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Influences of Spray Drying Conditions on the Physiochemical Properties of Karanda Fruit

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Karanda fruits are widely cultivated in Thailand. The fruit has several vitamins and minerals. One of the most fascinating possibilities is to transform it into a powdered drink. This study aimed to determine the optimal conditions for preparing karanda juice powder considering its physicochemical properties. Three levels of inlet air temperature were evaluated, 160 °C, 180 °C and 200 °C. Subsequently, three levels of maltodextrin (dextrose equivalent 10, DE10) were evaluated, 30%, 40%, and 50% by weight. Finally, three levels of whey protein (WPI) were evaluated, 5%, 10%, and 15% by weight. The moisture content dropped by 48.51% when the input air drying temperature rose from 160-200 °C. Yield increased by 15.08% and solubility by 5.06%. The maltodextrin content was increased from 30% to 50%, resulting in a 23.17% increase in product yield, while the WPI content was increased from 5% to 15%, leading in an 82.88% increase in anthocyanin content. SEM investigation indicated that the particle morphology was spherical with smooth surfaces, but an increase in inlet air temperature led to greater deformation and particle surface roughness. Additionally, the optimal parameters for spray drying karanda fruit were an inlet air temperature of 174 °C, maltodextrin (MD) content of 32%, and WPI content of 15% of soluble solids, with a product yield of 55.93±0.25%, solubility of 85.51±0.54%, and anthocyanin concentration of 12.58±0.36 mg/l.

1. Introduction

Karanda, or *Carissa carandas* L., is an extensively utilized plant in Asia and other regions. It is a Thai fruit that people are starting to recognize and for which demand has soared (Sunil and Pallavi, 2013). Karanda has a significant nutritional value that includes many phytochemical elements, such as phenolic compounds, along with flavonoids, anthocyanins, acids, sugars, and vitamin C, among others. Unfortunately, the shelf life of this fruit is short, and vitamins in particular are susceptible to deterioration during storage. There are numerous methods for extending the shelf life of fruits and preventing their decomposition, including drying, modified atmosphere packing, and use of some coatings. Of these methods, drying is the most common method for preserving fruit. Since the fruit's wetness creates high relative humidity, enzymatic activity and microbial proliferation are boosted. Spray drying is a popular and commonly employed technique for turning liquid food into powder. The quality of the product depends on the factors utilized in the manufacturing process, such as input temperature, dry air flow rate, liquid feed rate, coating medium type, and spray drying nozzle design, among other factors. During spray drying, the bulk solution is atomized into tiny droplets that are then exposed to hot air, resulting in heat and mass transfer. Even though there is a high particle-to-volume ratio, the powdered feed should not agglomerate when it removed from the spray drier. Nonetheless, if the solution is sugary, stickiness may be a problem depending on the sugar content and temperature. The final product should be a free-flowing powder that can be collected using a cyclone. The present investigation was done to determine the optimal conditions for spray-drying Karanda juice. The study aims are to formulate a product based on this locally grown fruit that has extend shelf life. The product should be easy to store and eat, supplying customers with health dietary supplements. The objectives of the current study are to determine: (1) the optimal conditions for production of a spray-dried karanda powder and (2) the inlet air temperature and auxiliary drying agents that have the greatest impact on the quality and yield of karanda powder.

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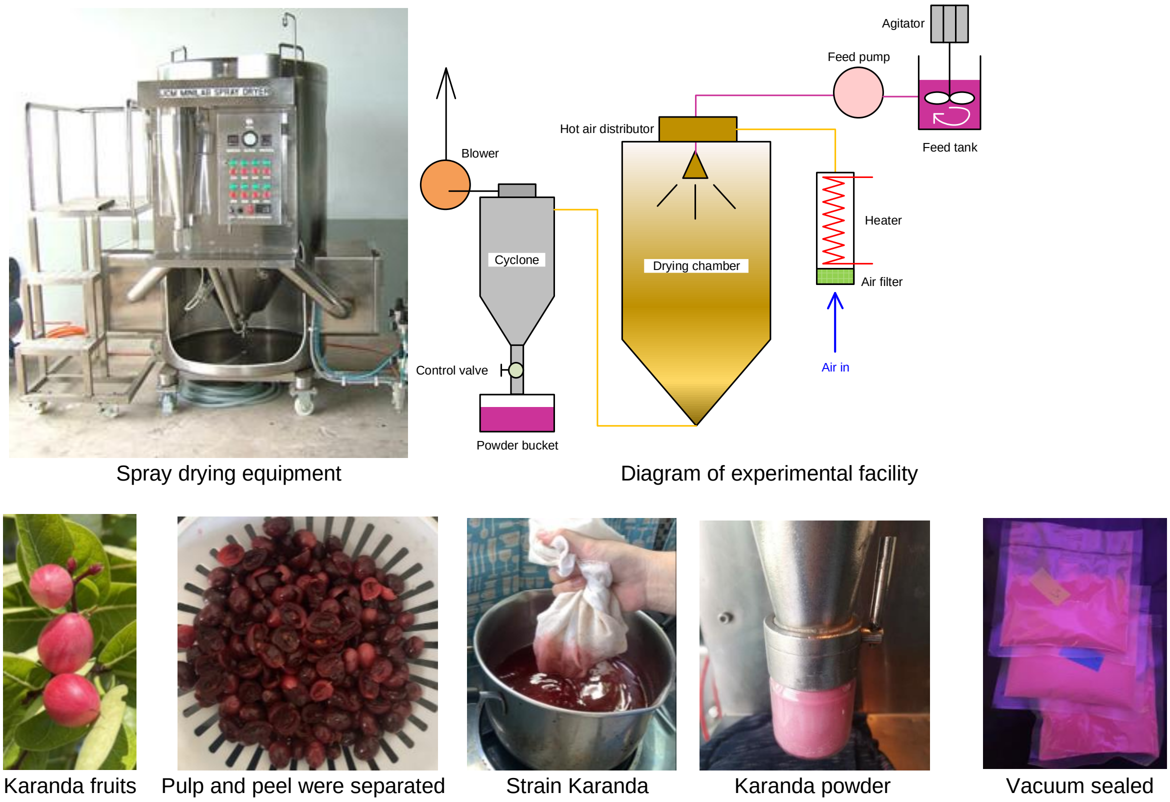


Figure 1. Experimental facility.

2. Materials and methods

The samples used in the current study consisted of ripe Karanda fruit from the Lung Yot Farm, Kanchanaburi Province, Thailand. In these experiments, the karanda fruits were cut in half and separated from their seeds. The fruit was washed, after which the pulp and skin were removed prior to processing. A 1:0.1 ratio of pulp to peel was achieved. The fruit was blended with water at a ratio of 1:2, twice filtered through a water strainer and stored at 4 °C prior to further processing. A spray drier, as well as a blender, electronic balance, pH meter, brix-scale refractometer, magnetic stirrer, impulse sealer and thermometer, were utilized in this experiment. Karanda juice was combined with maltodextrin (dextrose equivalent 10, DE10) and concentrated to 18 °Brix, measured using a hand-held refractometer. Before the juice was spray-dried, its pH and weight were recorded. The spray dryer (MINILAB SDE-10 from Thai Ferrite Industry Co., LTD.) used in the drying process is shown in Figure 1. Its outlet air temperature was 75 °C (Bakar *et al.*, 2013), the blower speed was 2800 rpm, and the feed rate was 1.5 kg/hr.

Yield: The resultant product quantity was measured by weight (digital balance), and the starting solid quantity was determined from the moisture content.

%yield = $((A - B)/A)$ x 100% (1)

Where A is the weight of juice before spray drying and B is the weight of powder obtained from spray drying.

%Moisture content: The moisture content of the powder was determined by weighing the powder sample into a metal cup and subjecting the samples to a vacuum at 0.13 kPa for 8 hours at 70 °C. The equation of Caparinoa *et al.* (2012) was utilized to determine the moisture content.

Moisture content = $(w_1 - w_2)/w_1$ x 100% (2)

Where w_1 is the initial sample weight (g) and w_2 is the sample weight at the end of drying (g)

Water activity (a_w): An Aqua Lab Model Series 3 TE was utilized to measure water activity.

Brix measurement: Total soluble solids (TSS) is a weight-per-volume percentage measure of water-soluble substances such as sugars and organic acids. Their concentration is measuring from the degree of refraction of light through a solution using a refractometer. These refractometer readings are given in degrees Brix (°Brix).

Color analysis: In the CIE system, color is characterized by of the measurement L*, a*, and b* parameters. We were able to determine the degree of color shift (E) using data from a colorimeter (Juki Instrument, Model JC801, Japan). This is expressed as

$$\Delta E=\sqrt{(L_1^*-L_2^*)^2+(a_1^*-a_2^*)^2+(b_1^*-b_2^*)^2} \quad (3)$$

Where L^* is the brightness value, a^* is the red or green color and b^* is the yellow or blue color
Bulk density: This quantity was determined by filling a metal cup of known volume and weight with a powder sample. Then, density was determined as
Bulk density = *M/V* (4)
Where *M* is mass and *V* is volume in appropriate units.
Solubility: 40 grams of powder was added to 200 ml of room-temperature water. Solubility was determined from the time required for a sample to dissolve while being stirred at a constant speed using a magnetic stirrer (Caparinoa *et al.*, 2012).
Anthocyanin: Analysis of total anthocyanin content of Karanda extract use a pH-differential method. Karanda were extracted, and the resulting juice solutions were diluted with KCl buffer (pH 1.0) at a ratio of 1:100. The samples were left at room temperature for 30 min. Then, their absorbance was measured using UV-visible spectroscopy at a wavelength of 520 nm. The results were expressed as the milligrams of total anthocyanins per liter of solution. Determination of anthocyanin by pH-differential method was done using the equation
Anthocyanin (mg/L) = $A \times MW \times 1000 / \varepsilon \times l$ (5)
Where *A* is the absorbance of the sample added to the pH 1.0 buffer solution, *MW* is molar mass of cyanidin-3-glucoside 499.2 g/mol and ε is Molar secretly likes Tivity.
Scanning electron microscopy: A small amount of powder is taken from the powder samples and mounted on metal stubs. They are coated with a thin layer of platinum . Under a high vacuum, the surface scatters electrons from the electron beam in a manner that reveals its surface morphology.

3. Experimental results

3.1 Percentage of powdered product obtained (%yield)

The yield of the powdered product obtained from the test was in the range of 44.74±1.47% to 66.36±1.73%. Increased inlet air temperature resulted in higher powder yield due to better heat and mass transfer as seen in Figure 2. Increasing the concentration of the maltodextrin promoted yield and reduced stickiness by encapsulating the active substance. Maltodextrin and whey protein have excellent coating properties. Whey protein comprises over 90% protein and the remainder is skimmed milk which contributes significantly to throughput. From a statistical examination, it was found that whey protein and maltodextrin levels as well as the inlet air temperature were statistically significant ($p < 0.05$) in changing the amount of powdered product obtained.

3.2 Moisture content

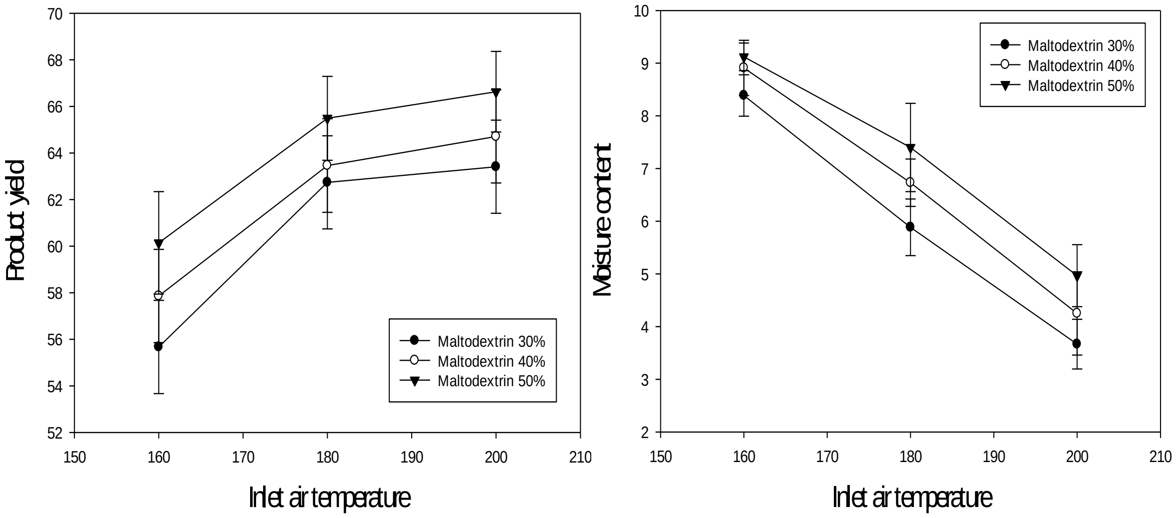
From the analysis of the products, the moisture obtained from the experiment was in the range of 4.25±0.37% to 10.41±0.56%. Higher inlet temperatures promoted heat transfer into the particles. Evaporation of moisture and increasing the concentration of the drying agent make it more difficult for water molecules to diffuse, resulting in a more stable powder product. A formulation with 5% WPI, 30% maltodextrin and an inlet air temperature 200 °C produced a product with the lowest moisture content, 4.25±0.37%.

3.3 Water activity

From the analysis of the obtained products, the free water content obtained from the experiments ranged from 0.13±0.00% to 0.36±0.01% as seen in Figure 3. Higher inlet temperatures decreased the free water content. The free water content in the product has important effects on shelf life, deterioration and food safety. The optimum inlet air temperature used in the experiment was 200 °C, which enabled production of a powdered product with a water activity of less than 0.6. The product was fine, friable, had a long shelf life, and was free of microbial growth. With 5% WPI and a 200 °C inlet air temperature, a product containing 50% maltodextrin had the lowest free water content, 0.13±0.00%. The inlet air temperature had the highest impact ($p < 0.05$) on water activity followed by maltodextrin and WPI.

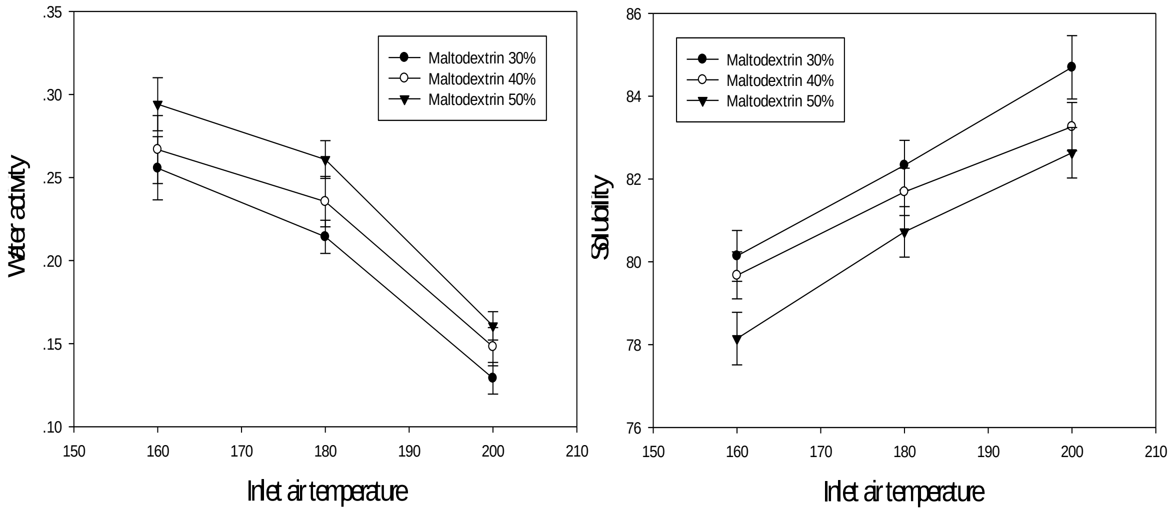
3.4 Solubility of the product

From the analysis of the experimental products in Figure 3, the solubility of 40 grams of powder in 200 ml of room-temperature water is between 70.51±0.8% to 85.47±0.7%. Higher air temperature may cause the product particles to swell forming a hollow interior, which is indicated by a lower density powder, resulting in more contact area with the solvent. Increased amounts of WPI improves powder. The resulting powder has good water solubility and coating properties with reduced interaction between particles due to their high surface activity. Therefore, it has good solubility, while the increased maltodextrin results in reduced solubility due to particle agglomeration. WPI and the inlet air temperature had the highest impact (p<0.05) on solubility followed by maltodextrin and WPI.



(a) 15% WPI *(b) 5% WPI*

Figure 2 Effect of Maltodextrin on % yield and moisture content.

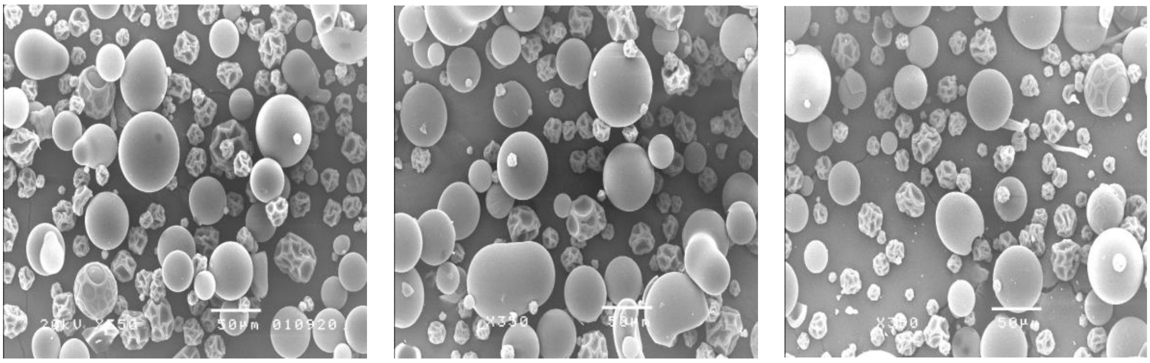


(a) 5% WPI (b) 15% WPI

Figure 3 Effect of maltodextrin on water activity and solubility

3.5 Particle properties

From the SEM micrographs in Figure 4(a), it can be observed that as the inlet air temperature is increased, a hard shell formed on the particle surface and the structure fractured. This was caused by rapid water evaporation and pressure cracks. Greater particle sizes during drying also results in a lower density and a more porous structure of the powder particles. Particles with very rough surfaces collapse and this may accelerate the degradation of some bioactive compounds, such as anthocyanin, phenolic compounds and vitamin C, among others. Figure 4(b) shows SEM micrographs of spray dried powders with 50% maltodextrin, 5% WPI and an inlet air temperature of 180 °C. The particles have a higher moisture content because a large amount of drying agent may cause agglomeration and a higher density along with wet surfaces promotes particle agglomeration. However, both maltodextrin and WPI significantly contribute to reducing inter-surface oxidation, have good surface coating properties, increased glass transition temperature, thereby reducing encapsulation and particle surface roughness. These factors may affect degradation of heat-sensitive substances. Figure 4(c) shows SEM micrographs of powders with 30% maltodextrin, 5% WPI and an inlet air temperature of 180 °C. The particles are scattered and have low densities. The spray-dried powder particles may have some contractions and rough surfaces due to the rapid evaporation of water. At a high inlet temperature, there is some adhesion between the particles.



(a) 30%, WPI 5%, T_{in} = 200°C (b) 50%, WPI 15%, T_{in} = 180°C (c) 30%, WPI 5%, T_{in} = 180°C

Figure 4: SEM micrographs various maltodextrin and WPI content, and inlet air temperatures

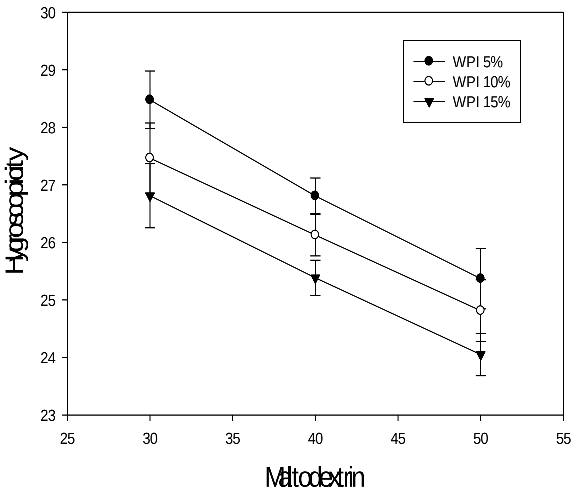


Figure 5: Effect of WPI on hygroscopicity.

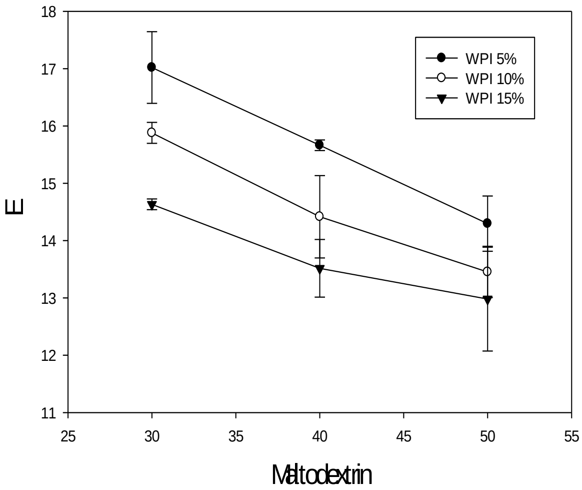


Figure 6: Effect of WPI on ΔE.

3.6 Hygroscopicity

The capability of powder particles to absorb surrounding moisture can cause stickiness that leads to agglomeration of powder particles (Figure 5). Maltodextrin may promote particle adhesion. These particles have much adhesion, low porosity and less moisture absorption area. Moisture penetration between the particles is more difficult, resulting in moisture adsorption. Lower moisture with higher WPI contents tends to cause particle breakage, resulting in less moisture absorption. Increased inlet air temperature and rapid evaporation of the powder results in a puffy appearance of the powder particles. Low-density hollow interiors may allow more surface area to absorb moisture. Maltodextrin may also have the effect of reducing the powder particle size, making the powder particles less porous, thus reducing stickiness and their ability to absorb moisture with 15% WPI. A minimum moisture absorption of 24.05±0.35 g of moisture/100 g of solids was observed at 50% (wt/wt) of maltodextrin and an inlet air temperature of 160 °C.

3.7 Color difference value (ΔE)

From Figure 6, increased inlet air temperature resulted in a greater change in ΔE, while increasing the maltodextrin and whey protein isolate (WPI) content resulted in a decreased and statistically significant ($p <$ 0.05) change in ΔE. At 30% MD and 5% WPI with an inlet air temperature 160°C, a maximal ΔE, 35.54±1.41, was observed. The inlet air temperature clearly affects the color of the powdered product. This may be due to changes in the constituent properties, while the increased levels of the drying agent results in better color retention.

3.8 Anthocyanin content analysis

The inlet air temperature had an inversely proportional effect on the anthocyanin content. Higher temperature leads to greater losses of important substances such as anthocyanins, which are more heat sensitive and susceptible to oxidation. However, encapsulation by both maltodextrin (MD)10DE and WPI, tended to preserve the anthocyanin content. Increased inlet air temperature also results in hollow particles with greater roughness, promoting anthocyanin losses (Figure 7). Higher inlet air temperatures increase water evaporation and result in greater losses of important substances. Maltodextrin especially contributes to the agglomeration of particles, which is good for maintaining anthocyanin levels. Protein isolates with coating properties (film forming) that increase product stability of powder tend to decrease anthocyanin losses. During the drying process, addition of two encapsulants, maltodextrin and WPI, helped prevent anthocyanin losses during the high temperature drying process. This is because WPI can form a network with starch molecules to form a film. Maltodextrin, however, can form a film due to its insoluble polysaccharides and inter-particle attraction making them very cohesive with low porosity. This treatment enables retention of active substances. In the current study, at 50% MD and 15% WPI with a 160°C inlet air temperature, the maximum anthocyanin content was16.82±0.26 mg/l.

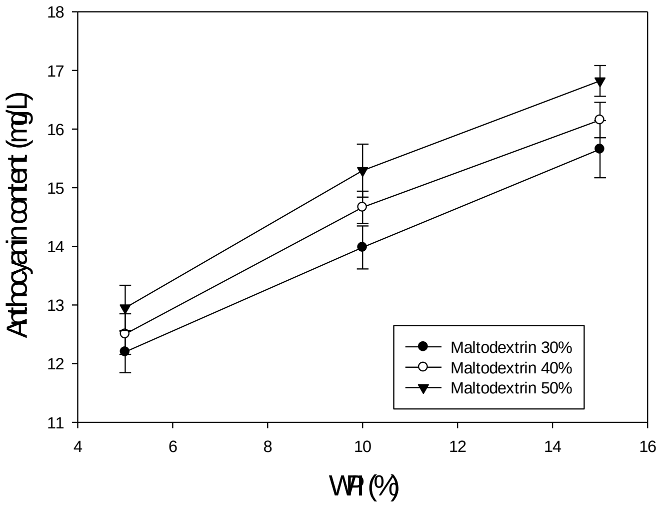


Figure 7: Effect of maltodextrin on anthocyanin content.

4. Conclusions

The current study was done to determine the optimal conditions for production of a spray-dried karanda powder and the inlet air temperature as well as the auxiliary drying agents that have the greatest impact on the quality and yield of karanda powder. The following are our key findings.

- Higher inlet air temperatures resulted in greater losses of anthocyanins because they are heat-sensitive. These greater air temperatures also cause formation of hollow particles with roughened surfaces that better retain anthocyanin particles.
- When maltodextrin and WPI levels were increased, particle agglomeration and coating improved, which had a positive effect on the retention of anthocyanins.
- The best conditions for spray drying karanda fruit were an inlet air temperature of 174 °C, MD content of 32%, and WPI content of 15%. The product yield was 55.93±0.25%, and the anthocyanin concentration was 12.58±0.36 mg/l.

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