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Original Research Article

Production of Spray Dried Tomato Powder from Enzymatic Liquefied Juice

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Abstract: This study aimed to produce spray-dried tomato powder with improved product yield and powder quality. The experiment for this investigation entailed the use of two carrier agents which were maltodextrin (MD) dextrose equivalent (DE) 20 and gum Arabic (GA) from acacia tree G9752, each at 10% concentration. The carrier agents were combined and mixed with three different enzymes, alpha-amylase from porcine pancreas (AAPP) A6255, pectinase from *Aspergillus aculeatus* (PAA) P2611, and pectinase from *Aspergillus niger* (PAN) P4716, each at 1% v/w concentration. This study was conducted by altering the spray drying inlet temperatures to 140°C, 160°C, and 180°C separately. The physicochemical analysis of the tomato powder samples was conducted on the moisture content, powder yield, hygroscopicity, colour features, and 2,2-diphenil-1-picrylhydrazyl (DPPH) radical scavenging activity (RSA). The powder analysis conducted presented the moisture content of 1.30%-7.00%, colour analysis indices of $a*$ at 1.31–5.72, $b*$ at 7.5–9.8, $L*$ at 89.6–95.39, the production yield of 27.73%–42.65%, hygroscopicity value at 1.05%-6.79%, and antioxidant activity value of 9.51 mg/mL–28.81 mg/mL. Results indicated that sample TP9 was the best powder produced with output analysis of moisture content percentage of 1.3%, colour analysis $a*$ value of 3.14, production yield 42.65%, hygroscopicity 1.05%, and antioxidant activity value of 11.94 mg/mL. The study revealed that at higher inlet temperatures and in combination with enzyme PAN it is possible to produce powder characteristics with low moisture content, high $a*$ colour index, high production yield, low hygroscopicity value, and high antioxidant activity.

Keywords: carrier agents; maltodextrin; gum Arabic; spray drying; enzyme

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1. Introduction

Solanum lycopersicum, also known as the tomato, is considered a vegetable rather than a fruit, despite the numerous debates surrounding it. Tomatoes and tomato-based products are good sources of carotenoids, particularly lycopene, and ascorbic acid such as vitamin C, vitamin E, flavonoids, and potassium. Tomato powder helps to induce cell-to-cell communication in human cell activities and modulates the hormone system, immune system, and other metabolic pathways (Bhat *et al.*, 2020; Souza *et al.*, 2018). The high moisture content of tomatoes, however, usually leads to increased water activity, resulting in quality deterioration. Therefore, dried food powder is produced using the spray drying technique, which can help to lower postharvest losses while increasing the value of the raw material. Spray drying is a popular technique for converting a liquid condition into a powder form. Additionally, the most popular microencapsulation method, spray drying, is a successful approach for safeguarding probiotics and bioactive chemicals (Adak *et al.*, 2017; Krishnaiah *et al.*, 2015; Muzaffar *et al.*, 2016; Sousa *et al.* 2008). Spray drying of fruit juices, however, is difficult because of the liquids' large content of low molecular weight organic acids and sugars, which causes them to behave thermoplastically (Yongji *et al.*, 2017).

In fruit juice powders with a high sugar content, spray drying, which offers a lot of processing flexibility and speed, creates problems with stickiness. Several encapsulating or carrier substances, such as maltodextrin (MD), gum Arabic (GA), liquid glucose, and dietary fibre, are employed to overcome the stickiness (Bhandari *et al.*, 1993; Igual *et al.*, 2014). Spray drying of fruit juices, however, is difficult because of the liquids' large content of low molecular weight organic acids and sugars, which causes them to behave thermoplastically (Bhandari & Howes, 2005; Muzaffar *et al.*, 2015). To minimise stickiness, MD has been demonstrated to be the most effective drying agent (Cabral *et al.*, 2009). Each carrier has advantages and disadvantages in terms of its price, the efficiency of its shield, and its physical attributes. MD is commonly used either alone or in combination with other components in food, the production of vitamins, dietary supplements containing aromatic compounds, and plant extracts (Goula & Adamopoulos, 2005; Goula & Adamopoulos, 2008). According to a study conducted by Chegini and Ghobadian (2007), the utilisation of MD in the production of orange juice resulted in a production yield ranging from 18% to 35%. According to Quek *et al.* (2007), MD and GA are primarily used in spray drying due to their high solubility and low viscosity, which are essential properties of the spray-dried powder. The main goal of adding carrier agents to the spray drying process used to produce powder was to increase yield while lowering the stickiness and hygroscopicity of the finished powdered product.

Moreover, the application of carrier agents reduces costs and increases productivity by adjusting the transition temperature, total soluble solids, and viscosity of the solution (Santana *et al.,* 2017; Yousefi *et al.,* 2011).

In juice and beverage industries, enzymes are generally used to clarify juice, increase colour, flavour, extraction yield, and operational efficiency (Abdullah *et al.,* 2007; Chaudhri & Suneetha, 2012; Chang *et al.,* 2020; Li *et al.,* 2020; Shrestha *et al.,* 2022; Tran & Nguyen, 2018). They are also used to liquefy fruit before processing (Bhat *et al.,* 2020). According to Chang *et al.* (2020), the enzyme-treated papaya puree used for spray drying was examined for its physical and chemical characteristics. Since many different inactivation paths exist for enzymes, some of them are manufactured using the encapsulation method to prevent inactivation while being stored. In the food business, this product can be encapsulated using a variety of techniques, including extrusion, fluidised bed coating, spray drying, spray chilling, coacervation, and spray chilling (Bazaria & Kumar, 2018; Chegini & Ghobadian, 2007; Phisut, 2012).

Hence, the purpose of this study was to elucidate how coating agents MD and GA affect the enzymatic characteristics. A mixture of tomato juice with enzymes alpha-amylase from porcine pancreas (AAPP) A6255, pectinase from *Aspergillus aculeatus* (PAA) P2611, and pectinase from Aspergillus niger (PAN) P4716 were produced. The powdered tomato for each mixture was analysed according to their physico-chemical properties including moisture content, colour indices value, powder yield, hygroscopicity, and radical scavenging activity (RSA).

2. Materials and Methods

2.1. Materials

The raw materials that were used in this study were tomato fruits which were purchased from the local market. Enzymes AAPP A6255, PAA P2611, and PAN P4716 were supplied by Sigma Aldrich. Carrier agents MD dextrose equivalent DE20 and GA from acacia tree G9752 were also supplied by Sigma Aldrich.

2.2. Equipment

The equipment and instruments used include a spray dryer (Mobile Minor TM, GEA, USA), a thermometer (Immersion, England), a blender, an analytical balance (Metler-Toledo, Switzerland), a laboratory oven (Binder, Germany), and a colorimeter (Colour Flex, Hunter Lab, USA). A major piece of apparatus for the study was a spray dryer on a pilot scale, which was utilised to spray dry the tomato juices. The samples were fed into a Mobile Minor TM, GEA, USA, pilot-scale spray dryer. The spray dryer was equipped with a peristaltic pump and a revolving atomiser or two-fluid spray nozzle that was maintained at a pressure of 5.0 bar. The cylindrical drying chamber measures 0.62 m in height, 0.80 m in diameter, and has a conical base with a 60 angle. Co-current mode was selected for the spray dryer's operation. The drying process was conducted under variable input air temperature settings ranging from 140°C to 180°C to a fixed outlet temperature of 85°C. The pump rotation speed controls the feed flow rate (set at 18 rpm). The peristaltic pump was used to modulate the flow rate, keeping the drying air's output temperature at 85°C while maintaining its entrance temperature at 140°C followed by 160°C and 180°C. Two temperature sensors placed in the fluid bed were used to control and monitor the temperature of the outflow powder. Spray drying resulted in the removal of dried powder from the cyclone's base. To analyse the colour characteristics of tomato powder, a colour spectrophotometer (Colorflex D65/10O, Hunterlab, USA) was used. The results were expressed as $L*$ (lightness), $a*$ (redness), and $b*$ (yellowness) values of the samples by CIELAB system using the spectrophotometer for colour. The equipment is calibrated using a white plate (L=93.87, a=-0.73, b=+2.06) and a green plate (L=51.23, a =-25.32, b=15.14) before sample analysis. Five copies of each sample were analysed, and average values were obtained.

2.3. Preparation of Tomato Juice

In order to produce tomato juice, the tomato fruit was washed in lukewarm water to remove any surface pollutants present. The tomato's bottom was cross-sectional cut before being blanched for 1 min in boiling water. The juice obtained was filtered using a cloth strainer filter.

2.4. Preparation of Tomato Juice with Carrier Agents

To prepare tomato juice with carrier agents, first, 250 mL of tomato juice was added into a water jug with carrier agents. The tomato-MD DE20 and tomato-GA mixtures were prepared with of 10% concentration of carrier agents. A low concentration of carrier agents may result in the formation of a sticky powder. On the other hand, if more than 10% is added, the powder formed will more likely lose the appealing red-orange colour (Quek *et al.*, 2007). Hence, the carrier agent solutions of 10% were prepared by dissolving the carrier agents in hot water and mixed with tomato juices using a blender. The mixture was then further heated and stirred between 30°C and 50°C using a water bath (Chang *et al.*, 2020). The final volume of the juice mixture was kept at 500 mL for every sample.

2.5. Preparation of Tomato Juice with Enzymes

A 500 mL beaker containing 250 g of tomato juice with carrier agents was filled with 1% v/w AAPP. According to a literature survey on the application of enzyme treatment in various studies of spray drying powder, it was found that enzyme concentration varied from 0.03–1.5% v/w (Chang *et al.*, 2020; Tochi *et al.*, 2009; Wong *et al.* 2015). The enzyme and blended juice were combined, mixed with a spatula for 30 secs, and then incubated in a water bath at 50^{o}C for 2 h while being agitated at 100 rpm. Thereafter, the mixture was then heated to 95^{o}C in a water bath for 5 min to inactivate the enzyme (Chang *et al.*, 2020). To ensure a smooth consistency, the tomato purees were sieved three times using a cloth strainer filter after being liquefied by the enzyme. The procedure was repeated with another 2 enzymes which were the PAA and PAN.

2.6. Preparation of Tomato Powder

The formulation to create 9 separate samples is shown in Table 1. To make sure the atomiser can operate properly during the spray drying process, the spray dryer (Mobile MinorTM, GEA, USA) must go through a start-up procedure. The spray dryer's intake and outlet temperatures were set to the desired temperatures of 140^{o}C, 160^{o}C, and 180^{o}C (Chang *et al.*, 2020), respectively, with a fixed outlet temperature of 85^{o}C. The two-fluid atomiser nozzle on the spray drier has a diameter of 1.0 mm. Co-current and fountain atomisation were carried out with an atomiser pressure of 5 bar. Using a peristaltic pump at 18 rpm, samples were fed into the spray dryer. The produced powdered sample was taken from the cyclone after spray drying and stored in a sealable zip-lock bag. The gathered powdered samples were weighed and kept at room temperature in an airtight container with silica gel. Samples were stored for 2 days pending additional analysis. Each analytical task for the examination of tomato powder was completed in triplicate.

Table 1. Formulation for the 9 samples

Samples	Volume of tomato juice, mL	Enzyme used	Weight of enzyme used, g	Inlet temperature, ^{o}C
TP1				140
TP2	250	AAPP A6255	2.5	160
TP3				180
TP4				140
TP5	250	PAA P2611	2.5	160
TP6				180
TP7				140

Samples	Volume of tomato juice, mL	Enzyme used	Weight of enzyme used, g	Inlet temperature, ºC
TP8	250	PAN P4716	2.5	160
TP9				180

*TP: Tomato powder

2.7. Analysis of Tomato Powder

2.7.1. Moisture content

The Association of Official Agricultural Chemists (AOAC) method was used to determine the moisture content of the powder sample (AOAC, 2012). An oven, crucible, and analytical balance were the required pieces of equipment. To dry the crucible and lid, a laboratory oven (Binder, Germany) was used, followed by a desiccator for cooling. The size of the empty, lidded crucible was determined in step (a), and a sample of powder weighing about 2 g was added. The crucible's weight with the 2.0 g sample was noted (b). Without the lids, the crucible was placed inside the oven. The sample is dried in a laboratory oven (Binder, Germany) at 105°C for 24 hours or until it reaches a consistent weight. The sample was then taken out of the oven and was allowed to cool in a desiccator before being weighed. The samples are weighed following a 15-min chilling period (c). Three evaluations of the samples are conducted, and the mean value is noted. The powder samples' estimated moisture content is calculated following Equation 1:

$$Moisture\ content, \% = \frac{b-c\ (g)}{b-a(g)} \times\ 100 \tag{1}$$

where, a = weight of crucible + lid; b = weight of sample + crucible + lid before drying process; c = weight of sample + crucible + lid after drying process

2.7.2. Powder Yield

Process yield was calculated by the composition between the quantities of total powder collected, which is expressed in mass, towards the total mass of solids in the feed as of Equation 2:

$$Powder\ yield, \% = \frac{Weight\ of\ powder\ collected}{weight\ of\ additives \times sample\ volume} \times\ 100 \tag{2}$$

The determination of solids content in the formulation was carried out using gravimetric methods as outlined by the AOAC.

2.7.3. Hygroscopicity

To determine hygroscopicity, at 25°C, approximately 1 g of each powder sample was placed in a glass jar in a desiccator that contained a saturated NaCl solution of 75.29% relative humidity. The analysis was done in triplicates and the samples were to be weighed after a week (Tonon *et al.*, 2009; Tonon *et al.*, 2011). The hygroscopicity is represented as g of absorbed moisture per 100 g of dry solids as shown in Equation 3.

$$Hygroscopicity, \% = \frac{b - a\ (g)}{a\ (g)} \times 100 \quad (3)$$

where, a = weight of the initial sample; b = weight of the sample after a week

2.7.4. Colour Analysis

In the context of analysing the colour of spray-dried tomato powder, three Hunter parameters are commonly used: the "L" value, the "a" value, and the "b" value. These parameters provide insights into the lightness, redness/greenness, and yellowness/blueness of the dried sample, respectively. The "L" value ranges from 0 (representing black) to 100 (representing white), while the "a" and "b" values can vary from -60 to +60. To assess the colour qualities of food powders, it is important to evaluate these parameters using a spectrophotometer. The $a*$ is a coordinate representing the scale of green to red, in this case, $a*$ more than 0 is red, while less than 0 is green. Similarly, $b*$ values represent negative values for blueness and positive values for yellowness. The colour of the dried sample can vary depending on the source materials used in the production process. By employing the total colour difference equation, the colour attributes can be determined accurately. For the analysis, the $L*$, $a*$, and $b*$ values are measured in triplicates using a colorimeter which is the Colour Flex from Hunter Lab, USA. The colorimeter measures the reflectance or transmittance of light at specific wavelengths and calculates the corresponding colour values. The mean values of the triplicate measurements are then obtained for further analysis.

2.7.5. Antioxidant Activity

To calculate the overall cumulative antioxidant activity, a 2,2-diphenil-1-picrylhydrazyl (DPPH) assay is used (Isildak *et al.*, 2022). Initially, 4 mg of DPPH is dissolved in 100 mL of 99% methanol for this analysis, and it will be kept at a temperature of -18°C away from any light until it is required. Then, 1g of tomato powder and 25 mL of the methanol solution are combined to create the working solution. The sample was shaken at 100 rpm for 2.5 h at 25°C in a shaking water bath. The solution is then centrifuged at a speed between 4000 and 6000 rpm for 15 min. After adding 3 mL of the previously made DPPH solution, a sample solution series is placed in the dark for 30 min to allow the reaction to take place. The next step is the measurement of absorbance using an ultraviolet-visible (UV-Vis) spectrophotometer with a 517 nm wavelength. The absorbance is measured for each solution series. The procedures are repeated for each additional sample. A reference control was made and examined without any extract added. The following Equation 4 was used to determine the % of RSA after collecting absorbance for the control and sample. Lee *et al.* (2003) described the DPPH method used to assess the antioxidant activity of the samples.

$$RSA, \% = \frac{A_{control} - A_{sample}}{A_{control}} \times 100 \quad (4)$$

2.7.6. Final Verdict

To ensure a comprehensive and systematic evaluation, a master table was created to consolidate and analyse all the collected data. This table allows for a clear comparison and ranking of the tested samples based on various parameters and criteria. Each sample was assigned points based on its ranking in different analyses, with higher ranks receiving more points. This approach enables the identification of the most favourable characteristics among the samples. The resulting table provides valuable insights into the overall performance and ranking of the samples, facilitating informed decision-making.

3. Results and Discussions

3.1. Moisture Content

Figure 1 shows the moisture content data for all 9 samples. The moisture content analysis was carried out to assess how much water was contained in the spray-dried tomato powder.

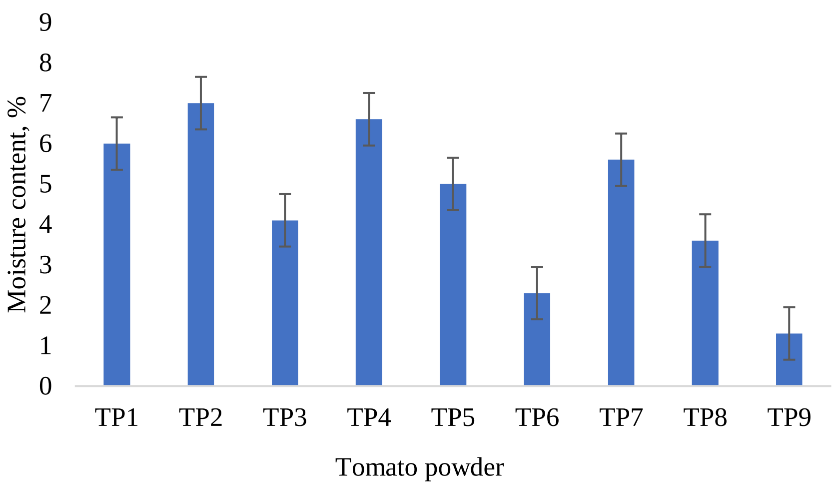

Figure 1. The moisture content of the spray-dried tomato powders

The range of moisture content detected in the final tomato powder, according to the results, is between 1.30% and 7.00%. The main factor affecting the stability of the powder is its moisture content because even a small amount of water can raise the temperature to the point where it increases the matrix's mobility while being stored (Osman & Endut, 2009; Bhandari *et al.*, 1993). Based on Figure 1, the highest moisture content was found on TP 2 with 7.00% where it consists of enzyme AAPP combined with carrier agent MD and GA in the ratio of 7:3 (w/w) and concentration of 10% (w/w). The inlet temperature for this sample was 160^{o}C with an outlet temperature of 85^{o}C. This indicates that tomato powder with lower inlet temperatures and usage of enzyme AAPP results in high moisture content compared to others. Although the inlet temperature has the mid value among the other two inlet temperatures which were 140^{o}C and 180^{o}C, this still indicates the temperature was lower than the highest value. For enzyme PAA, the highest moisture contents are TP4 with an inlet temperature of 140^{o}C and the lowest moisture content is TP6 with an inlet temperature of 180^{o}C. Lastly, for enzyme PAN, the highest moisture content was TP7 with an inlet temperature of 140°C and the lowest moisture content was TP9 with an inlet temperature of 180^{o}C. The lowest moisture content percentage is TP9 with results of 1.30%. This indicates that enzyme PAN combined with MD and GA with an operational inlet temperature of 180^{o}C can produce the best tomato powder with low moisture content so that the product will last longer. Osman and Endut (2009) stated that the moisture content of the sprayed powder decreased as the inlet temperature climbed in their study using roselle pineapple powder increased. The same conclusion was reached by Jittanit *et al.* (2011) researching tamarind powder. In addition, Jittanit *et al.* (2010) also showed that high temperatures reduce the powder's moisture content through trials with pineapple powder. Moisture content is a crucial powder parameter that is connected to drying effectiveness. Due to its impact on the glass transition, the moisture content of a microencapsulated product plays a critical role in determining its flow characteristics, adhesion, and storage robustness as well as crystallisation traits (Phisut, 2012). According to Tran and Nguyen (2018), the carrier agent MD and GA in the ratio of 7:3 (w/w) and concentration of 10% (w/w) are the most efficient. There are variations of different moisture content due to enzyme activity and interaction. Enzymes like AAPP and AAP can interact with tomato slurry components and alter drying behaviour. The concentration and activity of enzymes might vary, resulting in changes in starch and pectin breakdown, which influences the moisture content of the powder. Moreover, spray dryer inlet temperature can cause faster evaporation and lower moisture content, whilst lower temperatures can cause greater moisture retention. By increasing the carrier agent concentration, there is more potential in lowering the percentage of moisture contained in the tomato powder. According to Caparino *et al.* (2012), moisture content in tuna powder also decreased from 7.465 to 4.63% when the percentage of maltodextrin increased by up to 26%.

3.2. Powder Yield

Figure 2 shows the finding for powder yield % value that has been calculated using Equation 2.

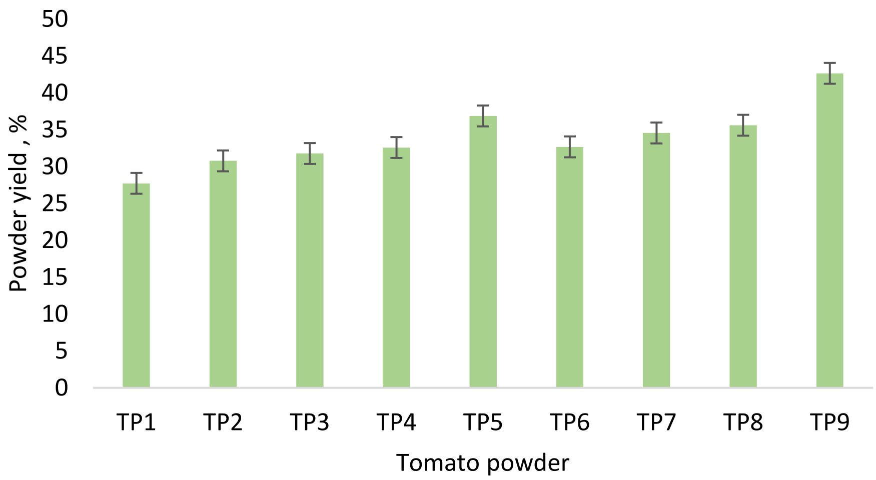

Figure 2. Production yield

The highest production yield goes to TP9 and the lowest production yield goes to TP1 (Figure 2). The production yield of spray drying is significantly influenced by the temperature of the incoming air. Higher temperatures may cause drying to occur more quickly and evaporation to be greater, increasing yields. However, extremely high temperatures might also result in problems with product quality and reduced yield (Tay *et al.*, 2021). According to Quek *et al.* (2007), carrier agents like MD can alter the surface stickiness of low molecular weight sugars (such as glucose, sucrose, and fructose) and organic acids. This can speed up drying and lessen the stickiness of products that are spray-dried. The factor affecting the production yield is the drying efficiency. The spray dryer's efficiency in eliminating moisture from liquid has a substantial impact on output yield. The addition of MD and GA can increase the production yield. The droplet size is impacted by the atomisation process, which also affects the production of powder and drying effectiveness. When compared to bigger droplets, finer droplets typically have faster drying rates and higher yields (Bhandari & Howes, 2005).

3.3. Hygroscopicity

Figure 3 shows the finding for the hygroscopicity value that has been calculated using Equation 3.

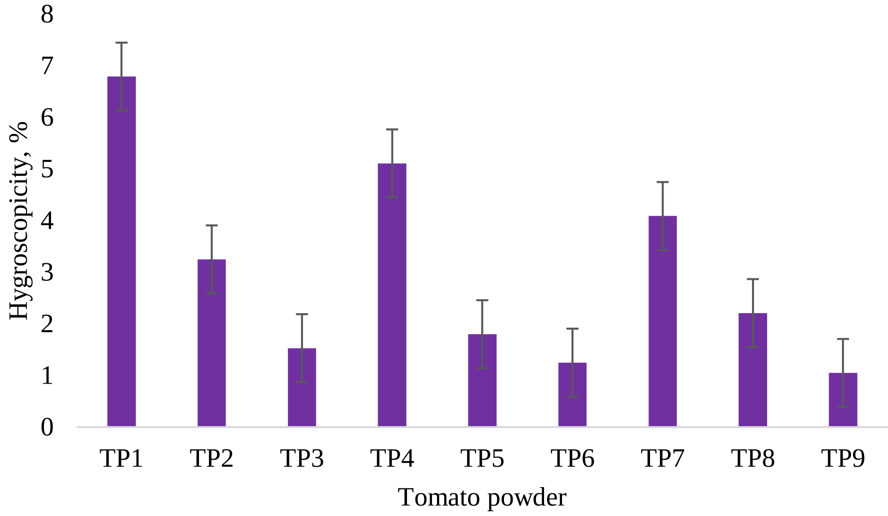

Figure 3. Hygroscopicity value of tomato powder

Based on the findings, TP1 has the highest hygroscopicity value. The inlet temperature for this spray-dried powder is 140^{o}C. TP1 can become bad faster due to its high hygroscopic value. This is due to the lower inlet temperature factor that affects it. On the other hand, the lowest and the best hygroscopic characteristic of tomato powder is TP9. This is due to the high inlet operational temperature which is 180^{o}C. Li *et al.* (2015), for instance, investigated the hygroscopicity of spray-dried pineapple powder that contained enzymes and discovered that the enzymes improved the powder's moisture sorption isotherms and hygroscopic behaviour. Similar results could be anticipated from tomato powder that contains enzymes. When compared to tomato powder without enzymes, spray-dried tomato powder with enzymes may have different hygroscopic behaviour. High hygroscopicity in fruit powder may not always be regarded as desirable because it might cause the powder to clump, cake, and lose its quality because of absorbing moisture from the environment (Sarkar *et al.*, 2015). Fruit powders are expected to have some degree of hygroscopicity, but too much hygroscopicity might harm the product's appearance, texture, and shelf life. The hygroscopic characteristics of spray-dried tomato powder may be affected by the presence of enzymes. Enzymes are protein-based molecules that can hold onto water, potentially increasing the powder's hygroscopicity (Li *et al.* 2015). While for hygroscopicity, it is preferable to manufacture food powder with low hygroscopicity since higher hygroscopicity indicates a greater inclination to absorb water and generate stickiness (Muzaffar *et al.,* 2015; Tonon *et al.,* 2011; Tonon *et al.,* 2009).

3.4. Colour Analysis

Table 2 lists the powders' colour parameters (L^*, a^*, and b^*) and displays the colour analysis findings for each sample. Redness, yellowish, and brightness-resistant levels were used to display colour results. To determine how different the colour values were after drying, each sample was examined for each colour. The samples were then categorised based on values and evaluated for the enzyme used and carrier agents present. The three results acquired from colour analysis where the a^* values, reveal whether a sample is primarily red or green and are without a doubt the most crucial since they are used to determine priority order. The value of b^*, which is followed by a measurement of the sample's yellowness or blueness. L^* values, also referred to as luminance, are units of brightness or lightness that range from 0 to 100, where 0 corresponds to entire darkness and 100 to total brightness.

Table 2. Colour analysis

Sample	L^*	a^*	b^*
TP1	94.35	2.02	7.50
TP2	92.65	2.43	7.50
TP3	95.39	1.31	7.81
TP4	92.85	3.13	8.01
TP5	92.36	3.27	8.54
TP6	91.15	3.82	8.84
TP7	89.73	4.66	9.80
TP8	89.60	5.72	9.19
TP9	92.44	3.14	9.25

Unacceptably low values were found for the tomato powder's a^*, or reddish level. These numbers fall between 1.31 and 5.72. For each enzyme, the highest values of a* for AAPP, PAA, and PAN were TP2, TP6, and TP8, respectively. On the other hand, the lowest values of a^* for AAPP, PAA, and PAN were TP3, TP4, and TP9, respectively. The highest value of a^* among the whole result was TP8, where the tomato powder contained enzyme PAN combined with carrier agent of 10% concentration MD and GA with an operational inlet temperature of 160^{o}C. TP8 shows the highest value due to lycopene preservation. Tomatoes are high in red pigments, particularly lycopene, which contributes to their distinctive red colour. The use of modest input temperatures of 160^{o}C during spray drying helps retain lycopene's stability and prevents excessive degradation or loss of colour. As a result of this, the spray-dried tomato powder retains more of its original red colour, resulting in a higher redness ($a*$) score in the colour analysis. The chosen inlet temperature of 160°C likely provides an optimal combination between efficient moisture removal and little colour component degradation. The drying process can be sufficiently rapid at this temperature to minimise the moisture content in the tomato powder while keeping the integrity of red pigments, resulting in a greater redness ($a*$) value (Grabowski *et al*. 2006). The lowest value of $a*$ obtained from this study is TP3, where the tomato powder contains enzyme AAPP combined with carrier agent of 10% concentration MD and GA with operational inlet temperature of 180°C. During spray drying, the use of carriers MD and GA might dilute the colour of the tomato solids, influencing the final colour of the powder. Other than that, the powder has less $a*$ value because the tomato was sieved 3 times to obtain a smooth juice, therefore the tomato colour is less prone to red colour due to the tomato debris left at the sieve. The loss of pigments caused by the process's increase in temperature, tomato powder has lower values for $a*$ (redness) and b* (yellowness). Given that tomato juice is red and carrier agents like MD and GA are white, the concentration of carrier agents also contributes to the reduction in $a*$ and $b*$ values. As a result, all powdered goods have a lighter colour. A comparable decline in redness ($a*$ value) and yellowness ($b*$ value) was seen with an increase in MD concentrations in research by Grabowski *et al.* (2006) on sweet potato powders.

Because lycopene degrades more quickly at higher temperatures, the drop in the red hue ($a*$ value) is inversely related to the rise in input temperature. For all samples, the trend shows a stable $b*$ value and the sample that has the most $b*$ value was TP7 with a value of 9.80. TP7 was the tomato juice powder that contains enzyme PAN with carrier agent of 10% concentration MD and GA with an operational inlet temperature of 140°C. The samples that have the least b* values were TP1 and TP2 with the same values of 7.50. TP1 and TP2 were tomato juice powders that contained enzyme AAPP and carrier agent of 10% concentration MD and GA each with operational inlet temperatures of 140°C and 160°C respectively.

For the $L*$ values, the findings show they vary between 89.60 and 95.39. According to Jittanit *et al.* (2010), a small amount of powder that did not completely dissolve in the solution may be the cause of the loss in brightness seen in the tomato powder sample solution. The diminished brightness might be caused by this insufficient disintegration. Additionally, the amount of carrier agent present in the tomato powder may have an impact on how much the sample solution colour differs from the control tomato samples. The highest $L*$ value is TP3 with the enzyme of AAPP and inlet temperature of 180°C. The high intake temperature of 180°C allows for faster moisture evaporation during the spray drying process. Because of the quick drying, water is efficiently removed from the tomato slurry, resulting in lower moisture content in the final powder. Lower moisture content can lead to a higher lightness (L*) value since less water causes the powder to appear lighter in colour. The lowest L* value was TP8 with enzyme PAN and inlet temperature of 160°C. This proves that high inlet operational temperatures can reduce the redness of the tomato powder.

3.5. Antioxidant Activity by DPPH Method

Since tomatoes are known to contain antioxidants, the powder's antioxidant capabilities are the main focus of the investigation. 2,2-diphenyl-1-picrylhydrazyl (DPPH) was used in the evaluation to determine the total antioxidant activity. The absorbance data from each sample as measured by a UV-VIS spectrophotometer at a wavelength of 517 nm are shown in Table 3.

Table 3. Resulting absorbance

Sample (mL)	Concentration, (mg/mL)	TP1	TP2	TP3	TP4	TP5	TP6	TP7	TP8	TP9
Control	0	1.4213	1.4301	1.3110	3.5702	0.9023	3.8001	1.6940	1.5528	1.5629
1	4	1.3588	1.3348	1.2801	3.4878	0.8631	3.6226	1.5051	1.4261	1.4010
2	8	1.3478	1.3205	1.2608	3.4262	0.7990	3.3743	1.3957	1.3672	1.3761
3	12	1.3318	1.3041	1.2254	3.3724	0.7982	3.3262	1.3832	1.3524	1.3330
4	16	1.3126	1.3001	1.2114	3.3295	0.5300	3.2137	1.3848	1.3561	1.3260
5	20	1.2131	1.1891	1.2038	3.2501	0.6933	3.0969	1.3956	1.3411	1.3211

To obtain the % of RSA, Equation 4 was used. When the % of RSA was obtained, it was then plotted onto a graph to get the half-maximum inhibitory concentration, or IC_{50}, where this number is the concentration of the sample that can use the DPPH free radical scavenging method to remove 50% of DPPH free radicals. The amount of leftover DPPH is directly correlated with the absorbance, which is inversely correlated with the tomato powder's capacity to scavenge free radicals. The tomato powder's ability to act as an antioxidant is demonstrated by this % of RSA value (Smith *et al.*, 2022). Figure 4 shows the %RSA for TP1, TP2, and TP3 where the samples contain enzyme AAPP with inlet temperatures of 140°C, 160°C, and 180°C, respectively. Figure 5 shows the % of RSA for TP4, TP5, and TP6 where the samples contain PAA with inlet temperatures of 140°C, 160°C, and 180°C, respectively. Figure 6 shows the %RSA for TP7, TP8, and TP9 where the samples contain enzyme pectinase from PAN with inlet temperatures of 140°C, 160°C, and 180°C, respectively.

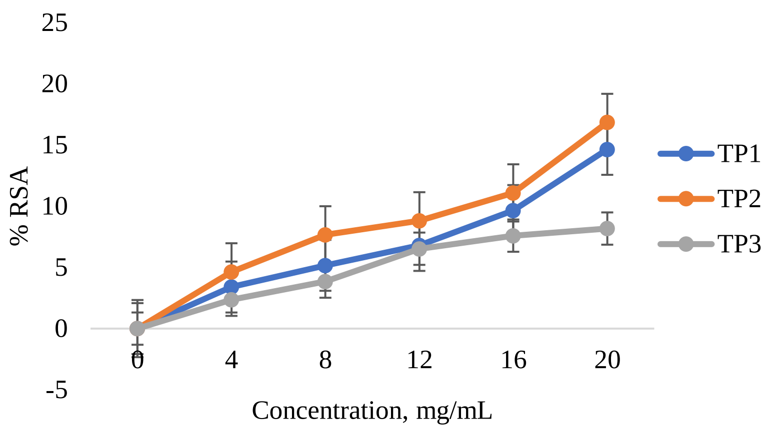

Figure 4. % of RSA for tomato powder that contain enzyme AAPP

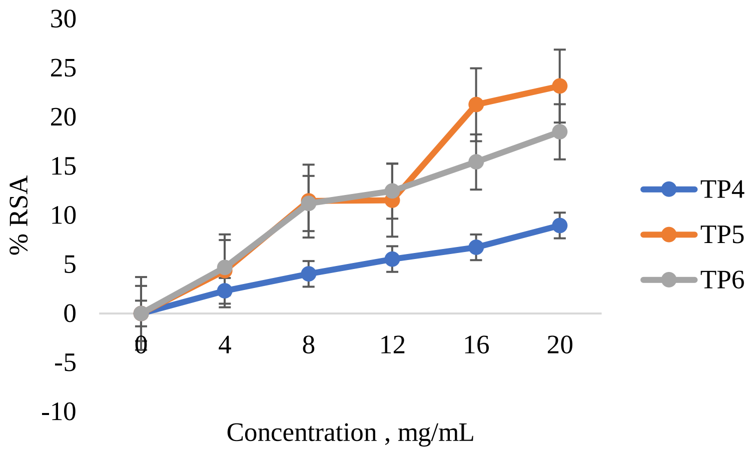

Figure 5. % of RSA for tomato powders containing enzyme PAA

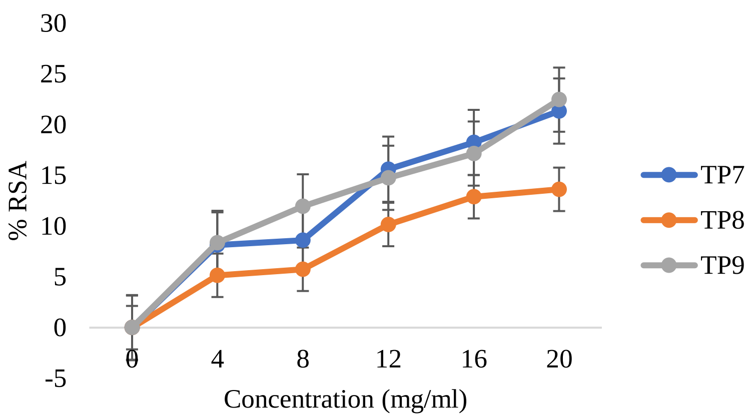

Figure 6. % of RSA for tomato powders containing enzyme PAN

Figure 7 shows all 9 samples of the DPPH assay graph which demonstrates the linear line for each tomato powder sample with the equation for Y-intercept and R^2 value. From the linear equation obtained from the DPPH assay graph, we can find the value of IC_{50} by intercepting from 50 on the y-axis and reflecting on the x-axis of the graph. Substituting 50 into 'y' in the equation of y = mx + c and solving to get the 'x' value which is the IC_{50} value. The values of IC_{50} are plotted in Figure 8.

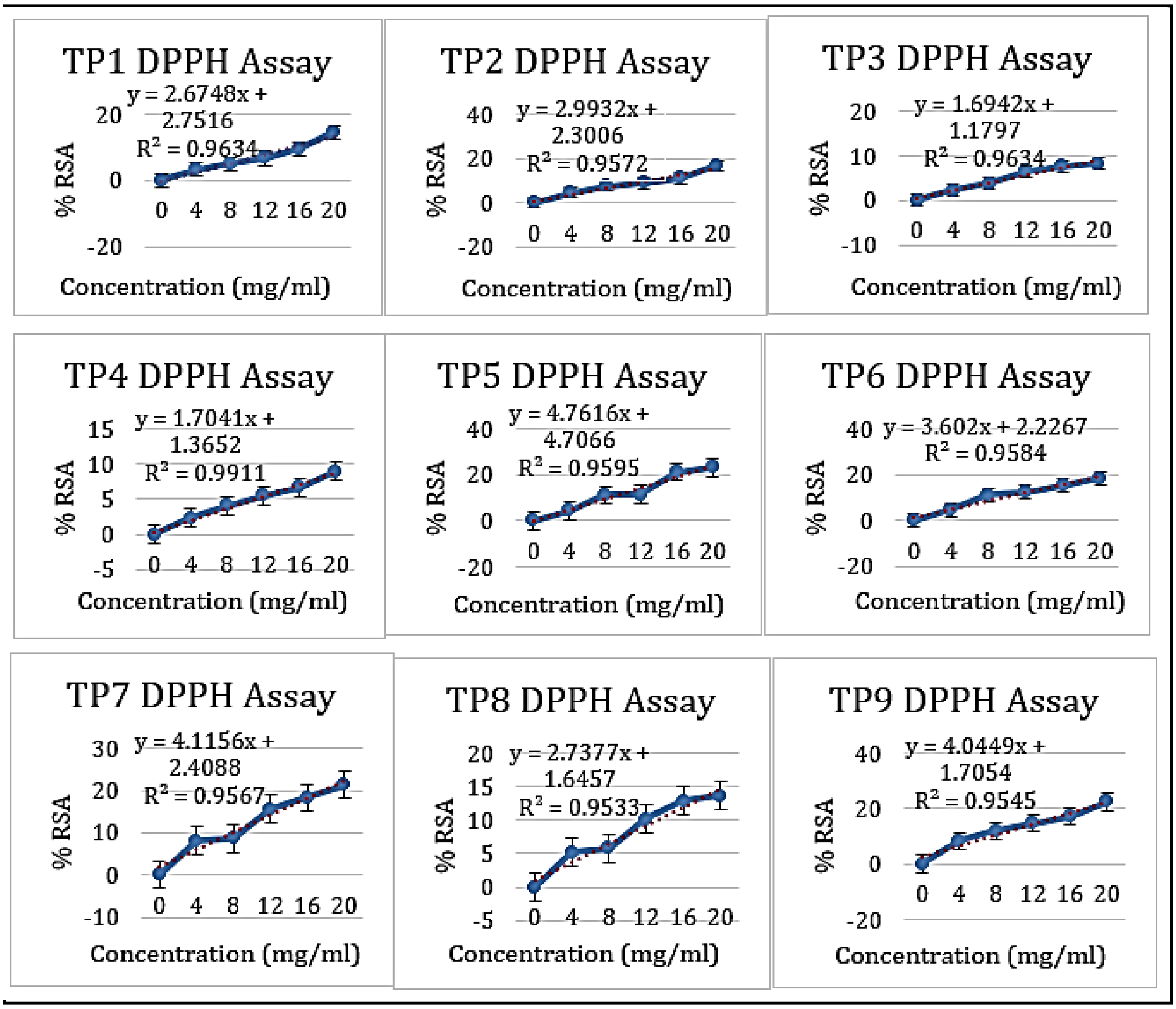

Figure 7. TP1-TP9 DPPH assay

The findings showed that all graphs achieved the linear best-fit slope. Higher and closer value of R^2 to 1, indicates a better fit of the model to the data. All of the samples DPPH assay chart have a good R^2 value which was more than 0.95. The IC_{50} value in the DPPH experiment denotes the amount of an antioxidant or chemical that is needed to scavenge 50% of the DPPH radicals. A low IC_{50} value means that less of the tested item must be present to scavenge the necessary amount of DPPH radicals, which denotes a greater antioxidant activity.

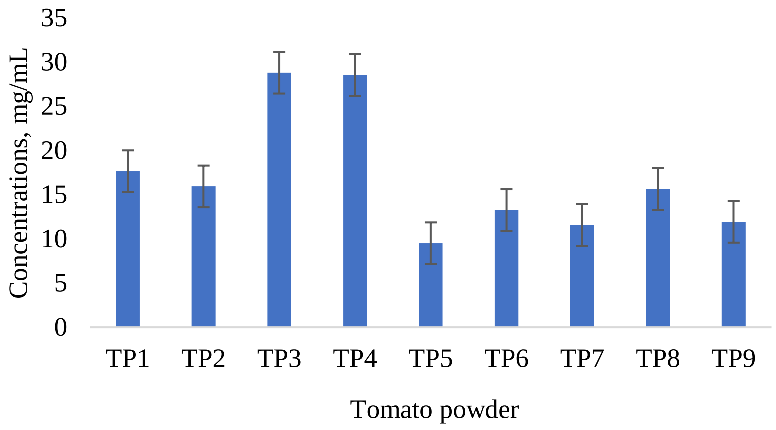

Figure 8. IC50 concentration

Figure 8 concludes that TP3 had the highest IC_{50} value among all samples. This indicates that enzyme AAPP in the tomato juice with the inlet temperature mentioned can produce the lowest quality tomato powder with a value of antioxidant near 50%. On the other hand, TP5 shows the lowest value of IC50 which is 9.51. Therefore, it indicates a smaller IC50 value. According to Leyva-Porras *et al.* (2021), a smaller IC50 means higher antioxidant activity. Despite the presence of a 10% carrier agent in the sample, the inlet temperature for this TP5 is slightly high which is 160°C, which is why it can produce a high antioxidant tomato powder. MD 10DE's antioxidant activity was studied over time by Tonon *et al.* (2009), who found a reduction in activity. It's interesting to note that at a higher temperature (35°C) compared to a lower temperature (25°C), antioxidant activity seems to be stronger. The antioxidant activity of dried red pitaya flesh was assessed by Wu *et al.* (2006) using the DPPH technique, which produced an IC50 value of 22.4±0.29.

3.6. Final Verdict

Table 4 represents the master table for the overall results ranking.

Table 4. Master table for overall results ranking

Description	**Samples**								
	TP1	**TP2**	**TP3**	**TP4**	**TP5**	**TP6**	**TP7**	**TP8**	**TP9**
Moisture content (%)	3	1	6	2	5	8	4	7	9
Colour (a* value prioritised)	2	3	1	4	6	7	8	9	5
Production yield	1	2	3	4	8	5	6	7	9
Hygroscopicity	1	4	7	2	6	8	3	5	9
Antioxidant activity	3	4	1	2	9	6	8	5	7
Total (sample)	10	14	18	14	34	34	31	33	39
Total (enzyme)		42			82			103	

Based on Table 4, the analysis shows that tomato powder sample TP9 gained the highest accumulated points among the other samples. The sequence of ranking was followed by a tie between TP5 and TP6, another tie between TP2 and TP4, and lastly TP1 as the most disregarded composition. From the findings, it can be concluded that tomato powder with a high inlet temperature is the most preferable sample. Another finding is that, from Table 4, we can see that tomato powder with the presence of enzyme pan which is TP7, TP8, and TP9 produces the highest points. Followed by tomato powder that contains enzyme PAA which are TP4, TP5, and TP6, and lastly, the least recommended samples are tomato powder that contains enzyme AAPP. This indicates that the enzyme PAN produces high-quality tomato powder with the help of carrier agents MD 20 DE and GA from Acacia Tree. Therefore, the tomato powder that is recommended is, TP9 with a moisture content percentage of 1.3%, colour analysis a* value of 3.14, production yield percentage of 42.65%, hygroscopicity % of 1.05%, and antioxidant activity value of 11.94 mg/mL.

4. Conclusions

Based on the results of the study, it is evident that the powder properties are significantly influenced by the inlet temperature and carrier agent concentration. The data obtained showed that the stability of the tomato powder is much better at higher temperatures (180^{o}C), a combination of both carrier agents at a concentration of 10%, and the usage of enzyme PAN in the concentration of 1% v/w. Findings show that a higher inlet temperature and combination with enzyme PAN can produce powder characteristics with low moisture content, high $a*$ colour index, high production yield, low hygroscopicity value, and high antioxidant activity. This indicates that the enzyme PAN produced high-quality tomato powder with the help of a carrier agent and inlet temperature. The powder analysis conducted in this study has a value of moisture content at 1.30%-7.00%, colour analysis indices of $a*$ at 1.31-5.72, $b*$ at 7.5-9.8, $L*$ at 89.6-95.39, production yield of 27.73%-42.65%, hygroscopicity value at 1.05%-6.79%, and antioxidant activity value of 9.51 mg/ml-28.81 mg/ml. From all the samples conducted in this study, TP9 was the best powder produced with a moisture content of 1.3%, colour analysis $a*$ value of 3.14, a production yield percentage of 42.65%, hygroscopicity % of 1.05%, an antioxidant activity value of 11.94 mg/mL. In this study, specific enzymes were employed solely for analysis, not for producing a product meant for consumption or ingestion. Hence, it is important to note that the enzymes used in the study were not meant to be incorporated into a final food product or consumed directly by humans. As a result, due to potential safety issues, the final spray-dried tomato powder is not advised for consumption. More research and testing are required to confirm the product's safety and compatibility for any future food-related uses.

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