DOI: http://doi.org/10.4038/jdza.v8i2.61

Journal of Dry Zone Agriculture, 2022, 8(2): 30 – 47

Development of spray drying technique for papaya (*Carica papaya*) fruit juice powder

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Received on November 12, 2022; Accepted on December 19, 2022

Abstract

Post-harvest losses of *Carica papaya* are considerably high throughout the supply chain due to variety of reasons. Spray drying is one of the potential preservation technologies to address this issue. Therefore, this research was conducted to identify the most acceptable carrier agent for papaya spray drying. The final quality of the product was tested with Maltodextrin and Glucose syrup with three different concentrations and at three different temperatures. Processing temperatures of 60 °C, 80 °C, and 100 °C were employed, with three concentrations (7.4%, 11.5%, and 15.3%) of carrier agents. The results revealed that temperature and carrier agent concentration had no effect on ascorbic acid, solubility, and pH ($P>0.05$). But the titratable acidity, moisture content and rehydration duration of dried powder differed. With increasing temperature, ascorbic acid and moisture content decreased while the pH of the solution increased with temperature and concentration.

Citation:
Wickramasinghe, W., Fernando, R., Perera, I., Samaraweera, M., and Rupasinghe, C. (2022). Development of spray drying technique for papaya (*Carica papaya*) fruit juice powder. *Journal of Dry Zone Agriculture*, *8*(2), 30-47.

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Changes in temperature have significantly effect on rehydration time. Better rehydration times were observed for maltodextrin and glucose syrup concentrations of 11.5% and 7.4%, respectively. There were two optimum treatment combinations: 11.5% maltodextrin at 80^{0}C and 7.4% glucose syrup at 60 ^{0}C.

Keywords: Papaya powder; Rehydration; Spray drying; Carrier agent; Drying temperature

Introduction

Papaya (*Carica papaya* L.) is an inexpensive fruit that belongs to the Caricaceae family and is available all year round, regardless of the season or weather. It is native to Mexico and northern South America but has become naturalized in many parts of the world, including tropical and subtropical regions (Sharma *et al*., 2020). Due to the obvious plant's economic and nutritional potential, it has become a popular fruit and vegetable. *C. papaya* is an excellent source of vitamins A and C (Atintunde *et al*., 2022). Thiamine, riboflavin, calcium, iron, potassium, magnesium, and sodium are all included in small quantities (Admad *et al*., 2013). Antioxidant content of papaya fruits is considerably high according the study conducted by Maisarah *et al*., (2013).

The recent studies revealed that papaya post-production losses are between 25%-40%, particularly in developing countries (Gunathilake *et al*., 2018). Mechanical damages during harvesting, transportation, and post-harvest diseases cause significant loss of papaya fruits. Several diseases, primarily of fungal origin, affect papaya fruits as they ripen, and a considerable percentage of fruits are lost after harvest. According to the Samithri *et al*. (2020), Phomopsis rot (*Phomopsis caricae-papayae*), stem-end rot (*Lasiodiplodia theobromae*) and Anthracnose (*Colletotrichum gloeosporioides*) are the most common postharvest diseases of papaya in Sri Lanka, causing up to 45% postharvest losses (Sarananda *et al*., 2004).

However, there is a growing interest in reducing these losses by processing fruits into value added products. Fruit juice powders provide several advantages and economic potentials over liquid alternatives; such as lower weight or volume, reduced packaging, better handling, transportation, and a considerably longer shelf life (Gomes et al., 2018). Dehydration is an effective way for fruit preservation since that decreases the water activity of fruits, which suppresses microbial development and enzymatic activity. According to of the literature revealed literature foam-mat drying, freeze drying, hot air oven and solar drying were used to produce papaya powder but limited studies in papaya powder production by spray drying (Chang *et al*., 2020).

Spray drying is one of the most used methods for producing heat-sensitive fruits and vegetables. The physicochemical characteristics of the powders are mostly determined by the operational conditions, carrier agent usage, and respective concentration. Lower amount of viscosity and homogenous consistency of feeding reduces clogging during drying and enhances spray drying effectiveness (Bazariya and Kumar, 2018; Gomes *et al*., 2018). A carrier agent is a substance that acts as a physical barrier and wall to protect functional ingredients from unfavorable environmental conditions. These materials improve the stability of active substances while maintaining product quality. An ideal carrier agent must have the following properties: adequate rheological properties (low viscosity) at high concentrations and simplicity of handling while processing, chemical affinity to disperse or emulsify the bioactive substance, as well as the ability to stabilize the emulsion produced, unreactive with the bioactive material during the drying process or storage conditions, ability to capture and retain the substance to be contained inside its structure; and capacity to shield the active substance from environmental conditions to the greatest extent possible (temperature, amount of air and humidity) (Wisniewski, 2015). Conventional spray drying technologies mainly influence end product characteristics of the dried fruit powders; including moisture content, solubility, vitamins, pH, yield and also product quality (Stavra *et al*., 2022).

The purpose of this study was to assess the feasibility of using spray drying technology to produce reconstitutable fruit juice powder. The current study aims to find the best carrier agent and better processing temperature with minimal impact to the available nutrient components in papaya spray drying process. The research findings will be beneficial to the commercialization of the papaya spray drying technology in Sri Lanka.

Materials and methods

Methodology was consisted of three steps. Such as sample preparation, homogenization and spray drying.

Sample preparation

The fruits were purchased from outlet of the A-farm Gannoruwa. Fruits were cleaned before being scraped with a spoon and weighed by balance. Pulp was extracted and blended with water, strained through stainless steel strainer to remove seeds and fibrous matter. Maltodextrin and Glucose syrup used as desirable carrier agent which assistance to transfer, drying and reconstitution of product. The flesh sample was then treated with a carrier agent (Maltodextrin or Glucose syrup). Following that, a carrier agent (Maltodextrin or Glucose syrup) was weighted and applied to the flesh sample.

Homogenization

A homogenizer was used to homogenize the prepared mixer. A homogenizer can be used for big quantities, while a high-speed blender is preferred for small quantities.

Spray drying

Prior initiating the operation, the spray dryer was switched on, and then allowed to attain an internal temperature to reach 100 °C. After reaching the desired temperature, the atomizer was turned on, and then sample was fed into the spray drier via atomizer's feed inlet. When the process was completed, the atomizer and other switches were turned off. End product was obtained from the bottom as well as the cyclone collector and then it was packed air tightly.

Product development trials

Two set of trials were conducted to determine suitable temperature and ratios for spray drier. In first set of trials, spray drying of papaya was conducted at three different temperatures as 60 °C, 80 °C and 100 °C. Same as previous other set of trails conducted with Glucose syrup in different ratios. The dry matter of the fruit pulp determines the percentage of carrier agent applied. The pulp-to-maltodextrin and pulp-to-glucose syrup ratios were given in Table 1. The ideal ratio of fruit pulp to maltodextrin and pulp Glucose syrup was chosen for product analysis and future investigations based on solubility, color, and reconstitutability (Lacerda *et al*., 2016).

Table 1: Pulp-to-maltodextrin and pulp-to-glucose syrup ratios

Sample No	Pulp to Maltodextrin (g)	Pulp to Glucose syrup (g)
1	100:8	100:8
2	100:13	100:13
3	100:18	100:18

Physio-chemical properties of papaya powder

Solubility

Solubility was determined according to the method used by Cano-Chauca *et al*. (2005). A dried, 50 mL centrifuged tube was filled with 2 g of papaya powder and 10 mL of water, mixed thoroughly to make a homogenous, lump-free paste and volume it up to 25 mL. The mixture was vigorously shaken for 3 minutes. The tube was centrifuged for 15 minutes at 4000± 100 rpm, and after that solution was put into a petri dish and was oven dried. Then weight differences of dish were used to measure solubility (%) by mass.

Dissolved solids

The 5 mL of solution was weighed with its contents and then placed in a boiling water bath for 15 minutes and then oven dried at 103 °C for 3 hours (Jazaeri, 2009).

Determination of residues

The residual solution was decanted off as thoroughly as possible without disturbing the sediment at the bottom of the tube. Contents of the tube were dried using boiling water bath and then 103 °C oven for 3 hours. The weight was taken in hourly intervals up to constant weight obtained (Yang *et al*., 2019).

Rehydration time

Powdered product 1 g was added into 50 mL of distilled water at room temperature (28°C). The mixture was agitated on a magnetic stirrer at 550 rpm until the powder disappears. The time taken for the powder to be completely disappearing was recorded.

Vitamin C (Ascorbic Acid)

The ascorbic acid content was measured using 2, 6-dichlorophenolindophenol as explained the AOAC (1995) and the content was calculated using the following equation (1).

$$Ascorbid\ acid\ (mg/100g) = \frac{Titre \text{ x } Dye\ factor \text{ x } Volume\ made\ up \text{ x } 100}{Aliquot\ of\ extract\ taken \text{ x Weight of sample}} \qquad \text{Equation 1}$$

Titratable acidity

Titratable acidity was calculated by titrating a known amount of powder (3 g) against a standard solution of 0.1 N sodium hydroxide, with phenolphthalein indicator. The findings were represented as a percentage of citric acid (Ranganna, 1986) and calculated using equation 2.

$$\%\ Titratable\ acidity = \frac{Titre \text{ x Normality of alkali x Equivalent weight of acid x 100}}{Volume\ of\ aliquot\ taken \text{ x Weight of sample taken x 100}} \qquad \text{Equation 2}$$

Determination of moisture content

The moisture content was calculated using the AOAC method (1995). A 2 g sample was weighed and added into pre-weighed and pre-dried moisture cans and dried at 103 ^{0}C for 6 hours. Then the dry samples were placed in a desiccator and cooled to room temperature. Then weighed, and the moisture content in percent was calculated using equation 3.

$$Per\ cent\ moisture = \frac{Loss\ in\ weight \text{ x } 100}{Weight\ of\ sample} \qquad \text{Equation 3}$$

pH

A 2 g of measured sample placed in a beaker and it was dissolved in 25 mL of distilled water. Then the reading was obtained using pH meter (model RM-131 Hand Held).

Sensory evaluation

Sensory evaluation was conducted to determine the best processing temperature and carrier agent concentration for maltodextrin and glucose syrup, based on chemical and physical property studies. Sensory analysis was conducted using a 30 untrained panel in order to assess whether there are significant differences among samples.

Statistical analysis

The experiment data were analyzed using one-way ANNOVA, and mean comparisons were done using LSD. The SAS version 9.1.3 (2007) computer software was used for analysis of data with a significance level of $p \leq 0.05$.

Results and discussion

Physicochemical properties

Solubility

Moisture content has the greatest influence on solubility as moisture content increases, solubility decreases with the moisture content (Grabowski *et al*. 2008). This could be due to a hard surface layer formed over the powder particle, preventing water molecules from diffusing through the particle as a result of very high inlet temperature (Fazaeli *et al*., 2012). According to the Cano- chauca *et al*. (2005) when the temperature reaches 100 °C, the caramelization of sugar in papaya fruit is affected. The solubility of spray dried papaya powder is reduced as a result of caramelization. Figure 1 depicts the physical property analyses of spray-dried papaya powder at different temperatures and carrier agent concentrations. According to the results shown in Figure 1a and 1b solubility of spray dried papaya powder was ranged from 18-31% for maltodextrin and 17-31% for glucose syrup carriers. Although, considering 60 ^0C solubility increased with increasing temperature in both glucose syrup and maltodextrin. But with 800 ^0C and 1000 ^0C temperatures it shows decreasing trend. Also, concentration of both maltodextrin and glucose syrup has no significance difference ($p \leq 0.050$).

Rehydration time

The rehydration time indicates the speed with which sprays dried powder reconstitute (Sathyashree *et al*., 2018). The speed of reconstitution is proportional to the moisture content of the processed powder. High moisture content has a high tendency for agglomeration, which helps to boost the powder's reconstitution speed and shorten rehydration time (Jinapong *et al*., 2008). According to the results shown below Figure 1c and 1d the range of results for maltodextrin and glucose syrup were 2.75 - 5 min and 3.23 - 5.09 min respectively. However, maltodextrin concentration is inversely proportional to rehydration time whereas the concentration of glucose syrup increases rehydration time. According to the results of statistical study, there is a significant difference in rehydration time between maltodextrin and glucose syrup as a carrier agent ($p \leq 0.05$).

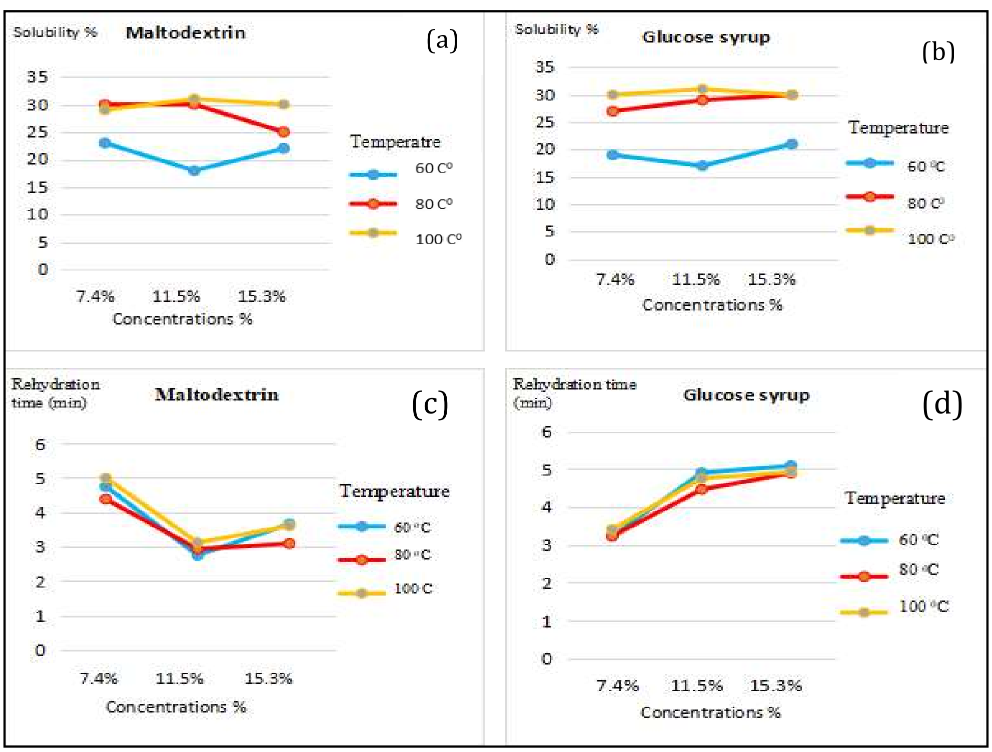

Figure 1: Physical properties of spray-dried papaya powder at different temperatures and carrier agent concentrations; (a) solubility with maltodextrin; (b) solubility with glucose syrup; (c) rehydration time with maltodextrin; (d) rehydration time with glucose syrup

Effect of moisture content with carrier agent concentration and temperature

The moisture content (MC) of papaya powder decreased as the maltodextrine concentration increased. The highest and lowest MC was found in papaya powder samples with maltodextrine concentrations of 7.4% and 15.3%, respectively. A similar finding is reported by Mishra *et al*. (2014). According to the Suhag *et al*. (2016), at higher temperature, the moisture content of the powder particles decreased. This might be attributed due to the faster rate of heat transfer into the particles at high temperatures, resulting moisture removal efficiency, in spray drying. It is also reported that as the drying temperature increases, the moisture content of apple juice powder, pomegranate juice, and lemon juice, decreased (Minim *et al*., 2009; Michalska, 2018; Jafari *et al*., 2017). The moisture content did not significantly change with temperature (60 °C, 80 °C, or 100 °C) at given concentration of maltodesxtrin. According to the Figure 2, the MC increases with increasing glucose syrup concentration up to 11.5% at 60 °C and 100 °C, then decreases with increasing glucose syrup concentration. There is a significant difference in moisture content between maltodextrin and glucose syrup as carrier agents.

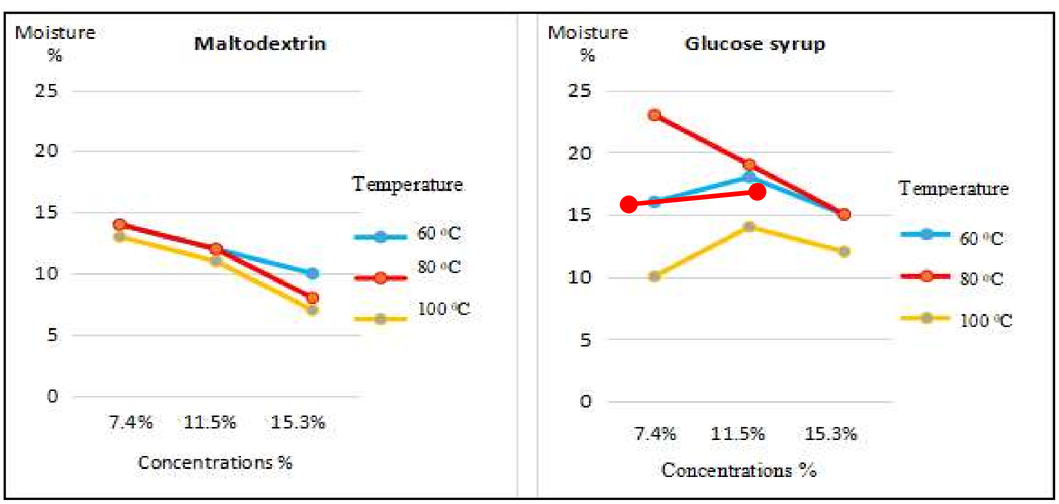

Figure 2: Effect of temperature and concentration of maltodextrin and glucose syrup on moisture content of spray dried papaya powder

Ascorbic acid

Spray dried papaya powder contains a small amount (0.55 mg/g) ascorbic acid (Surekha *et al*., 2018). Because of the heat sensitive features of ascorbic acid, the amount of ascorbic acid decreased as the temperature increased (Islam *et al*., 2016). Thankitsunthorn *et al*. (2019) reported that, at 140 °C, typical spray drying of gooseberries juice resulted in a 62.1% loss of vitamin C and around 28-51% of vitamin C losses at temperature between 220 °C to 250 °C from spray drying of cactus pear powder ((Rodríguez-Hernandez *et al*., 2005). Angel *et al*. (2009) shown that 27.47% of vitamin C was maintained throughout the drying process of kiwifruits without a carrier agent at 60 °C. The proportion of vitamin C maintained during spray drying of passion fruit with matodextrin at 180 °C and 190 °C ranged between 39.73% and 56.89%. This indicates that vitamin C is extremely heat and oxidation sensitive.

In this study the lowest ascorbic acid (0.09 mg/g) was observed in 11.5% of maltodextrin and glucose syrup concentrations at 100 °C (Figure 3). Highest ascorbic acid content (0.17 mg/g) was observed in glucose syrup carrier agent at 60 °C. According to the results, there is no statistically significant difference (P>0.05) between maltodextrin and glucose syrup as a carrier agent for content of ascorbic acid for three different temperatures.

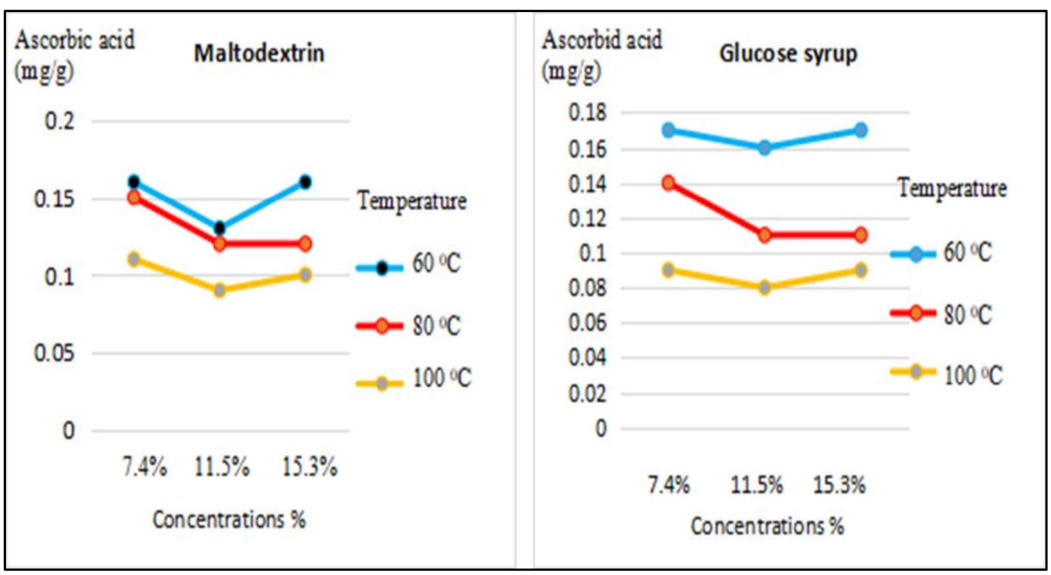

Figure 3: Effect of temperature and concentration on ascorbic acid of spray dried papaya powder with maltodextrin and glucose syrup carrier agents.

pH

The acidity level of the spray dried papaya powder has the greatest influence on pH. Spray dried powder has a better pH level of around 5 (Chang *et al*., 2020). According to the results which are depicted in Figure 4 maltodextrin with a concentration of 15.3% had the highest pH value at 100 °C. The highest pH was observed in 15.3% of glucose syrup as a carrier agent at 80 °C. The pH range of maltodextrin and glucose syrup was 4.9-5.3 and 4.9-5.4 respectively within all temperature levels. And there is no significance difference between pH for both maltodextrin and glucose syrup carrier agents (P>0.05).

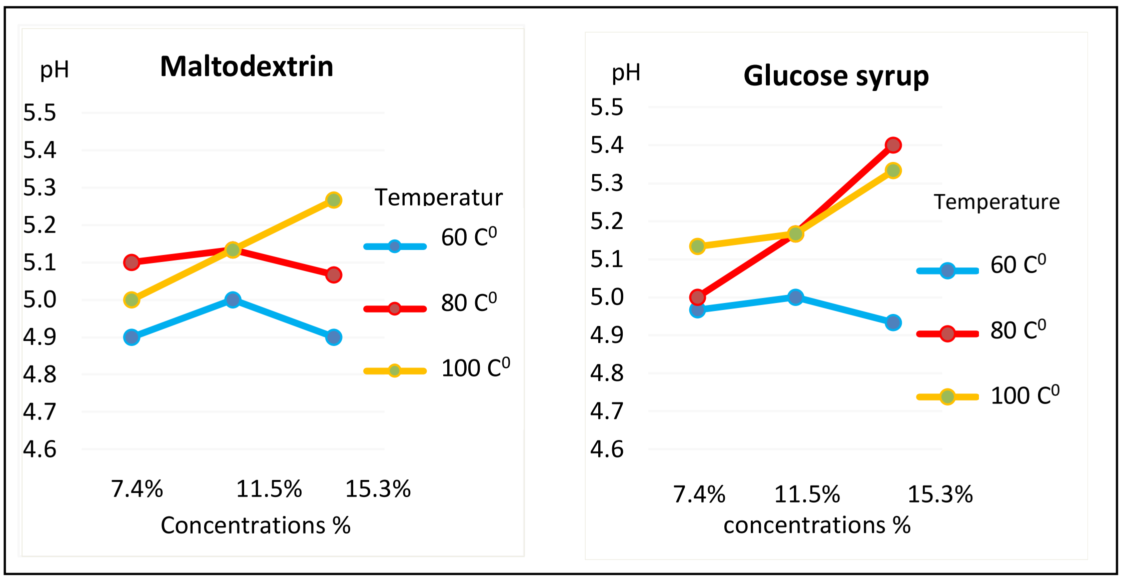

Figure 4: Effect of temperature and concentration of maltodextrin and glucose syrup on pH of spray dried papaya powder

Titratable acidity is an approximation of the solution's total acidity and is critical in the food processing sector. Further it has an impact on the shelf life period of the processed food. Commercially, a titratable acidity range of 0.5 to 0.8 is considered desirable (Karel & Lund, 2003). According to results shown in Figure 5, pH ranged from 0.53-0.89 for maltodextrine and 0.35-0.78 ± 0.12 for glucose syrup. When the concentration of maltodextrin was increased, the titratable acidity reduced. Consider glucose syrup as a carrier agent; it has the maximum titratable acidity at 11.5% concentration at all three temperatures. According to the results of statistical investigation, there is a significance difference in titratable acidity between maltodextrin and glucose syrup as a carrier agent (P>0.05).

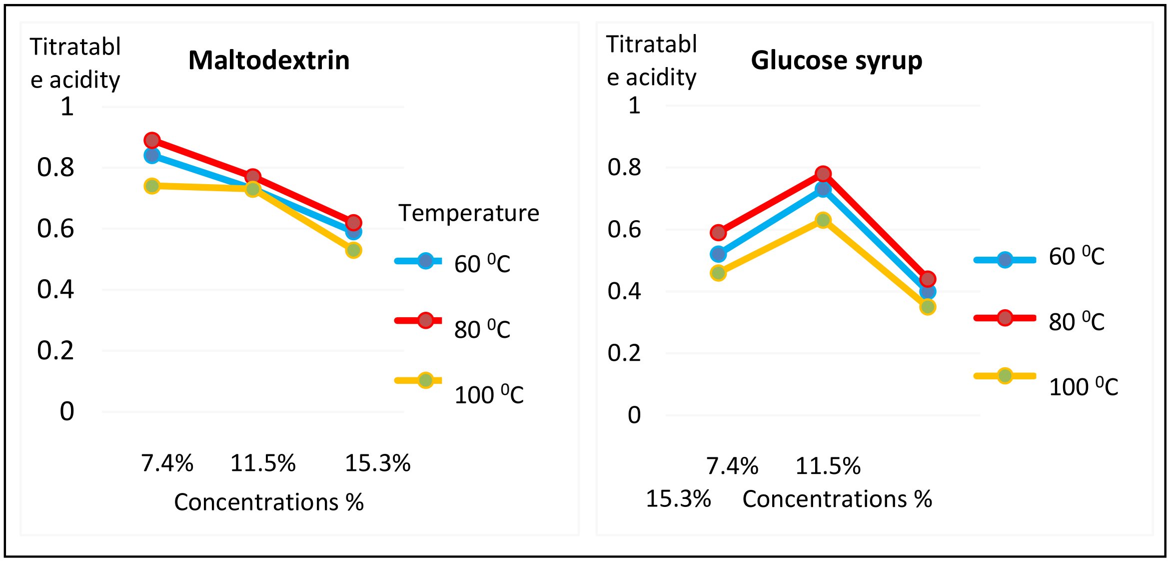

Figure 5: Effect of temperature and concentration on titratable acidity

Mean separation

According to the results shown in Table 2, there is a significant difference between three concentration levels of maltodextrin and different temperature levels. Maltodextrin concentrations of 11.5% and 15.3% received the greatest ranking value of 0.26 and the lowest ranking value of 0.17, respectively. Temperature levels of 80 °C and 100 °C had the highest ranking value of 0.17 and the lowest ranking value of 0.11. According to the results, a maltodextrin concentration of 11.5% at 80 °C shows a superior condition for the papaya spray drying process.

Table 2: Mean separation of maltodextrin

Concentration	Mean Rank	Grouping	Temperature	Mean Rank	Grouping
7.40%	0.21	B	60°C	0.14	B
11.50%	0.26	A	80°C	0.17	A
15.30%	0.17	C	100°C	0.11	C

According to the results in Table 3, there is a significance difference among three concentration levels of glucose syrup and different temperature levels. According to the results, glucose syrup concentrations of 7.40% and 15.3% had the greatest ranking value of 0.25 and the lowest ranking value of 0.13, respectively. Temperature levels of 60 °C and 100 °C had the highest ranking value of 0.17 and the lowest ranking value of 0.09. According to the results, a glucose syrup concentration of 7.40% at 60 °C is a superior condition for the papaya spray drying process.

Table 3: Mean separation of Glucose syrup

Concentration	Mean Rank	Grouping	Temperature	Mean Rank	Grouping
7.40%	0.25	A	60°C	0.17	A
11.50%	0.14	B	80°C	0.1	B
15.30%	0.13	C	100°C	0.09	C

Sensory evaluation

The best processing temperature and carrier agent concentration for maltodextrin and glucose syrup were determined based on chemical and physical properties. The sensory assessment result for the selected carrier agent concentration discovered by chemical and physical study for different temperatures is shown in Figure 6. Selected concentrations were 11.5% and 7.4% respectively maltodextrin and glucose syrup as suitable for spray drying.

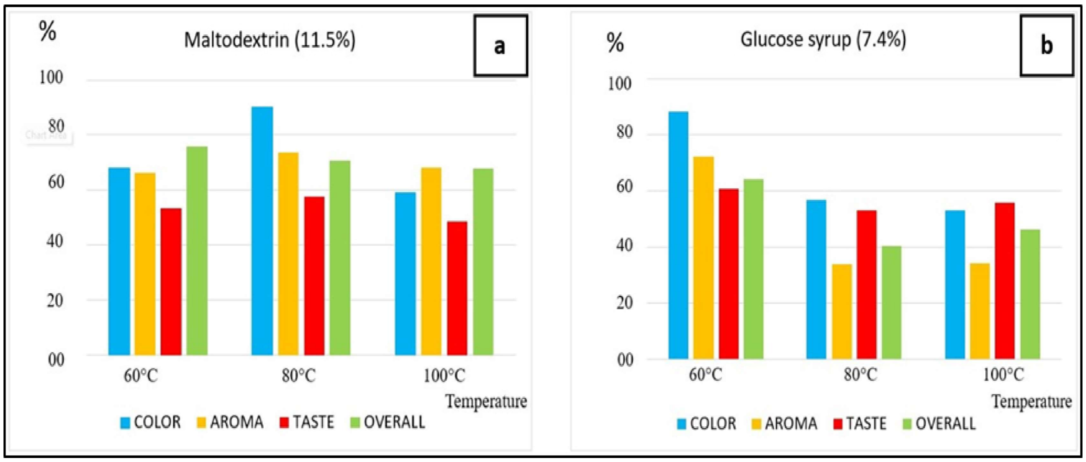

Figure 6: Sensory evaluation results; (a) maltodextrin concentration of 11.5%; (b) glucose syrup concentration of 7.4%

The sample processed with maltodextrin at 80 °C had higher sensory test scores than the other two temperatures. Color, aroma, and taste were scored at 80 °C with 90%, 74%, and 58%, respectively (Figure 6a). The sample processed with glucose syrup at 60 °C had higher sensory test scores than the other two temperatures. Color, aroma, and taste were scored at 60 °C with 88%, 72%, and 60%, respectively (Figure 6b).

Conclusion

According to findings of the study, Maltodextrin is the best carrier agent for the papaya spray drying method. The best processing temperature and the best Maltodextrin concentrations are 80 °C and 11.5% respectively. A comparable outcome may be accomplished with Glucose syrup at 60 °C and a concentration of 7.4%. When the processing temperature is raised, most of the nutritious components and physical properties of the food are deteriorated. Because keeping the temperature between 60 °C and 80 °C is best for preventing damage. If the temperature rises beyond 80 °C, the sugar in the fruit juice caramelizes, lowering the quality of the papaya powder. The sensory test results show that papaya reconstitutable powder may give acceptable sensory characteristics at 80 °C with Maltodextrin and 60 °C with Glucose syrup.

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