phenol (%)			pH		
	C	P	B	C	P	B	C	P	B
Maltodextrin (M)	7.08	7.74	7.36	0.45	0.08	0.25	4.11	4.10	4.13
Resistant dextrin (R)	7.00	7.62	7.33	0.44	0.07	0.24	4.10	4.07	4.12
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

C- Cashew apple juice powder, P – Pineapple juice powder, B – Blended juice powder.

Table : 50 Effect of packaging atmospheres on the moisture, total phenol content and pH under storage

Packing atmospheres	Moisture (%)			Total phenol (%)			pH		
	C	P	B	C	P	B	C	P	B
Vacuum (V)	6.77	7.78	7.23	0.46	0.08	0.24	4.16	4.16	4.15
Nitrogen (N)	8.23	8.42	8.28	0.44	0.07	0.25	4.12	4.10	4.14
Air –Refrigeration (L)	5.15	5.88	5.54	0.49	0.08	0.28	4.09	4.07	4.12
Air – Ambient (A)	8.01	8.64	8.33	0.39	0.07	0.21	4.04	4.02	4.10
CD (0.05)	0.232	0.341	0.302	0.057	0.015	0.038	NS	NS	NS

C- Cashew apple juice powder, P – Pineapple juice powder, B – Blended juice powder.

Table :51 Effect of storage period on the moisture, total phenol content and pH of powders under storage

Storage period	Moisture (%)			Total phenol (%)			pH		
	C	P	B	C	P	B	C	P	B
2nd month (S_2)	6.50	7.20	6.80	0.48	0.09	0.27	4.14	4.14	4.15
4th month (S_4)	7.17	7.85	7.49	0.45	0.07	0.24	4.09	4.06	4.12
6th month (S_6)	7.45	7.98	7.76	0.42	0.06	0.23	4.09	4.06	4.12
CD (0.05)	0.10	0.15	0.11	0.01	0.01	0.02	NS	NS	NS

C- Cashew apple juice powder, P – Pineapple juice powder, B – Blended juice powder.

Table : 52 Effect of interaction of carriers with packaging atmospheres on the moisture, total phenol content and pH under storage

Carriers	Packaging atmospheres	Moisture (%)			Total phenol (%)			pH		
		C	P	B	C	P	B	C	P	B
Maltodextrin (M)	Vacuum (V)	6.88	7.80	7.28	0.47	0.08	0.25	4.17	4.19	4.15
	Nitrogen (N)	8.27	8.37	8.21	0.44	0.07	0.26	4.13	4.07	4.14
	Air – Refrigeration (L)	5.20	6.04	5.55	0.51	0.09	0.30	4.09	4.10	4.12
	Air – Ambient (A)	7.98	8.75	8.42	0.38	0.07	0.22	4.04	4.05	4.11
Resistant Dextrin (R)	Vacuum (V)	6.67	7.76	7.19	0.45	0.07	0.24	4.16	4.14	4.15
	Nitrogen (N)	8.19	8.47	8.36	0.44	0.07	0.24	4.11	4.12	4.13
	Air – Refrigeration (L)	5.11	5.71	5.53	0.47	0.08	0.27	4.09	4.03	4.12
	Air – Ambient (A)	8.04	8.53	8.25	0.40	0.06	0.20	4.04	3.99	4.10
CD (0.05)		NS	NS	NS	NS	NS	NS	NS	NS	NS

C- Cashew apple juice powder, P – Pineapple juice powder, B – Blended juice powder.

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Table : 53 Effect of interaction of carriers and storage period on the moisture, total phenol content and pH under storage

Carriers	Storage period	Moisture (%)			Total phenol (%)			pH		
		C	P	B	C	P	B	C	P	B
Maltodextrin (M)	2nd month (S_1)	6.56	7.32	6.90	0.48	0.10	0.28	4.15	4.16	4.15
	4th month (S_2)	7.21	7.88	7.48	0.46	0.07	0.25	4.09	4.08	4.12
	6th month (S_3)	7.47	8.02	7.71	0.42	0.06	0.23	4.09	4.08	4.12
Resistant Dextrin (R)	2nd month (S_1)	6.44	7.09	6.70	0.47	0.09	0.26	4.13	4.12	4.14
	4th month (S_2)	7.14	7.82	7.50	0.44	0.06	0.23	4.08	4.05	4.11
	6th month (S_3)	7.43	7.94	7.80	0.41	0.05	0.22	4.08	4.05	4.11
CD (0.05)		NS	NS	NS	NS	NS	NS	NS	NS	NS

C- Cashew apple juice powder, P – Pineapple juice powder, B – Blended juice powder

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Table : 54 Effect of interaction of packaging atmospheres and storage period on moisture, the total phenol content and pH of powders under storage

Packaging atmospheres	Storage period	Moisture (%)			Total phenol (%)			pH		
		C	P	B	C	P	B	C	P	B
Vacuum (V)	2nd month (S_1)	6.35	7.33	6.79	0.49	0.09	0.27	4.18	4.19	4.15
	4th month (S_2)	6.95	7.99	7.37	0.46	0.07	0.24	4.16	4.15	4.15
	6th month (S_3)	7.02	8.03	7.54	0.44	0.07	0.23	4.16	4.15	4.15
Nitrogen (N)	2nd month (S_1)	7.39	7.80	7.54	0.47	0.09	0.28	4.16	4.15	4.16
	4th month (S_2)	8.42	8.59	8.50	0.44	0.06	0.23	4.10	4.07	4.13
	6th month (S_3)	8.87	8.88	8.81	0.41	0.06	0.24	4.10	4.07	4.13
Air – Refrigeration (L)	2nd month (S_1)	5.01	5.75	5.35	0.52	0.11	0.31	4.19	4.18	4.17
	4th month (S_2)	5.17	5.92	5.56	0.49	0.07	0.28	4.17	4.13	4.15
	6th month (S_3)	5.29	5.96	5.71	0.47	0.06	0.26	3.92	3.90	4.04
Air – Ambient (A)	2nd month (S_1)	7.26	7.94	7.51	0.43	0.08	0.22	4.03	4.03	4.12
	4th month (S_2)	8.16	8.91	8.53	0.40	0.06	0.21	3.92	3.90	4.04
	6th month (S_3)	8.62	9.07	8.96	0.35	0.05	0.19	4.17	4.13	4.15
CD (0.05)		0.207	0.297	0.213	NS	NS	NS	NS	NS	NS

C- Cashew apple juice powder, P – Pineapple juice powder, B – Blended juice powder.

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Table : 55 Effect of interaction of carriers and packaging atmospheres with storage period on moisture, the total phenol and pH of powders under storage

Carriers	Packaging atmospheres	Storage period	Moisture (%)			Total phenol (%)			pH		
			C	P	B	C	P	B	C	P	B
Maltodextrin (M)	Vacuum (V)	2nd month (S_1)	6.48	7.42	6.91	0.49	0.09	0.27	4.19	4.22	4.16
		4th month (S_2)	7.04	7.98	7.45	0.47	0.07	0.24	4.16	4.17	4.15
		6th month (S_3)	7.12	8.01	7.48	0.45	0.07	0.23	4.16	4.17	4.15
	Nitrogen (N)	2nd month (S_1)	7.42	7.82	7.50	0.48	0.09	0.29	4.18	4.14	4.16
		4th month (S_2)	8.48	8.50	8.40	0.44	0.07	0.25	4.11	4.04	4.14
		6th month (S_3)	8.91	8.79	8.71	0.41	0.06	0.23	4.11	4.04	4.14
	Air – Refrigeration (L)	2nd month (S_1)	5.09	5.97	5.48	0.53	0.12	0.32	4.19	4.20	4.17
		4th month (S_2)	5.20	6.05	5.56	0.51	0.08	0.29	4.17	4.13	4.15
		6th month (S_3)	5.31	6.10	5.61	0.49	0.07	0.27	3.93	3.96	4.05
	Air – Ambient (A)	2nd month (S_1)	7.27	8.06	7.69	0.43	0.08	0.22	4.03	4.05	4.13
		4th month (S_2)	8.13	9.00	8.52	0.39	0.07	0.22	3.93	3.96	4.05
		6th month (S_3)	8.55	9.20	9.04	0.33	0.06	0.20	4.17	4.13	4.15

C- Cashew apple juice powder, P – Pineapple juice powder, B – Blended juice powder.

Moisture ingestion between second and fourth month as well as fourth and sixth month is non-significant in refrigerated storage.

Powders of pineapple juice powders under refrigerated storage had lower moisture contents in all the storage period in comparison to other packaging atmospheres. Moisture ingestion between second and sixth month of storage is non-significant in refrigerated storage.

Refrigerated storage of blended juice powder resulted lower moisture content during entire storage period in comparison to other packaging atmospheres. Moisture ingestion between second and fourth month as well as fourth and sixth month is non-significant in refrigerated storage (Table 54).

4.3.2 Total Phenol

Carriers, and all interaction effects were non-significant in influencing the total phenol of all instant juice powders during storage as presented in table 49, 52, 53 54 and 55. Effect of packing atmospheres and effect of storage period were significant as depicted in table 50 and 51.

4.3.2.1Effect of Packaging Atmospheres on Total Phenol

The effect of storage atmosphere on total phenol of powders during storage is presented in the table 50.

The cashew apple juice powder under refrigerated storage had highest phenol content (0.49 per cent) which was on par with powder packed under powder packed under vacuum and under nitrogen (0.44 per cent). Lowest phenol content has been noted for powder packed ordinary with air and stored in ambient temperature (0.39 per cent).

The pineapple juice powder under refrigerated storage had highest phenol content (0.08 per cent) which was on par with powder packed under vacuum (0.08 per cent) and under nitrogen (0.07 per cent). Lowest phenol content has been noted in the normal (conventional) package under ambient temperature (0.067 per cent).

Blended juice powder under refrigerated storage retained highest phenol content (0.28 per cent) which was on par with powder packed under vacuum (0.24 per cent) and under nitrogen (0.25 per cent). Lowest phenol content has been noted in the normal (conventional) pouch under ambient temperature (0.21 per cent).

4.3.2.2 Effect of Storage Period on Total Phenol

The effect of storage period on total phenol of powders during storage is presented in the table 51.

The phenol content of cashew apple juice powder was inversely proportional to the storage period. Phenol content was reduced to 0.477 per cent at second month of storage from the initial content (phenol content before storage) of 0.605 which further reduced to 0.45 per cent at fourth month and to 0.42 per cent at sixth month.

The phenol content of pineapple juice powder was reduced as the storage period advanced. Phenol content was reduced to 0.09 per cent at second month of storage from the initial content (phenol content before storage) of 0.13 which further reduced to 0.07 per cent at fourth month and to 0.06 per cent at sixth month.

Phenol content of blended juice powder was reduced to 0.27 per cent at second month of storage from the initial content of 0.33 which further reduced to 0.24 per cent at fourth month and to 0.23 per cent at sixth month (Table 51).

4.3.3 pH

None of the treatment combinations significantly influenced pH of powders during the entire six month storage in all fruit juice powders as presented in table 49, 50, 51,52, 53, 54 and 55.

4.3.4 Titrable Acidity

Carriers, and all interaction effects were non-significant in influencing the titrable acidity of all instant juice powders during storage as presented in table 56, 59, 60 61 and 62. Effect of packing atmospheres and effect of storage period were significant as depicted in table 57 and 58.

4.3.4.1Effect of Packaging Atmospheres on Titrable Acidity

The effect of storage atmosphere on titrable acidity of powders during storage is presented in the table 56. Cashew apple powder under refrigerated storage maintained titrable acidity (0.97 per cent) than other packaging atmospheres. Powders kept in atmospheres other than refrigeration had similar but higher acidity among them which ranged from 1.07 to 1.13 per cent.

The pineapple juice powder under refrigerated storage had least titrable acidity (1.42 per cent) which was on par with vacuum packaged powder. Nitrogen packaging and conventional package under ambient storage were on par and had higher acidity which ranged from 1.52 to1.56 per cent.

The blended juice powder under refrigerated storage had least titrable acidity (1.10 per cent) followed by powder packed under powder packed under vacuum (1.17 per cent). Nitrogen packaging and conventional package stored under ambient temperature were on par and had higher acidity of 1.24 and 1.25 per cent respectively.

4.3.4.2 Effect of Storage Period on Titrable Acidity

The effect of storage period on titrable acidity of powders during storage is presented in the table 57. The titrable acidity of cashew apple powder was directly proportional to the storage period. Titrable acidity was 1.04 per cent during second month of storage which elevated to 1.07 per cent at fourth month. There was no significant difference in titrable acidity between fourth and sixth month.

The titrable acidity of pineapple powder was directly proportional to the storage period. Titrable acidity increased to 1.472 per cent at second month of storage which again elevated to 1.185 per cent at fourth month. There was no significant difference between acidity of powders in fourth and sixth month.

Titrable acidity of blended juice powder was recorded as 1.15 per cent at second month of storage which elevated to 1.19 per cent at fourth month and 1.23 per cent at sixth month.

4.3.5 Microbial Count

The microbial load of all treatment combinations were observed at bimonthly intervals by pour plating reconstituted solution of 10^{-3} dilution and without dilution in potato dextrose agar and nutrient agar media. The results revealed no microbial growth in either of the media even with a reconstituted solution without dilution.

4.3.6 β carotene

Carriers, and all interaction effects were non-significant in influencing the β - carotene of instant juice powders of pineapple and blended juice during storage as presented in table 56, 59, 60, 61 and 62. Effect of packing atmospheres and effect of storage period were significant as depicted in table 57 and 58.

4.3.6.1 Effect of Packaging Atmospheres on β carotene

The effect of packaging atmosphere on β carotene of powders during storage is presented in the table 57. The pineapple juice powder under refrigerated storage had highest β-carotene content (10.06 μg/100g) which was on par with powder packed under vacuum (7.91μg/100g). Lowest phenol content has been noted in the ordinary packed powder stored in ambient temperature (5.45μg/100g).

The blended juice powder under refrigerated storage had highest β-carotene content (4.85 μg/100g) followed by powder packed under vacuum(3.47μg/100g). Lowest β-carotene content has been noted in the conventional package stored in ambient temperature (2.26μg/100g).

4.3.6.2 Effect of Storage Period on β carotene

The effect of storage period on β-carotene of powders during storage is presented in the table 58. β-carotene content was inversely proportional to the storage period. β-carotene content was reduced to 8.81 μg/100g by second month of storage which further reduced to 6.83 μg/100g by fourth month. β-carotene content did not differ significantly between fourth and sixth month of storage.

β-carotene content was 4.09 μg/100g by second month which was reduced to 3.03μg/100g by fourth month. β-carotene content did not differ significantly between fourth and sixth month of storage.

4.3.7 Vitamin C

Carriers, and all interaction effects were non-significant in influencing the total phenol of all instant juice powders during storage as presented in table 56, 59, 60, 61 and 62. Effect of packing atmospheres and effect of storage period were significant as depicted in table 57 and 58.

Table : 56 Effect of carriers on the titrable acidity, β -carotene and vitamin C under storage.

Carrier	Titrable acidity (%)			β-carotene (µg/100g)		Vitamin C (mg/ 100g)		
	C	P	B	P	B	C	P	B
Maltodextrin (M)	1.05	1.49	1.18	7.66	3.37	557.80	24.10	233.18
Resistant dextrin (R)	1.09	1.50	1.20	7.56	3.40	563.24	23.21	232.06
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

C- Cashew apple juice powder, P – Pineapple juice powder, B – Blended juice powder.

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Table : 57 Effect of packaging atmospheres on the titrable acidity, β-carotene and vitamin C under storage

Packaging atmospheres	Titrable acidity (%)			β-carotene (μg/100g)		Vitamin C (mg/100g)		
	C	P	B	P	B	C	P	B
Vacuum (V)	1.07	1.48	1.17	7.91	3.47	584.71	24.49	243.84
Nitrogen (N)	1.12	1.52	1.24	7.02	2.94	534.86	21.37	213.36
Air –Refrigeration (L)	0.97	1.42	1.10	10.06	4.85	640.21	28.71	267.72
Air – Ambient (A)	1.13	1.56	1.25	5.45	2.26	482.28	20.05	205.56
CD (0.05)	0.07	0.07	0.05	2.18	0.26	50.08	1.95	20.34

C- Cashew apple juice powder, P – Pineapple juice powder, B – Blended juice powder.

Table : 58 Effect of Storage period on the titrable acidity, β-carotene and vitamin C under storage.

Storage period	Titrable acidity (%)			β-carotene (μg/100g)		Vitamin C (mg/100g)		
	C	P	B	P	B	C	P	B
2nd month (S_1)	1.04	1.47	1.15	8.81	4.09	579.76	24.93	246.06
4th month (S_2)	1.07	1.50	1.19	6.83	3.03	557.22	23.73	231.64
6th month (S_3)	1.11	1.52	1.23	7.19	3.03	544.57	22.30	220.16
CD (0.05)	0.05	0.03	0.02	0.96	0.13	19.79	1.23	9.25

C- Cashew apple juice powder, P – Pineapple juice powder, B – Blended juice powder.

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Table: 59 Effect of interaction of carriers and packaging atmospheres on the titrable acidity, β-carotene and vitamin C under storage

Carriers	Packaging atmospheres	Titrable acidity (%)			β-carotene (µg/100g)		Vitamin C (mg/100g)		
		C	P	B	P	B	C	P	B
Maltodextrin (M)	Vacuum (V)	1.06	1.46	1.16	8.07	3.41	585.03	25.07	246.55
	Nitrogen (N)	1.09	1.51	1.22	7.56	3.03	534.52	21.83	213.21
	Air – Refrigeration (L)	0.94	1.43	1.11	9.54	4.81	635.38	29.31	265.16
	Air – Ambient (A)	1.12	1.56	1.23	5.47	2.20	476.27	20.18	207.81
Resistant Dextrin (R)	Vacuum (V)	1.07	1.51	1.18	7.75	3.54	584.40	23.90	241.14
	Nitrogen (N)	1.15	1.54	1.25	6.48	2.85	535.20	20.90	213.51
	Air – Refrigeration (L)	1.00	1.40	1.08	10.57	4.88	645.04	28.11	270.27
	Air – Ambient (A)	1.14	1.56	1.28	5.44	2.31	488.30	19.91	203.31
CD (0.05)		NS	NS	NS	NS	NS	NS	NS	NS

C- Cashew apple juice powder, P – Pineapple juice powder, B – Blended juice powder.

Table : 60 Effect of interaction of carriers and storage period on the acidity, β-carotene and vitamin C under storage

Carriers	Storage period	Titrable acidity (%)			β-carotene (μg/100g)		Vitamin C (mg/100g)		
		C	P	B	P	B	C	P	B
Maltodextrin (M)	2nd month (S_1)	1.02	1.46	1.14	8.27	4.02	581.53	25.54	246.85
	4th month (S_2)	1.05	1.49	1.18	7.02	3.04	556.32	24.26	232.09
	6th month (S_3)	1.08	1.51	1.22	7.69	3.04	535.55	22.50	220.61
Resistant Dextrin (R)	2nd month (S_1)	1.06	1.48	1.16	9.35	4.15	578.00	24.32	245.27
	4th month (S_2)	1.09	1.50	1.19	6.64	3.02	558.13	23.20	231.19
	6th month (S_3)	1.13	1.53	1.24	6.69	3.02	553.58	22.10	219.71
CD (0.05)		NS	NS	NS	NS	NS	NS	NS	NS

C- Cashew apple juice powder, P – Pineapple juice powder, B – Blended juice powder.

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Table: 61 Effect of interaction of packaging atmospheres and storage period on titrable acidity, β-carotene and vitamin C under storage

Packaging atmospheres	Storage period	Titrable acidity (%)			β-carotene (µg/100g)		Vitamin C (mg/100g)		
		C	P	B	P	B	C	P	B
Vacuum (V)	2nd month (S_1)	1.02	1.46	1.15	9.79	4.31	609.91	26.13	261.04
	4th month (S_2)	1.07	1.49	1.16	6.81	3.06	584.70	24.19	242.57
	6th month (S_3)	1.10	1.50	1.19	7.14	3.06	559.53	23.15	227.93
Nitrogen (N)	2nd month (S_1)	1.08	1.49	1.18	8.55	3.79	558.70	22.30	224.33
	4th month (S_2)	1.11	1.52	1.24	5.76	2.52	531.53	21.58	212.61
	6th month (S_3)	1.17	1.56	1.29	6.76	2.52	514.35	20.23	203.15
Air –Refrigeration (L)	2nd month (S_1)	0.95	1.41	1.08	9.97	5.44	651.35	29.96	279.28
	4th month (S_2)	0.96	1.42	1.09	10.10	4.55	642.37	28.97	267.12
	6th month (S_3)	1.00	1.43	1.11	10.10	4.55	626.92	27.21	256.76
Air – Ambient (A)	2nd month (S_1)	1.10	1.53	1.19	6.92	2.80	499.10	21.35	219.60
	4th month (S_2)	1.13	1.57	1.26	4.67	1.99	470.28	20.18	204.28
	6th month (S_3)	1.16	1.59	1.31	4.76	1.99	477.47	18.61	192.80
CD (0.05)		NS	NS	NS	NS	NS	NS	NS	NS

C- Cashew apple juice powder, P – Pineapple juice powder, B – Blended juice powder.

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Table : 62 Effect of interaction of carriers and packaging atmospheres with storage period on titrable acidity, β-carotene and vitamin C under storage

Carriers	Packaging atmospheres	Storage period	Titrable acidity (%)			β-carotene (µg/100g)		Vitamin C (mg/100g)		
			C	P	B	P	B	C	P	B
Maltodextrin (M)	Vacuum (V)	2nd month (S_1)	1.00	1.43	1.14	9.73	4.27	614.41	27.12	263.06
	Vacuum (V)	4th month (S_2)	1.07	1.47	1.15	6.91	2.98	582.00	24.95	243.70
	Vacuum (V)	6th month (S_3)	1.11	1.48	1.18	7.57	2.98	558.67	23.15	232.88
	Nitrogen (N)	2nd month (S_1)	1.06	1.47	1.17	8.31	3.80	554.93	22.88	223.42
	Nitrogen (N)	4th month (S_2)	1.07	1.50	1.23	6.19	2.65	533.33	21.98	213.51
	Nitrogen (N)	6th month (S_3)	1.12	1.54	1.27	8.19	2.65	515.30	20.63	202.70
	Air – Refrigeration (L)	2nd month (S_1)	0.91	1.42	1.10	8.16	5.31	645.07	30.27	279.28
	Air – Refrigeration (L)	4th month (S_2)	0.93	1.44	1.10	10.23	4.56	637.87	29.91	264.86
	Air – Refrigeration (L)	6th month (S_3)	0.97	1.44	1.13	10.23	4.56	623.20	27.75	251.35
	Air – Ambient (A)	2nd month (S_1)	1.11	1.53	1.17	6.86	2.69	511.70	21.89	221.62
	Air – Ambient (A)	4th month (S_2)	1.12	1.57	1.24	4.77	1.96	472.07	20.18	206.31
	Air – Ambient (A)	6th month (S_3)	1.13	1.59	1.28	4.77	1.96	445.03	18.47	195.50

C- Cashew apple juice powder, P – Pineapple juice powder, B – Blended juice powder.

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Table : 62 Effect of interaction of carriers and packaging atmospheres with storage period on titrable acidity, β-carotene and vitamin C under storage (continued)

Carriers	Packaging atmospheres	Storage period	Titrable acidity (%)			β-carotene (μg/100g)		Vitamin C (mg/100g)		
			C	P	B	P	B	C	P	B
Resistant Dextrin (R)	Vacuum (V)	2nd month (S_1)	1.00	1.43	1.14	9.73	4.27	614.41	27.12	263.06
		4th month (S_2)	1.07	1.47	1.15	6.91	2.98	582.00	24.95	243.70
		6th month (S_3)	1.11	1.48	1.18	7.57	2.98	558.67	23.15	232.88
	Nitrogen (N)	2nd month (S_1)	1.06	1.47	1.17	8.31	3.80	554.93	22.88	223.42
		4th month (S_2)	1.07	1.50	1.23	6.19	2.65	533.33	21.98	213.51
		6th month (S_3)	1.12	1.54	1.27	8.19	2.65	515.30	20.63	202.70
	Air –Refrigeration (L)	2nd month (S_1)	0.91	1.42	1.10	8.16	5.31	645.07	30.27	279.28
		4th month (S_2)	0.93	1.44	1.10	10.23	4.56	637.87	29.91	264.86
		6th month (S_3)	0.97	1.44	1.13	10.23	4.56	623.20	27.75	251.35
	Air – Ambient (A)	2nd month (S_1)	1.11	1.53	1.17	6.86	2.69	511.70	21.89	221.62
		4th month (S_2)	1.12	1.57	1.24	4.77	1.96	472.07	20.18	206.31
		6th month (S_3)	1.13	1.59	1.28	4.77	1.96	445.03	18.47	195.50
CD (0.05)			NS	NS	NS	NS	NS	NS	NS	NS

C- Cashew apple juice powder, P – Pineapple juice powder, B – Blended juice powder.

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Table : 62Effect of interaction of carriers and packaging atmospheres with storage period on moisture, total phenol and pH under storage (continued)

Carriers	Packaging atmospheres	Storage period	Moisture (%)			Total phenol (%)			pH		
			C	P	B	C	P	B	C	P	B
Resistant Dextrin (R)	Vacuum (V)	2nd month (S_1)	6.231	7.242	6.668	0.487	0.09	0.26	4.177	4.15	4.14
		4th month (S_2)	6.855	7.989	7.293	0.447	0.67	0.237	4.147	4.13	4.157
		6th month (S_3)	6.922	8.056	7.612	0.43	0.06	0.227	4.147	4.13	4.157
	Nitrogen (N)	2nd month (S_1)	7.364	7.771	7.579	0.463	0.083	0.273	4.15	4.15	4.153
		4th month (S_2)	8.369	8.69	8.598	0.44	0.06	0.217	4.097	4.107	4.117
		6th month (S_3)	8.838	8.96	8.908	0.403	0.053	0.237	4.097	4.107	4.117
	Air – Refrigeration (L)	2nd month (S_1)	4.924	5.526	5.217	0.5	0.1	0.307	4.187	4.15	4.17
		4th month (S_2)	5.131	5.792	5.569	0.473	0.07	0.267	4.177	4.127	4.147
		6th month (S_3)	5.261	5.813	5.81	0.443	0.06	0.243	3.913	3.827	4.033
	Air – Ambient (A)	2nd month (S_1)	7.251	7.828	7.333	0.433	0.08	0.217	4.023	4.01	4.11
		4th month (S_2)	8.184	8.82	8.535	0.397	0.057	0.193	3.913	3.827	4.033
		6th month (S_3)	8.682	8.945	8.872	0.36	0.043	0.187	4.177	4.127	4.147
CD (0.05)			NS	NS	NS	NS	NS	NS	NS	NS	NS

C- Cashew apple juice powder, P – Pineapple juice powder, B – Blended juice powder

4.3.7.1 Effect of Packaging atmospheres on Vitamin C

The effect of packaging atmosphere on β carotene of powders during storage is presented in the table 57.

The cashew apple juice powder under refrigerated storage had highest vitamin C content (640.21mg/100g) followed by powder packed under vacuum (584.71mg/100g). Lowest vitamin C content has been noted in ordinary packed pouch kept in ambient temperature (482.28 mg/100g).

The pineapple juice powder under refrigerated storage had highest vitamin C content (28.71 mg/100g) followed by powder packed under vacuum 24.49 mg/100g). Lowest vitamin C content has been noted in the powder packed under nitrogen (21.37 mg /100 g) and ordinarily packed pouch kept in ambient temperature (20.05 mg/100g).

The blended juice powder under refrigerated storage had highest vitamin C content (267.72 mg/100g) followed by powder packed under vacuum (243.84 mg/100g). Lowest vitamin C content has been noted in the ordinarily packed powder kept in ambient temperature (205.56 mg /100 g) and nitrogen packed pouch (213.36 mg/100g).

4.3.7.2 Effect of Storage Period on Vitamin C

The effect of storage period on β-carotene of powders during storage is presented in the table 58. Vitamin C content of cashew apple powders was recorded as 579.76 mg/100g in second month which further reduced to 557.22 mg/100g in fourth month. Vitamin C content did not differ significantly between fourth and sixth month of storage.

Vitamin C content of pineapple powder was inversely proportional to the storage period. Vitamin C content was recorded as 24.93 mg/100g by second month of storage which further reduced to 22.297 mg/100g by sixth month. Vitamin C content did not differ significantly between second and fourth month of storage.

Table: 63 Sensory parameters under storage

Carriers	Packaging atmospheres	Appearance								
		2nd month (S_2)			4th month (S_4)			6th month (S_6)		
		C	P	B	C	P	B	C	P	B
Maltodextrin (M)	Vacuum (V)	4.77 (97.60)	4.50 (87.50)	4.38 (87.23)	3.38 (89.42)	3.77 (92.37)	3.69 (92.35)	3.15 (101.06)	2.58 (76.98)	3.50 (98.50)
	Nitrogen (N)	4.69 (93.69)	4.38 (79.65)	4.19 (71.46)	3.35 (83.98)	3.58 (83.04)	3.65 (90.90)	3.08 (100.94)	2.69 (84.40)	3.69 (109.12)
	Refrigeration (L)	7.88 (181.88)	8.27 (180.98)	8.04 (180.00)	7.08 (180.90)	7.23 (178.52)	7.00 (179.23)	6.42 (180.06)	6.81 (180.35)	6.42 (180.75)
	Air – Ambient (A)	4.00 (60.12)	3.77 (44.58)	4.08 (65.62)	2.85 (59.81)	3.15 (62.60)	3.42 (77.13)	2.38 (58.56)	2.31 (56.92)	2.15 (38.40)
Resistant Dextrin (R)	Vacuum (V)	4.85 (102.37)	5.04 (117.19)	4.42 (88.38)	3.58 (103.13)	4.00 (104.94)	3.65 (93.29)	2.88 (87.42)	2.96 (94.35)	3.31 (86.77)
	Nitrogen (N)	4.15 (65.42)	4.58 (91.35)	4.35 (83.77)	3.12 (76.52)	3.31 (71.38)	3.08 (58.87)	2.42 (61.92)	2.73 (90.04)	3.50 (98.50)
	Refrigeration (L)	7.92 (182.65)	8.50 (184.02)	8.35 (185.00)	7.27 (184.10)	7.73 (185.25)	7.42 (185.37)	6.77 (184.94)	7.08 (184.58)	6.69 (184.06)
	Air – Ambient (A)	3.85 (52.27)	3.88 (50.73)	4.19 (74.54)	2.81 (58.13)	3.08 (57.90)	3.08 (58.87)	2.42 (61.10)	2.46 (68.38)	2.35 (39.90)
K value		140.817	154.84	131.34	137.72	134.05	135.548	140.72	136.99	160.317
CV		14.07	14.07	14.07	14.07	14.07	14.07	14.07	14.07	14.07
CD (0.05)		50.62	50.08	49.77	50.16	50.66	49.77	50.38	49.51	50.67

C- Cashew apple juice powder, P – Pineapple juice powder, B – Blended juice powder. Data represents mean scores. Data in the parenthesis represents mean ranks.

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Table: 63 Sensory parameters under storage (continued)

Carriers	Packaging atmospheres	Colour								
		2nd month (S_2)			4th month (S_4)			6th month (S_6)		
		C	P	B	C	P	B	C	P	B
Maltodextrin (M)	Vacuum (V)	5.12 (120.67)	5.69 (110.77)	4.96 (123.63)	3.85 (104.08)	4.58 (103.15)	4.85 (121.13)	3.50 (125.27)	3.69 (123.46)	3.38 (124.50)
	Nitrogen (N)	4.88 (113.56)	5.23 (89.50)	4.65 (107.79)	4.35 (127.46)	4.54 (93.96)	4.35 (99.35)	2.65 (87.85)	3.46 (111.81)	3.08 (113.19)
	Refrigeration (L)	7.31 (185.63)	7.38 (178.25)	7.81 (177.40)	7.00 (186.96)	6.73 (170.38)	6.85 (179.33)	6.27 (183.56)	6.77 (183.92)	6.65 (181.62)
	Air – Ambient (A)	4.15 (68.65)	3.85 (29.00)	4.42 (100.29)	3.19 (65.79)	3.31 (36.00)	4.42 (103.42)	2.23 (66.54)	1.81 (25.21)	2.65 (92.60)
Resistant Dextrin (R)	Vacuum (V)	4.38 (81.69)	5.62 (107.10)	3.38 (44.35)	3.46 (78.38)	5.31 (136.15)	3.81 (70.65)	3.08 (108.29)	3.19 (98.21)	1.88 (57.06)
	Nitrogen (N)	3.85 (49.19)	5.15 (85.85)	3.65 (59.29)	2.92 (50.21)	4.88 (63.23)	3.46 (52.19)	1.88 (49.87)	2.50 (59.50)	1.65 (45.40)
	Refrigeration (L)	6.77 (172.88)	7.69 (183.87)	8.35 (187.44)	6.50 (177.81)	6.96 (177.12)	7.08 (184.04)	6.12 (181.44)	6.88 (81.08)	6.73 (183.38)
	Air – Ambient (A)	3.73 (43.71)	4.42 (51.67)	3.23 (35.81)	2.81 (45.31)	3.69(56.00)	2.77 (25.88)	1.54 (33.19)	2.38 (52.81)	1.50 (38.25)
K value		156.09	156.49	173.47	163.24	146.99	168.81	169.51	178.92	171.73
CV		14.07	14.07	14.07	14.07	14.07	14.07	14.07	14.07	14.07
CD (0.05)		50.21	50.99	50.84	50.5	50.85	50.77	50.79	50.75	51.04

C- Cashew apple juice powder, P – Pineapple juice powder, B – Blended juice powder. Data represents mean scores. Data in the parenthesis represents mean ranks.

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Table: 63 Sensory parameters under storage (continued)

Carriers	Packaging atmospheres	Texture								
		2nd month (S_2)			4th month (S_4)			6th month (S_6)		
		C	P	B	C	P	B	C	P	B
Maltodextrin (M)	Vacuum (V)	5.88 (97.06)	6.04 (88.42)	4.88 (91.60)	4.04 (89.42)	5.12 (87.17)	4.73 (99.56)	3.73 (101.69)	3.73 (63.73)	4.46 (94.27)
	Nitrogen (N)	5.42 (77.35)	6.35 (104.87)	5.04 (97.83)	4.58 (108.73)	5.15 (99.12)	4.54 (91.19)	3.96 (108.08)	4.04 (76.62)	4.62 (99.98)
	Refrigeration (L)	6.31 (88.37)	7.19 (147.40)	6.65 (157.06)	4.77 (110.92)	6.88 (159.56)	6.00 (152.31)	3.92 (106.54)	6.00 (160.94)	6.15 (165.88)
	Air – Ambient (A)	6.27 (102.96)	5.88 (77.33)	4.65 (79.13)	4.38 (101.62)	5.38 (100.92)	4.19 (77.04)	4.00 (109.65)	4.27 (93.15)	4.19 (85.48)
Resistant Dextrin (R)	Vacuum (V)	6.23 (120.46)	6.04 (89.87)	5.23 (111.58)	4.65 (113.46)	4.96 (84.23)	5.00 (112.75)	4.04 (110.12)	4.38 (90.98)	4.62 (102.69)
	Nitrogen (N)	6.58 (117.85)	6.04 (90.83)	4.85 (89.81)	4.27 (97.81)	4.85 (86.33)	4.35 (81.25)	3.12 (81.56)	4.12 (88.94)	4.04 (71.83)
	Refrigeration (L)	5.96 (109.58)	7.23 (148.77)	6.42 (153.23)	4.69 (115.35)	6.69 (149.12)	5.92 (139.50)	4.15 (115.58)	6.12 (160.87)	5.88 (149.83)
	Air – Ambient (A)	6.58 (122.38)	6.00 (88.52)	4.31 (55.77)	4.23 (98.69)	4.54 (69.56)	4.27 (82.40)	3.77 (102.79)	4.46 (100.77)	3.85 (66.04)
K value		13.82	41.54	67.04	4.24	56.16	41.93	5.44	70.02	66.80
CV		14.07	14.07	14.07	14.07	14.07	14.07	14.07	14.07	14.07
CD (0.05)		NS	50.62	50.12	NS	50.46	50.89	NS	51.10	50.88

C- Cashew apple juice powder, P – Pineapple juice powder, B – Blended juice powder. Data represents mean scores. Data in the parenthesis represents mean ranks.

Table: 63 Sensory parameters under storage (continued)

Carriers	Packaging atmospheres	Flavour								
		2nd month (S_2)			4th month (S_4)			6th month (S_6)		
		C	P	B	C	P	B	C	P	B
Maltodextrin (M)	Vacuum (V)	5.73 (107.04)	6.23 (109.69)	5.35 (97.56)	4.88 (102.83)	5.35 (124.46)	5.15 (119.62)	4.15 (102.58)	4.31 (98.81)	4.38 (111.65)
	Nitrogen (N)	5.35 (92.77)	6.08 (104.46)	5.15 (91.92)	4.96 (106.25)	5.08 (111.77)	4.85 (102.88)	4.38 (114.98)	4.62 (115.35)	4.12 (94.56)
	Refrigeration (L)	7.42 (172.83)	8.04 (176.77)	7.96 (180.60)	7.08 (176.94)	7.46 (183.19)	6.69 (173.50)	6.58 (181.17)	7.08 (174.88)	6.46 (177.94)
	Air – Ambient (A)	4.73 (63.75)	4.46 (43.62)	4.12 (50.71)	4.19 (69.85)	3.54 (36.35)	4.08 (61.13)	3.35 (65.27)	2.46 (21.12)	4.35 (106.29)
Resistant Dextrin (R)	Vacuum (V)	5.54 (98.42)	5.85 (94.62)	5.65 (111.06)	5.08 (112.27)	4.38 (78.73)	4.92 (107.19)	4.27 (108.44)	4.69 (114.19)	4.27 (103.10)
	Nitrogen (N)	5.27 (86.27)	5.96 (103.58)	4.42 (63.94)	3.81 (51.88)	4.58 (87.23)	4.04 (61.33)	2.96 (50.08)	3.69 (69.42)	2.77 (41.42)
	Refrigeration (L)	7.04 (156.48)	7.92 (171.65)	7.77 (178.15)	6.88 (173.31)	7.19 (176.33)	6.54 (168.92)	6.46 (175.40)	7.12 (175.48)	6.19 (171.69)
	Air – Ambient (A)	4.58 (58.44)	4.04 (31.62)	4.35 (62.06)	3.65 (42.67)	3.58 (37.94)	3.69 (41.42)	2.73 (38.08)	3.65 (66.75)	2.35 (29.35)
K value		87.71	140.23	131.89	134.28	164.11	128.94	152.67	148.86	148.37
CV		14.07	14.07	14.07	14.07	14.07	14.07	14.07	14.07	14.07
CD (0.05)		50.95	51.26	51.33	50.92	50.96	50.53	50.50	51.01	50.89

C- Cashew apple juice powder, P – Pineapple juice powder, B – Blended juice powder. Data represents mean scores. Data in the parenthesis represents mean ranks.

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Table: 63 Sensory parameters under storage (continued)

Carriers	Packaging atmospheres	Taste								
		2nd month (S_2)			4th month (S_4)			6th month (S_6)		
		C	P	B	C	P	B	C	P	B
Maltodextrin (M)	Vacuum (V)	5.31 (122.87)	5.69 (122.60)	5.38 (107.42)	4.92 (109.35)	5.46 (120.46)	5.15 (111.33)	4.31 (100.42)	4.96 (121.38)	4.54 (112.35)
	Nitrogen (N)	4.69 (85.62)	5.81 (125.13)	5.12 (91.94)	4.42 (74.37)	5.65 (130.06)	5.04 (99.35)	4.35 (102.77)	4.77 (112.75)	4.69 (119.73)
	Refrigeration (L)	7.27 (172.87)	7.88 (180.69)	7.46 (179.92)	6.96 (177.29)	7.08 (161.90)	6.85 (162.77)	6.62 (179.02)	6.88 (178.40)	6.81 (179.60)
	Air – Ambient (A)	4.35 (59.31)	4.38 (50.19)	5.19 (96.38)	4.27 (67.02)	4.38 (61.85)	4.38 (75.46)	2.85 (56.08)	2.69 (47.79)	3.27 (65.25)
Resistant Dextrin (R)	Vacuum (V)	4.73 (88.54)	4.69 (67.85)	5.08 (89.75)	4.92 (106.81)	4.92 (95.46)	4.69 (95.65)	4.77 (123.21)	4.81 (114.31)	4.65 (117.88)
	Nitrogen (N)	4.50 (71.00)	4.65 (66.08)	4.35 (47.90)	4.15 (58.65)	4.31 (56.58)	4.31 (69.77)	2.81 (55.46)	2.69 (46.62)	2.08 (32.46)
	Refrigeration (L)	7.15 (176.50)	7.65 (177.81)	7.31 (177.77)	7.08 (181.08)	6.96 (167.52)	7.15 (169.17)	6.38 (170.15)	6.77 (178.23)	6.65 (180.69)
	Air – Ambient (A)	4.35 (59.31)	4.31 (45.65)	4.23 (44.90)	4.19 (61.44)	4.04 (42.17)	3.96 (52.50)	2.77 (48.88)	2.27 (36.52)	1.88 (28.04)
K value		128.45	160.90	139.24	140.89	126.28	98.71	137.00	166.60	181.64
CV		14.07	14.07	14.07	14.07	14.07	14.07	14.07	14.07	14.07
CD (0.05)		49.33	50.67	50.59	49.18	50.12	49.68	50.74	51.38	51.3

C- Cashew apple juice powder, P – Pineapple juice powder, B – Blended juice powder. Data represents mean scores. Data in the parenthesis represents mean ranks.

Table : 64 Cost of production (Rs)

Instant juice powder	Variable cost (Rs)					Fixed Cost (Rs)	Gross Cost (Rs)	Production (kg)	Cost / kg (Rs)
	Maintanence	Energy	Labour	Raw material	Total				
$CM_5T_2LS_3$	24250	76110	180000	49960	330320	169660	499980	474.06	1054.67
$PM_5T_2LS_3$	24250	76110	180000	272425	552785	169660	722445	838.6	861.49
$BM_5T_2LS_3$	24250	76110	180000	161137	441497	169660	611157	607.16	1006.58
$CR_5T_2LS_3$	24250	76110	180000	238690	519050	169660	688710	805.82	854.67
$PR_5T_2LS_3$	24250	76110	180000	508210	788570	169660	958230	1195.68	801.41
$BR_5T_2LS_3$	24250	76110	180000	373115	653475	169660	823135	937.86	877.67

Table: 65 Consumer acceptability

Instant juice powder	*Product preference	*Price fairness @ Rs 1100/kg	*Payment Intention @Rs1100/kg	**Perceived Value/Kg (Rs)
$CM_5T_2LS_3$	2.69 (31.63)	1.15 (46.96)	1.38 (43.00)	215.38
$PM_5T_2LS_3$	4.58 (118.37)	2.42 (106.96)	2.54 (110.23)	410.2
$BM_5T_2LS_3$	3.69 (70.88)	1.92 (84.08)	2.12 (85.69)	316.67
$CR_5T_2LS_3$	3.38 (58.81)	1.19 (49.08)	1.19 (31.75)	217.95
$PR_5T_2LS_3$	4.62 (120.42)	2.46 (109.65)	2.73 (121.38)	423.07
$BR_5T_2LS_3$	3.69 (70.88)	1.69 (74.27)	2.00 (78.94)	325.64
K value	88.88	55.4	95.37	
CV	11.07	11.07	11.07	
CD (0.05)	34.23	33.87	33.85	

*The data represents mean scores under 5 point Scale, *Data in parenthesis represents the mean rank, **Perceived value represents mean of the perceived value of the product

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Vitamin C content of blended juice powder was reduced to 246.06 mg/100g by second month which further reduced to 231.64 mg/100g by fourth and 220.16 mg/100g by sixth month.

4.3.8 Sensory parameters

Sensory analysis of fruit powders under storage were conducted in a 9 point hedonic scale in bimonthly interval to find the stability in organoleptic qualities. Analysis of the data on appearance of stored powder exhibited reduction in sensory scores during storage period in all fruit juices under the study. The instant juice powders that were packed conventionally but stored at refrigerated condition received better scores in appearance, colour, texture, flavor and taste consistently at storage periods. The same powders when stored under ambient temperature received least scores consistently. Moreover the refrigerated material received scores in the range of "likedness" (scores of 6-9) and while same powders stored under ambient temperature received scores in the range of "dislikedness" (scores of 1-5). The powders packed under vacuum and nitrogen received intermediate scores.

4,3.9 Selection of powders

Since refrigerated storage could maintain vitamin C, β-carotene, moisture content, titrable acidity, total phenol and high sensory acceptability of fruit powders, two powders from each juice (one from each carrier) that stored under refrigeration were selected independently from cashew apple ($CM_5T_2LS_3$ and $CR_5T_2LS_3$), pineapple ($PM_5T_2LS_3$ and $PR_5T_2LS_3$) and blended juice ($BM_5T_2LS_3$ and $BR_5T_2LS_3$) for computation of cost of production and consumer acceptability.

4.3.10 Cost of production

Cost of production of the selected powders is represented in table 64. Cost of production of cashew apple juice powder using maltodextrin as carrier at juice solid to carrier ratio of 40 :60 and drying at inlet temperature of 160°C ($CM_5T_2LS_3$) was Rs 1054.67/ kg while it was Rs 854.67/kg using resistant dextrin ($CR_5T_2LS_3$).

Cost of production of pineapple juice powder using maltodextrin as carrier at juice powder solid to carrier ratio of 40 :60 and drying at inlet temperature of 160°C ($PM_5T_2LS_3$) was Rs 861.49/ kg while it was Rs 801.41/kg using resistant dextrin ($PR_5T_2LS_3$).

Cost of production of blended juice powder using maltodextrin as carrier at juice solid to carrier ratio of 40:60 and drying at inlet temperature of 160°C ($BM_5T_2LS_3$) was Rs 1006.58/ kg while it was Rs 877.67/kg using resistant dextrin ($BR_5T_2LS_3$).

4.3.11 Consumer Acceptability

Consumer acceptability of the six instant juice powders were studied through organoleptic scoring of reconstituted juice with 15 per cent concentration to assess rationality of price with the value perceived by customers, willingness to pay the money to purchase the item, and preference of the product. The non parametric data collected in five point scale was analysed by kruskal wallis test and the multiple comparisons were done. The result presented in the table 65 revealed that preference of the consumers was in the order of pineapple, blended juice and cashew apple powder. Consumers rated price of Rs 1100/kg powder as medium high and very high for pineapple, blended and cashew apple juice powders Consumers expressed intention of purchase as medium, low and very low for pineapple, blended and cashew apple juice powders at price of Rs 1100/kg. Perceived value of the product ranged from Rs 215 to Rs 423 in which pineapple powder had the highest perceived value followed by blended powder.

Discussion

5. DISCUSSION

The present investigation was under taken to produce instant juice powders of cashew apple, pineapple and blended juices by optimizing the process parameters for spray drying evaluating the effect of drying on physical chemical and nutritional quality parameters of fruit powders, and assessing organoleptic quality, storage stability, economics and consumer acceptability of the standardised formulations. In order to achive desired outcome spray drying was done as envisaged and the data generated from the spray drying, subsequent quality analysis, storage study, computation of cost of production and investigation on consumer acceptability were discussed in detail in this chapter as three parts.

5.1 OPTIMISATION OF PROCESS PARAMETERS FOR INSTANT FRUIT POWDER PRODUCTION BY MICRO ENCAPSULATION THROUGH SPRAY DRYING

In order to optimize process parameters spray drying of three juices were conducted independently by adding carriers in different proportion and drying at different inlet temperatures. The data received on recovery of powder either fine (from cyclone), coarse (from chamber) and bulked powders (total powder) and feed rate employed were assessed and the thrice replicated data were analysed in three factor completely randomized design with carrier, concentration and inlet temperature as factors and the result is dicussed in detail in this section.

5.1.1 Product Recovery

The data revealed that without adding sufficient carrier material, powder production and recovery will not be possible since pure juice or even small amount of carrier (ratio of 80:20 juice solid to carrier) could not recover any powder. The material sticked to the wall as a viscous paste which could not be removed even after scratching. The material got burned and browned at higher inlet temperature but never converted to powder and hence addition of carriers is the main pre requisite needed in spray drying as shown in the plate 9 earlier. As discussed by Ameri and Maa (2006) 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, recover powder.

Moreover, according to Bhandari *et al.* (1997) sticky behaviour of sugar and acid rich materials can be attributed to low molecular weight sugars such as fructose, glucose, 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: 62^0C, fructose:-5^0C, glucose: 32^0C). 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.*(2007) 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.*(2010).

Within carriers, resistant dextrin had profound effect in increasing powder recovery from cyclone in the form of fine powders, from drying chamber in the form of coarse powders and in total recovery when both these were bulked in all fruit juices as shown in figure 7, 9 and 11 as well as in Table 3. While drying cashew apple juice, resistant dextrin improved total powder recovery by 111 per cent in which increment in powder recovery in cyclone and chamber was 243 and 64 per cent respectively. Similarly powder recovery improved by 85 and 42 per cent in cyclone

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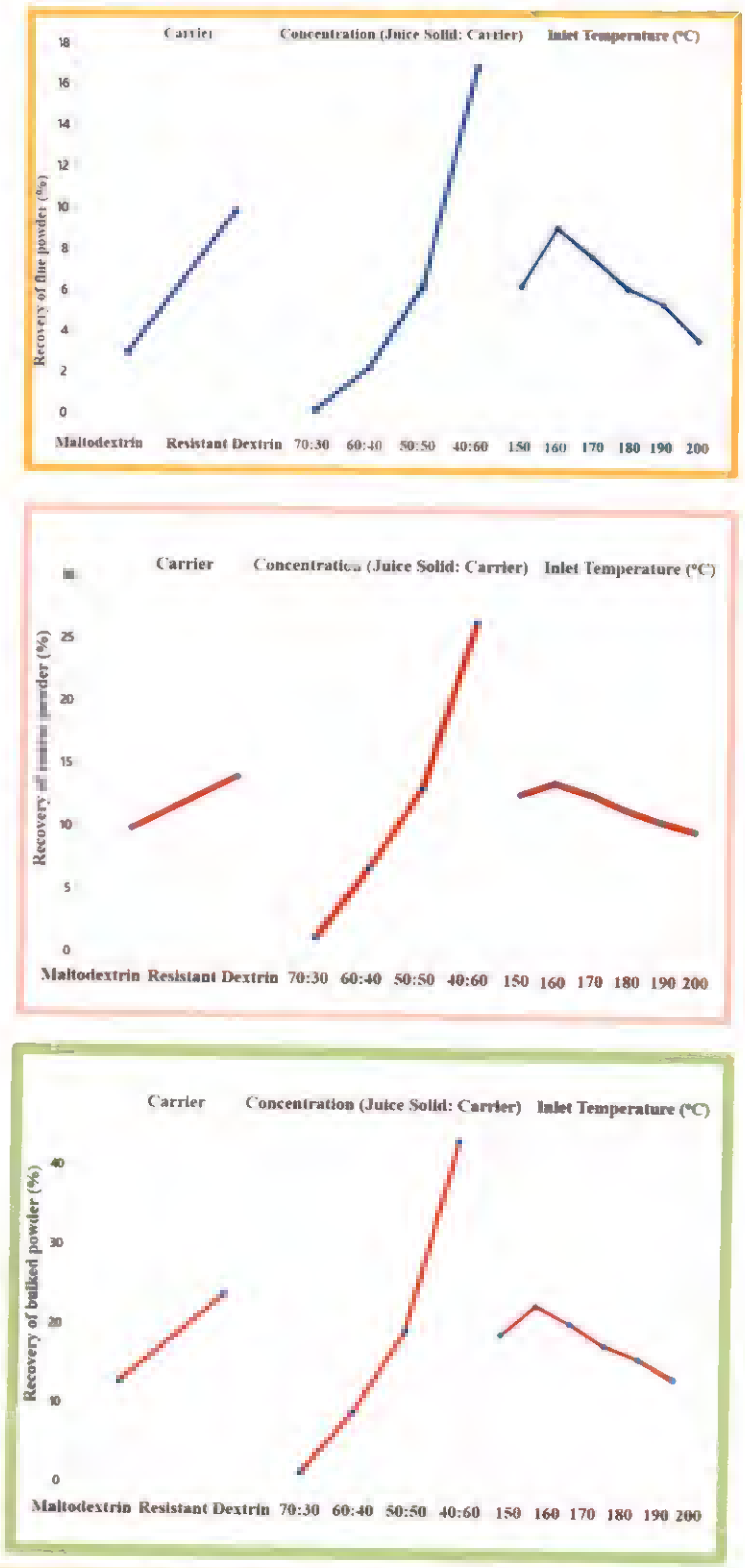

Figure 7: Effects of carrier, concentration and inlet temperature on fine, coarse and bulked powder recovery of cashew apple juice

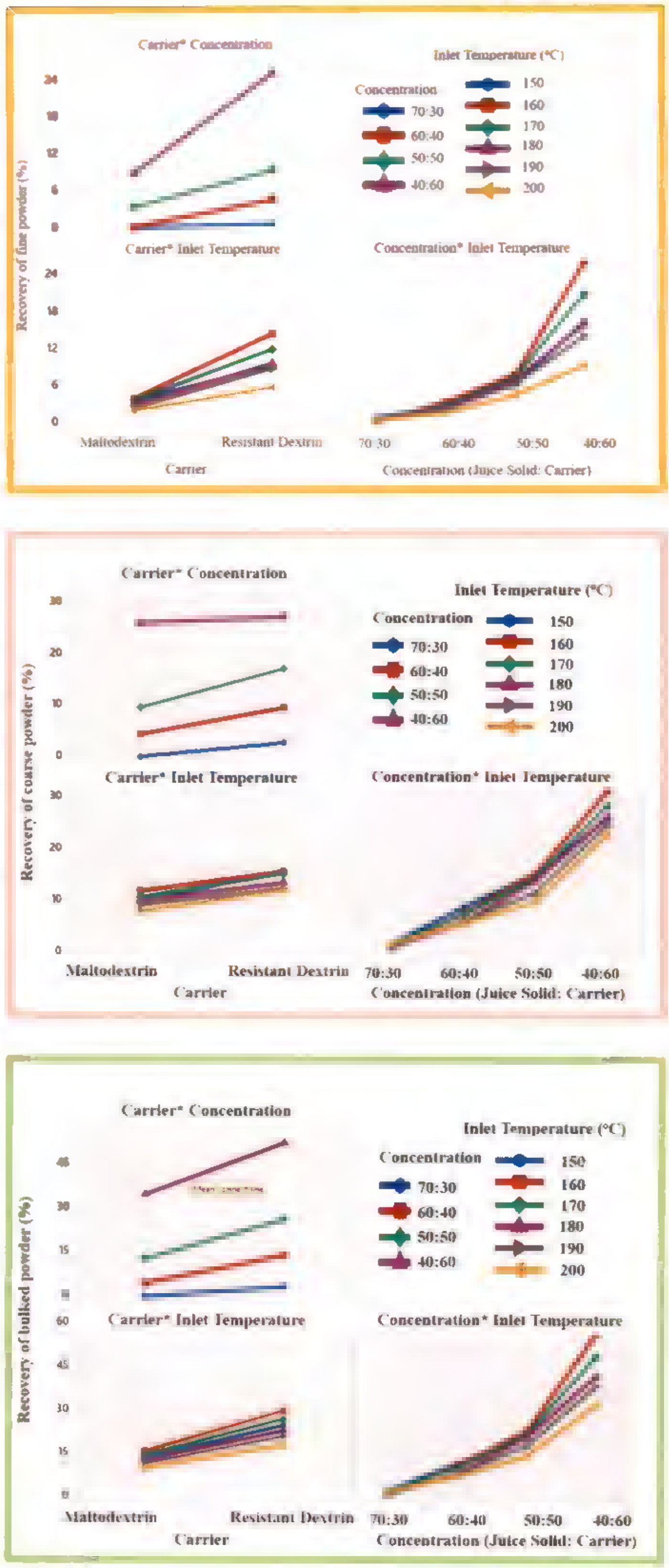

Figure 8: Interaction effects on fine, coarse and bulked powder recovery of cashew apple juice

and chamber which in turn led to 60 per cent increase in total powder with respect to pineapple juice. Resistant dextrin improved powder recovery in drying of blended juice too. The increase in powder recovery were 170, 31 and 77 per cent from cyclone, from chamber and for bulked powders.

Better recovery of powder with resistant dextrin could be attributed to the lower dextrose equivalence (DE) 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.* (2007) who tested level of stickiness of droplets reported that low DE carrier reach a state of non adhesion faster than high DE carriers. Moreover effect of resistant dextrin was more profound in increasing recovery in the form of fine powder from cyclone. Higher cyclone recovery indicate higher efficiency in spray drying since it is not economical for frequent shutdown of the drier for collection of powder from the chamber. Since resistant dextrin yielded less stickier powder more of it might have translocated to cyclone.

Moreover, increase in carrier concentration led to higher yield irrespective of place of recovery of powder or type of juice as depicted in figure 7, 9 and 11 as well as in Table 4. The lowest carrier ratio (80:20) did not yield any powder since the entire feed particles sticked to chamber wall as a highly viscous sticky paste. When the carrier concentration increased from 70:30 to 60:40, recovery of powder from cashew apple juice enhanced by 50, 23 and 31 times in fine, coarse and bulked powders respectively. In pineapple juice, the increment in recovery was 28, 18 and 22 times respectively. Blended juice also witnessed huge difference of 70, 12 and 20 times in recovery of powders from cyclone, chamber and bulked powder respectively. The juice solid to carrier ratio of 40:60 had a marked effect even from the adjacent lower ratio of 50:50. In cashew apple juice higher carrier content in 40:60 ratio raised the yield by 2.6, 2 and 2.2 times in fine, coarse and bulked powders. In pineapple, the incremental proportion was 2.1. 2.6 and 2.4 times respectively. In blended juice, the recovery of powder was higher by 2.2, 1.9 and 2.1 times than the lower 50:50 ratio.

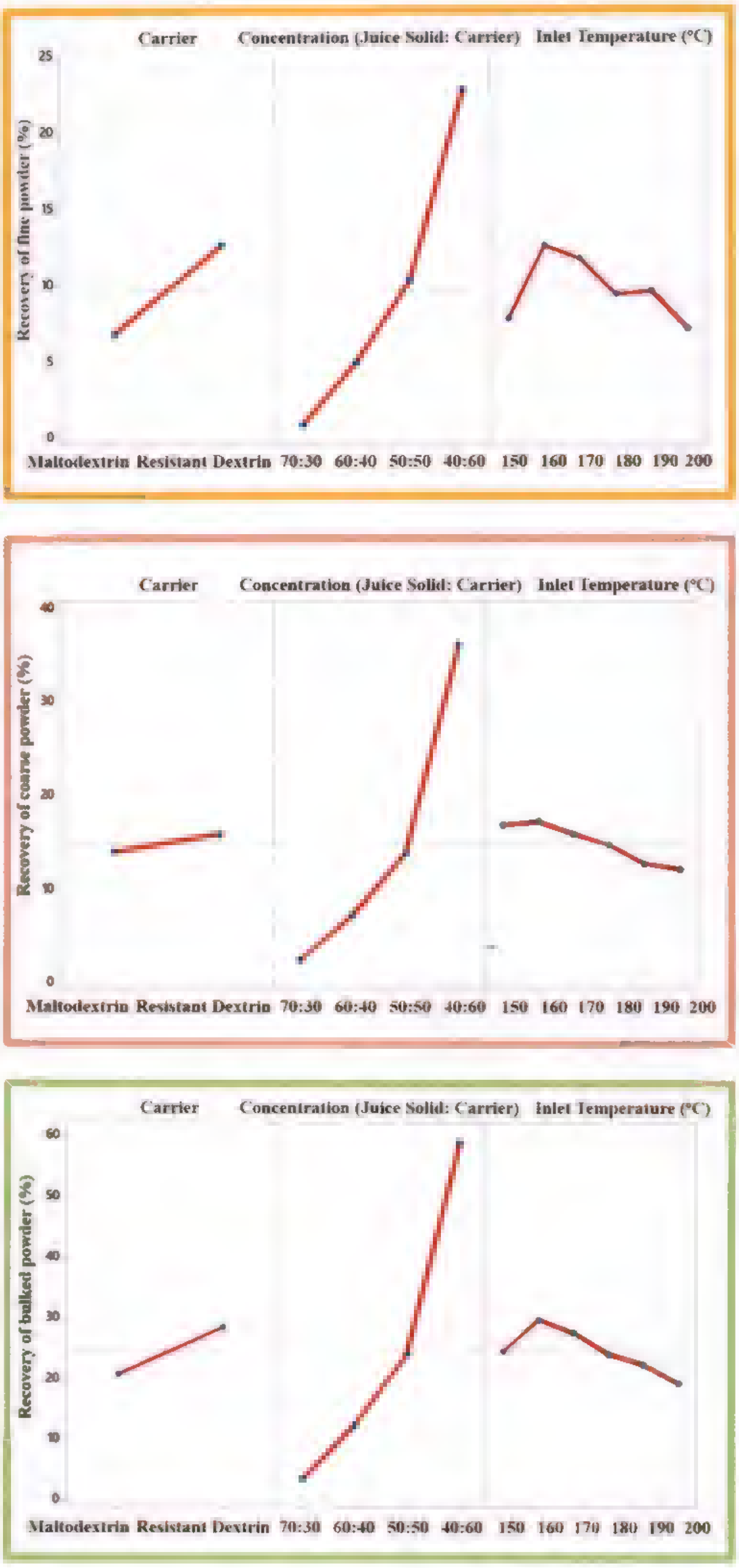

Figure :9 Effects of carrier, concentration and inlet temperature on fine, coarse and bulked powder recovery of pineapple juice

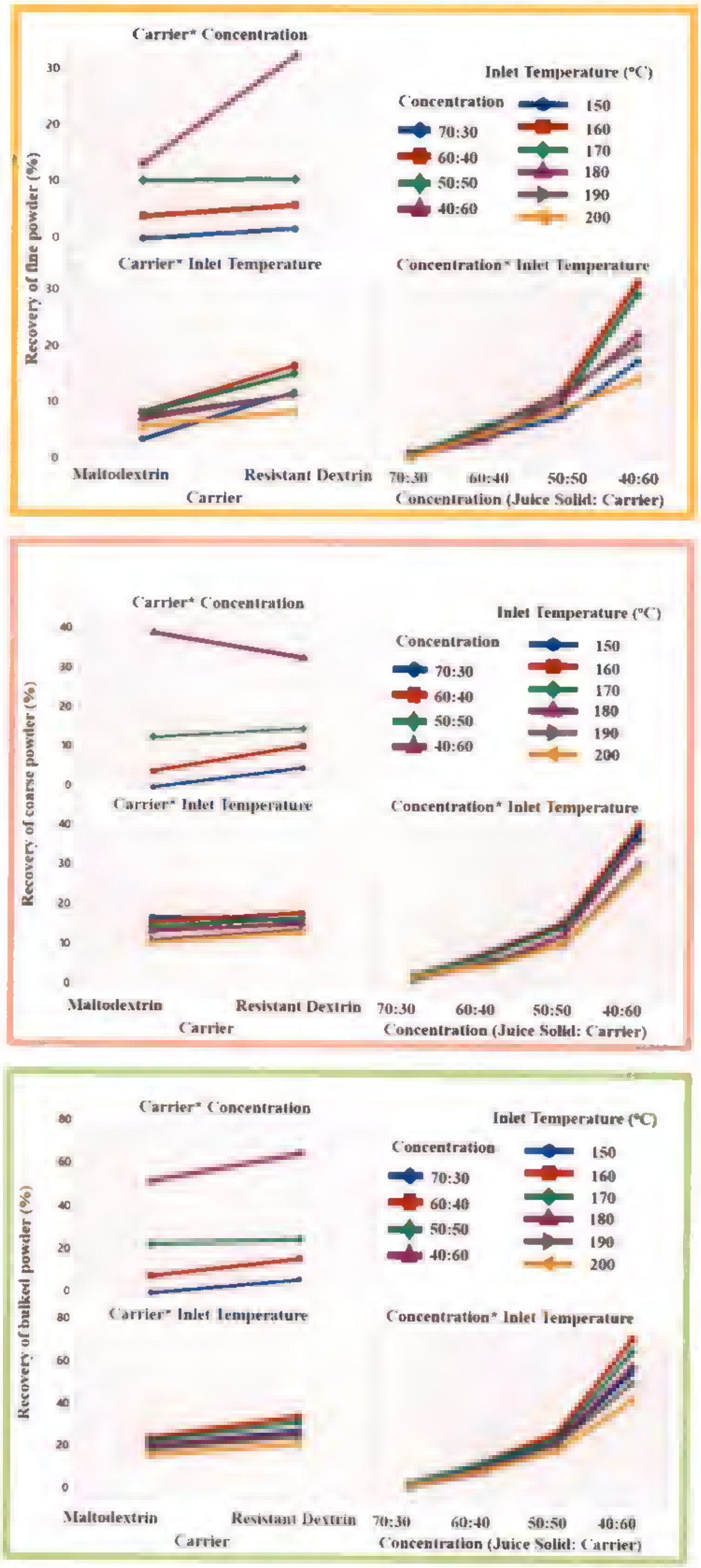

Figure 10 : Interaction effects on fine, coarse and bulked powder recovery of pineapple juice

The effect of carrier concentration in translocating more powder from chamber to cyclone was also evident in these facts.

Similarly when Quek *et al.* (2007) dried watermelon juice there were hardly any powders accumulated in the collector if sufficient quantity of carrier was not added to the feed. The increment in yield corresponding to the increase in carrier concentration could be explained by the observations made by some authors (Bhandari *et al.*, 1997, Shreshta *et al.*, 2007 and Quek *et al.*, 2007) on the increased the *Tg* values when carrier concentration was increased. As discussed elsewhere (Papadakis *et al.*, 1998 and Roustapour *et al.*, 2009) increase in the carrier content results in an increase of the recovery of feed solids in the product. However Jittanit *et al.* (2010) pointed that increase in carrier concentration beyond optimum reduced the yield.

Nevertheless, Quek *et al.* (2007) reported a decrease in moisture content with the addition of more carrier material due to an increase in total solid content of the feed solution. Jittanit *et al.* (2010) reported that the increase of maltodextrin concentration decreased moisture content of pineapple juice powder. The carrier has the capability to hurdle the sugars in the fruit powder that have high hygroscopic nature of absorbing the humidity in the surrounding air (Shrestha *et al.*, 2007). According to Tonon *et al.* (2009) the glass transition temperature increased with decreasing moisture content due to the lower plasticizing effect of water. The higher glass transition temperature of the powder which contain higher carrier content might have improved recovery of powder. As reported by Wang *et al.* (2012) in soy sauce powders, higher carrier concentrations elevate glass transition temperature of a product as a result of the reduced equilibrium moisture content. Water as a significant plasticizer could enable the mobility of molecules and reduce glass transition temperature of amorphous powders. Moreover, since the glass transition temperature of a powder increases with its molecular weight, an addition of large molecular carbohydrates in higher quantities stabilized the powder.

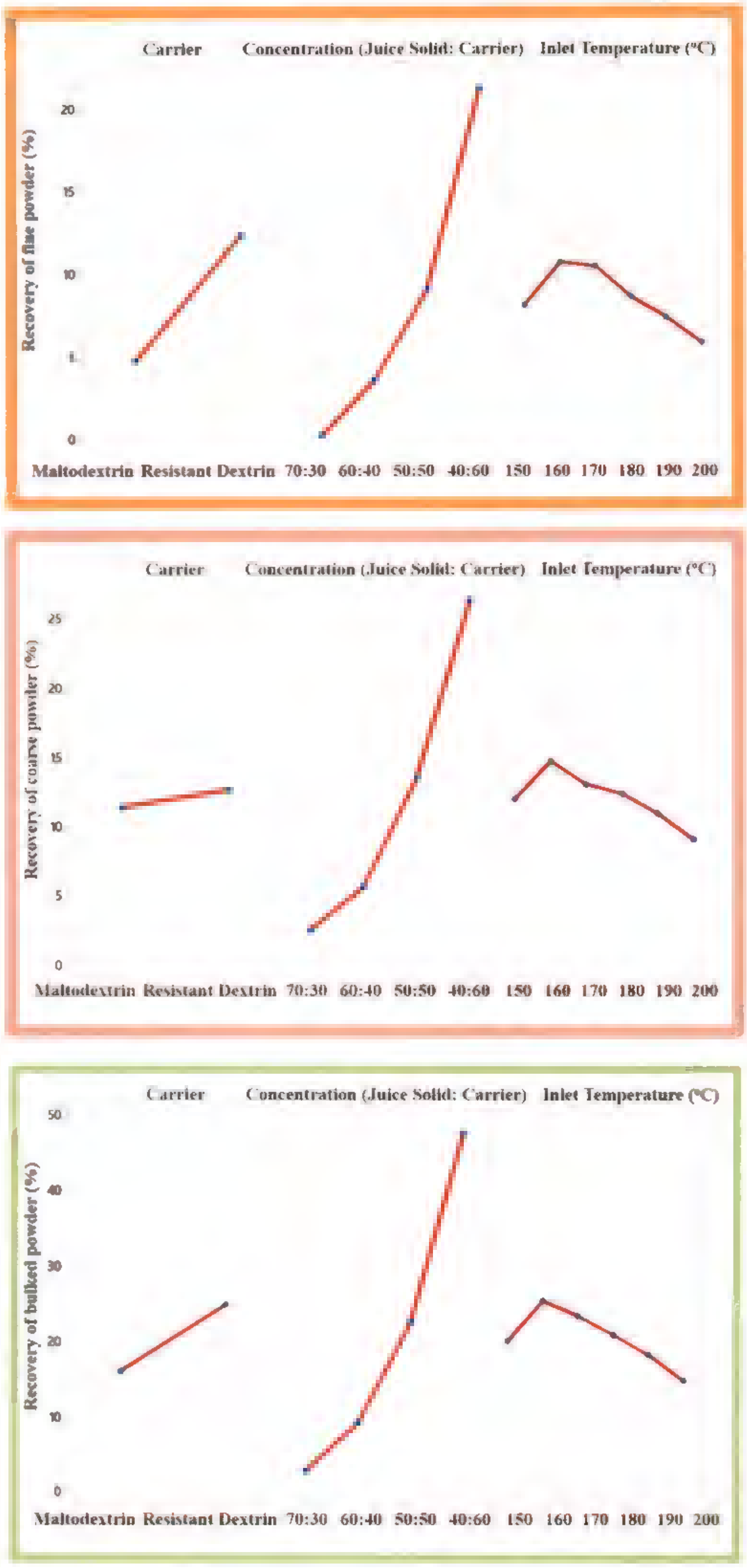

Figure 11: Effects of carrier, concentration and inlet temperature on fine, coarse and bulked powder recovery of blended juice

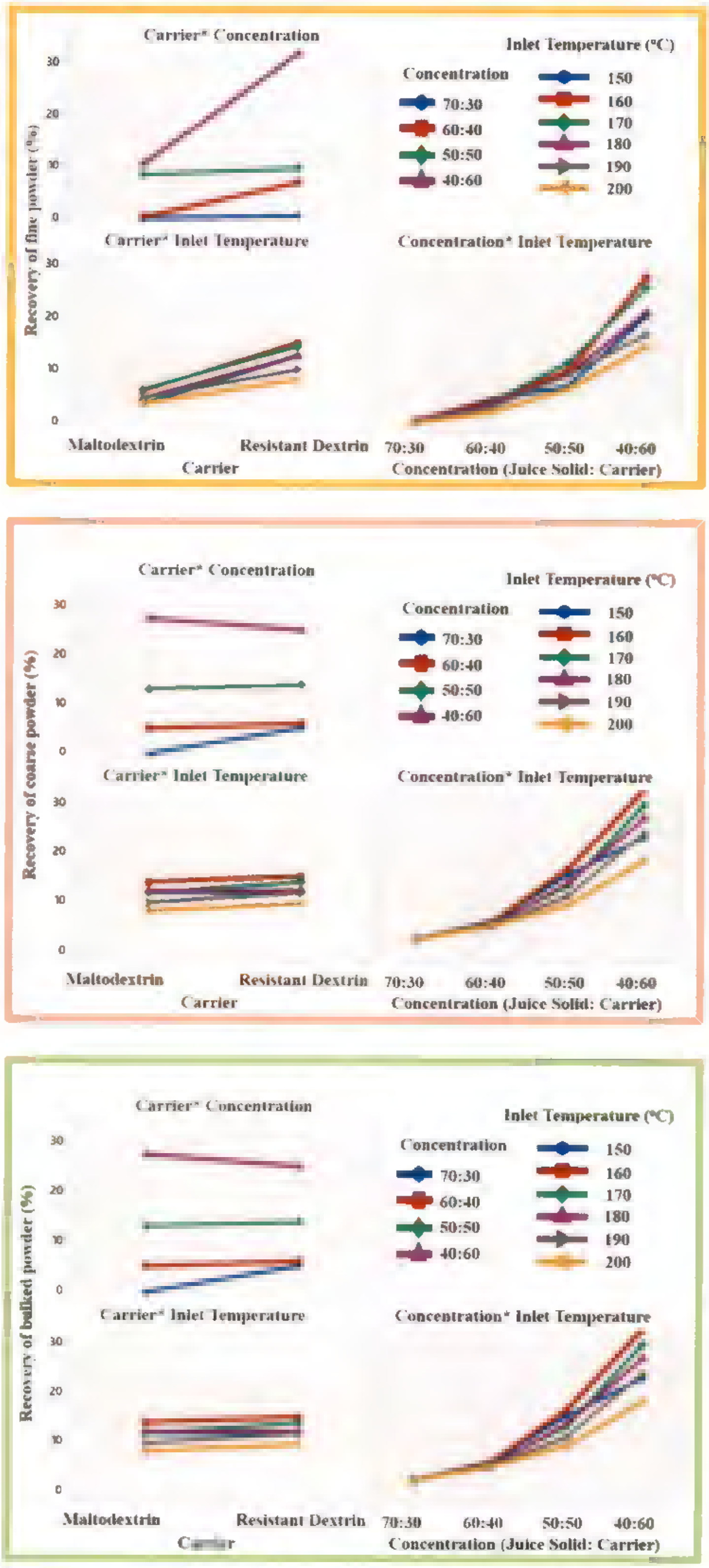

Figure 12: Interaction Effects on fine, coarse and bulked powder recovery of blended juice

Mahendran (2010) observed that spray drying of heat sensitive food material containing a high proportion of hygroscopic sugars is often associated with problems of non-uniform atomization and wall deposition. Stickiness decreased as a function of carrier concentration for the spray drying of guava juice. The product remained in the lower part of the chamber instead of reaching the cyclone collector. The powder could readily be dislodged by knocking the chamber walls, suggesting that the air broom or vibrating hammer devices available on larger spray driers would overcome this problem. When carrier material was added to juice, it formed a film around the solids in the feed that facilitated the production of flowing powder. This behaviour occurs because the particles are better dispersed, while decreases cohesive force between them. Based on these results, it can be stated that the addition of carrier to fruit juice caused changes in the microstructure of the dehydrated powder, influencing the functional characteristics of the powder which improved powder recovery in higher concentrations.

Brennan *et al.* (1971) reported the wall deposition problem in the spray drying of orange juice concentrate and indicated that wall deposition was dependent on the thermoplasticity and hygroscopicity of the powders. Tonon *et al.* (2008) demonstrated that the hygroscopicity of spray dried acai powder gets lower as the concentration of carrier was increased.

The data on recovery of powder exhibited marked interaction of concentration with carrier that reiterated the above findings as shown in figure 8, 10 and 12 as well as in table 6. 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. Powder yield due to the interactive effect of carrier with the highest concentration was nearly 12, 8 and 10 times higher than the lowest carrier concentration combination in which powder was recoverable. Moreover, the combination of resistant dextrin with the carrier ratio of 40: 60 expressed the highest yield over maltodextrin irrespective of place of collection of powder or type of juices except in case of coarse powder in cashew apple and pineapple. The coarse powder recovery of resistant dextrin combination with 40:60 ratio was at par with maltodextrin in cashew apple and less in pineapple. The fine powder recovery was high by 2.85, 2.47 and 3.06 times by the combination of resistant dextrin and 40: 60 ratio in cashew apple pineapple and blended juice respectively. Higher concentration in maltodextrin could only yield at par with subsequent lower concentration of resistant dextrin. This treatment combination also improved total powder yield by 1.49, 1.25 and 1.5 times. Thus the efficacy of the combination of resistant dextrin at the ratio of 40:60 in translocating more powder to cyclone along with increase in yield was clearly evident from the results. This effect might be due to the additive effect of elevation of glass transition temperature, reduced moisture content and low hygroscopicity of powders.

The powder recovery decreased with higher temperatures as depicted in figure 7, 9 and 11 as well as in Table 5. In general 160 °C could be adjudged as optimum due to the consistency in improving powder yield irrespective of nature of powder or type of juice dried. The temperature 170 °C could only able to perform at par in pineapple juice. It could not express equal performance in total powder recovery of other juices. The inlet temperature of 200°C recorded lowest yield irrespective of the nature of powder of juice dried. The 40°C reduction in inlet temperature from 200°C could improve fine powder yield by 111, 64 and 75 per cent in cashew apple, pineapple and blended juice respectively. However, in coarse powder yield the increase in the yield was by the magnitude of 34, 40 and 53 per cent only. Altogether, the change in temperature from 200 °C to 160 °C improved total recovery of powder by 56, 49 and 61 per cent in cashew apple, pineapple and blended juice respectively. The data clearly elucidate that lower temperature improve the yield and the effect is stronger with respect fine powder from cyclone. However, further reduction of temperature from 160 °C to 150 °C reduced the yield. The elevation of 10 °C from 150 °C improved fine powder yield by 28, 55 and 30 per cent in cashew apple, pineapple and blended juice respectively. But this elevation could not significantly influence coarse powder yield in cashew apple and pineapple but yield in blended juice was improved by 12 per cent. Hence, the total powder recovery which went up by 12, 19 and 20 per cent in cashew apple, pineapple and blended juice respectively could mainly be attributed to the improved yield in cyclone.

The cohesion of powder particles might have played a crucial role with respect to the effect of inlet temperature on the yield of powders. Troung *et al.* (2005) 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. The increased inlet temperature might melt the powder causing higher cohesion (Dolinski, 2001). The higher cohesion of the powder to wall at higher temperature might have reduced powder recovery as experienced by Jittanit *et al.*(2010).

However according to Tonon *et al.* (2008) 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. Moreover, as observed by Cai and Corke (2000) higher drying temperature resulted in faster drying and higher powder productivity but under constant feed flow rates.

The interaction effect of carrier with inlet temperature improved fine powder recovery in all fruit juices as depicted in figure 8, 10 12 and Table 7. This interaction effect led to 7.1, 4.3 and 4.46 times yield difference from the extreme ends. Effect of inlet temperature on resistant dextrin was superior to the effect on maltodextrin in improving the yield. With respect to cashew apple juice resistant dextrin was superior to maltodextrin by yielding 3.13, 3.61, 3.21 times by the interaction with lowest (150°C), optimum (160°C) and highest (200°C) temperature respectively. In pineapple resistant dextrin was better by 3.47, 1.89 and 1.58 times at these temperature levels. In blended juice also inlet temperature exhibited similar influence on resistant dextrin to improve the yield by 3.88, 2.64 and 2.34 times at lowest, optimum and highest temperature respectively. However, interaction effect of carrier with inlet temperature was non-significant in the coarse powder obtained from chamber. This clearly indicate that as the resistant dextrin reduced stickiness, the recovery improved, and the effect of other operating parameters became more evident. Moreover, the variation in process parameters had higher influence in the cyclone recovery than powder from chamber.

Effect of concentration was significantly influenced by inlet temperature as depicted in figure 8,10,12 and Table 8. Profound effect of concentration in determining the yield parameters was clearly evident since no other carrier concentration level was at par with 40: 60 at similar temperature levels. Treatment combinations which involve lower carrier concentrations and temperature levels exhibited less significantly differentiated groups than high carrier concentration combinations. Lower ranges of temperature exhibited higher yields at higher concentration levels. In the highest concentration levels 160°C was the optimum temperature since it exhibited higher recovery from the nearest higher and the lower one. However in the lower concentration levels these lower temperature ranges did not exhibit any marked deviation pattern in yield.

As a combination, carrier resistant dextrin, juice solid to carrier ratio of 40:60 and 160°C inlet temperature resulted in high recovery of fine, coarse and bulked fruit powders. This combination recovered 72.09, 85.62 and 74.70 per cent of total solid content from juice carrier mix of cashew apple, pineapple and their equal blend respectively of which 40.55, 47.06 and 42.02 per cent were from cyclone (Table 9).

5.1.2 Feed rate

The data on Table 10 clearly depicted that the feed rate did not vary between the carriers while drying cashew apple and pineapple juices. However, varying proportions of the carriers and inlet temperature positively influenced feed rate in a significant manner in all fruit juices. Increase in concentration of carrier materials in the feed mix realised higher feed rates as the combination with highest carrier content (40:60) recorded 66 per cent higher feed rates in cashew apple and 59 per cent in both pineapple and blended juice over the least carrier content (80:20) as given in table 11. Quicker drying of the feed mix with higher carrier content might be due the lower content of water in the feed mix. 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.

Moreover, higher inlet temperature invariably led to higher feed rates as expressed in table 12. A fifty degree increment from the lowest inlet temperature of 150°C led to 138, 153 and 121 per cent increase in feed rate in cashew apple pineapple and blended juice respectively. Highest temperature under trial needed the highest feed rate irrespective of type of juice. Increment of 20°C from the lowest temperature of 150°C raised feed rates by 41, 53 and 41 per cent in cashew apple pineapple and blended juice respectively while an equal increase from 170°C could only obtain 31, 24 and 25 per cent higher feed rates. Thus the increment in temperature levels exerted higher influence in lower temperature levels.

Though both interaction effects that involve carrier were not significant, the effect of concentration was influenced by inlet temperature as depicted in table 15. The influence exerted by higher concentration of carrier in elevating the feed rate is significantly supported by the higher inlet temperature. The highest carrier ratio with 200°C recorded highest feed. As reviewed by Phisut (2012) 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.

However possibility for lower yields at high temperatures as discussed earlier 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. As observed by Chegini and Ghobadian (2007) 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. As reported by Leon- Martinez *et al.* (2010) low feed rates might have improved atomization which resulted in higher yield. Kaur *et al.*(2015) also noted an increase on mass production rate with increasing air temperatures and decreasing pump speeds in spray drying.

5.1.3 Selection of powders from part-1

The data on recovery of powder clearly indicated superiority of juice solid to carrier ratio of 40: 60 to yield higher and no other concentration was ever at par irrespective of nature of powder or type of juice. With respect to inlet temperature, the highest temperature under study (200°C) consistently recorded the lowest yield irrespective nature of powder or type of juice.

Hence, ten treatment combinations which had higher recovery percentages from each juice (five each from resistant dextrin and maltodextrin) which involve juice solid to carrier ratio of 40: 60 dried at temperature levels from 150 to 190°C were selected for cashew apple, pineapple and blended juice in order to assess physico chemical and sensory properties in Part-2 of the programme.

5.2 QUALITY EVALUATION OF MICROENCAPSULATED FRUIT POWDERS

5.2.1 Physical parameters

5.2.1.1 Moisture content

The powder produced by using resistant dextrin had lower moisture content than maltodextrin as expressed in figure 17. Reduction to the extent of 12, 19 and 14 per cent could be obtained by using resistant dextrin as carrier in cashew apple, pineapple and blended juice respectively (Table 18).

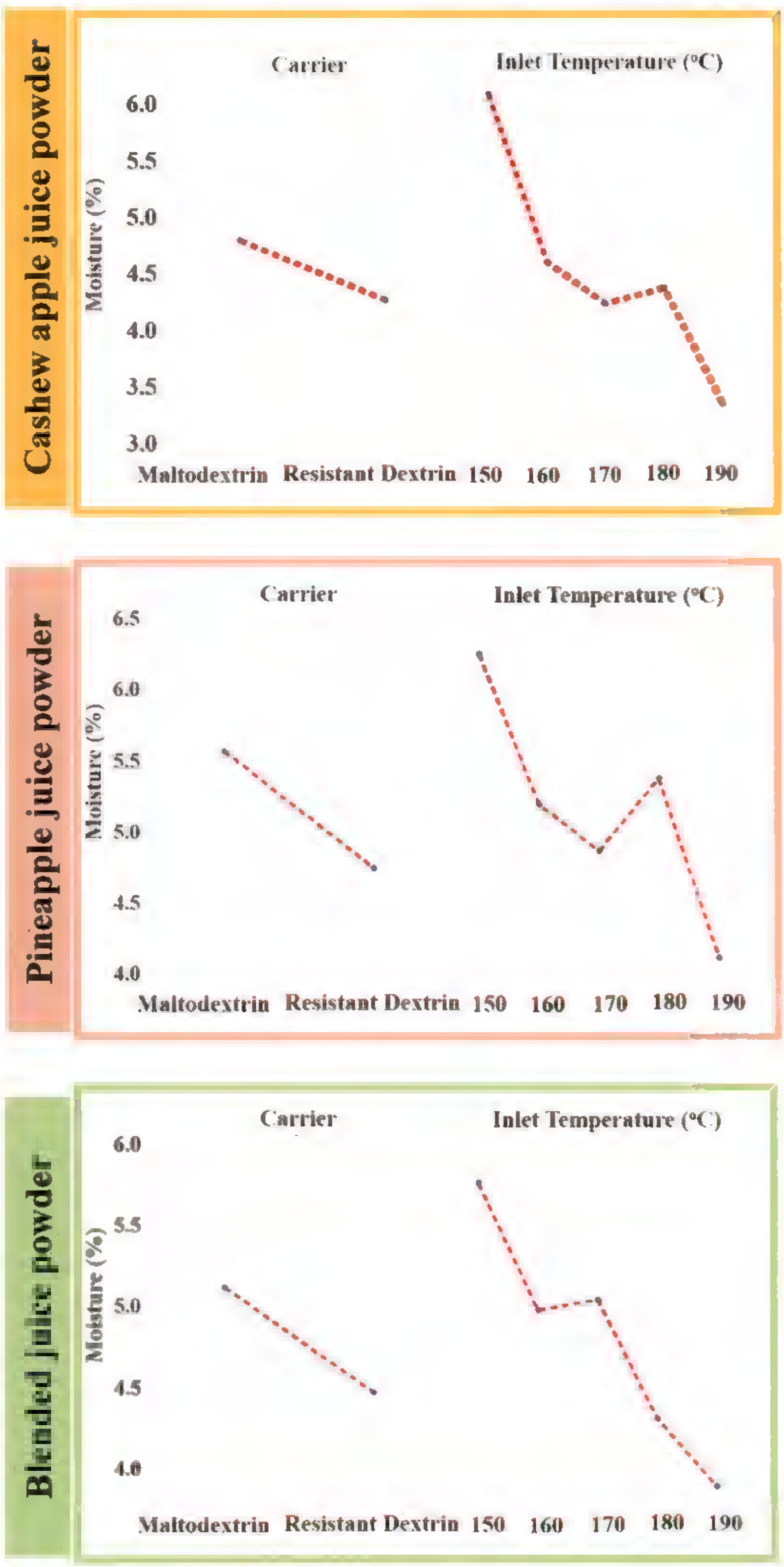

Figure 13 : Effects of carrier and inlet temperature on moisture content of cashew apple, pineapple and blended juice powders

Higher maltodextrin dextrose equivalent might have increased powder moisture content since it developed stickiness. Stickiness results in agglomeration which result in less surface contact with the heating medium and low surface area from which the moisture can escape (Goula and Adamopoulos, 2005) and hence high DE carriers reach state of non-adhesion later than low DE carriers (Goula and Adamopoulos, 2008).

Moreover, as explained by Truong *et al.* (2005) the higher dextrose equivalent of maltodextrin might have elevated moisture content of the powder due to the chemical structure with high number of ramifications with hydrophilic groups, that easily bind to water molecules from the ambient air during powder handling after the spray drying.

Moisture content of juice powder was inversely proportional to inlet temperature as expressed in figure 13 and Table 19. The highest temperature recorded 81, 52 and 48 per cent lower moisture content than the lowest temperature in cashew apple, pineapple and blended juice respectively. A ten degree increment from 150 °C could significantly reduce moisture content by 32, 20 and 16 per cent in cashew apple, pineapple and blended juice respectively.

As observed by Quek *et al.*(2007)in watermelon, Grabowski *et al.(*2006) in sweet potato and Suhaimi *et al.*(2011) in pineapple, when the inlet air temperature increased, greater temperature differences between the feed and the drying air occurred providing adequate driving force for moisture removal that led to powders with lower moisture content. The greater difference of temperature cause greater rate of heat transfer into the particles. When water is driven out of the particles as water vapor, it may create a saturated atmosphere at the particle surface hampering the rate of subsequent water removal if not carried away. Hotter air will hold more vapour toward saturation. Hence, High temperature surrounding of feed particles will draw more moisture out of the food than cooler air (Goula and Adamopoulos, 2005). In contrast Loh *et al.* (2005) reported that inlet air temperature did not influence moisture content of the spray-dried pandan powder. The moisture content of the samples may depend on the type and concentration of wall materials. Moreover feed rate also might have played a role in changing the moisture content through atomization. Higher feed rates reduce the heat contact period of the feed particles in drying chamber effecting a less efficient heat transfer. This may result in less water evaporation, and therefore higher moisture content (Leon-Martinez *et al.* 2010).

Interaction effect of carrier with inlet temperature did not exhibit any significant influence as given in table 20. The juice powder with maltodextrin dried at 150°C had moisture content of 6.23, 6.67 and 6.28 per cent while drying at 190 °C retained 3.86, 4.58 and 3.80 per cent moisture in cashew apple, pineapple and blended juice respectively. However, when resistant dextrin was added as carrier, the moisture content at 150°C were 5.99, 5.85 and 5.26 per cent which got reduced to 2.88, 3.67 and 4 per cent at 190°C. Drying at 160°C with maltodextrin retained 4.79, 5.83 and 5.34 per cent moisture while resistant dextrin added powder had 4.43, 4.59 and 4.64 per cent moisture in cashew apple, pineapple and blended juice respectively. Sinija and Mishra (2008) suggested a target range of 3-5 per cent moisture content for instant tea powder to provide better stability during packaging and storage. Spray dried sumac powder contained 1.89 to 2.94 per cent moisture (Caliskan and Dirim, 2013) while guava powder ranged between 2.14 to 2.24 per cent (Mahendran, 2010). Spray dried raisin juice concentrate had moisture content between 0.6 to 4.5 per cent and pineapple powder had 4-5.8 per cent moisture (Jittanit *et al.* 2010). However Suhaimi *et al.*(2011) could obtain pine apple powder with 1.65 to 2.65 per cent. These varying results might be due to the varied process parameters used in the drying process of different experiments. Uncontrolled factors viz. relative humidity of drying air, temperature of air used for atomization, temperature of feed, degree of feed aeration could explain the deviation in the studies.

5.2.1.2 Bulk density, particle density and volume occupied by particles.

Bulk density of cashew apple and blended juice powder were significantly improved by maltodextrin while it did not cause significant change in the particle density of these powders as given in figure 14 and table 21. Instead, maltodextrin significantly elevated volume occupied by the particles and therefore reduced the porosity. Maltodextrin improved bulk density by 11 and 12 per cent in cashew apple and blended juice. The volume occupied by the particle were also higher by 10, 9 and 12 per cent in cashew apple, pineapple and blended juice respectively.

Bulk density and volume occupied by particles were inversely proportional to inlet temperature as shown in figure 14 and table 22. The lowest temperature improved bulk density by 30, 27 and 29 per cent over the highest temperature in cashew apple, pineapple and blended juice powders respectively. Similarly powder particles produced by lowest temperature occupied 22, 11 and 9 per cent higher volume in comparison to the lowest temperature. The true particle density exhibited increasing trend towards the lower temperature levels but the difference was significant only in blended juice powder.

The interaction effect between carrier and inlet temperature did not influence bulk density, particle density and volume occupied by the particles indicating the importance of the main effect of carrier and inlet temperature as depicted in table 23. Bulk density of powder ranged between 0.43 to 0.62 cashew apple juice, 0.48 to 0.66 in pineapple juice powder and 0.44 to 0.64 in blended juice powders. Similarly bulk density ranged 0.59 - 0.77 g/ml (Caliskan and Dirim, 2013) 0.64–0.67 g/cm^3 (Papadakis *et al.,* 2006), 0.54–0.61 g/cm^3 (Mahendran, 2010) and 0.57–0.77 g/ml (Leon - Martinez *et al.,* 2010) in spray dried sumac powder, raisin juice concentrate, guava concentrate, and aqueous solutions of mucilage respectively.

Higher bulk density and less porosity of maltodextrin might be associated with the higher sticky nature of powder. As suggested by elsewhere Goula and Adamopoulos (2008) and Shrestha *et al.* (2007) particles that tend to stick together

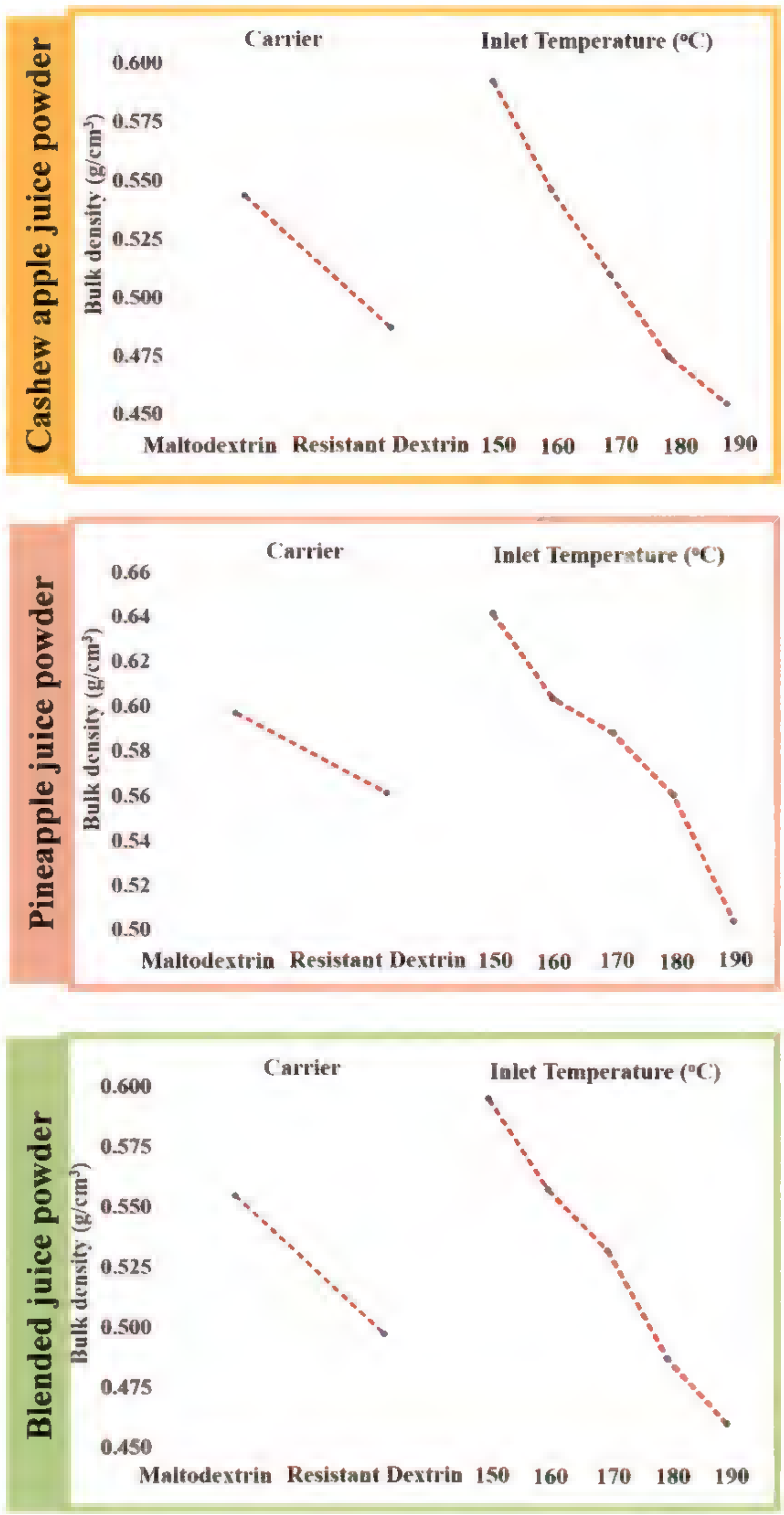

Figure 14 : Effects of carrier and inlet temperature on bulk density of cashew apple, pineapple and blended juice powders

leave less interspaces between them and consequently resulted in a smaller bulk volume leading to higher bulk density. Higher sticky nature is also associated with higher moisture content, high dextrose equivalence and low glass transition temperature as explained earlier.

As observed by Chegini and Ghobadian (2005), the effect of temperature on bulk density might depend on powder moisture content, as higher moisture lead to higher bulking weight since water is considerably denser than the dry solid. Hence, the powder produced at lower temperature ranges might have exhibited higher bulk density and lower porosity.

In addition, Walton (2000) suggested that elevated drying air temperature decreased bulk and particle density and particles exhibited greater tendency to be hollow. As explained by Leon – Martinez *et al.* (2013) higher drying temperatures produce a higher ratio of surface to volume for the spray dried capsules which leads to the formation of vapor impermeable films on the droplet surface, followed by the formation of vapor bubbles that cause droplet expansion and creation of hollow particles. Consequently, the more hollow particles might have alleviated bulk density of powder dried at higher inlet temperature.

5.2.1.3 Total soluble solids

Total soluble solids of reconstituted solutions (percentage of reconstitution was based on potential yield as discussed earlier) revealed that instant juice powders produced with carrier maltodextrin had higher TSS compared to resistant dextrin in all fruit juices as depicted in figure 15 and table 24. These powders exhibited 13,15, and 11 per cent higher TSS than resistant dextrin. Higher TSS content of maltodextrin based powder might be due to the higher reducing sugar content. Maltodextrins are products of starch hydrolysis, consisting of D-glucose units linked mainly by (1-4) glycosidic bonds. According to the degree of hydrolysis, dextrose equivalent value (DE) is assigned and higher the DE value indicate shorter the glucose chain, higher reducing sugar content and sweetness (Murugesan and Orsat, 2012). In contrast

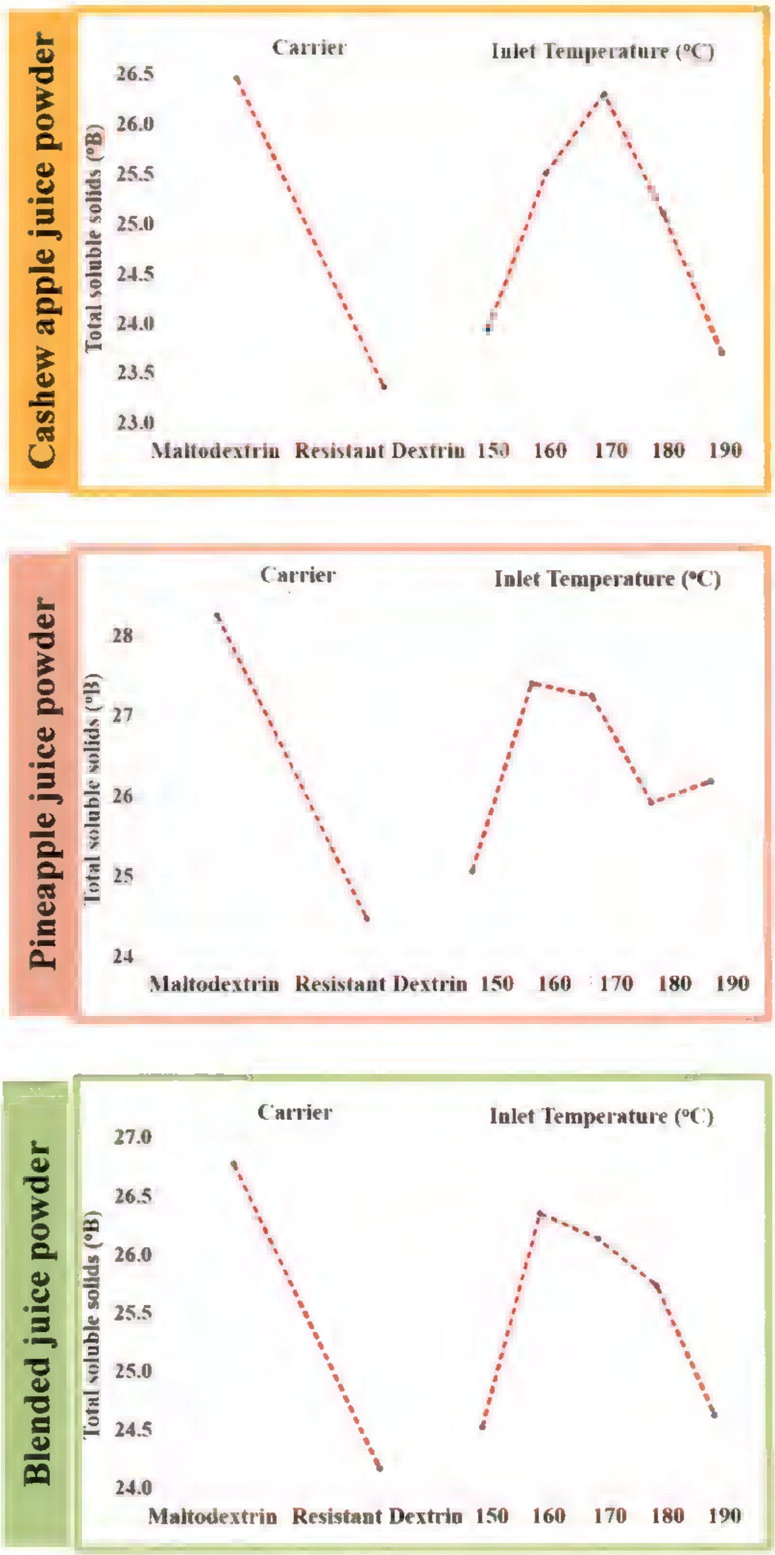

Figure 15 : Effects of carrier and inlet temperature on total soluble solids of cashew apple, pineapple and blended juice powders

resistant dextrin is a glucose polysaccharide with lower amounts of reducing groups and a lower degree of hydrolysis produced from edible starch through exposure to high temperature in the presence of an acid catalyst. The dextrin is further purified with activated carbon, demineralised by exchange resins and subjected to chromatographic partitioning that removes glucose and lower molecular weight oligosaccharides (Laetitia Guerin-Deremaux *et al.,* 2010).

The inlet temperature influenced TSS of cashew apple juice powder as given in figure 15 and table 25. The TSS content increased by 10 per cent from 150°C to 170 °C and then decreased by 11 per cent to 190 °C. While drying guava juice concentrate, Mahendran (2010) also observed an increase in TSS following drying, which might be due to concentration accompanied by the hydrolysis of carrier during drying process. Furthermore, caramelisation of sugar at high temperature due to burning of powder might have reduced the sugar content at 190 °C.

The interaction of carrier with inlet temperature did not significantly influence TSS content of powders as depicted in Table 26. The TSS ranged from 21.83 to 27.367 when cashew apple powder were reconstituted to 30 per cent solution with distilled water. The TSS of pineapple juice powder was ranged from 23.47 to 29.57 in 35 per cent reconstituted solution. A 32.5 per cent solution had TSS range of 23.6 to 28.133 with blended juice powder.

5.2.1.4 Per cent soluble solids and dispersible solids

Both the carriers were efficient in producing powders with high soluble solids and low dispersible solids though resistant dextrin was slightly better with approximately two per cent improvement in all fruit juice powders as depicted in figure 16 and table 24. Inlet temperature (Figure 16 and Table 25) and effect of interaction between carrier and inlet temperature (Table 26) did not significantly influence the solubility of powder particles. The soluble solid percentage ranged 93.367 to 96.4 per cent in cashew apple, 91.1 to 94.567 per cent in pineapple and 90.03 to 93.767 in blended juice powders.

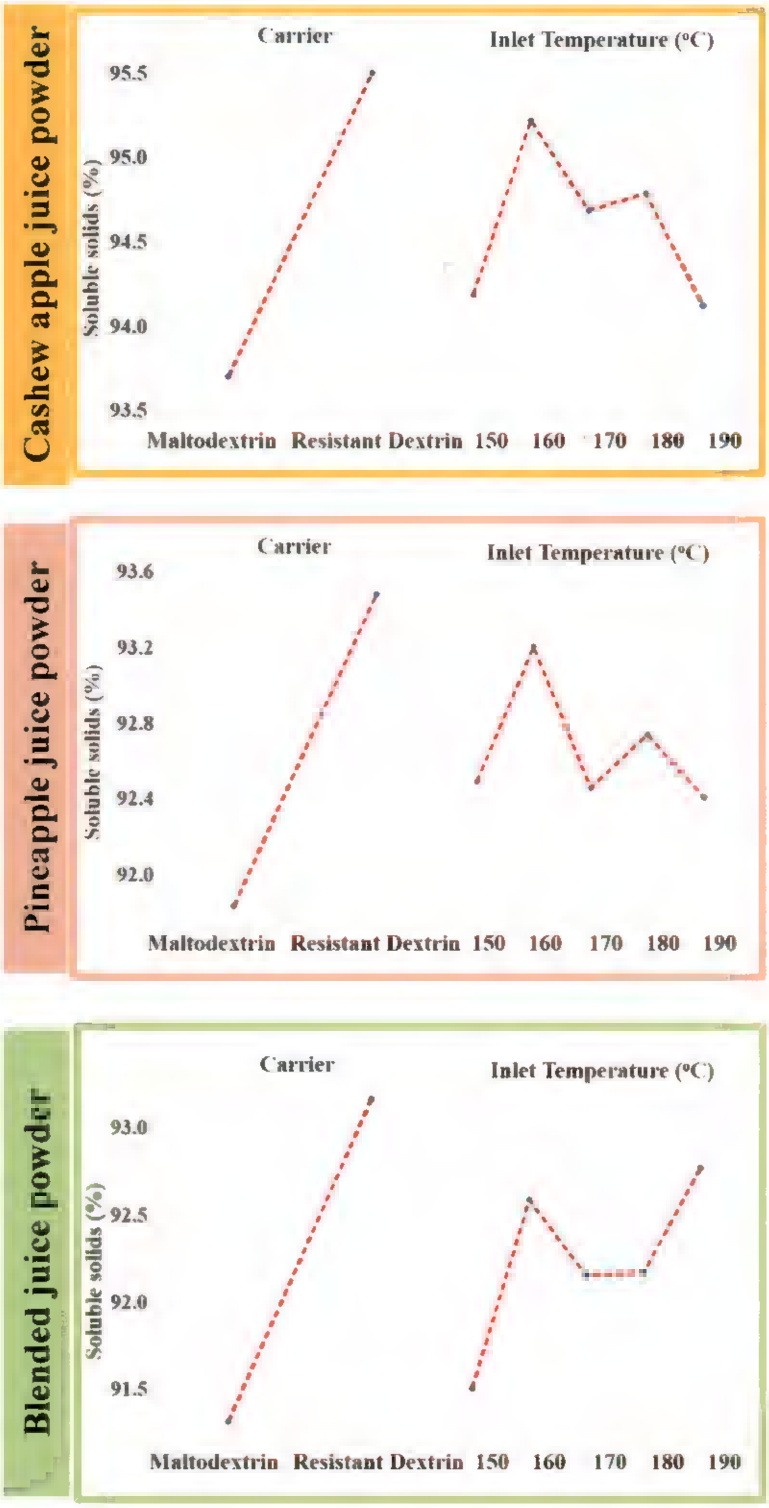

Figure 16 : Effects of carrier and inlet temperature on percent soluble solids of cashew apple, pineapple and blended juice powders

As explained by Cano-Chauca *et al.* (2005) that solubility of spray dried powders were higher when starch derivatives were added during spray-drying. These materials served as coating agent as the particle crust developed during spray drying making product highly soluble (Desai and Park, 2004). This hard surface layer formed caused changes in the microstructure of the powders. In the absence of fat and surface active components like proteins, the formation of a hard crust occurred on the droplet surface when there was super saturation (Caliskan and Dirim, 2013). The composition of the crust formed was determined by the solubility of the dissolved components since the crust had developed by precipitation of the least soluble substance from the saturated solution. Hence, the formed crust probably was composed of either resistant dextrin or maltodextrin which had high solubility.

In addition, the atomization of fruit juice particles during spray drying might have contributed to solubility of spray-dried product as suggested by Caparino *et al.* (2012). Fibers present in fruit juice might have been shred into tiny particles due to high atomization of the feed to result in high solubility.

Furthermore, amorphous nature of powders might have influenced solubility of powders. The superiority of resistant dextrin over maltodextrin in producing powders with high percentage of soluble solids and low dispersible solids might be explained by its better amorphous nature due to lower dextrose equivalence, moisture content, agglomeration and bulk density. As observed by Fazaeli *et al.* (2012) higher dextrose equivalence of carrier reduced powder solubility. This effect can be better explained by the observation made by Goula and Adamopoulos (2008) on effect of powder moisture on solubility. Lower moisture content was associated with fast rehydration due to less stickiness and better contact with rehydration water due to higher surface area. Jittanit *et al.* (2010) found that agglomerated powder had less solubility due to low surface area for contact. Moreover, there could be an inverse relationship between bulk density and solubility as observed by Fazaeli *et al.* (2012).

5.2.1.5 Sinkability

None of the treatments significantly influenced sinkability of powder (Table 27, 28 and 29). The very high content of soluble solids than dispersible solids might have contributed to this effect. As soon as the powder was dusted on the surface of water it got solubilized leaving less particles than enough that were needed to be sank.

5.2.1.6 Hunter color value.

5.2.1.6.1 L value (Lightness)

Both carriers yielded powders with high lightness (L* values were above 90) and resistant dextrin was slightly but significantly better in all fruit juices with higher L* values than maltodextrin (Table 30). High lightness in powders might be due to the addition of carriers. Pure resistant dextrin is a darker carrier than pure maltodextrin Pure maltodextrin and resistant dextrin had L* values of 97.47 and 94.13 respectively before addition to fruit juice. Less burning of powder occurred in those treatment combinations where resistant dextrin was added as carrier. Burning of powder led to more brown colored particles consequently more darkness. Superiority of resistant dextrin in lightening effect could be attributed to the improved recovery of powder at cyclone by the same carrier as explained earlier. Cyclone recovered powders are the true representative of spray dried powder. Chamber recovered powder received more intense heat treatment, might become scorched and exhibit different physical properties than powder recovered at cyclone (Goula and Adamopoulose, 2005).

Lightness of powder was inversely proportional to inlet temperature (Table 31). The lowest temperature recorded two and four per cent improvement in lightness of cashew apple and pineapple juice powders respectively. In blended juice powders optimum temperature for lighter powder was 160°C with 5 per cent improvement over 190°C. The result is in conformity with reduction of lightness observed by Quek *et al.* (2007) in water melon powders at higher inlet temperature due to browning. Moreover, higher darkness at higher temperature can also be attributed to caramelisation of sugar as observed by Caparino *et al.* (2012) in mango powder.

Inlet temperature exhibited interaction effect on carrier in blended juice powder (Table 32). Resistant dextrin combination dried at 160°C had the highest lightness and the L* values ranged 87.75 to 94.28. Range of L values were 89.72-92.75 and 90.27-94.82 in cashew apple and pineapple juice powders respectively.

5.2.1.6.2 a* and b* values

The interpretation of a* values clearly indicated that resistant dextrin exhibited powders with higher greenness (higher negative values) and maltodextrin exhibited lower greenness or higher redness (lower negative or positive values) in all fruit juices (Table 30). Pure maltodextrin and resistant dextrin had a* values of – 0.54 (lower greenness) and – 1.37 (higher greenness) respectively before addition to fruit juice. Hence the color of powder was influenced by the color of the respective carriers.

Moreover, powders dried at lower temperature exhibited a* value towards greenness (higher negative values) and higher temperature exhibited the shift towards redness (lower negative or positive values) in all fruit juices (Table 31).

Interpretation of b* values showed varying color shift with respect to carriers. Resistant dextrin exhibited color of cashew apple powder with more yellowness (higher positive values). However, pure maltodextrin and resistant dextrin had b* values of 1.43 (lower yellowness) and 10.6 (higher yellowness) respectively. Though, resistant dextrin had higher b* values (yellowness) before drying, the rate of shift towards yellowness by resistant dextrin was less at drying than maltodextrin with respect to cashew apple juice powder. In addition, resistant dextrin exhibited powder with lower yellowness (lower positive values) than maltodextrin in pineapple and blended juice powders. This clearly indicated superiority of resistant dextrin in avoiding burning of powder.

Drying at lower temperature shifted color towards lower yellowness (lower positive values) and high temperature towards higher yellowness (higher positive values). Similar tendency of increasing b values in proportion to inlet temperature was also reported by Quek *et al.* (2007).

5.2.1.6.3 Hue

Hue angle measures the tonality of color by which perception of a color as red, yellow, green and blue are identified. Chroma value indicates the color intensity or saturation which distinguishes between vivid and dull colors. Both hue angle and chroma are calculated from a* and b* values obtained from the colorimeter as explained earlier.

Instant juice powders with resistant dextrin recorded higher hue angle in all fruit juices (Table 30). Hue of pure maltodextrin and resistant dextrin were 110.75° and 98.36° respectively. Juice powder with maltodextrin recorded 93.29°, 90.57° and 90.52° whereas powders with resistant dextrin had 94.79°, 92.67° and 96.01° hue angles in cashew apple, pineapple and blended juice respectively. Hence it was obvious that hue angle shifted towards yellow due to drying with both carriers and the extent of shift was lower in resistant dextrin. Similar result in the three juice powders asserted the superiority of resistant dextrin in alleviating burning of powders.

Hue angle was inversely proportional to drying temperature (Table 31). Drying temperature of 150°C recorded higher hue angle in cashew apple and pineapple while 160°C was optimum in blended juice. The highest temperature recorded the lowest hue angle in all fruit juices. Drying at higher temperature shifted the powder hue to yellow in cashew apple powder and to yellow - red in pineapple and blended juice powder. The change in powder hue to more yellow and to yellow-red indicated browning of powders due to burning.

Interaction between carrier and inlet temperature was also significant in cashew apple and blended juice powders (Table 32). Optimum combination with lowest burning was resistant dextrin was noticed in combinations with 150°C in cashew apple juice powder and 170°C in blended juice powders. The hue of cashew apple juice powders was yellow with angles range of 91. 85° to 100.13°. The hue of

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pineapple powders were mainly yellow though the highest temperature over crossed to the red spectrum since the hue angle range from 0°-90° fall in red spectrum and hue values ranged from 89.26° to 96.51°C in pineapple powders. Blended juice powder also expressed yellow hues with similar over cross and hue range was 86.71°C to 101.73°C.

5.2.1.6.4 Chroma

Chroma value indicates the color intensity or saturation which distinguishes between vivid and dull colors. Chroma is calculated from a* and b* values obtained from the colorimeter as explained earlier.

Resistant dextrin exhibited higher color saturation in cashew apple juice powder but lower in pineapple and blended juice (Table 30). Resistant dextrin exhibited chroma values of 17.19, 12.71 and 14.7 while maltodextrin expressed chroma values of 11.6, 13.03 and 14.45 in cashew apple, pineapple and blended juice powders respectively. However, chroma of pure resistant dextrin and maltodextrin were 10.8 and 1.53 respectively. The extent of increase in saturation was lower in case of resistant dextrin. Since the powder hues are yellow, higher saturation indicate higher yellowness which might have been caused by burning. Hence resistant dextrin was superior in producing powders with low burning.

Saturation of powder color was directly proportional to inlet temperature (Table 31). The lowest color saturation was recorded at 150°C in cashew apple and pineapple powder but at 160°C in blended juice powder. The highest saturation level was at 190°C in all fruit juice powders. Therefore, the data clearly elucidated that higher temperature elevate yellowness due to browning by burning.

Interaction effect of carriers with inlet temperature also exhibited significant influence on carriers in all fruit juices (Table 32). The chroma values ranged from 7.91 to 19.47, 9.87 to 16.43 and 11.91 to 19.75 in cashew apple pineapple and blended powder respectively.

Optimum combination for resulting in low burning was resistant dextrin combinations at 150 °C in cashew apple and pineapple and 160°C in blended juice since, these powders exhibited least deviation from the initial saturation level of carrier.

5.2.1.7 Relative Viscosity

Relative viscosity of reconstituted fruit powders was significantly influenced by carriers (Table 33). Powders with resistant dextrin recorded slightly but significantly lower viscosity. The viscosity of treatment combinations ranged from 7.27 to 8.25, 8.16 to 8.83 and 7.88 to 8.29 mPs in cashew apple pineapple and blended powder respectively as depicted in table 35.

The low viscosity of the reconstituted juice powders confirms the observations made by Gharsallaoui *et al.* (2007) and Laetitia - Guérin-Deremaux *et al.* (2011) on low viscous properties of carrier maltodextrin and resistant dextrin respectively. The higher total soluble solids in the juice powders with maltodextrin may have contributed to the higher viscosity in comparison to resistant dextrin as suggested by Bastos *et al.* (2011). Inlet temperature and its interaction with carrier could not significantly influence viscosity in contrast to the observations made by Medina-Torres *et al.* (2013) in which thermal degradation at high temperature (> 170°C) reduced viscosity in mucilage powders.

5.2.1.8 Flowability (Angle of Repose)

With respect to carriers, resistant dextrin exhibited 5, 5.4 and 15 per cent lower angle of repose than maltodextrin in cashew apple, pineapple and their equal blend respectively (Figure 17 and Table 33). The powders dried under highest temperature recorded 19.8 13.33 and14.36 per cent lower angle of repose than the lowest temperature (Figure 17 and Table 34). The temperature range of 160°C - 180°C did not vary significantly among them in cashew apple and blended juice powders but 160 °C produce powders with higher angle of repose within this range in pineapple juice.

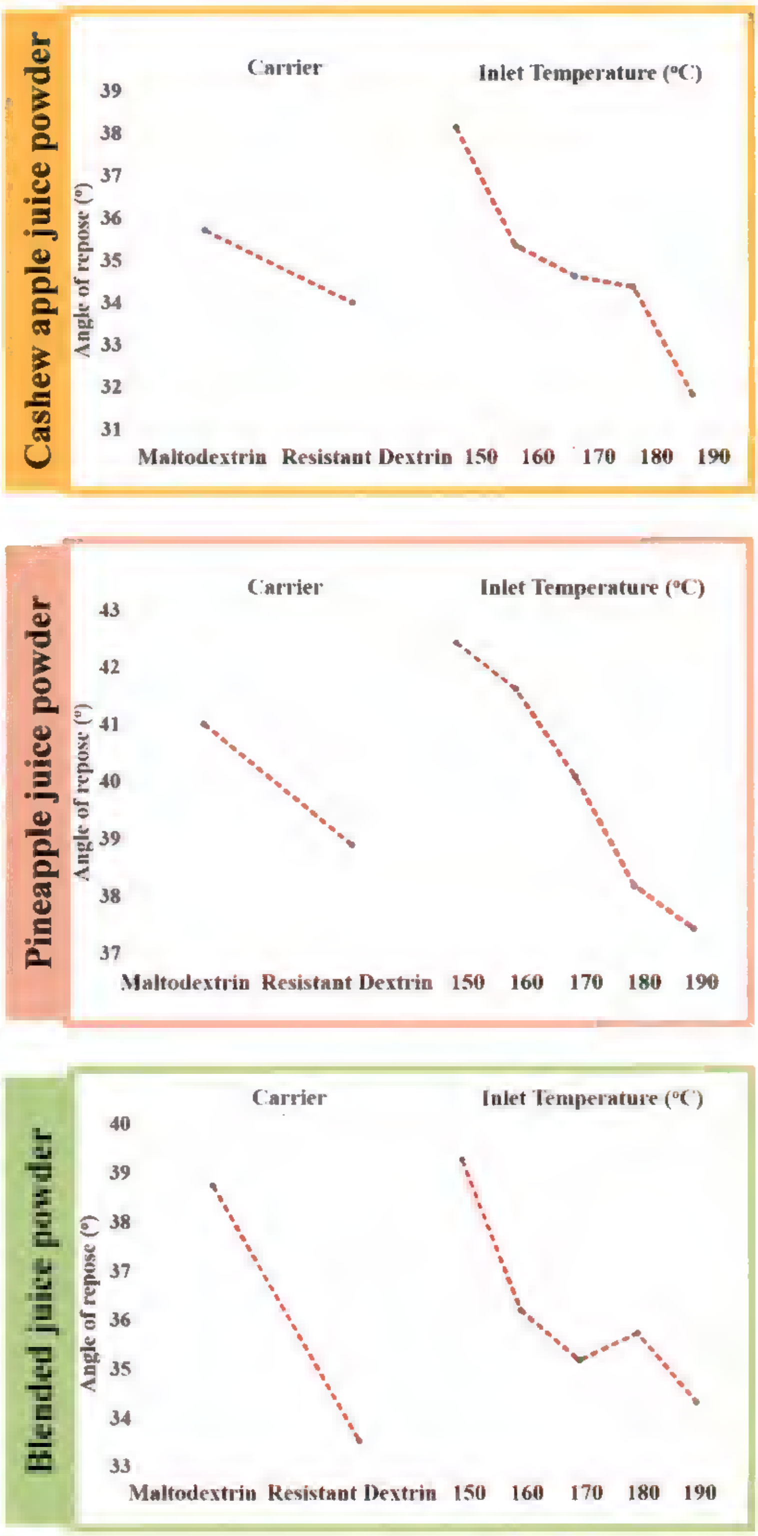


Figure 17 : Effects of carrier and inlet temperature on angle of repose of cashew apple, pineapple and blended juice powders

Angle of repose is directly proportional to cohesiveness of powder. Hence, lower angle of repose represents more free flowing material (Wouters and Geldart, 1996). Therefore, Patil *et al.* (2014) suggested that the angle of repose can be used as a rough flowability indicator and is applied by food industry quality control in order to evaluate flowability.

Higher flowability exhibited by resistant dextrin and higher inlet temperature can be attributed to the lower moisture content of powders. As observed by Fitzpatrick (2005) lower moisture content improve and higher moisture content impair flowability. This effect could be attributed to higher glass transition temperature of powder since a small amount of water is able to depress Tg of the powder as suggested by Bhandari and Hartel (2005). Oliveira *et al.* (2009) confirmed that higher glass transition temperature of powder improves powder flowability.

Cohesive behavior of solids may be affected by other mechanisms such as inter particle forces and geometrical interlocking of granular materials. Hygroscopic materials exhibit strong inter particle bonds in the form of liquid bridges. Increased number of liquid bridges and higher capillary forces acting on the particles of hygroscopic powders as suggested by Scoville and Peleg (1981) might have impaired flowability of powders produced with maltodextrin and at lower inlet temperature.

Riley *et al.* (1978), classified powders according to their flowability using the angle of repose, as indicated below (Table 66)

Table: 66 Classification of powder flowability based on angle of repose

SLNo	Description	Angle of Repose
1	Very free flowing	25-30°
2	Free flowing	30-38°
3	Fair to passable flow	38-45°
4	Cohesive	45-55°
5	Very cohesive	>55°

Interpretation of angle of repose as per above classification revealed that none of the powder was either very free flowing or cohesive. Cashew apple powder produced with maltodextrin at inlet temperature range of 160°C to 190°C were free flowing. However, drying at 150°C reduced the flowability to fair and passable. With respect to the powder produced with resistant dextrin as carrier all cashew apple powders were free flowing.

The pineapple juice powders produced under combination of resistant dextrin at temperature range of 180-190°C were of free flowing nature. All other pineapple juice powders could be classified as fair with passable flow.

The blended juice powders produced by adding maltodextrin as carrier expressed fair to passable flow. In contrast, resistant dextrin made the powders free flowing.

5.2.1.9 Water activity

Resistant dextrin reduced water activity of pineapple powder while both carriers were equally effective in influencing water activity of cashew apple and blended juices (Figure 18 and Table 33). Water activity of cashew apple and blended juice powder dried at 150°C were significantly higher than those produced at temperature range of 160 °C - 190°C (Figure 18 and Table 34). Water activity of pineapple powder produced at temperature range of 150 °C to 170 °C was higher than those produced at 180-190°C range. The result was consistant with studies of Nadeem *et al.* (2013) in which water activity of mountain tea (*Sideritis stricta*) powder decreased about 15 per cent when inlet temperature was elevated from 145 °C to 165 °C and the change in water activity exhibited similar pattern of moisture content. The slight deviations in water activity pattern from the moisture pattern might be explained based on remarks by Fazaeli *et a.l* (2012) who opinioned that water activity differs from moisture content though it is related to moisture content, since it is the measure of available free water in food which is responsible for biochemical reactions, while the moisture content represents the water composition. Water activity may

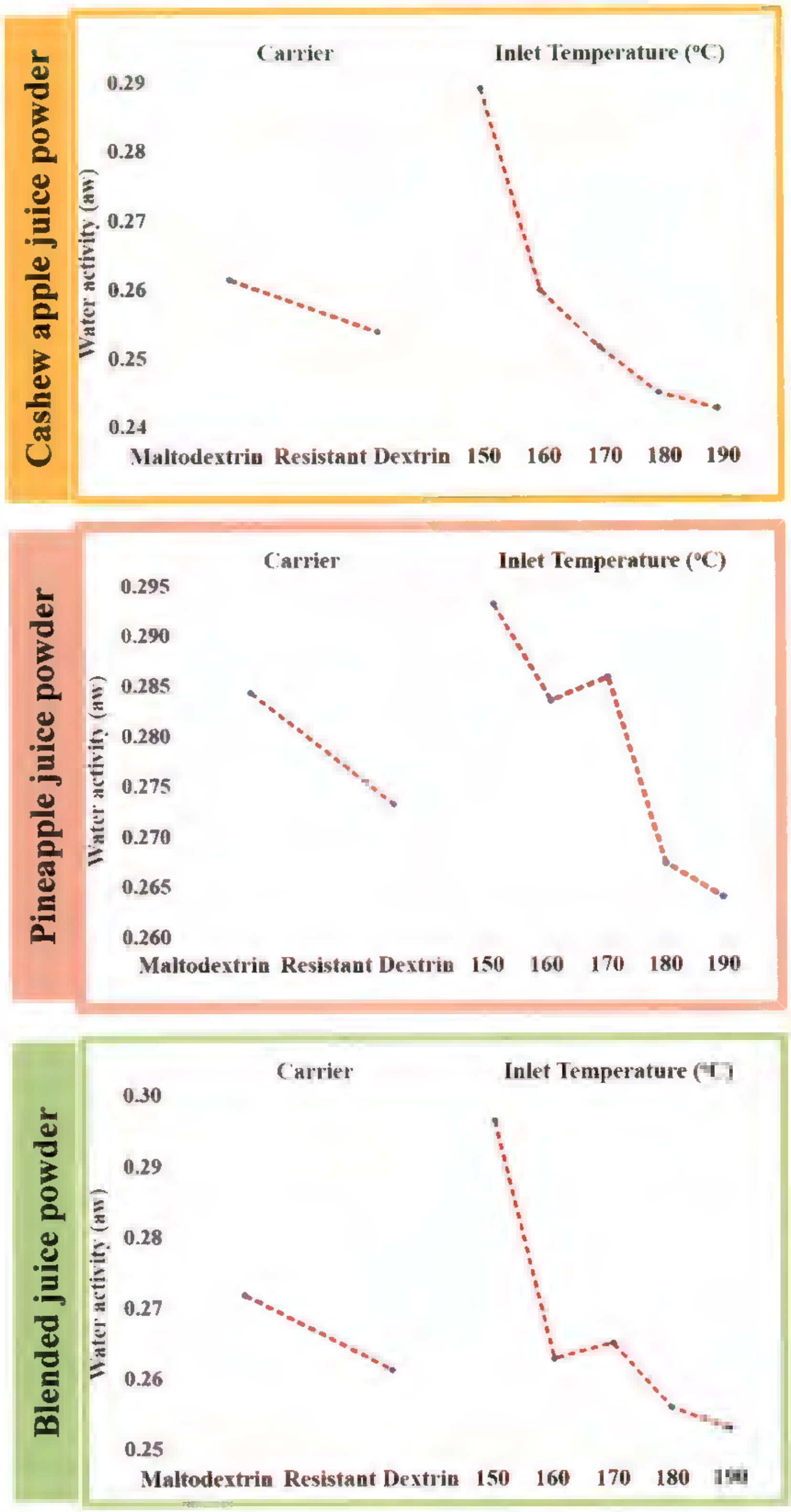


Figure 18 : Effects of carrier and inlet temperature on water activity of cashew apple, pineapple and blended juice powders

also depend on feed parameters and powder properties. Kha *et al.* (2010) reported that though moisture content was reduced quickly by increasing inlet temperature from 120°C to 200 °C, water activity of Gac (*Momordica cochinchinensis*) powders were not significantly different.

Interaction between carrier and inlet temperature did not significantly influence the water activity of treatment combinations(Table 35). Water activity values of the treatment combinations ranged from 0.24 to 0.30, 0.26 to 0.31 and 0.24 to 0.30 aw in cashew apple, pineapple and blended powder respectively. The results are in conformity with the findings of many authors. Water activity values ranged 0.38 - 0.54, 0.258- 0.402, 0.15 to 0.32, 0.221- 0.311, and 0.157 and 0.215 in Gac (Khan *et al.,* 2010) Mountain tea (Nadeem *et al.,* 2011), black mulberry (Fazaeli *et al.* 2012) sage (Nadeem *et al.*2013), and sumac (Caliskan and Dirim, 2013) respectively. Products with water activity values below 0.6 represents microbiologically stable product and at 0.20 and 0.40 product is stable against browning reactions, lipid oxidation, auto-oxidation and enzymatic activity respectively (Caliskan and Dirim, 2013). Hence, instant juice powders of cashew apple, pineapple and blended juice can be considered microbiologically stable.

5.2.2 Chemical parameters

5.2.2.1 Vitamin C

The carrier resistant dextrin exhibited higher retention of ascorbic acid in cashew apple powders (Figure 19 and Table 36)) similar to observations of Rodríguez-Hernández *et al.* (2005) in cactus pear powders that low dextrose equivalent carrier improved Vitamin C retention.

Vitamin C content was inversely proportional to inlet temperature (Figure 19 and Table 37). Drying at lowest temperature retained 3.6, 6.9 and 8.7 per cent more vitamin C than the highest temperature in cashew apple, pineapple and blended juice respectively. The lower temperature range of 150°C – 160°C did not differ

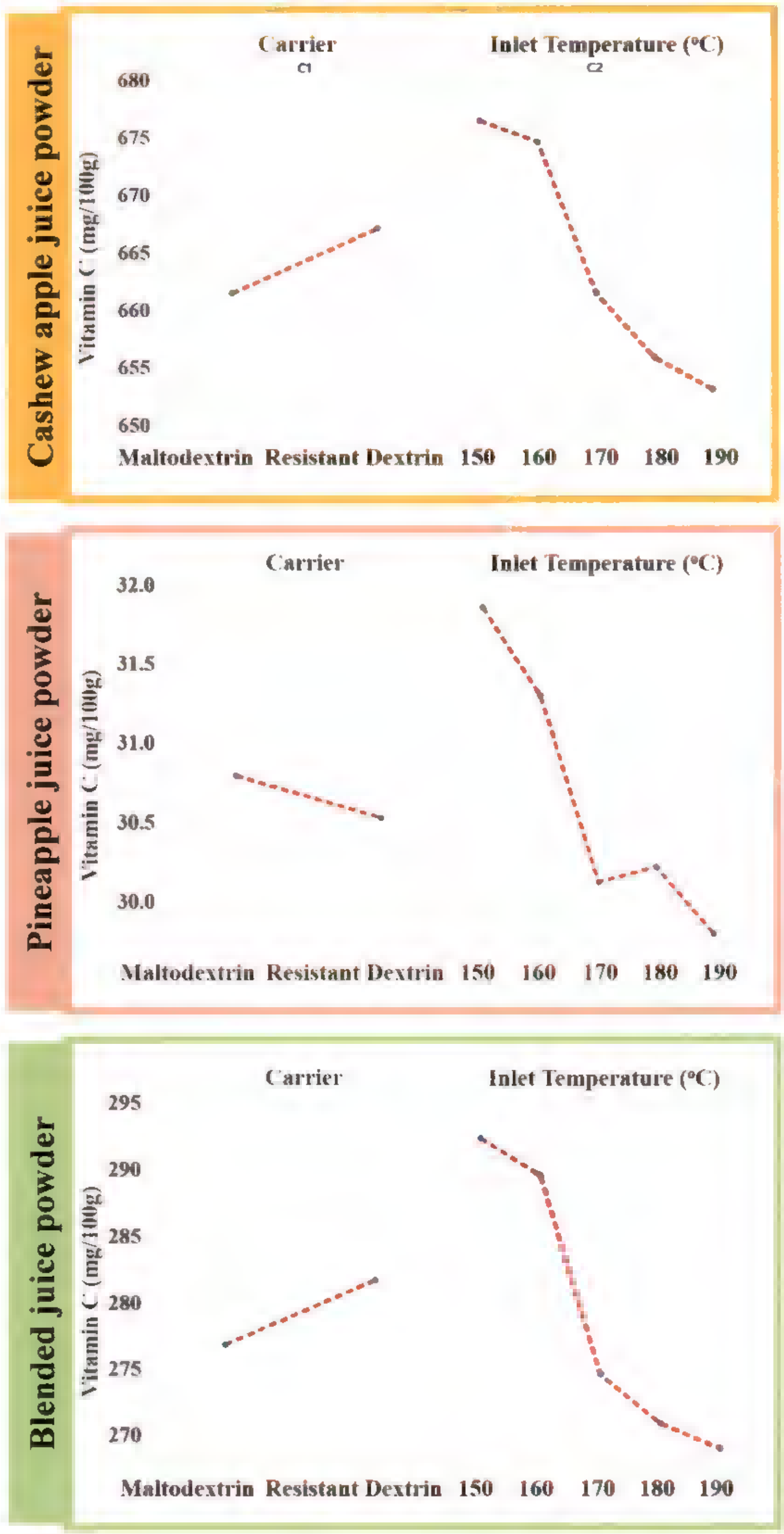


Figure19 : Effects of carrier and inlet temperature on vitamin C of cashew apple, pineapple and blended juice powders

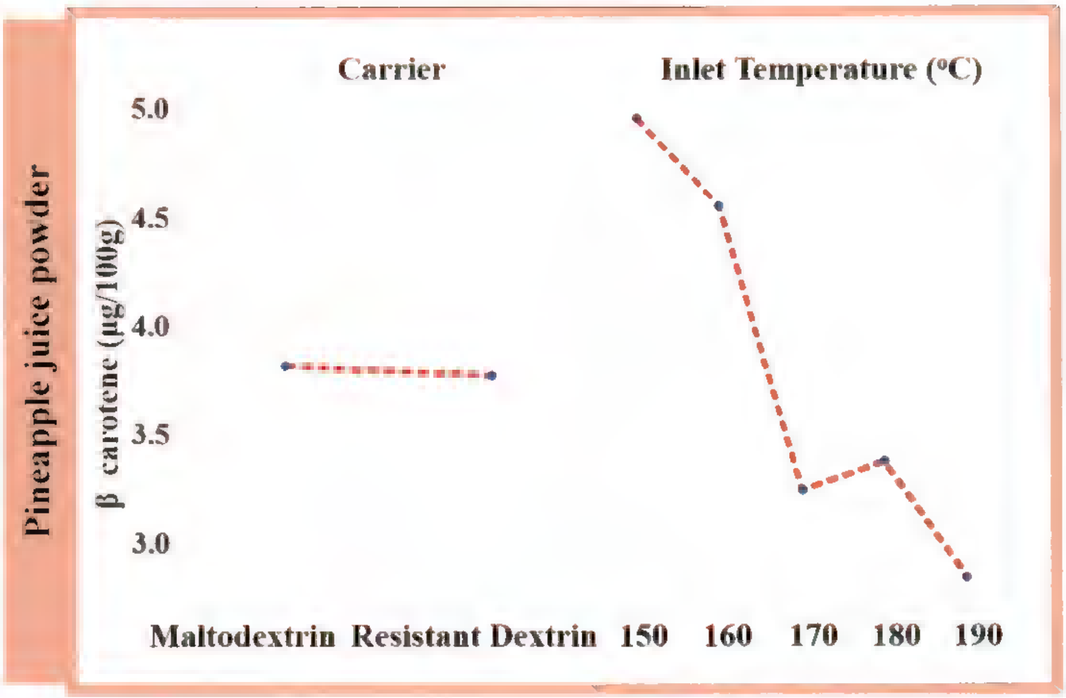
significantly between them. Least vitamin c was recorded by 190°C inlet temperature in cashew apple juice powder and temperature range from 170-190°C in pineapple and blended juice powder.

Interaction between carrier and inlet temperature did not vary significantly (Table 38). The vitamin C of treatment combinations ranged from 652.33- 680.37, 29.81-to 31.96 and 265.42-293.46 mg/100g in cashew apple, pineapple and blended powder respectively. If the total amount of ascorbic acid present in 100g sample is compared to amount of ascorbic acid theoretically expected in each sample based on the vitamin C content of pure juice, vitamin C retention ranged 84.19- 87.81, 81.92-to 87.83 and 81.73-90.36 per cent in cashew apple, pineapple and blended powder respectively. The result is in agreement with Oliveira *et al.* (2009) who observed 95 per cent retention when cashew apple juice was encapsulated using maltodextrin and cashew tree gum. Moreover Uddin *et al.* (2001) and Esposito *et al.* (2002) observed less than 2 per cent loss during vitamin C encapsulation. High retention of vitamin C in spray drying could be attributed to lower exposure time of particles to heat as suggested by Moreira *et al.* (2009). Though inlet temperatures are high, increased surface area to volume ratio of the droplets, helps in fast drying, and the higher air flow rate shortens residence time of droplet in the drying chamber (generally 1–2 seconds), so that the product temperature never reached 100°C.

Higher loss of vitamin C at higher inlet temperature was in in conformity with observations of Solval *et al.* (2012) in *Cucumis melo* powders.

5.2.2.2 β carotene

Different carriers and its interaction did not cause any significant variation in the β-carotene content of fruit powders (Figure 20 and Table 36). However, β-carotene content was inversely proportional to inlet temperature as depicted in figure 20 and table 37. Drying at lowest temperature retained 16.5,and 11.98 per cent more β-carotene than the highest temperature in pineapple and blended juice respectively. The



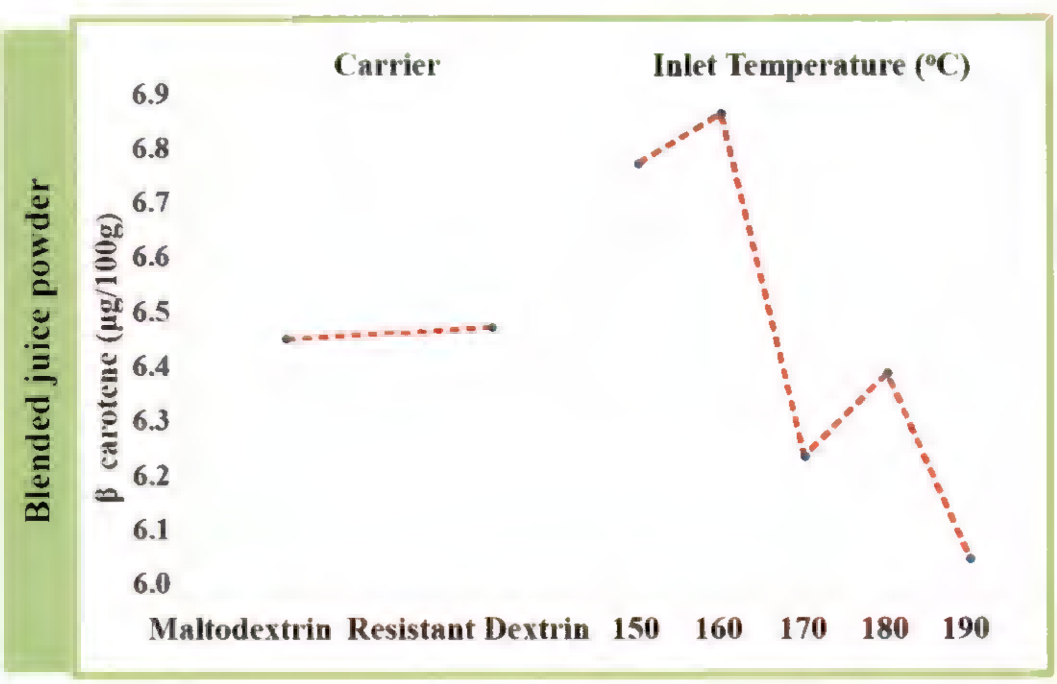


Figure 20: Effects of carrier and inlet temperature on β carotene of pineapple and blended juice powders

lower temperature range of 150°C – 160°C did not differ significantly between them. The least β-carotene was recorded when both powders are dried at temperature range from 180-190°C in both powder. Solval *et al.* (2012) also observed higher β-carotene loss at high temperature while spray drying *Cucumis melo* juice and suggested that heat destruction, oxidation and isomerization might have led to the loss.

Bechoff *et al.* (2010) observed higher level of β-carotene loss at lower water activities and vice versa. However, the effect of water activity in breakdown of β-carotene was lesser than effect of temperature.

The β-carotene powders dried at different treatment combinations ranged from 12.27- 15.3 and 5.99- 6.9 μg/100g in pineapple and blended powder respectively (Table 38). If the total amount of β-carotene present in 100g sample is compared to amount of β-carotene theoretically expected in each sample based on the β-carotene content of pure juice (Table 1), the efficiency of β-carotene retention ranged 48.74- 30.08 and 34.30- 39.51 per cent in pineapple and blended powder respectively. The loss of β-carotene observed in the present study was more than eleven per cent loss as observed by Desobry *et al.* (1997) while encapsulation of pure β-carotene with maltodextrin. Quek *et al.* (2007) observed that β-carotene had higher loss compared to other pigment lycopene in watermelon powders with 27 per cent and 24 per cent loss respectively at same inlet temperature and hence concluded that β-carotene is more sensitive to inlet temperature.

5.2.2.3 Crude fibre

None of the treatment combination significantly influenced crude fibre content of powders and the powders contained very low amount of crude fibres which ranged 0.523- 0.667, 0.577-to 0.633 and 0.55-0.657 per cent in cashew apple, pineapple and blended powder respectively (Table 38). The low crude fibre content might be due to the use of clarified juice and carriers with very low crude fibre content for spray drying. The pure maltodextrin and resistant dextrin had crude fibre content of 0.5 per cent each.

5.2.2.4 Total ash

None of the treatment combination significantly influenced ash content of powders and the ash content ranged 1.346 – 1.53, 1.39- 1.638 and 1.35-1.493 per cent in cashew apple, pineapple and blended powder respectively (Table 38). The low crude fibre content might be due to the use of clarified juice and low content of ash in carriers that used in spray drying. The pure maltodextrin and resistant dextrin had 1.33 and 1.26 per cent ash content respectively.

5.2.2.5 Total, reducing and non reducing sugars

Instant juice powders formulated with maltodextrin recorded higher reducing and non reducing sugars which invariably led to higher total sugar content as depicted in figure 21, figure 22 and table 39. Maltodextrin exhibited 16.64,17.17 and 13.58 per cent improvement in total sugars due to 9.02, 7.33 and 5.18 per cent increase in reducing sugars and 54.16,72.76, and 62.39 per cent increase in non reducing sugars in cashew apple, pineapple and blended powder respectively. The higher content of sugars in carrier maltodextrin improved sugar content in the powders formulated with it. Chemical analysis of resistant dextrin revealed 9.67, 5.8 and 3.87 per cent total, reducing and non reducing sugar respectively. However, maltodextrin had 18.57, 11.3 and 7.27 per cent total, reducing and non reducing sugar respectively.

Inlet temperature influenced reducing sugar content of all fruit powders and total sugar content of cashew apple juice powder as shown in figure 21, figure 22 ant table 40. Cashew apple juice and blended juice dried at the temperature range between 160°C-180°C exhibited highest reducing sugar content. In pineapple juice powder temperature range between 150°C-180°C exhibited highest reducing sugar content. Inlet temperature did not significantly influence the non reducing sugar content in all

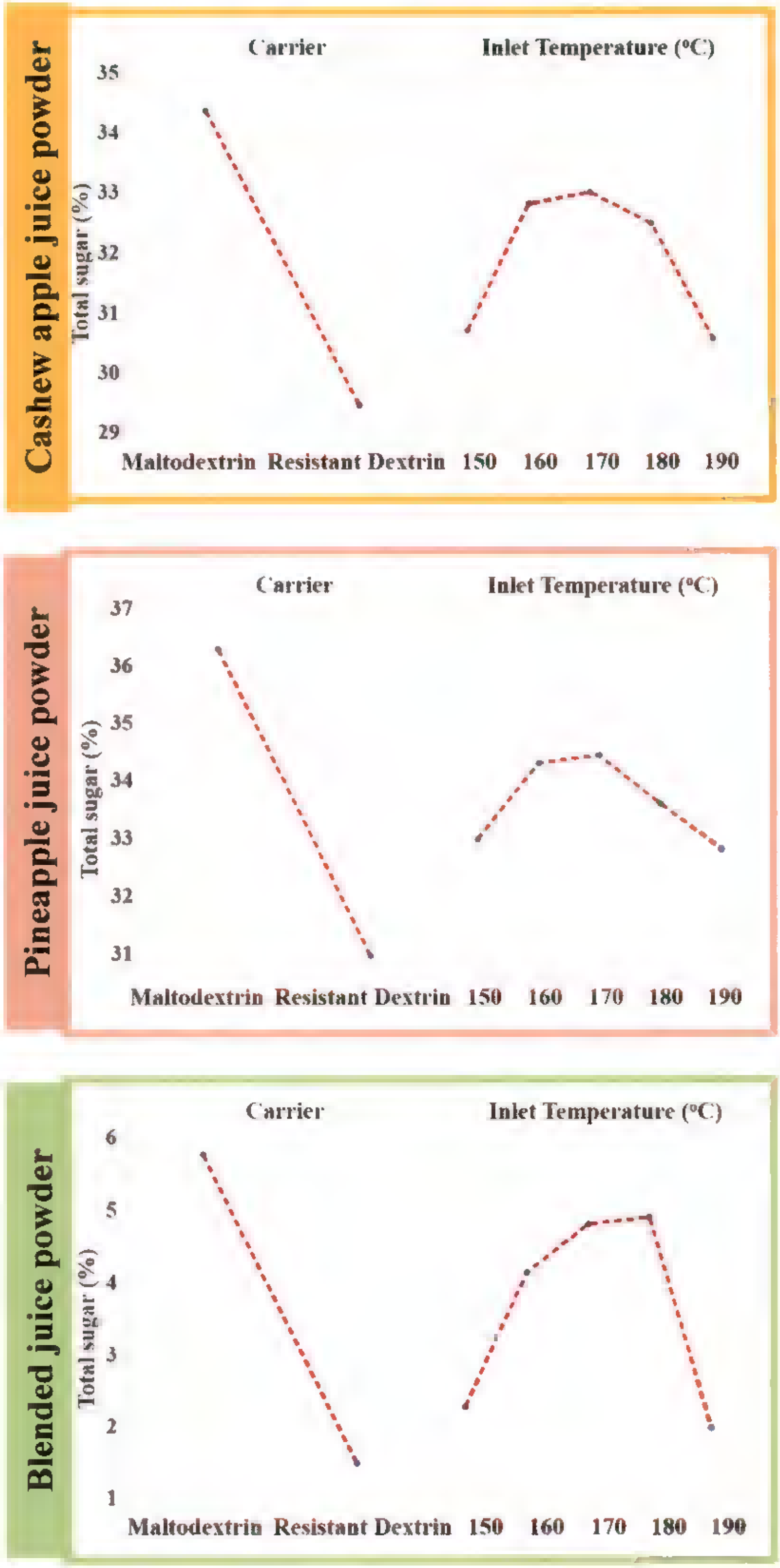


Figure 21: Effects of carrier and inlet temperature on total sugar of cashew apple, pineapple and blended juice powders

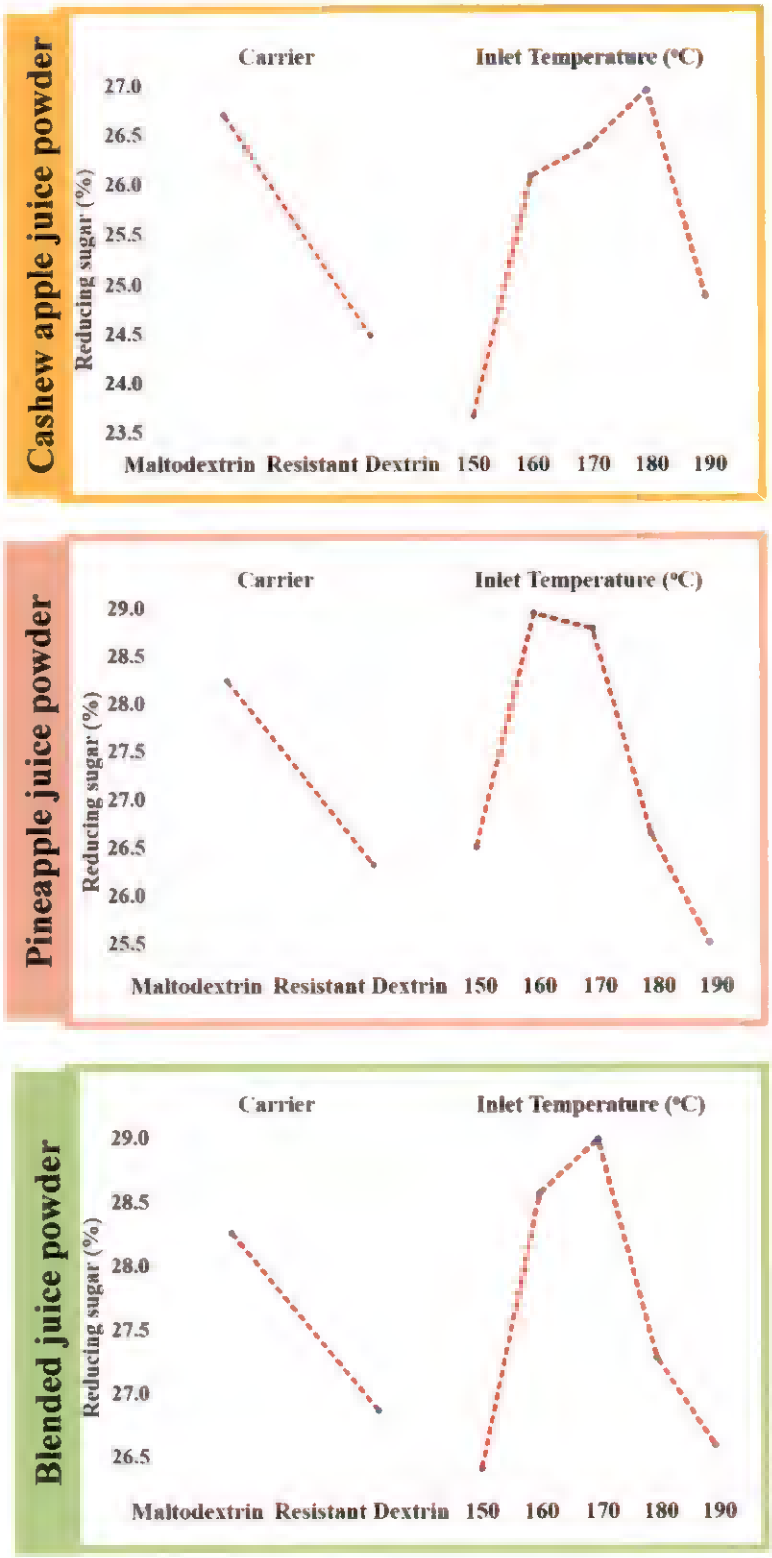


Figure 22 : Effects of carrier and inlet temperature on reducing sugar of cashew apple, pineapple and blended juice powders

three fruit juices. However, temperature range between 160°C-180°C exhibited highest total sugar content in cashew apple juice powder.

Negative effect on inlet temperature on sugar content in lowest and highest temperature might be attributed to the higher moisture content and caramelisation of sugar respectively. These possibilities could be established with visual observations on stickiness and browning of powder at lowest and highest temperature respectively.

Interaction of carrier with inlet temperature did not have any significant effect in total reducing and non reducing sugar content of all fruit juice powders. The total sugar content of treatment combinations ranged from 28.25- 35.49, 30.20- 37.61 and 28.25-36.99 per cent in cashew apple, pineapple and blended powder respectively and range of reducing sugar was 22.97-28.83,24.69-30.53 and 25.72-30.05 per cent.

5.2.2.6 pH

The different treatments or its combination did not differ significantly among them (Table 42, 43 and 44). The pH value of the treatment combinations ranged from 4.18-4.24, 4.12-4.29 and 4.15-4.26 per cent in cashew apple, pineapple and blended powder respectively (Table 44). The increase in pH values of reconstituted juice in comparison to the original juice might be due to the addition of carriers which had higher pH values. pH of maltodextrin solution in distilled water with the same carrier solid content as in feed mix of cashew apple, pineapple and blended juice were 5.03, 5.09 and 5.05 respectively. Similarly pH of resistant dextrin solution was 4.9, 5.12 and 5.01 respectively indicating that higher pH value of carriers increased pH of powders.

5.2.2.7 **Titrable acidity**

None of the treatments significantly influenced titrable acidity of the powders. The titrable acidity of the juice powders ranged from 0.804-1.06, 1.39-1.45 and 1.019-1.116 per cent in cashew apple, pineapple and blended powder respectively (Table 44). The carriers did not express any titrable acidity on chemical analysis. Hence, if the total amount of titrable acidity present in a sample of powder is compared to amount of titrable acidity theoretically expected in the sample, the efficiency of acidity retention ranged 65.78- 86.72, 72.52- 75.70 and 76.43-83.7 per cent in cashew apple, pineapple and blended powder respectively.

***5.2.2.8* Energy value**

None of the carriers influenced energy value of the powder. However, energy value increased in proportion to inlet temperature. The temperature range of 180-190°C recorded highest energy value in cashew apple and blended juice powders (Table 43). The temperature range of 170 to 190°C produced energy rich pineapple powders. Interaction of carrier with inlet temperature did not exhibit any significant influence. The energy value ranged 3408.24- 3595.77, 3472.25-3666.99 and 3401.69-3667.92 cal/g in in cashew apple, pineapple and blended powder respectively.

Since both the carriers are carbohydrate polymers, the energy required for combustion might not differ significantly. The increase in energy value of powders at higher inlet temperature might be related to low moisture content and high solid content in the sample since the percentage of combustibles was more. Moreover, the portion of the generated combustion heat that evaporate the additional water in a moist sample get wasted partially since it may not condense fully to supply entire heat back to the system which in turn decrease the temperature rise of the sensor and consequently energy value get decreased.

5.2.3 Sensory parameters

Sensory analysis of all the fruit powders dried at a temperature of 160°C – 190°C have been done, the scores in 9 point hedonic scale on appearance, color, texture, flavor and taste were subjected to Kruskal Wallis test and mean ranks were computed. The reconstituted juices are visually represented in six plates (Plate 24 to 29).

Cashew apple juice

CM_5T_1

CM_5T_2

CM_5T_3

CM_5T_4

CM_5T_5

Plate 24:Reconstituted Cashew apple juice powders formulated with maltodextrin

C- Cashew apple juice, M_5 – Maltodextrin@40:60 (Juice: Carrier) T_1-150°C, T_2- 160°C. T_3- 170°C. T_4- 180°C, T_5- 190°C

Cashew apple juice

CR_5T_1

CR_5T_2

CR_5T_3

CR_5T_4

CR_5T_5

Plate 25:Reconstituted Cashew apple juice powders formulated with resistant dextrin

C- Cashew apple juice, R_5 -Resistant dextrin@40:60 (Juice: Carrier), T_1-150°C, T_2- 160°C. T_3- 170°C T_4- 180°C, T_5- 190°C

5.2.3.1 Appearance

Powders formulated with resistant dextrin had better appearance in general than the powders with maltodextrin.

Appearance of cashew apple powders formulated with resistant dextrin was liked moderately by the panelists while powders with maltodextrin was liked slightly (Plate 24 and 25). These resistant dextrin combinations did not vary with changes in inlet temperature. The better appearance of resistant dextrin combination was due to the better miscibility of those powders. The powders formulated with resistant dextrin were clear while maltodextrin caused more turbidity of the reconstituted juice.

Pineapple powders with resistant dextrin dried at a temperature of 160°C – 190°C had better appearance due to high miscibility (Plate 26 and 27). Appearance of these powders was very much to moderately liked by the panelists while powders with maltodextrin were liked slightly. Within a carrier, the powder produced by drying at lowest temperature of 150°C exhibited more turbidity and hence scored lower ranks.

All blended juice powders (Plate 28 and 29) formulated with resistant dextrin and those powders with maltodextrin dried at the temperature range of 180-190°C had better appearance. Appearance of these powders was liked moderately by the panelists whereas other powders were liked slightly.

5.2.3.2 Color

The scores on color exhibited significant variation among treatments in cashew apple powders (Plate 24 and 25). Pair wise comparison of the mean ranks revealed that powder produced at temperature range of 150-160°C had better color in both carriers. Color of the powders produced at the temperature range of 180-190°C had the lowest scores in both carriers. Color of the powder formulated with maltodextrin at the lowest temperature was very much liked by the panelists while the juice color produced at lower temperature range upto 170°C with both carriers liked moderately by the

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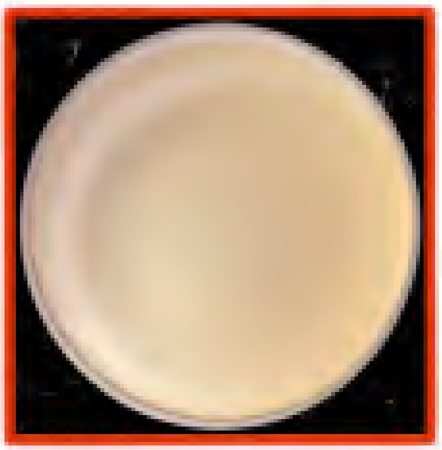


Pineapple juice

PM_5T_1

PM_5T_2

PM_5T_3

PM_5T_4

PM_5T_5

Plate 26:Reconstituted pineapple juice powders formulated with maltodextrin

P- Pineapple juice, M_5 – Maltodextrin@40:60 (Juice: Carrier) T_1-150ºC, T_2- 160ºC. T_3- 170ºC. T_4- 180ºC, T_5- 190ºC

Pineapple juice

PR_5T_1

PR_5T_2

PR_5T_3

PR_5T_4

PR_5T_5

Plate 27:Reconstituted pineapple juice powders formulated with resistant dextrin

P- Pineapple juice, R_5 -Resistant dextrin@40:60 (Juice: Carrier), T_1-150°C, T_2- 160°C. T_3- 170°C. T_4- 180°C, T_5- 190°C panelists. All remaining combinations were liked slightly. The deviation from the original color of the fruit juice towards brownish colour as with higher temperature range might have led to the lower scores on color.

In contrast, the powders produced at higher temperature range of 180- 190°C received better scores for color with respect to reconstituted pineapple juice (Plate 26 and 27). The powders produced at this temperature with both carriers were very much liked by the panelists. All the remaining treatment combination of resistant dextrin were liked moderately whereas the juice color of the powders dried at the lower temperature range of 150-160°C with maltodextrin as carrier was only liked slightly by the panelists. The data clearly indicate that drying at higher temperature shifted the color to more yellowish shade and compensated for the color loss of the juice caused by addition of carrier which led to the better score on color.

Resistant dextrin combinations received higher scores for color with respect to blended juice (Plate 28 and 29) and inlet temperature could not make a significant difference in mean ranks among its combinations. Color of the reconstituted juice produced from powder formulated with maltodextrin at 150°C received lowest score and was neither liked nor disliked by the panelists. Yellow color of blended juice was preferred since the pure blended juice had yellow color. Slight yellow color of resistant dextrin improved the color in comparison the white maltodextrin.

5.2.3.3 Texture

The texture of reconstituted powders showed significant variation among treatment combinations in cashew apple solution and blended juice. The texture of cashew apple solution (Plate 25) formulated with resistant dextrin at temperature range of 170-190°C was very much to moderately liked by the panelists. The treatment combinations of maltodextrin (Plate 24). at higher temperature range of 180-190°C were slightly liked by panelists. The texture of powder formulated with maltodextrin at 150°C were disliked. The low scores of maltodextrin combination could be

Blended juice

BM_5T_1

BM_5T_2

BM_5T_3

BM_5T_4

BM_5T_5

Plate 28:Reconstituted blended juice powders formulated with maltodextrin

B-Blended juice, M_5 – Maltodextrin@40:60 (Juice: Carrier), T_1-150°C, T_2- 160°C. T_3- 170°C. T_4- 180°C, T_5- 190°C

Blended juice

BR_5T_1

BR_5T_2

BR_5T_3

BR_5T_4

BR_5T_5

Plate 29:Reconstituted blended juice powder formulated with resistant dextrin

B- Blended juice, R_5 -Resistant dextrin@40:60 (Juice: Carrier), T_1-150ºC, T_2- 160ºC. T_3- 170ºC T_4- 180ºC, T_5- 190ºC attributed to its foamy texture. The foamy texture of maltodextrin slightly decreased as the temperature increased and hence the maltodextrin powders produced at higher temperature received higher scores in comparison to powders produced at lower temperature with same carrier. Resistant dextrin combinations were juice like without any foam formation.

The texture scores of pineapple did not differ significantly and all the powders were moderately liked by the panelists since the reconstituted juice exhibited juice like texture.

The juice like texture of reconstituted blended juice powder formulated with resistant dextrin were very much to moderately liked whereas maltodextrin related powders were moderately liked.

5.2.3.4 Flavor

The flavor of cashew apple powder solution (Plate 24 and 25) produced under different combinations varied significantly. The powders produced at inlet temperature of 150-160°C had better fruit flavor and were very much to moderately liked by the panel and received higher scores irrespective of carrier and the range of 170-190°C led to powders with reduced (slightly liked) flavor.

The lower temperature range of 150-160°C yielded pineapple juice powders that could be reconstituted to solutions (Plate 26 and 27) which had good fruit flavor and were very much liked irrespective of carriers. As the drying temperature increased, flavor gradually subsided to lower scores and slightly liked taste.

Similar tendency of reducing fruit flavor due to increase in temperature was observed in reconstituted of blended juice powder too (Plate 28 and 29) and the temperature range of 150-160°C was optimum for better flavor.

Effect of carrier on fruit flavor was not evident since both carriers followed a similar pattern. Flavor loss at high temperature might have led to the lower scores but none of the combinations exhibited any off flavor.

5.2.3.5 Taste

Taste of reconstituted juice significantly varied among treatment combinations. Reconstituted cashew apple juice powders (Plate 24 and 25) dried at temperature range 150-160°C and 150-170°C were adjudged as sweet fruit juice with slight to moderate likeness with maltodextrin and resistant dextrin respectively. As the temperature elevated taste subsided. Maltodextrin related powder dried at 190°C were disliked while the powder were neither liked or disliked with resistant dextrin.

Reconstituted pineapple juice powders (Plate 26 and 27). dried at temperature range 150-160°C and 150-170°C with maltodextrin and resistant dextrin carriers respectively were adjudged as sweet fruit juice with very much liked taste. However, the taste got reduced in direct proportion to inlet temperature. The powders produced at highest temperature under study were only slightly liked.

The blended juice powders (Plate 28 and 29) produced at lower temperature range of 150-160°C had very much to moderately liked taste and received higher scores irrespective of carriers when reconstituted juice were subjected to sensory analysis. As the temperature increased the taste lowered down to reach a state of neither liked or disliked as observed at highest temperature.

5.2.4 Selection of powders

The physico chemical and sensory analysis revealed that inlet temperature of 160°C yielded powders with higher bulk density from all the three fruit juices and with high particle density from blended fruit juices. Besides, 160°C could lower water activity in cashew apple and water activity, chromaticity and angle of repose in blended juice. Moreover, 160°C improved total soluble solids in cashew apple and hue angle in blended juice. Inlet temperature of 160°C yielded vitamin C rich powders from all fruits as well as β-carotene rich pineapple powder. This temperature improved reducing sugar content of pineapple and blended juice powder as well as total sugar of cashew apple juice powder. In addition, fruit powders dried at 160°C could also obtain superior scores in sensory analysis.

The data clearly indicated that the treatment combination involving inlet temperature of 160°C possessed optimum quality parameters under investigation. Hence, the treatment combination of 160°C inlet temperature from both carriers were selected from cashew apple (CM_5T_2 and CR_5T_2), pineapple (PM_5T_2 and PR_5T_2) and blended juice (BM_5T_2 and BR_5T_2), independently for further analysis on three physical parameters viz. sorption behavior, glass transition temperature and microstructure as well as storage study.

5.2.5 Sorption behavior of powder

Moisture sorption isotherms plotted with equilibrated moisture content (EMC) on Y axis as a function of equilibrium relative humidity (ERH) on X axis denoted hygroscopic relationship between the moisture content of the powder and the relative humidity of the surrounding environment at room temperature. The moisture content increased along with ERH and powders turned to viscous fluids with slight brown color finally. The humidity - moisture equilibrium curves revealed highly hygroscopic nature of all fruit powders since the increase in moisture content is steep beyond 50 per cent RH as suggested by Ranganna (1986). The sorption isotherms followed a characteristic J shape associated with high sugar foods as similar to the observations by Akoy *et al.* (2013).

Experimental sorption isotherms of juice powders indicated that powder with resistant dextrin was low hygroscopic than maltodextrin in all fruit juices. The cashew apple juice power formulated with maltodextrin just started lumping at EMC of 6.18 equilibrated with 27.55 per cent relative humidity whereas critical points were 6.17 per cent EMC and 29.7 per cent ERH with resistant dextrin. The safety range of powder formulated with maltodextrin was 4.91- 6.18 per cent EMC equilibrated with 22.55- 27.55 per cent ERH. Powder formulated with resistant dextrin exhibited a wider safety range of 4.6 – 6.17 per cent EMC equilibrated with 24.7 and 29.7 ERH respectively indicating low hygroscopicity and more flexibility in selecting packaging materials. The packing material selected for powder with maltodextrin should not allow the product to reach to 4.91 per cent EMC at 22.55 ERH since its safety margin was 4.79 - 4.91 per cent EMC equilibrated with 20.13 – 22.55. However, the safety margin of the powder formulated with resistant dextrin was 4.43- 4.6 EMC with 24.5-24.7 ERH, indicating lower hygroscopicity and packing material can allow little more ingress of moisture.

Pineapple powders formulated with resistant dextrin remained free flowing till 6.21 per cent EMC equilibrated with 36.5 per cent ERH whereas powder with maltodextrin started to form lumps at 26.3 per cent ERH with 6.3 per cent EMC. The powder formulated with resistant dextrin showed a wider safety range with 4.6 to 6.21 per cent EMC equilibrated with 31.5 to 36.5 per cent ERH and safety margin with 4.59 to 4.6 per cent EMC equilibrated with 30.3 and 31.5 per cent ERH while initial moisture content of the powder with maltodextrin had already crossed the danger point indicating lack of a safe margin for any error in packaging conditions. The initial point of powder with 5.82 per cent EMC and 25.8 per cent ERH was very near to critical point (6.3 per cent EMC and 26.3 per cent ERH) pointing towards higher hygroscopicity and the possibility of quick lump formation and caking.

Blended fruit juice powder formulated with resistant dextrin remained free flowing till the critical point of 6.18 per cent EMC equilibrated with 33.8 per cent ERH and lumping, caking and sticky fluid formation occurred as the EMC and ERH progressed. The powder exhibited safety range with 5.41- 6.18 per cent EMC equilibrated with 28.8-33.8 per cent ERH and safety margin of 4.63-5.41 EMC with 25.81-28.8 ERH. Initial moisture content of the powder formulated with maltodextrin had already crossed danger point of 5.31 per cent EMC with 21.68 per cent ERH and lump formation started earlier at 26.68 ERH at 6.22 per cent EMC. Lack of a safety margin and narrow safety range indicated higher hygroscopicity and elevated risk of spoilage

The data clearly indicated that microcapsule structure was altered by the ingression of water vapour under high humidity that led to plasticization, since the presence of water elevate hydrogen bonds producing an increase in motion as suggested by Medina – Torres *et al.* (2013). The physical changes were similar to hygroscopic powders described by Tonon *et al.* (2009). Initially lumping and caking took place resulting from the compaction, thickening of inter particle bridges, reduction of inter particle spaces and deformation of particle clumps with loss of system integrity. Due to further ingress of water inter particles bridges disappeared, sample liquefied and low molecular weight fractions are solubilized to create viscous sticky fluids.

As observed by Goula and Adamopoulose (2010) physical changes in low-moisture, sugary dehydrated powders due to hygroscopicity can be attributed to the glass transition temperature and the higher glass transition temperature reduced hygroscopicity. Higher dextrose equivalence of maltodextrins due to shorter chains and greater number of ramifications with hydrophilic groups might have led to quick absorption of water from surroundings as suggested by Tonon *et al.* (2009). These results suggested that instant juice powders should be handled and stored at a very narrow range of humidity and moisture content.

5.2.6 Glass transition temperature.

Resistant dextrin was consistent in improving glass transition temperature of instant juice powders of all fruit juices and with 68.7, 131.1 and 84.3 per cent improvement over maltodextrin in cashew apple, pineapple and blended juice respectively.

As Zhu *et al.* (2011) described glass transition as a gradual phase of transition of amorphous materials from a glassy state with low water mobility to a soft state with higher water mobility. The temperature at which this transition take place is glass transition temperature (Tg). If the temperature of the product is higher than glass transition temperature then it will be in the visco elastic state with high risk of stickiness. The critical temperature which cause stickiness is usually 10 to 20°C above the glass transition temperature and risk of stickiness increase in direct proportion to the gap between glass transition temperature and product temperature. Hence, stickiness problem is more common in powders with low glass transition temperature.

Fruit juice powders contain high amount of low molecular weight sugars such as sucrose, glucose, fructose and organic acids as tartaric, citric, malic acids which depresses the glass transition temperature (Tg) of the material which lead to viscous state from amorphous. Though addition of carrier to juices before drying can improve glass transition temperature of the product, the extent of increase is dependent on many factors. As Leon- Martinez *et al.* (2010) suggested that glass transition temperature is related to polymer chain structure and molecular chain stiffness which increase as cross link density increases. Maltodextrin had not only shorter molecular chains but also higher sugar content that can reduce the glass transition temperature.

Higher moisture content in a product can also suppress the glass transition temperature of a product. Goula and Adamopoulose (2010) observed that glass transition temperature alleviated with elevation of moisture content due to strong plasticizing effect of water. Powders formulated with maltodextrin had higher moisture content which might have led to lower glass transition temperature.

As Tonon *et al.* (2009) observed products from different juices may vary in glass transition temperature depending on quantity and type of sugars and acids in the juice. This may also explain the difference in Tg between juices.

5.2.7 Microstructure

The average particle size of 3 to 30 µm were in conformity with earlier studies. Prince *et al.* (2014) reported size of the microcapsules as 5 to 30 µm while microencapsulation of nutmeg oleoresin. Chegini and Ghobadian (2007) obtained orange powders with mean diameter rangingfrom 20 to 30 μm.

Smoother powder particles formulated by maltodextrin might be related its high water and sugar content. As Shu *et al.* (2006) suggested the sugars could retain some water molecules linked to its own structure, and filled internal empty space of the microcapsules, preserved the hydration, thus avoided depressions on the surface leading to a more smooth and uniform micro capsule wall. Loksuwan (2007) observed that higher dextrose equivalence of a carrier produce spherical smoother surface due to the presence of greater amounts of reducing sugar which might act as plasticizer preventing shrinkage of the surface. The plasticizer alter polymers chains by reducing cohesion and change the hard,brittle coating to flexible and tough (Uddin *et al.*, 2001) leading to micro capsules with smoother surface.

Irregular spherical shape, occasional surface dents and shrinkages observed in powders formulated with resistant dextrin can be attributed to low moisture content, low sugars and change in the drying rates. Nadeem *et al.* (2010) observed that shrinkages on particle surface and the expansion of the particles occur due to the presence of carrier materials that decrease the water evaporation rate due to their high water holding characteristics. The dents are formed by shrinkage of the particles during drying. Similar dents were observed by Prince *et al.* (2014) which were attributed to shrinkage in latter stages after initial slow drying. High drying rates caused quick wall solidification and dent smoothening could not occur later.

Though powder formulated with maltodextrin exhibited smooth particle surface, the particles were strongly adhered to form agglomerates. Leon- Martinez *et al.* (2010) suggested that agglomerations of spray dried powders observed in scanning electron microscopy are composed of individual particles grouped together by submicron dust of same material and these structures may also bind to each other due to static electrical effects and van der waals forces. Chin *et al.* (2010) observed similar agglomeration with maltodextrin and implied that depletion of volatiles and other compounds could occur during agglomeration prior to collection from the drier.

Powders formulated with resistant dextrin exhibited comparatively more discrete particles. Fazaeli *et al.* (2012) observed that carriers with higher glass transition temperature produced black mulberry powders with more scattered particles due to less reducing capacity of carrier.

Powders did not exhibit apparent cracks, puffing pores or fissures indicating that the microcapsules had undergone to 'ballooning' which might destroy the microcapsule stability as observed by Prince *et al.* (2014).

5.3 STORAGE STABILITY OF PURE AND BLENDED FRUIT JUICE POWDERS.

The six instant juice powders selected from part two of the experiment were subjected to the following four packaging and storage conditions with bimonthly observations for six months. The four packaging atmospheres under investigation were modified atmospheric packaging under vacuum, modified atmospheric packaging with nitrogen, conventional (Air) packing with ambient storage and conventional packing with refrigerated storage. The thrice replicated data were analysed in three factor completely randomized design with storage period (2nd month, 4th month and 6th month) as a split plot on two main plots ie.carrier and packaging atmospheres for cashew apple, pineapple and blended juice independently and the result is discussed in detail in this section. Based on the outcome of the discussion, six powders with best storage stability and nutrient retention were selected and subjected to computation of cost of production and assessment of consumer acceptability.

5.3.1 Moisture under storage

The moisture of the powder under storage was not influenced by the carriers and interaction that involve carriers. However different package atmospheres, storage periods and its interaction significantly altered moisture content of the stored powder (Figure 23).

The lowest moisture ingression of cashew apple powders was exhibited by the conventional packaged material under refrigerated storage which accounts to 11.7 per cent increase from the initial product moisture (4.61 per cent). However, the storage of the same package in ambient temperature led to 73.8 per cent increase of moisture content which was at par with highest moisture content recorded with nitrogen packaged powder. The powder under nitrogen packaged condition absorbed 78.5 per cent more moisture. The vacuum packaged material was intermediate with 46.9 per cent increment of initial moisture (Table 50).

Similar results were obtained with respect to pineapple powder too as depicted in figure 23. The moisture ingression under refrigerated storage was very less (12.9 per cent). However normal packaged product and nitrogen packaged product exhibited 65.8 and 61.6 per cent increase from the initial moisture content (5.21 per cent) respectively. Moisture content of the vacuum packed powder was elevated by 49.3 per cent.

The effect of refrigerated storage in reducing the moisture ingression was evident in blended juice powder too (Figure 23). This storage atmosphere recorded 11 per cent increase from initial content (4.99 per cent). Ambient storage with conventional packaging and nitrogen packaging led to 66.9 and 65.9 per cent increase respectively whereas vacuum packaged material recorded 44.9 per cent increase in the same storage method.

The data clearly denoted that none of the treatments except refrigerated storage could keep the moisture content of the product below critical point. Cashew apple powder exhibited 9.5, 33.2 and 29.61 per cent increase from the average critical point (6.18 per cent) in vacuum, nitrogen and air packaged powders kept under ambient temperature. Pineapple powder exhibited 7.8, 35.2 and 38.7 per cent increase of the

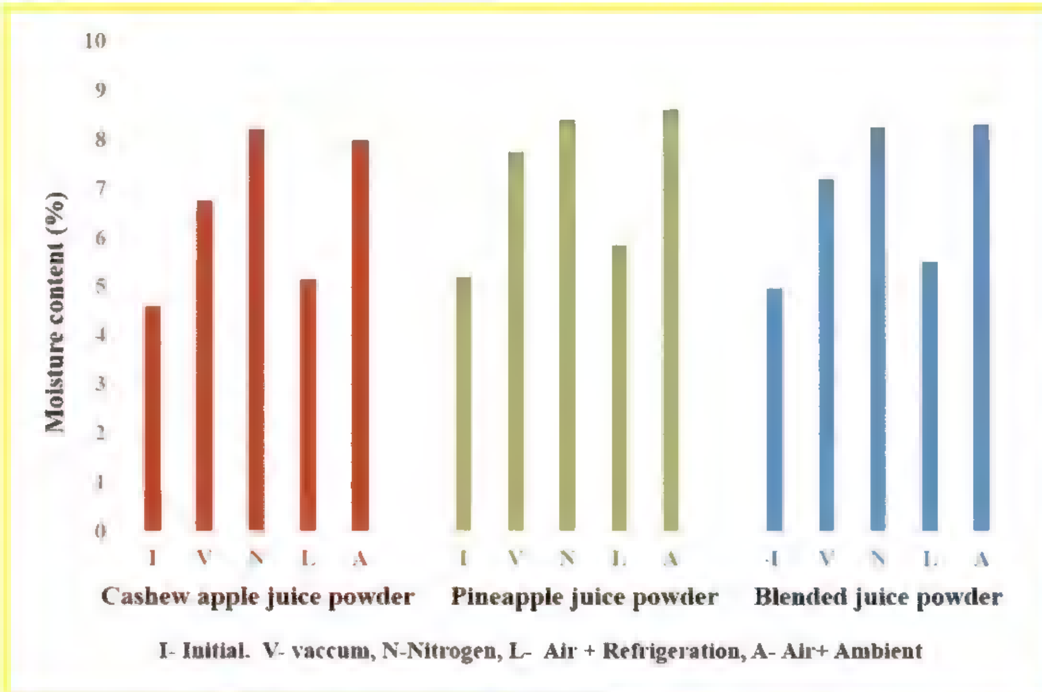


Figure 23 : Effects of packaging atmospheres on moisture content in stored powders

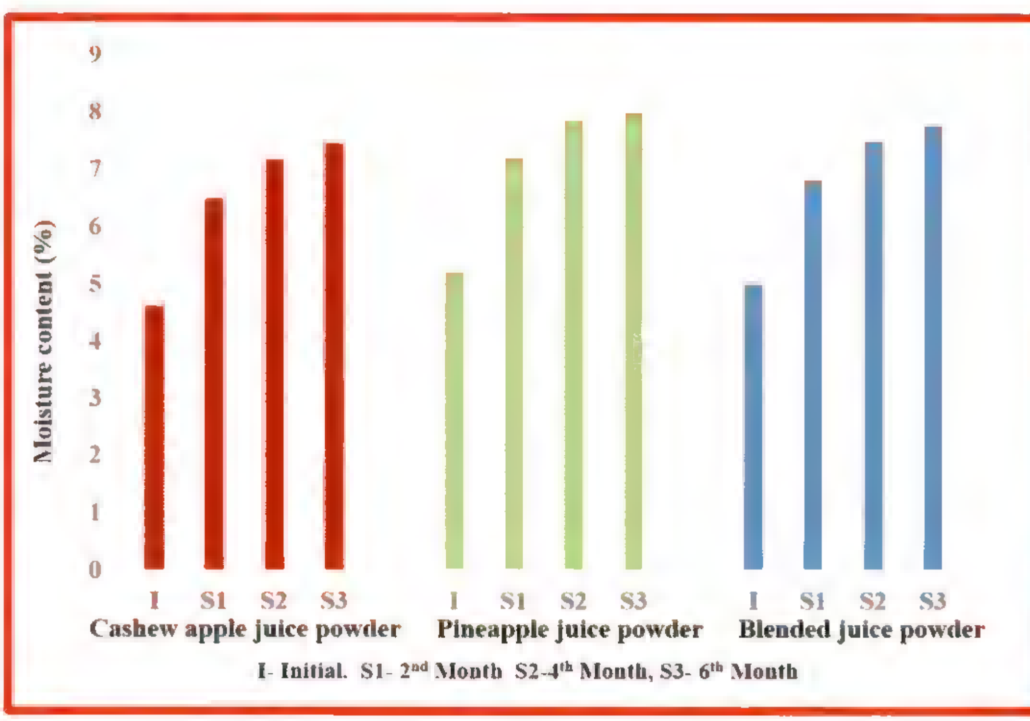


Figure 24 : Effects of storage period on moisture content in stored powders

average critical point (6.23 per cent) in vacuum, nitrogen and air packaged powders kept under ambient temperature. Blended juice powder exhibited 16.6, 33.5 and 34.4 per cent increase of the average critical point (6.2 per cent) in vacuum, nitrogen and air packaged powders kept under ambient temperature. Elevation of the moisture content above the critical point caused the product to be lumpy and sticky. The conventionally packed powder stored under refrigerated condition remained free flowing without alteration of physical properties since its moisture content never reached critical point.

The storage period also significantly influenced the moisture ingression of the product as depicted in figure 24 and table 51. The rate of ingression on moisture into the cashew apple powder was 41, 55.5 and 61 per cent of the initial moisture (4.61 per cent) during 2^{nd}, 4^{th} and 6^{th} month respectively. Moisture content of pineapple powder was increased by 38.2, 50.7 and 53.2 per cent from the initial moisture content (5.21 per cent) during 2^{nd}, 4^{th} and 6^{th} month respectively. As the storage period advanced, moisture content of the blended juice powder increased by 36.3, 50.1 and 55.5 per cent of initial moisture content (4.99 per cent) at 2^{nd}, 4^{th} and 6^{th} month respectively.

The data indicated that the moisture content increased as storage period advanced but the rate of increment slowed down since highest rate of elevation in the moisture was found at the initial sixty days of the storage (Figure 24). Moreover, all powders kept at ambient temperature were lumpy and sticky by the first two months itself since the mean moisture content got crossed over the critical point by then.

Interaction between packaging atmospheres and storage period also significantly influenced the moisture content of the product (Table 54). Under refrigerated storage moisture content of cashew apple powder increased over initial moisture content by meagre 5, 5.2 and 5.3 per cent during 2^{nd} , 4^{th} and 6^{th} month respectively and remained completely free flowing without much alteration of physical properties while the moisture content of powders kept at ambient temperature got crossed over the critical point, consequently got lumpy and sticky.

The high sticky nature of powder kept at ambient temperature could be related to the higher equilibrium relative humidity and consequently higher water activity that might have developed within the package while storage. Samborska and Bieńkowska (2013) suggested two possible reasons or the elevation of water activity in storage. The first possibility was related to water content of powder under storage and second possibility was related to the phase transition from the amorphous state to crystalline state of powder with in the package. During this transition some amount of water is released causing increase in water activity even if water content of the product had become stable. Hence water activity could continue rising regularly in storage even after stabilization of water content took place in the earlier stages of storage.

Moreover, caking of powder within the package could be attributed to the reduction in glass transition temperature of the product that took place by the absorption of moisture. As suggested by Moreira *et al.* (2009) a small amount of absorbed water could reduce the glass transition temperature enough to increase mobility of the matrix in storage. This might also explain the lumping observed in powders produced with resistant dextrin.

According to Wang *et al.* (2012) the difference between powder storage temperature and glass transition temperature represented the driving force for caking. As the temperature increased above glass transition temperature viscosity changes, structural deformations collapse and crystallization occurred. The better physical properties displayed by the refrigerated storage could be attributed to low temperature storage below the glass transition temperature. In addition the low temperature surrounding the packet would also restrict rise in equilibrium relative humidity inside the package since the equilibrium relative humidity is dependent on temperature of storage.

5.3.2 Total Phenol

Packaging atmospheres and storage period significantly influenced the total phenol content in stored powders. The carriers and interaction effects were non-significant (Figure 25 and Table 49). Opinions on effect of carrier in retention of nutritional substance were highly contradictory in literature. Kenyon and Anderson (1988) reported positive as well as negative effect of carriers with higher dextrose equivalence in retaining nutritional substances. In contrast, Ersus and Yurdagel (2007) reported that carrier materials with different dextrose equivalents did not differ in shelf life of anthocyanin content.

The maximum phenol content of cashew apple powders were retained by conventional packaged material under refrigerated storage in which 18.5 per cent loss from initial phenol content (0.605 per cent) was observed (Figure 25). However, the storage of the same package in ambient temperature led to 35.37 per cent loss of initial phenol content.

Similar results were obtained with respect to pineapple powder too (Figure 25). Loss of phenol content was similar in vacuum, nitrogen packages stored at ambient temperature and conventional package stored at refrigeration which amounted to loss of 41.5, 46.9 and 36.9 per cent of initial total phenol (0.13 per cent) respectively. However air packaged product kept under ambient temperature had significantly higher loss of 49 per cent of initial content.

Similar trend was evident in blended juice powder too (Figure 25). The refrigerated storage atmosphere recorded a loss of 13.9 per cent of the initial phenol content (0.33 per cent) which was at par with vacuum (loss of 26 per cent) and nitrogen (loss of 24.5 per cent) packaged powders. However, conventionally packaged product kept under ambient temperature had significantly higher loss of 37.2 per cent of initial content.

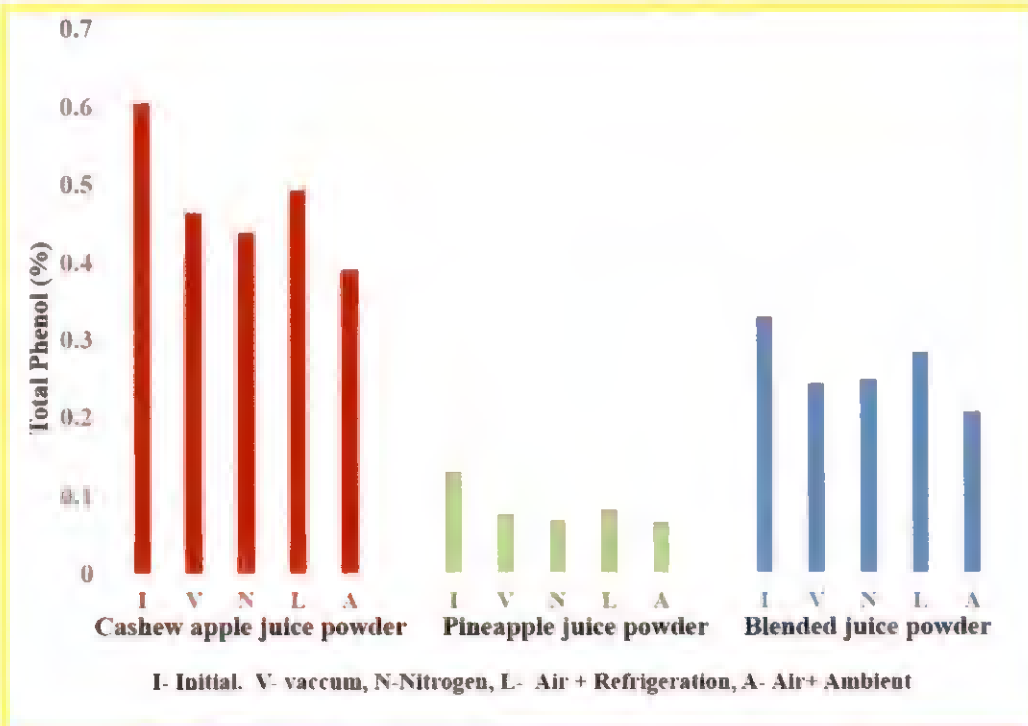


Figure 25 : Effects of packaging atmospheres on total phenol content in stored powders

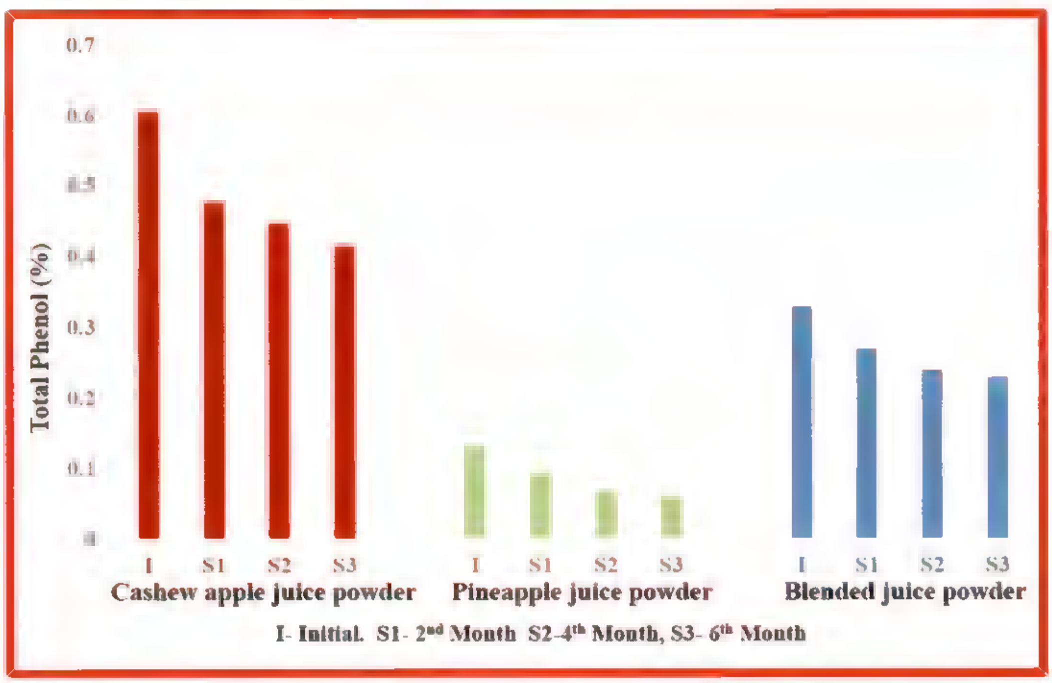


Figure 26: Effects of storage period on total phenol in stored powders

Storage period also significantly influenced total phenol content (Figure 26 and Table 51). The data indicated that the phenol content decreased as storage period advanced but the rate of but the rate of decrease was higher at the initial sixty days of the storage. Loss of total phenol in cashew apple powder was 21.2, 26.1 and 31.2 per cent of the initial phenol content (0.61 per cent) at 2nd, 4th and 6th month respectively. Total phenol of pineapple juice powders got reduced by 28.5, 48.5 and 54.6 per cent of the initial content (0.13 per cent) at 2nd, 4th and 6th month respectively. As the storage period advanced phenol content of the blended juice powder decreased by 18.2, 27.2 and 30.6 per cent of initial content (0.33 per cent) during 2nd, 4th and 6th month respectively.

The interaction effects were non-significant indicating the higher effects of the main factors in decreasing total phenol content. After six months of storage, powder formulated with maltodextrin at 160°C inlet temperature packed conventionally and stored in refrigeration contained 0.493, 0.067 and 0.273 per cent total phenol in cashew apple, pineapple and blended juice respectively while powders formulated with resistant dextrin in the same conditions exhibited 0.443, 0.06 and 0.243 per cent phenol content. Fang and Bhandari (2011) also observed a reduction in poly phenols of spray dried bay berry powders under storage and refrigerated storage was efficient in retaining more poly phenols. At storage temperature of 5°C phenol loss was 6-8 per cent whereas at 25°C and 45°C losses increased to 6-9 per cent and 9-37 per cent respectively.

5.3.3 pH

None of the treatment combinations influenced pH of the powders under storage.

5.3.4 Titrable acidity

The data on titrable acidity of stored powders revealed significant variation in factors except carriers.

Titrable acidity increased in cashew apple juice powders at all packing atmospheres (Figure 27). However, the rate of increase was lower in conventional packaged material under refrigerated storage which was higher by 2.1 per cent of initial acidity (0.95 per cent). However, the storage of the same package in ambient temperature led to increase by 19 per cent of initial acidity which was at par with increase in nitrogen packed powder (17.8 per cent) as depicted in table 57.

With respect to pineapple powder there was no acidity increase in conventionally packed powders that stored under refrigeration and vacuum packaged powders that stored under ambient temperature as shown in figure 27. However, nitrogen and air packaged powders that stored at ambient temperature recorded increase of 6.8 and 9.46 per cent of initial acidity (1.426 per cent) respectively.

Similar trend was evident in blended juice powder too. The refrigerated storage atmosphere recorded an elevation of 5.18 per cent of the initial acidity (1.041 per cent) followed by vacuum with an increase of 12 per cent. Nitrogen and conventionally packaged powders that stored at ambient temperature exhibited higher acidity with 18.6 and 20.5 per cent increase from the initial content respectively.

Storage period also significantly influenced titrable acidity in direct proportion as expressed in figure 28. The rate of increase in acidity in cashew apple powder was 9.36, 12.32 and 16.63 per cent from the initial phenol content (0.95 per cent) at 2nd, 4th and 6th month respectively. Acidity of pineapple juice powders was increased by 3.23, 5.05 and 6.52 per cent from the initial content of 1.43 per cent, during 2nd, 4th and 6th month respectively. As the storage period advanced titrable acidity of the blended

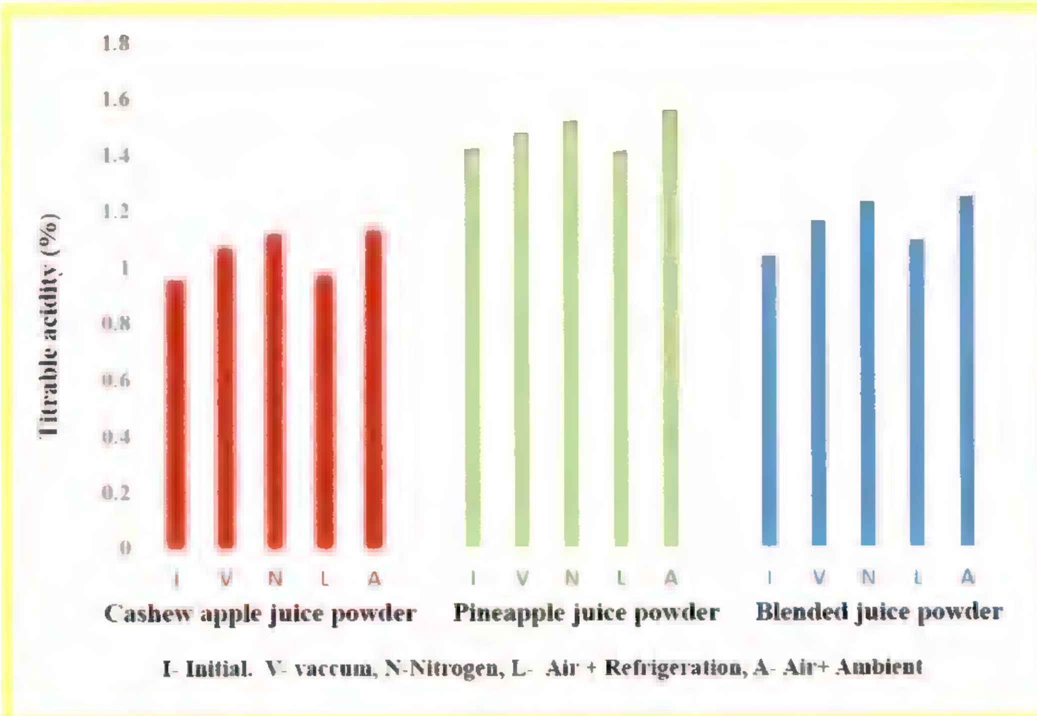


Figure 27 : Effects of packaging atmospheres on titrable acidity in stored powders

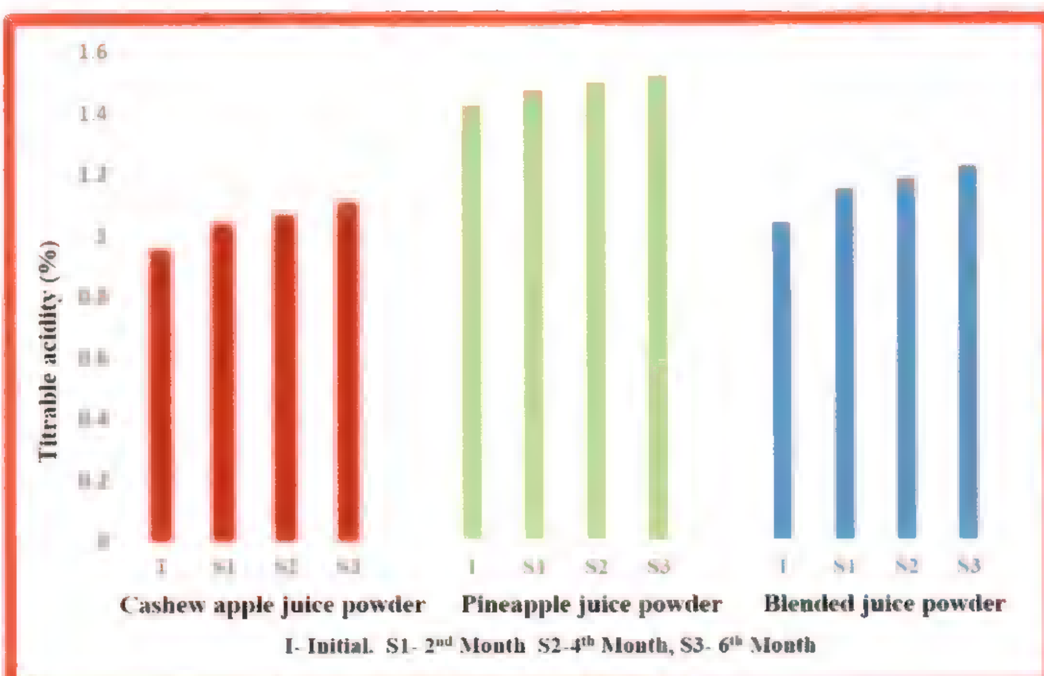


Figure 28 : Effects of storage period on titrable acidity in stored powders

juice powder increased by 10.76, 13.83 and 17.77 per cent of initial content (1.04 per cent) at 2nd, 4th and 6th month respectively as shown in table 58 and figure 28.

The interaction effects were non-significant indicating the higher effects of the main factors in increasing titrable acidity. After six months of storage powder formulated with maltodextrin at 160°C inlet temperature packed conventionally and stored in refrigeration contained 0.967, 1.436 and 1.131 per cent titrable acidity in cashew apple, pineapple and blended juice respectively while powders formulated with resistant dextrin in the same conditions exhibited 1.031, 1.415 and 1.095 per cent titrable acidity. Before subjecting to storage maltodextrin related powders had 0.903, 1.426 and 1.019 per cent titrable acidity in cashew apple, pineapple and blended juice respectively while powders formulated with resistant dextrin had 0.996, 1.426 and 1.063 per cent titrable acidity. Hence, the data clearly indicted superiority of refrigerated storage in maintaining the acidity since titrable acidity represents the sour taste of the product.

5.3.5 Microbial Count

Instant juice powders were analysed for its microbial quality (bacteria and fungi) at bimonthly interval for all the treatment combinations at 10^{-3} dilution and without dilution by pour plating technique with potato dextrose agar and nutrient agar media. Microbial growth was not observed in any of the plates indicating very good microbial stability of the product. The sterile conditions of drying lower water activity and the high temperature to which the powder was subjected at drying might have attributed to this microbial stability.

5.3.6 β carotene

Pineapple and blended juice powders on storage exhibited high β carotene loss and the packaging atmospheres and storage period exhibited significant variation. Interaction effects were non-significant.

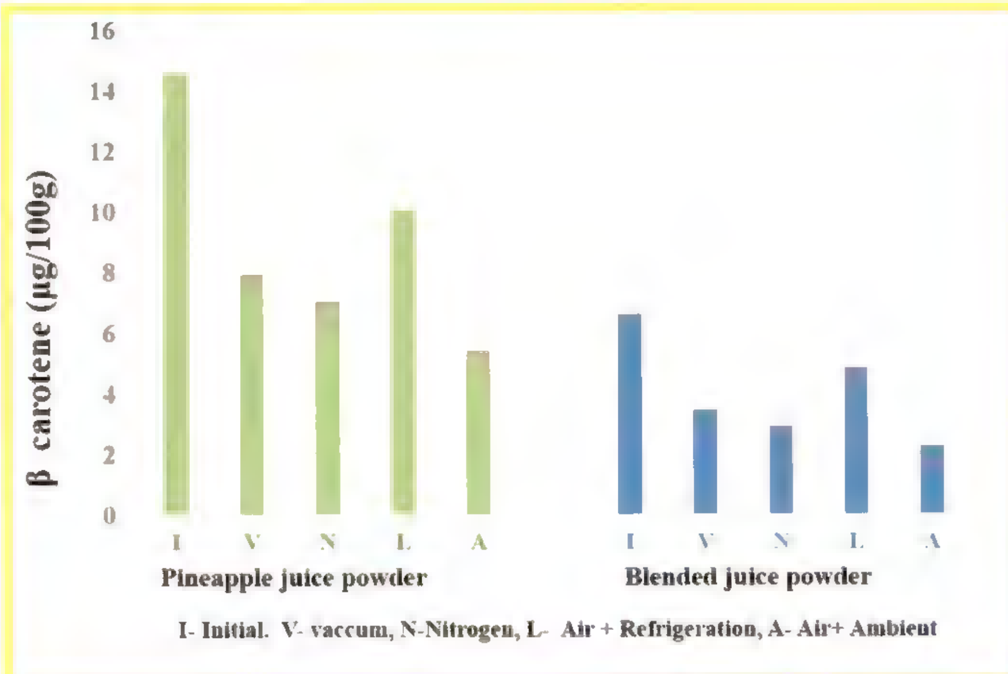


Figure 29 : Effects of packaging atmospheres on β carotene in stored powders

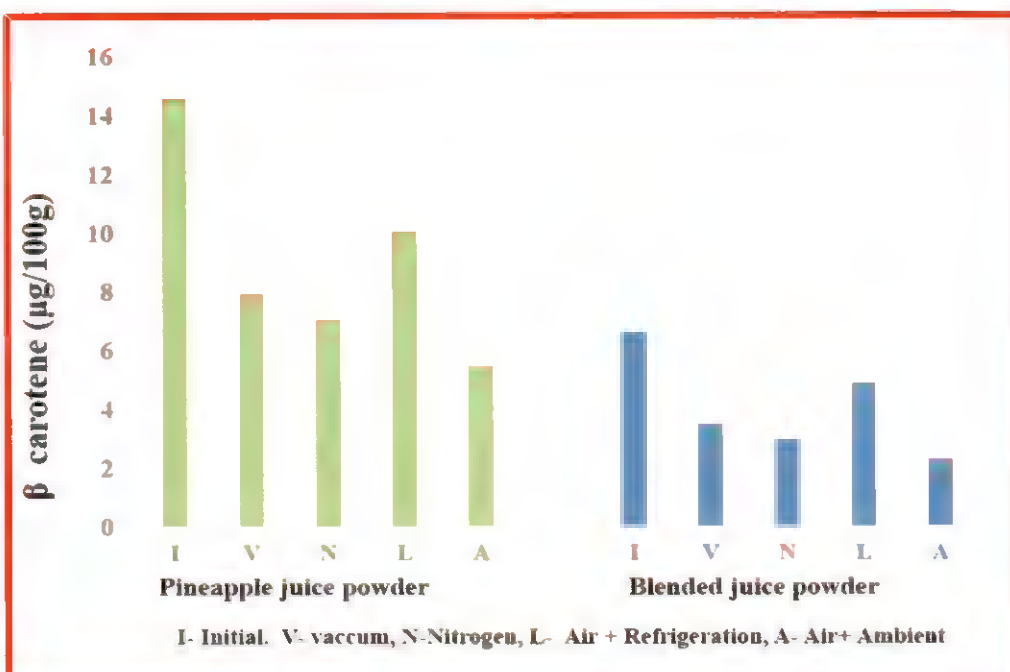


Figure 30 : Effects of storage period on β carotene in stored powders

Maximum β carotene content of pineapple powders were retained by conventionally packaged product stored under refrigeration which recorded 69 per cent of initial β carotene (14.57µg/100g) as given in figure 29. However, the storage of the same package in ambient temperature could only retain 37.4 per cent of initial β carotene.

In blended fruit powders conventional package stored at refrigeration retained 73.3 per cent initial β carotene (6.61µg/100g) as depicted in figure 29. Vacuum packaged powder kept at ambient temperature was better than nitrogen packaged powder since the retention percentage was 52.6 and 44.5 respectively. The lowest β carotene retention (34.2 per cent) was observed in conventionally packed powder stored at ambient temperature.

Storage period also significantly influenced β carotene as shown in figure 30. The data indicated that the β carotene content decreased as the storage period advanced. The rate of retention of β carotene in pineapple juice powder was 6.4, 46.9 and 49.3 per cent of the initial β carotene content (14.57µg/100g) at 2nd, 4th and 6th month respectively. β carotene of blended juice powders was retained as 61.8, and 45.8 per cent of the initial content (6.61µg/100g) during 2nd and 4th and β carotene content did not differ significantly between 4th and 6th month in both these powders indicating that β carotene loss was higher at early period of storage.

The interaction effects were non-significant indicating the higher effects of the main factors in decreasing β carotene. After six months of storage powder formulated with maltodextrin at 160°C inlet temperature packed conventionally and stored in refrigeration contained 10.23 and 4.56 µg/100g β carotene in pineapple and blended juice respectively while powders formulated with resistant dextrin in the same conditions exhibited 9.96 and 4.53 per cent β carotene content. Prior to storage maltodextrin related powders had 14.87 and 6.9 µg/100g vitamin C in pineapple and blended juice respectively while powders formulated with resistant dextrin had 14.27

and 6.26 μg/100gm. It is clear that refrigerated storage retained fair quantity of β carotene in the storage.

Desobry *et al.* (1997) observed that relative humidity had no effect on encapsulated β carotene on storage. Emenhiser *et al.* (1999) suggested oxidation as the main factor responsible for carotenoid degradation in storage. Sagar *et al* (2000) observed higher retention of carotenoids of mango powder at low temperature storage. During storage of encapsulated anthocyanin at 25°C and 4°C the higher storage temperature (25°C) led to higher anthocyanin loss as compared to the lower temperature of 4°C (Ersus and Yurdagel, 2007).

5.3.7 Vitamin C

Analysis of data on vitamin C revealed that packaging atmospheres and storage period significantly influenced the vitamin C content in stored powders.

The maximum vitamin C content of cashew apple powders were retained by conventional packaged material under refrigerated storage in which 5.1 per cent loss of initial vitamin C content (674.77mg/100g) was observe as depicted in figure 31. However, the storage of the same package in ambient temperature led to 28.5 per cent loss of initial vitamin C which was the highest loss among studied treatments.

Similar result was obtained with respect to pineapple powder too (Figure 31). Loss of vitamin C content was similar in nitrogen and conventional air packages stored at ambient temperature with 31.8 and 35.98 per cent loss of the initial vitamin C (31.31mg/100g). Conventional package stored under refrigeration retained 91.7 per cent of initial vitamin C. Vacuum packaged powder kept at ambient temperature was better than nitrogen packed powder since it retained 78.2 per cent of vitamin C.

The refrigerated storage with conventional packages retained 96 per cent of the initial vitamin C (277.6mg/100g) followed by vacuum (loss of 12.1 per cent) in blended juice powders (Figure 31). Nitrogen (loss of 24.5 per cent) and conventional

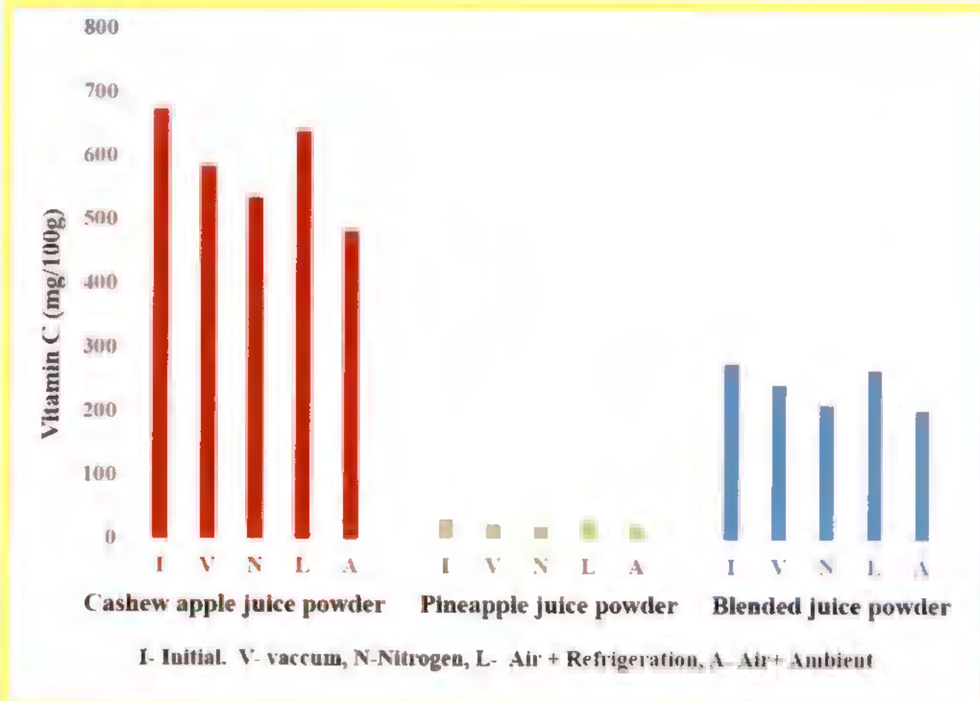


Figure 31: Effects of packaging atmospheres on Vitamin C in stored powders

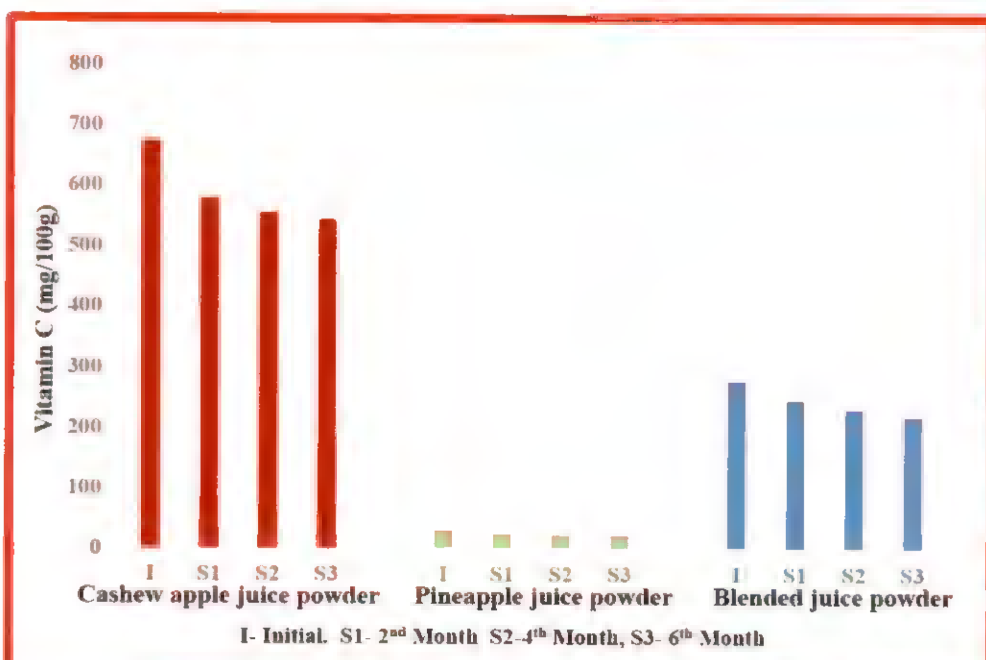


Figure 32: Effects of storage period on Vitamin C in stored powders

air packaged product kept under ambient temperature (loss of 25.9 per cent) had significantly lower retention of vitamin C.

Storage period also significantly influenced vitamin C as depicted in figure 32. The data indicated that the vitamin C content decreased and the rate of loss of vitamin C in cashew apple powder was 14.1, 17.4 and 19.3 per cent of the initial vitamin C content (674.77mg/100) at 2nd, 4th and 6th month respectively. Vitamin C of pineapple juice powders got reduced by 20.4, 24.2 and 28.8 per cent of the initial content (31.31mg/100g) at 2nd, 4th and 6th month respectively. Vitamin C content did not differ significantly between 4th and 6th month in both these fruit powders. As the storage period advanced vitamin C content of the blended juice powder decreased by 11.4, 16.5 and 20.7 per cent of initial content (277.57 mg/100g) till 2nd, 4th and 6th month respectively. Ammar *et al*. (1986) suggested that lower rate of reduction of ascorbic acid at later period of storage might be due to the loss of ascorbic acid oxidase over a period of time.

The interaction effects were non-significant indicating the higher effects of the main factors in decreasing vitamin C. After six months of storage, powder formulated with maltodextrin at 160°C inlet temperature packed conventionally and stored under refrigeration contained 623.2, 27.75 and 251.35 mg/100g vitamin C in cashew apple, pineapple and blended juice respectively while powders formulated with resistant dextrin in the same conditions exhibited 630.63, 26.67 and 262.16 per cent vitamin C content (Table 62). Before subjecting to storage maltodextrin related powders had 671.03, 31.4 and 267.29 mg/100g vitamin C in cashew apple, pineapple and blended juice respectively while powders formulated with resistant dextrin had 678.51, 31.22 and 287.85 mg/100gm. Hence, it is understood that the refrigerated storage retained much of the vitamin C in the storage, as Carrillo-Navas *et al.* (2011) positively correlated temperature with water activity and water activity with reduction in vitamin C in passion fruit juice powder. Since molecular mobility of the water is much greater, which can accelerate degradation reactions, the vitamin C reduction at higher temperature was higher. Oyetade *et al.* (2012) found that ascorbic acid was affected by storage time except in refrigeration condition. Indeed there were negative correlation between holding time and ascorbic acid content at different temperature except under refrigerated condition. This result therefore suggested refrigeration storage of vitamin C source. Moreover, Kurozwa *et al.* (2014) suggested that the nutrient loss, being a reaction dependent on oxygen diffusion in the matrix, was consistently reduced when storage temperature was lower than the glass transition temperature. Vitamin C degradation increased as the storage temperature increased above the glass transition temperature.

5. 3.8 Sensory parameters

Sensory analysis of fruit powders under storage were conducted in a 9 point hedonic scale in bimonthly interval to find the stability in organoleptic qualities. The state of powder after six months of storage was visually presented in three plates from plate 30 to plate 32. The visual representation of reconstituted solutions of these powders are presented in plate 33.

Analysis of the data on appearance of stored powder exhibited reduction in sensory scores during storage period in all fruit juices under the study. The powder that was packed conventionally but stored at refrigerated condition received better scores consistently at storage periods. During 2^{nd} month appearance of these powders were "very much" to "moderately liked" by the panel and at 4^{th} and 6^{th} month the scores for appearance were "moderate" to "slight". Vacuum and nitrogen packaged powders were disliked slightly by the panel in earlier stages of storage but moderately to very much disliked as the storage time progressed. The conventionally packed powder stored at ambient temperature received lowest scores consistently and the reconstituted juice of this powder was moderately disliked by the end of 2^{nd} month and very much disliked by the end of 6^{th} month.




$CM_5T_2VS_3$ $CM_5T_2NS_3$ $CM_5T_2AS_3$ $CM_5T_2LS_3$

Powders formulated with maltodextrin




$CR_5T_2VS_3$ $CR_5T_2NS_3$ $CR_5T_2AS_3$ $JR_5T_2LS_3$

Powders formulated with resistant dextrin

Plate 30: Cashew Apple Juice Powders Under Storage

C- Cashew apple juice, M_5 – Maltodextrin@40:60(Juice: Carrier). R_5 -Resistant dextrin@40:60 (Juice: Carrier), T_2- 160ºC , V- Vacuum, N-Nitrogen, A- Air(Ambient), L- Air (Refrigerated) S_3 -6th Month

$PM_5T_2NS_3$

$CM_5T_2NS_3$

$PM_5T_2AS_3$

$PM_5T_2LS_3$

Powders formulated with maltodextrin

$PR_5T_2VS_3$

$PR_5T_2NS_3$

$PR_5T_2AS_3$

$PR_5T_2LS_3$

Powders formulated with resistant dextrin

Plate 31: Pineapple Juice Powders Under Storage

P- Pineapple juice, M_5 – Maltodextrin@40:60 (Juice: Carrier). R_5 -Resistant dextrin@40:60 (Juice: Carrier), T_2- 160°C , V- Vacuum, N-Nitrogen, A- Air(Ambient), L- Air (Refrigerated) S_3 - 6th Month

$BM_5T_2VS_3$

$BM_5T_2NS_3$

$BM_5T_2AS_3$

$BM_5T_2LS_3$

Powders formulated with maltodextrin

$BR_5T_2VS_3$

$BR_5T_2NS_3$

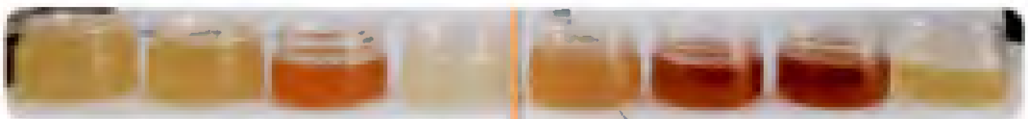
$BR_5T_2AS_3$

$BR_5T_2LS_3$

Powders formulated with resistant dextrin

Plate 32: Blended Juice Powders Under Storage

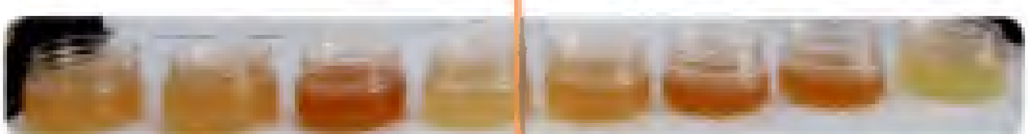
B- Blended juice, M_5 – Maltodextrin@40:60 (Juice: Carrier). R_5 -Resistant dextrin@40:60 (Juice: Carrier), T_2- 160°C , V- Vacuum, N-Nitrogen, A- Air(Ambient), L- Air (Refrigerated) S_3 - 6^{th} Month



V N A L V N A L

Maltodextrin based Resistant dextrin based

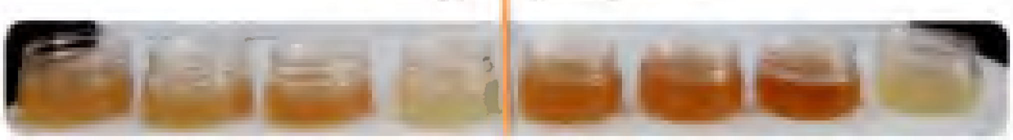
Cashew apple juice powders



V N A L V N A L

Maltodextrin based Resistant dextrin based

Pineapple juice powders



V N A L V N A L

Maltodextrin based Resistant dextrin based

Blended juice powders

Plate 33: Reconstituted juice powders under storage

(V- Vacuum, N- Nitrogen, A - Air(Ambient), L-Air(Refrigeration))

Lower scores on colour on packaging conditions other than the refrigerated condition was because of the off colour developed in the storage period. However, conventionally packed powder stored at refrigerated condition maintained colour during storage period.

The juicy texture was maintained by the storage at lower temperature even after conventional packing and this treatment combination received higher scores consistently in all storage periods. The other treatment combinations received scores for "slightly liked texture" at early period of storage but scores got reduced to "slight disliked texture" as storage progressed.

The scores on flavour also followed similar trend. The powder that packed conventionally but stored at refrigerated condition was received better scores consistently at storage periods. At 2nd month these powders had "very much to moderately liked" flavour and at 4th and 6th month the flavour got lowered down to "moderate and slight". Flavour of nitrogen and vacuum packed powders were "neither liked nor disliked" by the panel at early stages of storage but got lowered to "moderate to slight dislike"s as storage progressed. Flavour of the conventionally packaged powder stored under ambient temperature consistently received lower scores and were "very much disliked" by the end of 6th month storage period.

The powder that packed conventionally but stored at refrigerated condition maintained acceptable taste consistently at storage periods. At 2nd month these powders had "moderately liked" taste and at 4th and 6th month the taste got lowered down to "moderate and slightly liked". Taste of nitrogen and vacuum packed powders were "neither liked nor disliked or slightly disliked" by the panel at early stages of storage but got lowered to "slight to moderate dislike" as storage progressed. Taste of the conventionally packaged powder stored under ambient temperature consistently received lower scores and were "very much disliked to extremely disliked" by the end of 6th month storage period.

The data clearly denote that only refrigerated storage could maintain acceptable appearance, colour, texture,flavour and taste even after conventional packaging.

5. 3.9 Selection of powders from part -3

Storage study for six months under four packaging atmospheres, revealed no microbial growth. Refrigerated storage could maintain vitamin C, β-carotene, moisture content, titrable acidity, total phenol and high sensory acceptability of fruit powders. Hence, two powders from each juice; one from each carrier, stored under refrigeration were selected independently from cashew apple ($CM_5T_2LS_3$ and $CR_5T_2LS_3$), pineapple ($PM_5T_2LS_3$ and $PR_5T_2LS_3$) and blended juice ($BM_5T_2LS_3$ and $BR_5T_2LS_3$) for computation of cost of production and consumer acceptability.

5,3.10 Cost of Production

Cost of production of six instant juice powders were computed with due consideration to fixed and variable costs involved in production of powders. Powders formulated with resistant dextrin recorded lower cost of production consistently in all fruit juices. Cost of production was lower by 23.4, 7.5 and 14.68 per cent when resistant dextrin was used as carrier. The lower cost of powder formulated with resistant dextrin could be attributed to the higher yield of powder though the cost of resistant dextrin as a raw material was higher in comparison to maltodextrin. Yield of powders were higher by 69.99, 42.58 and 54.46 per cent in cashew apple, pineapple and blended powder respectively.

5.3.11 Consumer acceptability

Consumer acceptability of the six instant juice powders were studied through organoleptic scoring of reconstituted juice with 15 per cent concentration to assess rationality of price with the value perceived by the product, willingness to pay the money to purchase the item, and preference of the product

The consumers rated the fairness of the price as "medium high" for pineapple juice and very high for cashew apple and blended juices. Consumers expressed medium intention of purchase for pineapple juice, low intention for blended juice and very low intention for cashew apple juice at the price level of Rs 1100 / kg of powder. Pineapple powder was the most preferred powder with rating of high preference and blended fruit powder was medium preferred. Cashew apple powder formulated with resistant dextrin had medium preference while maltodextrin related juice powder received low preference rating. None of the instant juice powders received the extreme ratings of very high preference or very low preference. Perceived value of the product ranged from Rs 215- Rs 423 per kilo gram.

The low preference for cashew apple juices could be attributed to the native astringency of the pure juice. Even after clarification for removing the astringency, as described in the chapter of materials and methods, it was not completely removed and the astringency persisted in the spray dried powder too. The blending of cashew apple juice with pineapple juice prior to drying could lower the astringency and it reflected into the higher preference by the consumers.

The opinions of consumers on parameters like price fairness, payment intention and perceived values were not only related to the quality of product but also to the price of the product in relation to the instant juice powders available in the market. However, instant juice powders currently available in the market are sweeter due to addition of sugar and they contain 0 to below 1 per cent fruit content. Instant juice powder from the present study is less sweet due to non addition of sugar and exhibit some disadvantages like hygroscopicity due to the 40 per cent fruit content. The lower cost of product on a scaled up processing and better awareness about the nutritional aspects in consumers can invariably improve consumer acceptance of the product.

Cashew apple | Pineapple | Blended juice

Cashew apple | Pineapple | Blended juice

Plate 34: The best instant juice powder and its reconstituted juice

5.4 THE BEST INSTANT JUICE POWDER

Based on the analysis of the data resistant dextrin could be adjudged as better carrier material due to higher yield, quality and better economics in production. Resistant dextrin yielded fruit powders with low moisture, dispersible solids, viscosity, angle of repose and with high per cent soluble solids, lightness and hue angle. Moreover, resistant dextrin lowered chromaticity in pineapple and blended juice powder in contrast to the effect in cashew apple juice. It also lowered water activity in pineapple juice. Resistant dextrin could also yield cashew apple powder with high vitamin C. Concentration of 40:60 juice solid to carrier ratio yielded better and improved powder recovery from cyclone substantially. Inlet temperature of 160°C was superior in production of high quality instant juice powders in higher quantity. Refrigerated storage could maintain the storage stability and retain nutrients and possess better sensory properties.

Therefore, instant juice powders of cashew apple, pineapple and their equal blend produced by spray drying at 160°C with resistant dextrin as carrier in 40:60 juice solid to carrier ratio had optimum physical, chemical, nutritional and sensory qualities with six month shelf stability under refrigeration. The selected three instant juice powders and their reconstituted juice is categorized in plate 34.

5.5 FUTURE PROSPECTS

Further studies to improve shelf life of the product in ambient temperature, exploration on nutraceutical functions and development of spray drier for small scale industries with higher efficiency will be highly beneficial for improving cost effectiveness and commercialization of the technology which will in turn lead to exploitation of wasted cashew apple and improve processing opportunities of pineapple.

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Summary

6. SUMMARY

The present investigation entitled "Instant juice powders of cashew apple (*Anacardium occidentale* L.) and pineapple (*Ananas comosus* (L.) Merr.) was carried out in the Department of Processing Technology, College of Agriculture, Vellayani utilizing the facilities of Kelappaji College of Agricultural Engineering Technology, Tavanur and Cashew Research Station, Madakkathara of Kerala Agricultural University during the period 2013-2016 to to optimise the process parameters for micro encapsulation through spray drying of cashewapple and pineapple juices, to evaluate the effect of drying on physical, chemical and nutritional quality parameters of fruit powders, to formulate blended fruit powder, and to assess organoleptic quality, storage stability, economics and consumer acceptability of the standardised formulations. The whole programme was divided into three major parts.

1. Optimisation of process parameters for instant fruit powder production by micro encapsulation through spray drying
2. Quality evaluation of microencapsulated fruit powders
3. Storage stability of pure and blended fruit juice powders.

The major findings are summarized as follows

In order to optimize the process parameters for instant fruit powder production by micro encapsulation, feed mix of cashew apple, pineapple and their equal blend were independently prepared by mixing juice and carrier materials [Maltodextrin (M) or Resistant dextrin (D)] in varying proportions based on the total soluble solids, after evaluating the chemical parameters of juice. The juice carrier combinations were tried in four different proportions based on juice solid and carrier ratios as 80:20 70:30, 60:40, 50:50, 40:60. Properly mixed feed was then fed to co-current spray drier by a peristaltic pump for drying at six different inlet temperatures as 150°C, 160°C, 170°C, 180°C, 190°C, 200°C. 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.

Fine powder from cyclone and loose powder from chamber were separately weighed and then bulked. Rate of feed supply and recovery of spray dried powder were recorded and analyzed statistically with three factor Completely Randomised Design.

Increase in concentration of carrier materials in the feed mix realized higher feed rates as the combination with highest carrier content (40:60) recorded 66 per cent elevation in cashew apple and 59 per cent in both pineapple and blended juice over the least carrier content (80:20). Higher inlet temperature invariably led to higher feed rates. The highest carrier ratio with 200°C recorded highest feed rate.

Addition of carriers improved powder recovery and resistant dextrin had profound effect in increasing fine, loose and total powder recovery from all fruit juices.

Increase in carrier ratio led to higher yield irrespective of place of recovery of powder or type of juice. The lowest carrier ratio (80:20) did not yield any powder as the entire feed particles stuck to chamber wall as a highly viscous sticky paste.

There was marked interaction of concentration with carrier on powder recovery. 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.

The powder recovery decreased with higher temperatures. In general 160°C could be adjudged as optimum due to the consistency in improving powder yield irrespective of nature of powder or juice dried. The inlet temperature of 200°C recorded lowest yield. Reduction in temperature from 200°C to 160°C improved total powder recovery by 56, 49 and 61 per cent in cashew apple, pineapple and blended juice respectively.

The effect of carrier was significantly influenced by inlet temperature by improving fine powder recovery in all fruit juices and the effect on resistant dextrin was superior to the effect on maltodextrin. This clearly indicated that as the resistant dextrin reduced stickiness, the recovery improved, and the effect of other operating parameters became more evident.

Effect of concentration was significantly influenced by inlet temperature. In the highest concentration levels, 160°C was the optimum temperature. However, in the lower concentration levels these lower temperature ranges did not exhibit any marked deviation pattern.

As a combination, carrier resistant dextrin, juice solid to carrier ratio of 40:60 and 160°C inlet temperature resulted in high recovery of fine, coarse and bulked fruit powders. This combination recovered 72.09, 85.62 and 74.70 per cent of total solid content from juice carrier mix of cashew apple, pineapple and their equal blend respectively of which 40.55, 47.06 and 42.02 per cent were from cyclone.

Five treatment combinations involving juice solid to carrier ratio of 40: 60 dried at temperature of 150 to 190°C, which had higher recovery percentages were selected from each carrier for physico-chemical and sensory analysis in part two of the experiment.

The powder produced using resistant dextrin had lower moisture content than that produced using maltodextrin and moisture content of juice powder was inversely proportional to inlet temperature. The highest temperature recorded 81, 52 and 48 per cent lower moisture content in powders than the lowest temperature in cashew apple, pineapple and blended juice respectively.

Bulk density of cashew apple and blended juice powder were significantly improved by maltodextrin while it did not cause significant change in the apparent density of these powders. Instead, maltodextrin significantly elevated volume occupied by the particles and therefore reduced the porosity. Bulk density and volume occupied by particles were inversely proportional to inlet temperature. Bulk density ranged between 0.43 to 0.619 in cashew apple powder, 0.476 to 0.662 in pineapple juice powder and 0.441 to 0.635 in blended juice powders.

Instant juice powders produced with carrier maltodextrin had higher TSS compared to resistant dextrin in all fruit juices. Both the carriers were efficient in producing powders with high soluble solids and low dispersible solids though resistant dextrin was slightly better exhibiting two per cent improvement in all fruit juice powders. The soluble solid percentage ranged 93.367 to 96.4 per cent in cashew apple, 91.1 to 94.567 per cent in pineapple and 90.03 to 93.767 in blended juice powders.

None of the treatments significantly influenced sinkability of powder, but resistant dextrin was better in yielding powders with high lightness due to less burning of powder. Lightness of powder was inversely proportional to inlet temperature.

The interpretation of a* values clearly indicated that resistant dextrin exhibited powders with higher greenness (higher negative values) and maltodextrin exhibited lower greenness or higher redness (lower negative or positive values) in all fruit juices. Moreover, powders dried at lower temperature exhibited a* value towards greenness and higher temperature exhibited the shift towards redness in all fruit juices.

Interpretation of b* values showed varying colour shift with respect to carriers. Resistant dextrin produced cashew apple powder with more yellowness (Higher positive values). Though pure resistant dextrin had higher b* values (yellowness), the rate of shift towards yellowness by resistant dextrin was less at drying than maltodextrin with respect to cashew apple juice powder. In addition, resistant dextrin exhibited powder with lower yellowness (lower positive values) than maltodextrin in pineapple and blended juice powders. This clearly indicated superiority of resistant dextrin in avoiding burning of powder. Drying at lower temperature shifted colour towards lower yellowness (lower positive values) and high temperature towards higher yellowness (higher positive values).

Instant juice powders with resistant dextrin recorded higher hue angle in all fruit juices. It was obvious that hue angle shifted towards yellow due to drying with both carriers and the extent of shift was lower in resistant dextrin. Similar result in the three juice powders asserted the superiority of resistant dextrin in alleviating burning of powders.

Hue angle was inversely proportional to drying temperature. Drying temperature of 150°C recorded higher hue angle in cashew apple and pineapple while 160°C was optimum in blended juice. The highest temperature recorded the lowest hue angle in all fruit juices. Drying at higher temperature shifted the powder hue to yellow in cashew apple powder and to yellow - red in pineapple and blended juice powder. The change in powder hue to more yellow and to yellow-red indicated browning of powders due to burning.

Resistant dextrin exhibited higher colour saturation in cashew apple juice powder but lower in pineapple and blended juice, but the extent of increase in saturation was lower in case of resistant dextrin in all fruit juices. Hence resistant dextrin was superior to produce powders with low burning.

Saturation of powder colour was directly proportional to inlet temperature. Higher temperature elevates yellowness due to browning by burning. Drying at 150°C with resistant dextrin helped for low burning in cashew apple and pineapple and 160°C in blended juice, since these powders exhibited least deviation from the initial saturation level of carrier.

Relative viscosity of juices made by reconstitution of fruit powders was significantly influenced by carriers. Powders with resistant dextrin recorded significantly lower viscosity. The viscosity of powders ranged from 7.27 to 8.25, 8.157 to 8.833 and 7.877 to 8.293 mPas in cashew apple pineapple and blended powder respectively.

With respect to carriers, resistant dextrin exhibited 5, 5.4 and 15 per cent lower angle of repose than maltodextrin in cashew apple, pineapple and their equal blend respectively. The temperature range of 160°C - 180°C did not vary significantly among them in cashew apple and blended juice powders but 160°C produced powders with higher angle of repose in pineapple juice. Interpretation of angle of repose revealed that none of the powder was either very free flowing or cohesive. Cashew apple powder produced with maltodextrin at inlet temperature range of 160°C to 190°C was free flowing. However, drying at 150°C reduced the flowability to fair and passable. With respect to the powder produced with resistant dextrin as carrier, all cashew apple powders and pineapple juice powders produced at temperature range of 180-190°C were of free flowing nature. All other pineapple juice powders could be classified as fair with passable flow.

Resistant dextrin reduced water activity of pineapple powder while both carriers were equally effective in cashew apple and blended juices. Water activity of cashew apple and blended juice powder dried at 150°C were significantly higher than those produced at 160°C - 190°C. Water activity of pineapple powder produced at 150°C to 170°C was higher than those produced at 180-190 range. Water activity values of the powders indicated that they were microbiologically stable.

Analysis of chemical parameters revealed that the powders produced with resistant dextrin exhibited higher retention of ascorbic acid in cashew apple powders. Vitamin C content was inversely proportional to inlet temperature. Drying at lowest temperature retained 3.6, 6.9 and 8.7 per cent more vitamin C than drying at highest temperature in cashew apple, pineapple and blended juice respectively. The vitamin C ranged from 652.33- 680.37, 29.81-to 31.96 and 265.42-293.46 mg/100g in cashew apple pineapple and blended powder respectively.

β-carotene content was inversely proportional to inlet temperature. Drying at lowest temperature retained 16.5 and 11.98 per cent more β-carotene than the highest temperature in pineapple and blended juice respectively. The β-carotene ranged from 12.27- 15.3 and 5.99- 6.9 μg/100g in pineapple and blended powder respectively. None of the treatment combination significantly influenced crude fibre or ash content of powders.

Instant juice powders formulated with maltodextrin recorded higher reducing and non reducing sugars which invariably led to higher total sugar content.

Maltodextrin exhibited 16.64, 17.17 and 13.58 per cent improvement in total sugars due to 9.02, 7.33 and 5.18 per cent increase in reducing sugars and 54.16,72.76, and 62.39 per cent increase in non reducing sugars in cashew apple, pineapple and blended powder respectively. Inlet temperature influenced reducing sugar content of all fruit powders and total sugar content of cashew apple juice powder. Cashew apple juice and blended juice dried at 160°C-180°C and pineapple juice powder dried at 150°C-180°C exhibited highest reducing sugar content. Inlet temperature did not significantly influence the non reducing sugar content in all three fruit juices. However, temperature range of 160°C-180°C exhibited highest total sugar content in cashew apple juice powder. None of the treatments significantly influenced titrable acidity of the powders.

None of the carriers influenced energy value of the powder. However, energy value increased in proportion to inlet temperature. Temperature range of 180- 190°C recorded highest energy value in cashew apple and blended juice powders and the temperature of 170 to 190°C produced energy rich pineapple powders. The energy value ranged 3408.24- 3595.77, 3472.25-3666.99 and 3401.69-3667.92 cal/g in cashew apple, pineapple and blended powder respectively.

Analysis on the sensory scores in a nine point hedonic scale revealed that powder produced with resistant dextrin at 160°C had optimum sensory qualities.

Considering the optimum quality parameters under investigation, the treatment combinations of 160°C inlet temperature were selected from both the carriers for further study in all the three fruit juices independently. These powders were subjected to investigation on sorption behavior, glass transition temperature and microstructure.

The humidity - moisture equilibrium curves of these six powders revealed highly hygroscopic nature since increase in moisture content is steep beyond 50 per cent RH. The sorption isotherms followed a characteristic J shape associated with high sugar foods. Experimental sorption isotherms of juice powders indicated that powder with resistant dextrin was less hygroscopic than with maltodextrin in all fruit juices.

Cashew apple juice powder formulated with resistant dextrin exhibited a wider safety range of 4.6 – 6.17 per cent EMC equilibrated with 24.7 and 29.7 ERH, with a safety margin of 4.43- 4.6 EMC with 24.5- 24.7 ERH, indicating low hygroscopicity and more flexibility in selecting packaging materials than with maltodextrin.

Pineapple powders formulated with resistant dextrin remained free flowing till 6.21 per cent EMC equilibrated with 36.5 per cent ERH whereas powder with maltodextrin started to form lumps at 26.3 per cent ERH with 6.3 per cent EMC. Powders formulated with resistant dextrin showed a wider safety range with 4.6 to 6.21 per cent EMC equilibrated with 31.5 to 36.5 per cent ERH and safety margin with 4.59 to 4.6 per cent EMC equilibrated with 30.3 and 31.5 per cent ERH while initial moisture content of the powder with maltodextrin had already crossed the danger point indicating lack of a safe margin for any error in packing conditions.

Blended fruit juice powder formulated with resistant dextrin remained free flowing till the critical point of 6.18 per cent EMC equilibrated with 33.8 per cent ERH. Lumping, caking and sticky fluid formation occurred as the EMC and ERH progressed. The powder exhibited safety range with 5.41- 6.18 per cent EMC equilibrated with 28.8-33.8 per cent ERH and safety margin of 4.63-5.41 EMC with 25.81-28.8 ERH. Initial moisture content of the powder formulated with maltodextrin had already crossed danger point of 5.31 per cent EMC with 21.68 per cent ERH and lump formation started earlier at 26.68 ERH at 6.22 per cent EMC. Lack of a safety margin and narrow safety range indicated higher hygroscopicity and elevated risk of spoilage

Cashew apple powder produced using maltodextrin at juice solid and carrier ratio of 40: 60 at 160°C inlet temperature exhibited glass transition and the midpoint temperature as 8.68°C. When carrier was changed as resistant dextrin, glass transition temperature was 14.65°C. The pineapple powder exhibited glass transition with midpoint temperature of 13.48°C and 31.16°C with same conditions. Blended juice powder had 12.72°C glass transition temperature in maltodextrin related powders and 23.45°C in resistant dextrin related powders.

The powder particles showed a spherical shape and various sizes with no apparent cracks, puffing pores or fissures. The average particle size of powders ranged from 3 to 30 μm. The powders produced with maltodextrin were smaller, smoother regularly spherical particle without much surface dents or collapsed walls, but more agglomerated. Powder particles formed using resistant dextrin contained more number of discrete larger ones with irregular spherical shape and occasional surface dents and shrinkages. Surface dents were more prevalent in larger particles.

The six encapsulated fruit juice powders selected from part two of the experiment were subjected to a storage stability and nutrient retention analysis with four packaging atmospheres in metalized polyester pouches. Lowest moisture ingression was exhibited in the conventional packaged material under refrigerated storage of all fruit powders. None of the treatments except refrigerated storage could keep the moisture content of the product below critical point and the products became lumpy and sticky. The ordinary packed powder stored under refrigerated condition remained free flowing without alteration of physical properties since its moisture content never reached critical point. Moisture content increased as storage period advanced but the rate of increment slowed down since highest rate of elevation in the moisture was found at the initial sixty days of the storage.

The maximum phenol content of cashew apple powders was retained by conventional packaged material under refrigerated storage but same package kept under ambient temperature had the highest loss. None of the treatment combinations influenced pH of the powders under storage.

Titrable acidity increased in cashew apple juice powders at all packing atmospheres. However, the rate of increase was lower in conventional packaged material stored under refrigerated storage.

Microbial growth was not observed in any of the powders indicating microbial stability of the product.

The maximum vitamin C content of all fruit powders were retained by conventional packaged material under refrigerated storage, but storage of the same package in ambient temperature led to 28.5 per cent loss of initial vitamin C. The maximum β carotene content of pineapple powders were retained by conventional packaged product stored under refrigerated condition.

Sensory analysis of stored fruit powders revealed that only refrigerated storage could maintain the organoleptic quality.

Based on the results of storage study, two instant juice powders produced by spray drying of juice solid carrier in 40:60 ratio at 160°C, one from each carrier, stored under refrigeration were selected independently from cashew apple, pineapple and blended juice for computation of cost of production and consumer acceptability. Powders formulated with resistant dextrin recorded lower cost of production consistently in all fruit juices.

The consumers rated fairness of the price as medium high for pineapple powder and very high for cashew apple and blended powders. Consumers expressed medium intention of purchase for pineapple powder, low intention for blended juice and very low intention for cashew apple powder at the price level of Rs 1100 / kg of powder. Pineapple powder was the most preferred powder with high preference and blended fruit powder was medium preferred. Perceived value of the product ranged from Rs 215- Rs 423 per kilo gram.

Instant juice powders of cashew apple, pineapple and their equal blend could be produced by spray drying at 160°C with resistant dextrin as carrier in 40:60 juice solid to carrier ratio with optimum physical, chemical, nutritional and sensory qualities having six month shelf stability under refrigeration.

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Appendices

Appendix- 1

COLLEGE OF AGRICULTURE, VELLAYANI

Dept. of Processing Technology

Title of the thesis: "Instant juice powders of cashew apple *(Anacardium occidentale L.)*and pineapple *(Ananas comosus (L.)*Merr.)"

Score card for assessing the organoleptic qualities of fruit juice

Sample : Fruit juice

Instructions: You are given a set of samples. Evaluate them and give scores for each parameter (Please read the quality parameters before recording score)

Parameter	**Highest score**	**Medium score**	**Least score**
Appearance	Highly attractive (miscibility)	Medium attractive	Least attractive (Immiscible)
Colour	Color of respective fruit	Pale colour	Brownish
Texture	Juice like/ smoothy	Thick	Foamy
Flavor	Fruit flavor	Bland flavor	Off flavor
Taste	Sweet fruit juice	Burned, over cooked sour taste but acceptable	Bland Taste or non acceptable taste

A. Reconstituted juice

Sample No	Appearance	Colour	Texture	Flavour	Taste	Abnormalities If any	Other Remarks
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							

Score

Like extremely - 9

Like very much - 8

Like moderately - 7

Like slightly 6

Neither like nor dislike - 5

Dislike slightly - 4

Dislike moderately - 3

Dislike very much - 2

Dislike extremely - 1

Name and Signature

Appendix- 2

COLLEGE OF AGRICULTURE, VELLAYANI

Dept. of Processing Technology

Title of the thesis: "Instant juice powders of cashew apple *(Anacardium occidentale L.)*and pineapple *(Ananas comosus (L.)*Merr.)"

Score card for assessing the consumer acceptability

Sample : Powder and reconstituted fruit juice

Instructions: You are given a set of samples. Evaluate them and give scores for each parameter
(Please read the parameters and its description before recording score)

Parameter	Description
Preference	Based on your perception on taste, colour, flavor or other quality parameters
Price fairness	The price is Rs 1100/kg of powder which amounts to Rs 160/ litre of juice if reconstituted.. Please rate how rational is the price of powder based on your perceived value. Please mention the perceived value of the powder.
Payment intention	Please rate based on your intention to pay the money willingly for purchasing the product

Reconstituted juice

Sample No	Preference	Price fairness	Payment intention	Perceived value of the product (Rs)	Rem arks
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					

Score

Very high - 5

High - 4

Medium - 3

Low - 2

Very Low - 1

Name and Signature

Appendix -3

Estimation of cost of production of instant juice powder from cashew apple juice using maltodextrin as carrier.

Capacity of the Spray dryer	=	1000 g of water evaporation/ h
Working hour per shift	=	8 h
Number of shifts per day	=	2 shifts
Total capacity of the unit per day	=	16.0 kg/day
Cost of the Spray drier (S)	=	Rs. 12,00,000/-
Cost of the electric balance (B)	=	Rs. 10,000/-
Cost of juice press (P)	=	Rs 10000/-
Life span of the unit (n)	=	15 years
Annual usage (A)	=	300 days
Interest rate (i)	=	11 % per annum

(I) Fixed Cost per annum

Fixed cost of the spray drier unit (a)

$$= \frac{i(i+1)^n}{(i+1)^n - 1} \times S$$

$$= \frac{0.11(0.11+1)^{15}}{(0.11+1)^{15} - 1} \times 1200000$$

= Rs 166878/-

Fixed cost of the Electric balance (b)

$$= \frac{i(i+1)^n}{(i+1)^n - 1} \times B$$

$$= \frac{0.11(0.11+1)^{15}}{(0.11+1)^{15} - 1} \times 10000$$

= Rs 1391/-

Fixed cost of the juice press (c) = $\dfrac{i(i+1)^n}{(i+1)^n - 1} \times P$

= $\dfrac{0.11(0.11+1)^{15}}{(0.11+1)^{15} - 1} \times 10000$

= Rs 1391/-

Total fixed cost/ year (F) = a+b+c

= Rs 169660/-

(II)Variable cost per annum

Maintenance of spray drier(d) = 2% of initial cost of drier

= Rs 24000

Maintenance of electronic balance(e) = 2% of initial cost

= Rs 200

Maintenance of juicer (f) = Rs 50

Total maintenance and repair

charges (G) = d+e+f

= 24250

Cost of Energy

Energy requirement of spray drier = 40kWh/16 hr

Energy requirement for balance and lighting = 3kWh/16hr

Total energy requirement/day = 43kWh/16hr

Energy charges	=	Rs 5.9 /kWh
Electricity charges per annum (H)	=	No of days x energy/day x charges
	=	Rs 76110/-
Labour charges /annum (I) (One woman labour@ Rs 600/day)	=	Rs 180000/-
Cost of raw material		
Cashew apple required/day	=	20 kg
Cost of cashew apple /annum		
@ Rs 2/kg (J)	=	Rs 12000/-
Cost of maltodextrin		
Maltodextrin required per day	=	2.236 kg
Cost of maltodextrin/annum		
@ Rs 56.6/kg (K)	=	Rs 37960/-
Total variable cost (L)	=	G+H+I+J+K
	=	330320/-
Total cost for production of powder		
per annum (M)	=	F + L
	=	Rs 499980/-
Total Production of powder per annum		
@ 42.41% of total solids of feed	=	**474. 06kg**
Cost of powder /kg	=	**Rs 1054.67/-**
Cost of reconstituted juice /litre @15%	=	**Rs 158.12/-**

Appendix - 4

Estimation of cost of production of instant juice powder from cashew apple juice using resistant dextrin as carrier

Capacity of the Spray dryer	=	1000 g of water evaporation/ h
Working hour per shift	=	8 h
Number of shifts per day	=	2 shifts
Total capacity of the unit per day	=	16.0 kg/day
Cost of the Spray drier (S)	=	Rs. 12,00,000/-
Cost of the electric balance (B)	=	Rs. 10,000/-
Cost of juice press (P)	=	Rs 10000/-
Life span of the unit (n)	=	15 years
Annual usage (A)	=	300 days
Interest rate (i)	=	11 % per annum

(I) Fixed Cost per annum

Fixed cost of the spray drier unit (a)

$$= \frac{i(i+1)^n}{(i+1)^n - 1} \times S$$

$$= \frac{0.11(0.11+1)^{15}}{(0.11+1)^{15} - 1} \times 1200000$$

= Rs 166878/-

Fixed cost of the Electric balance (b)

$$= \frac{i(i+1)^n}{(i+1)^n - 1} \times B$$

$$= \frac{0.11(0.11+1)^{15}}{(0.11+1)^{15} - 1} \times 10000$$

= Rs 1391/-

Fixed cost of the juice press (c) = $\frac{i(i+1)^n}{(i+1)^n - 1} \times P$

= $\frac{0.11(0.11+1)^{15}}{(0.11+1)^{15} - 1} \times 10000$

= Rs 1391/-

Total fixed cost/ year (F) = a+b+c

= Rs 169660/-

(II)Variable cost per annum

Maintenance of spray drier(d) = 2% of initial cost of drier

= Rs 24000/-

Maintenance of electronic balance(e) = 2% of initial cost

= Rs 200/-

Maintenance of juicer (f) = Rs 50/-

Total maintenance and repair

charges (G) = d+e+f

= 24250/-

Cost of Energy

Energy requirement of spray drier = 40kWh/16 hr

Energy requirement for balance and lighting = 3kWh/16hr

Total energy requirement/day = 43kWh/16hr

Energy charges = Rs 5.9 /kWh

Electricity charges per annum (H)	=	No of days x energy /day x charges
	=	Rs 76110/-
Labour charges /annum (I) (One woman labour@ Rs 600/day)	=	Rs 180000/-
Cost of raw material		
Cashew apple required/day	=	20 kg
Cost of cashew apple /annum		
@ Rs 2/kg (J)	=	Rs 12000/-
Cost of resistant dextrin		
Resistant dextrin required per day	=	2.236 kg
Cost of Resistant dextrin/annum		
@ Rs 338/kg (K)	=	Rs 226690/-
Total variable cost (L)	=	G+H+I+J+K
	=	Rs 519050/-
Total cost for production of powder		
per annum (M)	=	F + L
	=	Rs 688710/-
Total Production of powder per annum		
@ 72.09 % of total solids of feed	=	**805.82kg**
Cost of powder /kg	=	**Rs 854.67/-**
Cost of reconstituted juice /litre @15%	=	**Rs 128.14/-**

Appendix - 5

Estimation of Cost of Production of instant juice powder from pineapple juice using maltodextrin as carrier

Capacity of the Spray dryer	=	1000 g of water evaporation/ h
Working hour per shift	=	8 h
Number of shifts per day	=	2 shifts
Total capacity of the unit per day	=	16.0 kg/day
Cost of the Spray drier (S)	=	Rs. 12,00,000/-
Cost of the electric balance (B)	=	Rs. 10,000/-
Cost of juice press (P)	=	Rs 10000/-
Life span of the unit (n)	=	15 years
Annual usage (A)	=	300 days
Interest rate (i)	=	11 % per annum

(I) Fixed Cost per annum

Fixed cost of the spray drier unit (a)

$$= \frac{i(i+1)^n}{(i+1)^n - 1} \times S$$

$$= \frac{0.11(0.11+1)^{15}}{(0.11+1)^{15} - 1} \times 1200000$$

= Rs 166878/-

Fixed cost of the Electric balance (b)

$$= \frac{i(i+1)^n}{(i+1)^n - 1} \times B$$

$$= \frac{0.11(0.11+1)^{15}}{(0.11+1)^{15} - 1} \times 10000$$

= Rs 1391/-

Fixed cost of the juice press (c) $= \frac{i(i+1)^n}{(i+1)^n - 1} \times P$

$= \frac{0.11(0.11+1)^{15}}{(0.11+1)^{15} - 1} \times 10000$

= Rs 1391/-

Total fixed cost/ year (F) = a+b+c

= Rs 169660/-

(II)Variable cost per annum

Maintenance of spray drier(d) = 2% of initial cost of drier

= Rs 24000/-

Maintenance of electronic balance(e) = 2% of initial cost

= Rs 200/-

Maintenance of juicer (f) = Rs 50/-

Total maintenance and repair

charges (G) = d+e+f

= 24250/-

Cost of Energy

Energy requirement of spray drier = 40kWh/16 hr

Energy requirement for balance
and lighting = 3kWh/16hr

Total energy requirement/day = 43kWh/16hr

Energy charges	=	Rs 5.9 /kWh
Electricity charges per annum (H)	=	No of days x energy /day x charges
	=	Rs 76110/-
Labour charges /annum (I) (One woman labour@ Rs 600/day)	=	Rs 180000/-
Cost of raw material		
Pineapple required/day	=	30 kg
Cost of pineapple /annum		
@ Rs 25/kg (J)	=	Rs 225000/-
Cost of Maltodextrin		
Maltodextrin required per day	=	2.793kg
Cost of Maltodextrin/annum		
@ Rs 56.6/kg (K)	=	Rs 47425/-
Total variable cost (L)	=	G+H+I+J+K
	=	Rs 552785/-
Total cost for production of powder		
per annum (M)	=	F + L
	=	Rs 722445/-
Total Production of powder per annum		
@ 60.05 % of total solids of feed	=	**838.60kg**
Cost of powder /kg	=	**Rs 861.49/-**
Cost of reconstituted juice /litre @15%	=	**Rs 129.15**

Appendix -6

Estimation of cost of production of instant juice powder from pineapple juice using resistant dextrin as carrier

Capacity of the Spray dryer	=	1000 g of water evaporation/ h
Working hour per shift	=	8 h
Number of shifts per day	=	2 shifts
Total capacity of the unit per day	=	16.0 kg/day
Cost of the Spray drier (S)	=	Rs. 12,00,000/-
Cost of the electric balance (B)	=	Rs. 10,000/-
Cost of juice press (P)	=	Rs 10000/-
Life span of the unit (n)	=	15 years
Annual usage (A)	=	300 days
Interest rate (i)	=	11 % per annum

(I) Fixed Cost per annum

Fixed cost of the spray drier unit (a)

$$= \frac{i(i+1)^n}{(i+1)^n - 1} \times S$$

$$= \frac{0.11(0.11+1)^{15}}{(0.11+1)^{15} - 1} \times 1200000$$

= Rs 166878/-

Fixed cost of the Electric balance (b)

$$= \frac{i(i+1)^n}{(i+1)^n - 1} \times B$$

$$= \frac{0.11(0.11+1)^{15}}{(0.11+1)^{15} - 1} \times 10000$$

= Rs 1391/-

Fixed cost of the juice press (c) = $$\frac{i(i+1)^n}{(i+1)^n - 1} \times P$$

$$= \frac{0.11(0.11+1)^{15}}{(0.11+1)^{15} - 1} \times 10000$$

= Rs 1391/-

Total fixed cost/ year (F) = a+b+c

= Rs 169660/-

(II)Variable cost per annum

Maintenance of spray drier(d) = 2% of initial cost of drier

= Rs 24000/-

Maintenance of electronic balance(e) = 2% of initial cost
= Rs 200/-

Maintenance of juicer (f) = Rs 50/-

Total maintenance and repair

charges (G) = d+e+f

= 24250/-

Cost of Energy

Energy requirement of spray drier = 40kWh/16 hr

Energy requirement for balance and lighting = 3kWh/16hr

Total energy requirement/day = 43kWh/16hr

Energy charges	=	Rs 5.9 /kWh
Electricity charges per annum (H)	=	No of days x energy /day x charges
	=	Rs 76110/-
Labour charges /annum (I) (One woman labour@ Rs 600/day)	=	Rs 180000/-
Cost of raw material		
Pineapple required/day	=	30 kg
Cost of pineapple /annum		
@ Rs 25/kg (J)	=	Rs 225000/-
Cost of resistant dextrin		
Resistant dextrin required per day	=	2.793kg
Cost of resistant dextrin/annum		
@ Rs338 /kg (K)	=	Rs 283210/-
Total variable cost (L)	=	G+H+I+J+K
	=	Rs 788570/-
Total cost for production of powder		
per annum (M)	=	F + L
	=	Rs 958230/-
Total Production of powder per annum		
@ 85.62 % of total solids of feed	=	**1195.68kg**
Cost of powder /kg	=	**Rs 801.41/-**
Cost of reconstituted juice /litre @15%	=	**Rs 120.15**

Appendix - 7

Estimation of cost of production of instant juice powder from equal blend of cashew apple and pineapple juice using maltodextrin as carrier

Capacity of the Spray dryer	=	1000 g of water evaporation/ h
Working hour per shift	=	8 h
Number of shifts per day	=	2 shifts
Total capacity of the unit per day	=	16.0 kg/day
Cost of the Spray drier (S)	=	Rs. 12,00,000/-
Cost of the electric balance (B)	=	Rs. 10,000/-
Cost of juice press (P)	=	Rs 10000/-
Life span of the unit (n)	=	15 years
Annual usage (A)	=	300 days
Interest rate (i)	=	11 % per annum

(I) Fixed Cost per annum

Fixed cost of the spray drier unit (a)

$$= \frac{i(i+1)^n}{(i+1)^n - 1} \times S$$

$$= \frac{0.11(0.11+1)^{15}}{(0.11+1)^{15} - 1} \times 1200000$$

= Rs 166878/-

Fixed cost of the Electric balance (b)

$$= \frac{i(i+1)^n}{(i+1)^n - 1} \times B$$

$$= \frac{0.11(0.11+1)^{15}}{(0.11+1)^{15} - 1} \times 10000$$

= Rs 1391/-

Fixed cost of the juice press (c) $= \dfrac{i(i+1)^n}{(i+1)^n - 1} \times P$

$= \dfrac{0.11(0.11+1)^{15}}{(0.11+1)^{15} - 1} \times 10000$

= Rs 1391/-

Total fixed cost/ year (F) = a+b+c

= Rs 169660/-

(II)Variable cost per annum

Maintenance of spray drier(d) = 2% of initial cost of spray drier

= Rs 24000/-

Maintenance of electronic balance(e) = 2% of initial cost

= Rs 200/-

Maintenance of juicer (f) = Rs 50/-

Total maintenance and repair

charges (G) = d+e+f

= 24250/-

Cost of Energy

Energy requirement of spray drier = 40kWh/16 hr

Energy requirement for balance
and lighting = 3kWh/16hr

Total energy requirement/day = 43kWh/16hr

Energy charges	=	Rs 5.9 /kWh
Electricity charges per annum (H)	=	No of days x energy /day x charges
	=	Rs 76110/-
Labour charges /annum (I) (One woman labour@ Rs 600/day)	=	Rs 180000/-
Cost of raw material		
Cashew apple required/day	=	10 kg
Cost of apple/ annum	=	Rs 6000/-
Pineapple required/day	=	15 kg
Cost of pineapple /annum @ Rs 25/kg (J)	=	Rs 112500/-
Cost of Maltodextrin		
Maltodextrin required per day	=	2.511kg
Cost of Maltodextrin/annum @ Rs 56.6/kg (K)	=	Rs 42637/-
Total variable cost (L)	=	G+H+I+J+K
	=	Rs 441497/-
Total cost for production of powder per annum (M)	=	F + L
	=	Rs 611157/-
Total Production of powder per annum @ 48.36 % of total solids of feed	=	**607.16kg**
Cost of powder /kg	=	**Rs 1006.5/-**
Cost of reconstituted juice /litre @15%	=	**Rs 150.89**

Appendix -8

Estimation of cost of production of instant juice powder from blended juice using resistant dextrin as carrier

Capacity of the Spray dryer	=	1000 g of water evaporation/ h
Working hour per shift	=	8 h
Number of shifts per day	=	2 shifts
Total capacity of the unit per day	=	16.0 kg/day
Cost of the Spray drier (S)	=	Rs. 12,00,000/-
Cost of the electric balance (B)	=	Rs. 10,000/-
Cost of juice press (P)	=	Rs 10000/-
Life span of the unit (n)	=	15 years
Annual usage (A)	=	300 days
Interest rate (i)	=	11 % per annum

(I) Fixed Cost per annum

Fixed cost of the spray drier unit (a)

$$= \frac{i(i+1)^n}{(i+1)^n - 1} \times S$$

$$= \frac{0.11(0.11+1)^{15}}{(0.11+1)^{15} - 1} \times 1200000$$

= Rs 166878/-

Fixed cost of the Electric balance (b)

$$= \frac{i(i+1)^n}{(i+1)^n - 1} \times B$$

$$= \frac{0.11(0.11+1)^{15}}{(0.11+1)^{15} - 1} \times 10000$$

	=	Rs 1391/-
Fixed cost of the juice press (c)	=	$\frac{i(i+1)^n}{(i+1)^n - 1} \times P$
	=	$\frac{0.11(0.11+1)^{15}}{(0.11+1)^{15} - 1} \times 10000$
	=	Rs 1391/-
Total fixed cost/ year (F)	=	a+b+c
	=	Rs 169660/-

(II)Variable cost per annum

Maintenance of spray drier(d)	=	2% of initial cost of drier
	=	Rs 24000/-
Maintenance of electronic balance(e)	=	2% of initial cost
	=	Rs 200/-
Maintenance of juicer (f)	=	Rs 50/-
Total maintenance and repair charges (G)	=	d+e+f
	=	24250/-

Cost of Energy

Energy requirement of spray drier	=	40kWh/16 hr
Energy requirement for balance and lighting	=	3kWh/16hr
Total energy requirement/day	=	43kWh/16hr
Energy charges	=	Rs 5.9 /kWh

Electricity charges per annum (H)	=	No of days x energy /day x charges
	=	Rs 76110/-
Labour charges /annum (I) (One woman labour@ Rs 600/day)	=	Rs 180000/-
Cost of raw material		
Cashewapple required/day	=	10 kg
Cost of cashew apple/annum	=	6000/-
Pineapple required/day	=	15 kg
Cost of pineapple /annum		
@ Rs 25/kg (J)	=	Rs 112500/-
Cost of resistant dextrin		
Resistant dextrin required per day	=	2.511kg
Cost of resistant dextrin/annum		
@ Rs338 /kg (K)	=	Rs 254615/-
Total variable cost (L)	=	G+H+I+J+K
= Rs 653475/-		
Total cost for production of powder		
per annum (M)	=	F + L
	=	Rs 823135/-
Total Production of powder per annum		
@ 74.70 of total solids of feed	=	**937.86kg**
Cost of powder /kg	=	**Rs 877.67/-**
Cost of reconstituted juice / litre		
@ !5 %	=	**Rs 131.58**

INSTANT JUICE POWDERS OF CASHEW APPLE

(*Anacardium occidentale* L.) AND PINEAPPLE (*Ananas comosus* (L.) Merr.)

by

RAFEEKHER M.

(2012-22-110)

Abstract of the thesis

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ABSTRACT

The present investigation entitled 'Instant juice powders of cashew apple (*Anacardium occidentale* L.) and pineapple (*Ananas comosus* (L.) Merr.)' was carried out in the Department of Processing Technology, College of Agriculture, Vellayani during 2013-2016 to optimise the process parameters for micro encapsulation through spray drying of cashew apple and pineapple juices, to evaluate the effect of drying on physical, chemical and nutritional quality parameters of fruit powders, to formulate blended fruit powder and to assess organoleptic quality, storage stability, economics and consumer acceptability of the standardised formulations.

Fruit juice mixed with a carrier, maltodextrin or resistant dextrin in 80: 20, 70:30, 60:40, 50:50 and 40: 60 solid ratios were fed to co-current spray drier at inlet temperatures of 150°C, 160°C, 170°C, 180°C, 190°C and 200°C for optimization of drying parameters of cashew apple, pineapple and their equal blend independently. Feed rate was varied to maintain the outlet temperature at $88 \pm 2^{O}C$ with 4 bar atomization pressure and 2000 rpm blower capacity. Carrier resistant dextrin, juice solid to carrier ratio of 40:60 and 160°C inlet temperature resulted in high recovery of fine, coarse and bulked fruit powders. This combination recovered 72.09, 85.62 and 74.70 per cent of total solid content from juice carrier mix of cashew apple, pineapple and their equal blend respectively of which 40.55, 47.06 and 42.02 per cent were from cyclone.

Based on higher recovery percentages, five treatment combinations (150°C to 190°C with 40:60 ratio) from each carrier were selected and subjected to physicochemical analysis. Resistant dextrin yielded fruit powders with low moisture, dispersible solids, viscosity, angle of repose and with high per cent soluble solids, lightness and hue angle, whereas maltodextrin yielded fruit powders with high total soluble solids. Resistant dextrin lowered chromaticity of pineapple and blended juice powder in contrast to the effect in cashew apple. Resistant dextrin produced pineapple powder with low water activity while maltodextrin improved bulk density of cashew apple and blended powder. Inlet temperature of 160°C yielded fruit powders with higher bulk density whereas

powder moisture and angle of repose were low at 190°C. Drying at 160°C could decrease water activity and improve total soluble solids of cashew apple powder whereas reduction in water activity and chromaticity along with improvement of hue angle were observed in blended juice powders. Powders with resistant dextrin had high glass transition temperature and low hygroscopicity. Powder particles were spherical with 3 - 30 μm size and had occasional surface dents. None of the treatment combinations influenced sinkability of powders.

Maltodextrin yielded fruit powders with high sugars and resistant dextrin yielded cashew apple powder with high vitamin C. Carriers did not significantly influence the energy value of fruit powders. Inlet temperature of 160°C yielded vitamin C rich powders from all fruits as well as β-carotene rich pineapple powder. None of the treatment combinations influenced crude fibre, pH, total ash or titrable acidity. Fruit powders with resistant dextrin dried at 160°C had superior scores in sensory analysis.

Good quality fruit powders produced at 160°C using each carrier, when subjected to a storage study for six months under four packaging atmospheres, microbial growth was totally absent. Refrigerated storage could maintain vitamin C, β-carotene, moisture content, titrable acidity, total phenol and high sensory acceptability of fruit powders. Cost of production of fruit powders with carrier resistant dextrin was comparatively less and highest consumer preference was for pineapple powder.

Instant juice powders of cashew apple, pineapple and their equal blend produced by spray drying at 160°C with resistant dextrin as carrier in 40:60 juice solid to carrier ratio had optimum physical, chemical, nutritional and sensory qualities with six month shelf stability under refrigeration. Further studies to improve shelf life of the product in ambient temperature, exploration on nutraceutical functions and development of spray drier for small scale industries with higher efficiency will be highly beneficial for improving cost effectiveness and commercialization of the technology.

സംഗ്രഹം

കശുമാങ്ങാ നീര്, കൈതച്ചക്ക നീര്, ഇവയുടെ തുല്യ മിശ്രിതം എന്നീ പഴച്ചാറുകളെ ചെറുകണങ്ങളാക്കി മാറ്റിയ ശേഷം ഉണക്കി തൽക്ഷണം ജലത്തിൽ ലയിപ്പിക്കാവുന്ന പൊടിയാക്കി മാറ്റാനുള്ള പരീക്ഷണം കേരള കാർഷിക സർവകലാശാലയുടെ വെള്ളായണി കാർഷിക കോളേജിൽ 2013-2016 കാലയളവിൽ നടത്തുകയുണ്ടായി.

പാഴാക്കപ്പെടുന്ന കശുമാങ്ങ, കൈതച്ചക്ക എന്നിവയുടെ വാണിജ്യാടിസ്ഥാനത്തിലുള്ള സംസ്കരണം പ്രാവർത്തികമാക്കാൻ സഹായിക്കുന്ന തരത്തിലുള്ള ഉത്പന്നം തയാറാക്കാനുള്ള സാങ്കേതികവിദ്യ ഉരുത്തിരിച്ചെടുക്കുന്നതിന് വേണ്ടിയാണ് പ്രസ്തുത പരീക്ഷണം നടത്തിയത്.

പ്രസ്തുത പഴച്ചാറുകൾ മാത്രമായി ഉണക്കി പൊടിയാക്കാൻ കഴിയാത്തതിനാൽ, പഴച്ചാറുകളെ മാൾടോഡെക്സ്ട്രിൻ, റെസിസ്റ്റന്റ് ഡെക്സ്ട്രിൻ എന്നീ ഭക്ഷ്യ പദാർത്ഥങ്ങളിൽ ഏതെങ്കിലും ഒന്നുമായി വ്യത്യസ്ത അനുപാതങ്ങളിൽ (80:20, 70:30, 60:40, 50:50, 40:60) കലർത്തിയ മിശ്രിതം ഉയർന്ന മർദ്ദത്തിലുള്ള വായുവുമായി കൂട്ടിയിണക്കി ചെറുകണങ്ങളാക്കി മാറ്റിയശേഷം ചൂടുവായുവിൽ ഉണക്കുന്ന ഉപകരണത്തിൽ വിവിധ താപനിലകളിൽ (150°C, 160°C, 170°c, 180°c, 190°C , 200°C) കൂടി കടത്തിവിട്ട് പൊടിയാക്കി മാറ്റി.

ഓരോ പഴച്ചാറിൽ നിന്നും ഏറ്റവും കൂടുതൽ ഉത്പാദനം രേഖപ്പെടുത്തിയ 10 പൊടികൾ വീതം തിരഞ്ഞെടുത്ത്, അവയുടെ ഭൗതികവും രാസപരവും പോഷകപരവുമായുള്ള സവിശേഷതകളെ വിലയിരുത്തി, ഓരോ പഴച്ചാറിൽ നിന്നും ഏറ്റവും ഉത്കൃഷ്ടമായ പൊടിയെ കണ്ടെത്തി. പഴച്ചാറിൽ റെസിസ്റ്റന്റ് ഡെക്സ്ട്രിൻ എന്ന ഭക്ഷ്യ പദാർത്ഥം 40:60 എന്ന അനുപാതത്തിൽ കലർത്തി 160°C താപനിലയിൽ ഉണക്കിയുണ്ടാക്കിയ പൊടിയാണ് ഏറ്റവും ഉത്കൃഷ്ടമായ സവിശേഷതകൾ പുലർത്തിയത്.

ഓരോ പഴച്ചാറിൽ നിന്നും നിർമ്മിച്ച പ്രസ്തുത പൊടിയെ ആറു മാസം വിവിധ സൂക്ഷിപ്പു രീതികൾക്ക് വിധേയമാക്കിയപ്പോൾ ശീതീകരണം വഴി ഭൌതികവും രാസപരവും പോഷകപരവുമായുള്ള സവിശേഷതകൾക്കു വലിയ മാറ്റങ്ങൾ വരാതെ സുരക്ഷിതമായി സൂക്ഷിക്കാമെന്ന് കണ്ടെത്തി. റെസിസ്റ്റന്റ് ഡെക്സ്ട്രിൻ ഉപയോഗിച്ച് ഉണ്ടാക്കിയ പൊടികൾക്ക് നിർമ്മാണച്ചിലവും കുറവാണ്. എല്ലാ പഴച്ചാറിൽ നിന്നുമുള്ള പൊടികളെ പറ്റിയും ഉപഭോക്താക്കൾ നല്ല അഭിപ്രായം രേഖപ്പെടുത്തി. കൈതച്ചക്കനീരിൽ നിന്നുള്ള പൊടി താരതമ്യേന കൂടുതൽ ഇന്ദ്രിയ അനുഭൂതി പുലർത്തുന്നുണ്ടെന്നും കണ്ടെത്തി.

പ്രസ്തുത പൊടി തത്ക്ഷണം വെള്ളത്തിൽ ലയിക്കുകയും അതാതു പഴച്ചാറിന്റെ സവിശേഷതകൾ പ്രകടിപ്പിക്കുണ്ടെന്നതിനാലും കശുമാങ്ങ, കൈതച്ചക്ക എന്ന പഴങ്ങളുടെ വാണിജ്യാടിസ്ഥാനത്തിലുള്ള സംസ്കരണത്തിനായി ഈ സാങ്കേതിക വിദ്യ ഉപയോഗപ്പെടുത്താവുന്നതാണ്. എന്നിരുന്നാലും, കൂടുതൽ ഉത്പാദനക്ഷമതയുള്ള ഉപകരണങ്ങളും, സാധാരണ താപനിലയിൽ സൂക്ഷിക്കാനുള്ള മാർഗങ്ങളും വികസിപ്പിക്കുന്നത് വാണിജ്യവത്കരണത്തിന് സഹായകമായിരിക്കും.