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THE PHYSICOCHEMICAL AND STORAGE PROPERTIES OF SPRAY-DRIED ORANGE JUICE POWDER

***Vishal Namdeo Sabhadinde**

Department of Food Science and Technology, College of Food Technology, Udgir

**Author for Correspondence*

ABSTRACT

A study was conducted Pilot plant Spray-dryer (S.M. Scientech, India) with a concurrent air flow was used for Orange juice powders using five different maltodextrin concentrations i.e 90:10, 87.5:12.5, 85:15, 82.5:17.5 and 80:20 (Kinnow juice: Maltodextrin), by weight, as the encapsulating agent with inlet/outlet temperatures of 200°C and 120°C, respectively. The spray-dried orange powders were analyzed for Glass Transition Temperature, Sticky point temperature, water solubility index, water absorption index, moisture content, hygroscopicity. Results demonstrated that as quantity of maltodextrin increased, the moisture content and hygroscopicity decreased. However, there were no significant changes in the water activities of the spray-dried powders for the inlet temperatures investigated. The physicochemical properties of powders produced by spray drying technique depend upon some process variables, such as the characteristics of the liquid feed (viscosity, particles size, flow rate) and of the drying air (temperature, pressure), as well as the type of atomizer and also the carrier agents (polymer or gum) used.

Keywords: *Spray Drying; Orange; Maltodextrin; Glass Transition Temperature; Sticky Point Temperature*

INTRODUCTION

Fully ripe fruits of kinnow Orange (*Citrus reticulata*), have bright and deep attractive color, tight and compact skin. The fruits are juicy and the fresh juice extracted from the fruit has refreshing flavor, characteristic pleasing aroma and thirst quenching properties during hot summer weather. Kinnow fruit is seasonal, and has a limited shelf life at ambient conditions. It creates heavy glut during production season and becomes scanty during off season.

Limited shelf life coupled with inadequate processing facilities resulted in heavy revenue loss in the country. Kinnow juice is proven to be a very concentrated source of ascorbic acid. The principle vitamin in the citrus fruits is vitamin C, the amount of which varies with variety, maturity and other factors. Ascorbic acid is relatively stable in citrus products during processing and storage.

The ascorbic acid content in kinnow was reported to be in the range of 13.3 to 46.9 mg/100 ml. Spray-drying process is designed on the basis of transformation feasibility of liquid feed into a defined solids particulate form. This is characterized by atomizing the fluid into a drying chamber, where the liquid droplets are passed through a hot-air stream.

The heat and mass transfer during the drying occurs rapidly between the air and vapor films surrounded by droplet at the saturation temperature. Spray dried fruit juice powder have some inherent problems such as stickiness, hygroscopicity and solubility because of presence of low molecular weight sugars and acids having low glass transition temperature. Thus powder can stick on the wall of chamber during drying process leading to lower yield and certain operational problems.

These problems can be resolved by addition of some carrier agents, like polymers and gums, to the product atomization. Along with reduction in substantial hygroscopicity of powder, polymers and gums can also be used for microencapsulation imparting protection to sensitive food components against unfavorable ambient conditions. It ultimately masks or preserves flavors and aromas, reduce the volatility and reactivity and provide additional attractiveness for the merchandising of food products.

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MATERIALS AND METHODS

2.1. Materials and Chemicals

Fresh Kinnow (*C. reticulata*), a hybrid variety of two citrus cultivars; “King” and “Willow Leaf”, were purchased from local market of Nagpur. Well matured, fully ripened kinnow fruit completely orange in color and free from blemishes and mechanical injuries were selected for the experiments. Maltodextrin (DE20) manufactured by Himedia laboratories was used as carrier agent. The Purified water used for the experiment was purified using RO filter.

2.2. Preparation of Fruit Juice and Spray Drying

Sweet mature fruits were preferred for the production of kinnow juice powder. Fruits were washed in cold tap water and drained. Fruits are manually cut up in to two halves and seeds are removed. The juice that is localized in the sacs was extracted with the help of a manually operated house hold ‘Hand juicer’ in which the juicy kinnow fruits pressed to extract juice. The juice obtained had a deep-orange color. The Orange juice obtained was vacuum-filtered through an 11 µm nylon mesh and then transferred into a vessel. The juice was stored in refrigerator for 1 h and then the top layer of clear liquid was carefully removed.

Analyses of the watermelon juice were carried out to determine the Titrable acidity, total solid and hygroscopicity, water soluble index, water absorption index, moisture content. The titrable acidity of the orange juice was measured using titration method using 0.1 N sodium hydroxide. The total soluble solid content of the juice was measured using using an Erma Tokyo A32 hand refractometer.

Pilot plant Spray-dryer (S.M. Scientech, India) with a cocurrent air flow was used for spray drying. The speed of blower was set at 2400 rpm for all the drying. Distilled water was pumped into the dryer at a set flow rate at 10 rpm (10 rpm = 30 ml/min) to achieve the inlet/outlet temperatures of 200°C and 120°C, respectively. All the parameter was selected by trial and error and in accordance with references. The dryer was run at this condition for about 10 min before the feed was introduced. The product was collected in a pre-weighed, insulated glass bottle connected at the end of cyclone collector.

Different proportions of kinnow juice (based on TSS) and maltodextrin (on dry basis) at 90:10, 87.5:12.5, 85:15, 82.5:17.5 and 80:20 (Kinnow juice: Maltodextrin), by weight, were chosen in accordance with references for spray drying of fruit juice. A blend of 1000 ml of kinnow juice and maltodextrin was prepared. At first maltodextrin solution was prepared in warm water (about 50°C) with constant stirring followed by addition of measured amount of kinnow juice.

2.3. Analysis of the Spray-dried Powder

The spray-dried powders were analyzed for their moisture content, TSS, titrable acidity, hygroscopicity, water solubility index, water absorption index, glass transition index, sticky point temperature.

2.3.1. Moisture Content

The moisture content was determined based on AOAC method. Samples of range powder (5 g each) were weighed and then dried in a vacuum oven at 70 °C for 24 h. The samples were removed from the oven, cooled in a desiccator and weighed. The drying and weighing processes were repeated until constant weigh were obtained.

2.3.2. Total Soluble Solids (TSS)

The total soluble solids (%) in the kinnow juice were recorded by using a Erma Tokyo A32 hand refractometer and the values were calibrated to 20°C with the help of temperature correction chart (AOAC, 1990) and expressed in percentage.

2.3.3. Titrable Acidity

Acidity of the reconstituted kinnow juice powder was determined by titrating known volume of juice with 0.1N sodium hydroxide. The percentage titrable acidity was expressed in terms of standard ascorbic acid.

$$(\%) \text{ Titrable acidity} = \frac{\text{Titrate} \times \text{N. of alkali} \times \text{Volume made} \times \text{Eq. wt of acid} \times 100}{\text{Volume of sample taken} \times \text{Weight of sample taken} \times 1000}$$

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2.3.4. Hygroscopicity

Hygroscopicity of kinnow juice powder was determined according to the method proposed by Cai and Corke (2000), with some modifications. Samples of each powder (approximately 1 g) were placed at 25 °C in a container with NaCl saturated solution (75.29%RH). After one week, samples were weighed and hygroscopicity was expressed as g of adsorbed moisture per 100 g dry solids (g/100 g).

2.3.5. Water Solubility Index (WSI)

The WSI of the kinnow juice powder was determined using the method described by Anderson, *et al.*, (1969). Spray-dried kinnow juice powder (2.5 g) and distilled water (30 ml) were vigorously mixed in a 100 ml centrifuge tube, incubated in a 37 °C water bath for 30 min and then centrifuged for 20 min at 10,000 rpm (11,410 g.) in a J2-MC Centrifuge (Beckman, USA). The supernatant was carefully collected in a pre-weighed beaker and oven dried at a temperature of 103 ± 2 °C. The WSI (%) was calculated as the percentage of dried supernatant with respect to the amount of the original 2.5 g kinnow juice powder.

$$\text{Water solubility index (\%)} = \frac{\text{Weight of supernatant}}{\text{Weight of sample}} \times 100$$

2.3.6. Water Absorption Index (WAI)

WAI of the kinnow juice powder was determined using the method described by Yamazaki, (1953). A suspension of 2.5 g kinnow juice powder in 25ml distilled water was agitated for 1h and centrifuged at 3000rpm for 10min. The free water was removed from the wet residue, which was then drained for 10min. The wet residue was then weighed.

$$\text{Water absorption index (\%)} = \frac{\text{Weight of residual}}{\text{Weight of sample}} \times 100$$

2.3.7. Measurement of Glass Transition Temperature (T_g)

Differential scanning calorimeter (DSC, Netzsch—Germany) was used to measure the glass transition temperature (Plate 3.3). The instrument was calibrated with indium kept in a closed aluminum pan (Roos and Karel, 1991; Roos, 1995). After the calibration, about 10-15 mg of the material was taken in the sample pan. An empty aluminum pan was used as a reference. During the measurement nitrogen was used as carrier gas (20 ml/60 s). Liquid nitrogen was used for sample cooling at the rate of 10°C/60 s to bring down the sample temperature to -30°C from the atmospheric temperature (30– 34°C). All the scans were taken at the same heating rate of 10°C/60 s from -30 to 200°C. Glass transition temperature was measured for the fruit powder samples at same moisture contents. Thermogram thus obtained were analyzed for the onset, mid, and end points of glass transition. Most researchers consider the midpoint temperature of a thermogram as the T_g .



DSC setup for measurement of glass transition temperature (T_g)

2.3.8. Measurement of Sticky Point Temperature (T_s)

The apparatus used for the measurement of sticky point has been shown below. The whole assembly was immersed into a constant temperature water bath, whose temperature was slowly raised while the powder was intermittently stirred by hand by rotating the sealing tube. At a certain temperature, the force required to turn the propeller rotating inside the powder increased dramatically. The temperature at which this

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occurred was usually characteristic and it was referred to as the sticky point temperature. This temperature was measured at several moisture contents using a thermocouple and a digital temperature indicator



Sticky Point Temperature measurement setup

RESULTS AND DISCUSSION

3.1.1 Physico-chemical Characteristics of Kinnow Fruit

Physical characteristics of kinnow fruit were studied before going to process the kinnow juice in to spray dried powder. The data in Table shows below, that kinnow fruit contains 58.27 % of edible part, the percentage of juice of total weight fruit was 16.57% and the percentage of juice on the basis of arils was 39.37%. The waste index of fruit was 57.90 % and 40.34 % of peel. The initial TSS and acidity of kinnow juice were 11° Brix and 0.91% respectively. Ascorbic acid and total antioxidant activity of kinnow juice were 34 mg/100g and 90% respectively.

Sr. No	Name	Quantity
1	Weight of Raw Material (kg)	20
2	Average weight of fruit (g)	168.76
3	Edible Part (%)	58.27
4	% Juice of weight of Fruit	16.57
5	Waste index (%)	57.90
6	TSS of juice (°Brix)	11
7	Acidity (% as citric acid of juice)	0.91
8	% Moisture content	89.12

3.1.2. Effect of Carrier Agent (Maltodextrin) on Glass Transition Temperature (T_g)

Different proportions of kinnow juice and maltodextrin at 90:10, 87.5:12.5, 85:15, 82.5:17.5 and 80:20 were taken for spray drying. The cyclone recovery of the powder was very low when kinnow juice : maltodextrin ratio was 90:10 as the product collected was highly sticky mass and firmly stuck inside the cyclone collector (glass container). Increase in maltodextrin level from 15 to 20 percent resulted in a significant increase in product recovery, further increase in maltodextrin level could increase the product recovery very slightly so maltodextrin concentration was varied only up to 20% . This study suggested

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that under the given spray drying conditions, the maximum kinnow juice can be dried in conjunction with a maltodextrin (DE20).

3.1.3. Effect of Carrier Agent (Maltodextrin) on Sticky Point Temperature (T_s)

In this study kinnow juice: maltodextrin (90:10) have sticky point temperature 56°C at this temperature very less powder was recovered in glass container, powder was highly sticky mass and firmly stuck inside the cyclone collector but rise in maltodextrin concentration (up to 20%) there was sharp increase in sticky point temperature to (64°C). cyclone recovery was also increased. Incorporation of 10% maltodextrin in kinnow juice increases T_s of kinnow juice powder 56°C . Further 20% addition of maltodextrin increased T_s of kinnow juice powder up to 64°C .

Kinnow Maltodextrin	juice:	Glass Temperature ($^\circ\text{C}$)	Transition Sticky Temperature ($^\circ\text{C}$)	Point Difference
90:10		50.5	56	5.5
87.5:12.5		51.8	58	6.2
85:15		53.9	60	6.1
82.5:17.5		54.8	62	6.8
80:20		59.6	64	6.8

3.1.4. Effect of Maltodextrin on Moisture Content of Kinnow Juice Powder in Spray Drying

Moisture is very important quality parameter in the processing of highly perishable fruits. Kinnow contains near about 90% of the moisture. Most of the moisture was evaporated during spray drying as it is very high temperature short time treatment so the moisture is significantly influenced by inlet temperature.

Table 4.3.1 shows decrease in moisture content with increase in maltodextrin concentration. kinnow juice powder with 90% juice and 10% maltodextrin contains 2.8 % of the moisture and then it has been reduced to 1.69 % when maltodextrin concentration was raised to 20% in the kinnow juice powder containing 80% kinnow juice.

Maltodextrin Concentration (%)	Moisture Content (%)
10.00%	2.80
12.50%	2.65
15.00%	2.40
17.50%	2.25
20.00%	1.69

3.1.5. Effect of Maltodextrin on Hygroscopicity of Kinnow Juice Powder in Spray Drying

The hygroscopicity of kinnow juice powder was significantly influenced by maltodextrin addition rate because in the powder sample containing 10% of maltodextrin and 90% of kinnow juice hygroscopicity was 6.14 (g/ 100 g) and it has been reduced to 3.14 (g/ 100 g) with increase in maltodextrin concentration in powder sample containing 80% kinnow juice and 20% maltodextrin.

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Maltodextrin Concentration(%)	Hygroscopicity (g/100 g)
10	6.14
12.5	5.85
15	5.00
17.5	4.14
20.	3.14

3.1.6. Effect of Maltodextrin on Water Solubility Index and Water Absorption Index of Spray Dried Kinnow Juice Powder

Water solubility index and water absorption index of kinnow juice powder containing 10% maltodextrin and 90% kinnow juice was 85.2% and 14.8% respectively. When maltodextrin concentration in kinnow juice powder was increased to 20% having kinnow juice (80%) the water solubility index was increased to 98.8% and water absorption index was decreased to 8.8%.

Maltodextrin (%)	WSI (%)	WAI (%)
10.00%	85.2	14.8
12.50%	88.0	12.0
15.00%	89.6	10.4
17.50%	91.2	9.60
20.00%	98.8	8.80

It means water solubility index increases with increase in maltodextrin concentration and water absorption index reduces with increase in maltodextrin concentration.

Conclusion

The initial TSS and acidity of kinnow juice were 11° Brix and 0.91% respectively. Kinnow juice contained ascorbic acid was, 34 mg/100g.. Incorporation of 10% maltodextrin in kinnow juice which increases T_g and T_s of kinnow juice powder up to 50.5 °C and 56 °C with a difference of 5.5 °C, further 20% addition of maltodextrin increases T_g and T_s of kinnow juice powder up to 59.6 °C and 64 °C with a difference of 6.8 °C respectively. It indicates that increase in maltodextrin addition rate not only increases the T_g and T_s but also difference between them. When maltodextrin varied from 10% to 20% moisture content of spray dried kinnow juice powder decreased from 2.80% to 1.69% respectively. Hygroscopicity of kinnow juice powder decreased from 6.14 g/100g to 3.14 g/100g respectively with addition of maltodextrin from 10% to 20%. When maltodextrin addition rate enhanced from 10% to 20% the bulk density of kinnow juice powder decreased from 0.476 gm/cm³ to 0.392 gm/cm³ respectively.

Water Solubility Index of kinnow juice powder was increased from 85.2% to 98.8% respectively and Water Absorption Index was decreased from 14.8% to 8.80% respectively by addition of maltodextrin from 10% to 20%. Maltodextrin concentration from 10% to 20% enhanced beta carotene content of kinnow juice powder from 99.28 µg/100 g to 446.78 µg/100 g respectively. Incorporation of maltodextrin during spray drying of kinnow juice from 10% to 20% decreased Total Antioxidant Activity of kinnow juice powder from 84.70% to 56.10% respectively.

Kinnow juice powder sample containing 10% maltodextrin was best from sensory and nutritional point of view.

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