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Effect of Carrier Types and Spray Drying Temperature on The Physicochemical Properties of Turmeric Coffee

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Abstract: Instant coffee has many issues regarding its ingredients and the amount of sugar contained in one sachet of 3 in 1 coffee. Nowadays, people have raised their awareness in practicing a healthy lifestyle thus by producing a healthier coffee mixture such as turmeric-coffee can be an alternative to promote a healthier lifestyle. On another hand, in producing turmeric coffee granules, the spray drying process would require a suitable operating condition to avoid problem such as stickiness of product material to the equipment glass and hence resulting in lower yield. This project aims to develop a healthier turmeric coffee-based granule with a suitable spray drying inlet temperature and its carrier as well as identifying the nutritional components such as total phenolic compound and total antioxidant activity. The bioactive ingredients of turmeric were extracted by using the subcritical water extraction method (SWE). The temperatures of 190 °C, 200 °C and 210 °C were chosen to determine the suitable inlet temperature of the spray drying process based on its physicochemical properties. For the best carrier and concentration, maltodextrin and Arabic gum at the concentration of 1.00 %, 3.00 % and 6.00 % were used were. The total phenolic content and antioxidant activity were determined using Folin-ciocalteu method and DPPH assay respectively. The study has successfully determined the best inlet temperature at 190 ˚C with 5.00 % Arabic gum as the optimum carrier for the highest yield (2.85 %) and solubility (94.70 %) contents and the lowest moisture content (4.17 %). When using maltodextrin as the carrier, both the TPC (18.67 GAE mg/mg) and the TAA (72.89 %) contents of the turmeric coffee granules were increased, probably due to the heat treatment from spray drying process. Meanwhile, the TAA decreased (44.66 %) when Arabic gum was used as the carrier. The findings of this study will shed the understanding upon the production of an alternative instant coffee as a healthy drink for the long term.

Keywords: Turmeric, *Curcuma Longa sp*, Turmeric Coffee, Spray Dry, Maltodextrin, Arabic Gum

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1. Introduction

Turmeric or the scientific name is *Curcuma Longa sp*. contains curcuminoids that have the greatest health-promoting effects. Three main bioactive compounds in the curcuminoids which are curcumin, demethoxycurcumin and bisdemethoxycurcumin were reported to have beneficial effects to health and the most being, curcumin [1]. Curcumin has various health benefits such as powerful anti-inflammatory, anti-oxidant, anti-microbial, anti-mutagenic and anti-cancer [2].

Coffee is a popular hot beverage in the world. The brew and aroma from the coffee in the morning can lift someone energy and mood. Most people in the world will start their day with a cup of coffee as the caffeine in the coffee can improve mood, brain function and also help in focusing and can reduce fatigue [3]. As coffee and turmeric have their respective benefits, the product incorporated both ingredients will add value and hence promote health advantages to human consuming it.

The instant 3 in 1 coffee has many issues and one of them is a lot of sugar as the main ingredient. Is it proposed that the instant coffee can be alternatively formulated to become a healthy beverage with the addition of turmeric as well as a substitution of regular white sugar with coconut sugar that has a low glycaemic index (GI). Moreover, the creamer or dairy ingredient in the make 3 in 1 coffee affecting lactose intolerant people as well as contributing to high calories and fat. The continuous consumption of instant 3 in 1 coffee might cause problems in the long term such overweight or obese, high blood pressure, heart attack and stroke [4]. Coconut milk instead of dairy milk is an alternative for lactose intolerant people as it is lactose-free milk with lower calories and fat contents. In addition, the use of coconut milk can increase the bioavailability of turmeric hence provide the health benefits it meant to give [2].

The spray-dried method is a thermal process that transforms liquid into powder. The two critical parameters for spray-dried process are their inlet temperature and the type of carrier used. The suitable inlet temperature and carrier are based on the sample's characteristics and compounds. Therefore, the different samples would require different inlet temperatures and carriers to be premium at quality. Thus, these parameters need to be identified and optimized before proceeding to the production using the spray-dried method. Hence, this project proposes an alternative instant drink with optimized processing conditions using a spray dryer with quantified nutritional contents of phenolic and antioxidant contents. In the long run, it is hoped that the intention of keeping a healthy lifestyle is achieved with this healthier ingredient instant coffee.

2. Methods

2.1 Extraction of turmeric using subcritical water extraction (SWE)

The root of the turmeric (*Curcuma longa*) was purchased freshly from Pahang. The subcritical water extraction (SWE) equipment has been developed by Dr. Mariam the founder of HALEA Natural Skin Care company, from a prototype on a laboratory size to a 70-litre industry-scale subcritical water extractor as shown in Figure 1. 10 kg turmeric was washed before being put into the grinder (MRC, United Kingdom) to grind into small size and place the ground turmeric in the extraction cell. The extraction cell was put into the SWE reactor and filled with 30 L reverse osmosis water. The ratio for the sample to water as a solvent is 1:3 and closed tightly. Then the nitrogen gas was purged into the reactor headspace for 1 hour to evacuate dissolved oxygen and refill with nitrogen gas [5]. Water was delivered through the system at a steady flow rate using a high-pressure pump. The water then fills the extraction cell through the bottom of the pressure cell. There is a heating jacket that surrounds the cell to heat the water and raise its temperature [5]. The setpoint is achieved by adjusting the pressure and temperature controls at 10 bar (1MPa) and 120 °C respectively. The extracts were exit the cell from the bottom after 15 minutes, passing through a heat exchanger and being cooled with water. The extracts in form of liquid were collected in a container. The extraction was filtered again before being put into a bottle to store in the freezer at 4 °C.

Figure 1: 70 L subcritical water extraction (SWE) equipment

2.2 Turmeric coffee mixture granules

16.0 g pure ground coffee (Kopi 434, Malaysia), 48.2 g coconut milk (Farm Fresh, Malaysia), 29.2 g coconut sugar (Caroma, Malaysia), 9.6 g turmeric and 1000 ml mineral water was weighed. The coffee was brewed with mineral water at room temperature for 12 hours. The coffee was mixed with coconut sugar and turmeric and stirred until dissolved before adding the coconut milk. All the mixture was stirred until homogenized. The sample was pumped into spray-dried with the condition of the air inlet temperature of the spray-dried (Solteq, United Kingdom) was set at 190 °C, 200 °C and 210 °C as the different parameters for this project [5]. The pump (Solteq, United Kingdom) speed of spray-dried is 10 rpm and the air blower (Solteq, United Kingdom) at 40 m^3/min is set as constant [5]. Lastly, the turmeric coffee in the form of granule were exist at the bottom of the spray-dried. The turmeric coffee granule was kept in an aluminium foil container to prevent the sample from being exposed to light and oxidised.

All the processes were duplicated but the sample will be added with a different carrier such as maltodextrin and Arabic gum with different concentrations that are 1.00 %, 3.00 % and 5.00 %.

2.3 Physicochemical analysis

2.3.1 Determination of Product yield

The method for yield analysis is taken from previous study with some alterations [6]. The sample before spray-dried in form of liquid was weighed and the reading was taken. After spray dried, the sample collected from the bottle sample on spray-dried in form of powder was taken and put on weighting boat to weighed it and the reading was taken. By using Eq. 1, the product yield of the sample will be calculated.

$$Yield = \frac{m_1}{m_2} \times 100.00\ \% \quad Eq.1$$

Where m_1 = mass of sample before spray dried (liquid)
m_2 = mass of sample after spray dried (powder)

2.3.2 Determination of Moisture content

For moisture content analysis the method is taken from the previous study with some modification [6], [7]. 0.60 g of sample (powder) were weighed in duplicate and placed on filter paper before being dried in drying oven at 105 °C for 2 hours with 40.00 % fan speed [6], [7]. The weighed sample will be taken out after 2 hours and the average will be calculated. The moisture content was calculated as in Eq. 2.

$$Moisture\ content = \frac{w - w_1}{w_1} \times 100\% \quad Eq. 2$$

Where w = mass sample before drying (0.6g)
w_1 = dry matter sample after 2 hours (g)

2.3.3 Determination of Solubility

The solubility analysis was determined according to the previous study with some modifications [6], [7]. 1 g sample (powder) was weighed and stirred with 100 mL water at ambient temperature using a magnetic stirrer for 5 minutes before being inserted into a 50 mL centrifuge tube. The sample was centrifuged at 9500 rpm for 10 minutes. The supernatant was poured into another beaker and the precipitate of the sample was collected and weighed on filter paper. The reading was taken and the sample was dried in a drying oven at 105 °C for 2 hours. The weight of the sample after 2 hours was taken. the solubility was calculated as in Eq.3.

$$Solubility = w - w_1 \, x \, 100\% \quad Eq. 3$$

Where w = mass before drying (precipitate) (g)
w_1 = mass after drying (g)

2.3.4 Determination of Colour

Colour analysis was carried out using Colorimeter (Hunter Lab, Australia) as shown in Figure 3 and the colour was expressed in the value of L* (darkness/whiteness), a* (greenes/redness) and b* (blueness/yellowness). 0.6 g of sample (powder) was at the sample port with the side to be measured toward the port. The powder was made flat against the port and completely coverered. The center button (GO) was pressed to take the reading. The sample is read and the value was displayed on the screen.

2.3.5 Determination of Total Phenolic Content (TPC)

The total phenolic content analysis was quantified using the Folin-Ciocalteu method as described by previous study with some modification [7], [8]. 10 ml of Folin-Ciocalteu solution (Sigma Aldrich, United States) was put into a 100 ml volumetric flask and was filled up with distilled water to the mark on the volumetric flask [8]. The volumetric flask was shaken gently to homogenize the solution. The flask was wrapped with aluminium foil because Folin-Ciocalteu is light sensitive. Before sample drying, 0.1 ml sample in form of liquid was pipetted into the test tube and mixed with 2 ml distilled water to dilute and for sample in form of powder. 0.05 g sample was dissolved in 10 ml of distilled water and 2 ml of sample was pipetted into the test tube. 2 ml of sodium carbonate (Sigma Aldrich, United States) is pipetted into the test tube and lastly, 2 ml of folin-ciocalteu was pipetted into the test tube. The colour of folin-ciocalteu will change from yellow to blue in the presence of phenolic compound. The test tube was wrapped with aluminium foil to incubate at room temperature for 1 hour before being put into a cuvette to test their absorbance by using a UV vis spectrophotometer at 760 nm. The methanol was used as blank. The calibration curve was produced using gallic acid as a standard. Good linearity of gallic acid was obtained (R^2 = 0.9653). The TPC was calculated as in Eq. 4.

$$y = 0.043x + 0.0199 \quad Eq. 4$$

Where y =absorbance
x = concentration from calibration curve

$$\text{Total phenolic compound} = \frac{cV}{m} \quad Eq. 5$$

$$x = cV \quad Eq. 6$$

Where c = concentration from calibration curve (mg/ml)
V = volume of the sample (ml)
m =mass of the sample (mg)

2.3.6 Determination of Total antioxidant activity (TAA)

2,2-diphenyl-1-picrylhydrazyl (DPPH) (Sigma Aldrich, United States) was used to determine the total antioxidant activity according to the previous study with some alteration [9]. 4 mg of 0.1 mM DPPH was inserted into the volumetric flask and methanol was added up until mark on the volumetric flask. The volumetric flask was covered with aluminium foil due to DPPH being sensitive to light. Before sample went through spray drying process (liquid), 0.5 ml sample was added into the test tube and then followed by 1.5 ml of 0.1 mM DPPH (Sigma Aldrich, United States). The test tube was vortexed and wrapped with aluminium to incubate at room temperature for 1 hour. For the sample in the form of powder, 0.05 g sample was dissolved in 10 ml distilled water and put into the test tube. After that, 2 ml of 0.1 mM DPPH was added into the test tube and was vortexed to mix the solution. The test tube was covered with aluminium foil and incubated at room temperature for 1 hour. The DPPH will turn colour from purple to yellow in the presence of antioxidant activity. The absorbance of the sample was analysed by using a UV-vis spectrometer (PG Instrument, India) at 516 nm. The methanol is used as blank and DPPH was used as control. Total antioxidant activity was calculated as in Eq. 7.

$$\text{Antioxidant activity (\%)} = \frac{Abs_{control} - Abs_{sample}}{Abs_{control}} \times 100 \quad Eq. 7$$

Where $Abs_{control}$ = absorbance reading of control
Abs_{sample} = absorbance reading of sample

3. Results and Discussion

3.1 Extraction of turmeric and Formulation of the tasty turmeric-coffee drink

The subcritical water extraction (SWE) equipment was operated at pressure and temperature of 10 bar (1 MPa) and 120 °C respectively. Time taken to extract the turmeric bioactive compound by using the SWE method is 15 minutes. The formulation of the tasty turmeric-coffee drink obtained from this project is 16.00 g coffee, 48.20 g coconut milk, 29.20 g coconut sugar, 9.60 g turmeric and 1000 ml mineral water.

The taste of the turmeric coffee has a hint of spice such as ginger and orange peel due to the taste of the turmeric powder itself being earthy and bitter with a bit of peppery spice [10]. The turmeric bitter flavour is subdued and replaced with a softer, more pleasant flavour when combined with coffee and coconut milk [10]. The coconut milk used in this project is from Farm Fresh, Malaysia which the taste of the coconut milk itself is creamy milk that has a pleasant aroma, a hint of sweetness and a lingering nutty after taste [11]. The sweetness of the turmeric coffee is added by the coconut sugar. Coconut sugar has a brown sugar flavour with traces of caramel that make the turmeric-coffee rich and warming, without being too sweet. The coconut sugar also contains inulin, a compound that could manage the blood sugar.

3.2 Suitable inlet temperature of spray-dried for turmeric-coffee

3.2.1 Product yield

Table 1 and Figure 2 show that at temperature 190 °C the yield of the product is highest (0.87 %) compared to 200 °C (0.46 %) and 210 °C (0.28 %). The relationship of the graph shows that the increase of the air inlet temperature of spray dryer, decrease the yield of the product. The behaviour of the yield product of turmeric coffee is the same as reported by previous study which the higher the air inlet temperature of the spray dryer, the lower the product yield of the orange juice powder [12]. This is due to the inadequate dry particles mostly adhered to the dried wall of the cyclone during the spray dry process at high temperatures such as 210˚C. From Figure 2, the graph concluded that the suitable inlet air temperature of spray-dried for turmeric coffee is at 190˚C at which product yield is at the highest. Hence, this temperature was used to evaluate the best carrier to be used in the spray-dry processing.

Table 1: Changes in the physicochemical properties of the spray-dried turmeric coffee granule

Qualitative analysis		Product yield (%)	Moisture content (%)	Solubility (%)	Colour		
					L*	a*	b*
Inlet air temperature of spray dry	190˚C	0.87	31.87	59.3	27.32	9.01	20.40
	200 ˚C	0.46	16.95	85.9	24.60	7.23	15.59
	210 ˚C	0.28	11.32	72.5	26.30	13.26	35.36

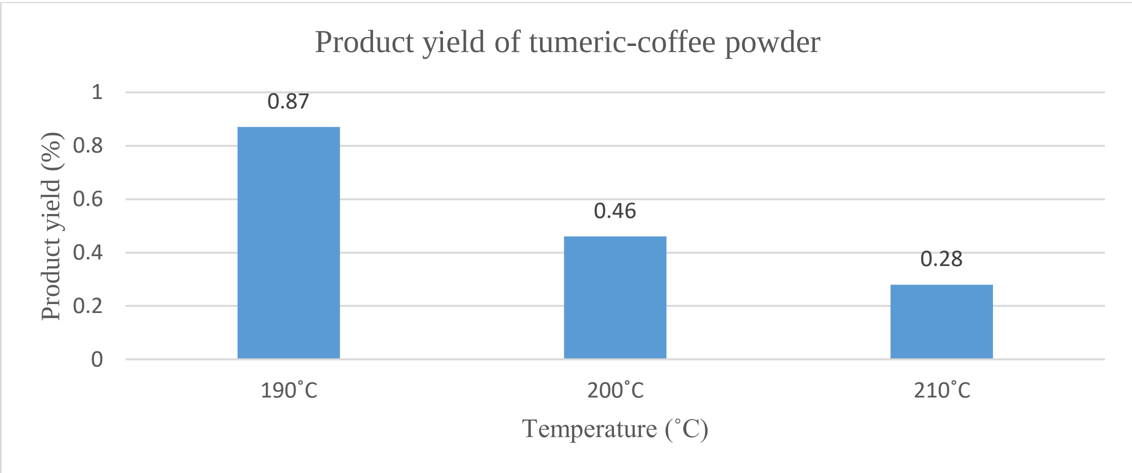


Figure 2: The product yield of turmeric coffee granules after spray dry at a different temperature

3.3 The Best Carrier and its Concentration for Producing Turmeric-Coffee Granules

The different types of carriers such as maltodextrin and Arabic gum were added into the turmeric coffee before being spray-dried to optimize the physicochemical properties of the powder. The different concentrations of the carrier such as 1.00 %, 3.00 % and 5.00 % were used to see which the best concentration is to produce the granules of turmeric coffee mixture.

3.3.1 Product yield

This is an analysis of the product yield of spray-dried turmeric coffee at the different types of carriers (maltodextrin and Arabic gum) and concentrations (1.00 %, 3.00 % and 5.00 %). Table 2 shows that the Arabic gum with 5.00 % concentration is the highest value of yield (2.85%) while at 1.00 % maltodextrin, the percentage of yield is the lowest (1.13 %). The yield of the product increases when carrier such as maltodextrin and Arabic gum is added into the turmeric coffee before spray drier.

Table 2: Changes in the physicochemical properties with different carriers concentration

Qualitative analysis		Product yield (%)	Moisture content (%)	Solubility (%)	Colour		
					L*	a*	b*
	1%	1.13	8.12	61.7	15.34	10.88	19.26

Maltodextrin	3%	1.90	10.70	87.1	32.65	3.60	28.49
concentration at 190˚C	5%	2.39	9.40	80.4	37.12	0.41	18.09
Arabic gum	1%	1.36	6.38	83.3	21.45	5.35	12.48
Concentration at	3%	2.25	7.91	89.5	32.26	3.15	18.86
190˚C	5%	2.85	4.17	94.7	46.53	0.97	23.73

The relationship of the graph in Figure 3 shows that the increased in the concentration of the carrier, will increase the yield of the product. The previous study also reported that a 3.00 % concentration of the carrier when added to the system can increase the product by three-fold [6]. The turmeric coffee, at 3.00 % concentration of the carrier was observed to increase approximately by twofold [6]. This statement proves that the presence of the carrier in the system can improve the product yield during the spray drying process. It can be concluded that the type of carrier and concentration of the carrier added into the turmeric coffee before spray-dried have a significant impact on the product yield of the turmeric coffee sample, where the highest yield is contributed by the 5.00 % Arabic gum as the carrier.

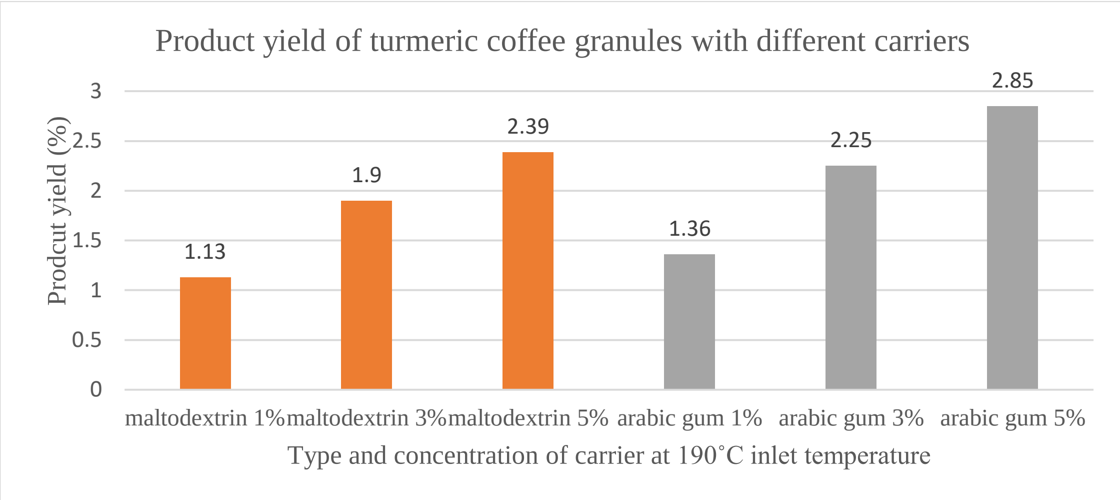


Figure 3: The product yield of turmeric coffee after spray dry at different types and concentrations of the carrier at inlet temperature of 190 °C

3.3.2 Moisture content

The data of moisture content for turmeric coffee after spray dried at the different types of the carrier (maltodextrin and Arabic gum) and concentration (1.00 %, 3.00 % and 5.00%) was shown in Table 2. Based on Figure 4, the moisture content is highest at 3.00 % maltodextrin (10.70 %) and the lowest moisture content is at 5.00 % Arabic gum (4.17 %). The relationship between moisture content and the concentration of carrier is fluctuate for both types of the carrier is maltodextrin and arabic gum. The moisture content is increased as the concentration increases at 1.00 % and 3.00 % before the moisture content drop at 5.00 % concentration. This can be supported with the previous study that reported with the addition of 3 g/100 g of carrier material raised the moisture content of mountain tea samples, which might be attributable to the hydrocolloid carriers improved water-holding ability [6].

However, raising the carrier material concentration from 3 to 5 g/100 g lowered the moisture content by roughly 13.00 %, which can be attributed to increased total solid content [6]. Similar findings also have been reported previous study [13]. Considering all of this, the presence of the carrier in the system has a significant role to reduce the moisture content of the product although the type of the carrier and the concentration of the carrier use does not give a huge impact on the moisture content. The lowest moisture content is preferable in a dried product, hence for this project 5.00 % arabic gum was the best.

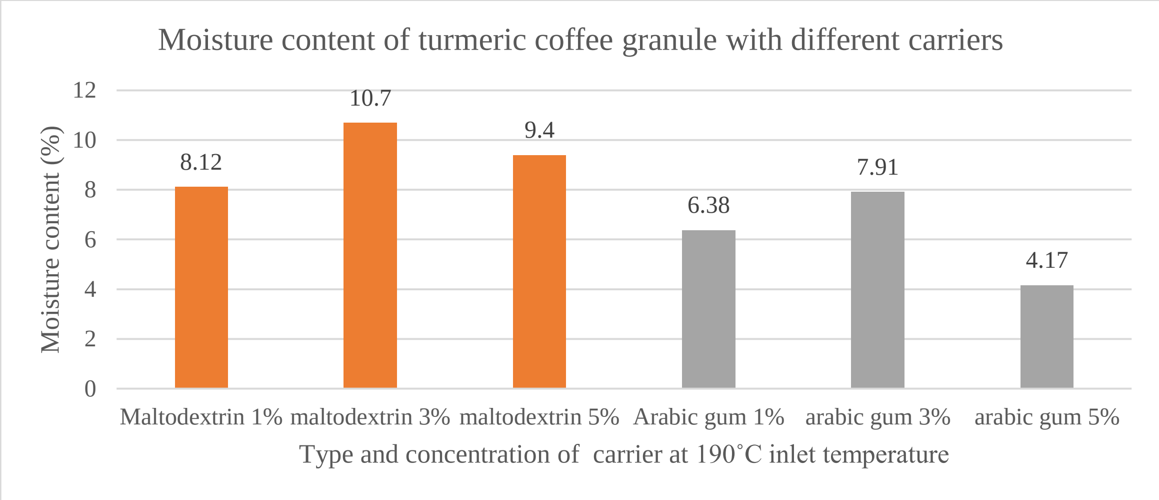


Figure 4: The moisture content of turmeric coffee after spray dry at a different type and concentration of carrier at inlet temperature of 190 °C

3.3.3 Solubility

Solubility is known as the ability of a powder to dissolve in water. It is desirable that the product has a high solubility so that it is easier to dissolve and prepared for consumption, rather than having the undissolved powder at the top of the liquid. Table 2 and Figure 5 shows that at 5.00 % Arabic gum at 190 °C has the highest solubility of the turmeric coffee powder (94.70 %). Meanwhile, at 1.00 % maltodextrin, the solubility of the powder is at the lowest. The relationship between the solubility and the concentration of the carrier is the solubility increases as the concentration of carrier increase for Arabic gum. While the maltodextrin trend for solubility and concentration of carrier is fluctuate which at higher at the concentrations of 1.00 % and 3.00 % the solubility increased and declined at concentration 5.00 %.

The previous study also has reported that with an increase in the concentration of the carrier material, the solubility of the mountain tea powders increased as well [6]. This is consistent with the previous studies that work on mango powder and sweet potato powder. The solubility of the powder at 190 °C inlet temperature (59.30 %) without carrier was increased by 30.00 % when the carrier (3.00 % Arabic gum) was added into the system before spray dry. This is because maltodextrin and arabic gum that is used as a carrier has a high property of solubility in water [14]. As a result, the type of carrier and concentration of carrier has a significant role in terms of solubility and 5.00 % Arabic gum added into the turmeric coffee can give the highest value of solubility.

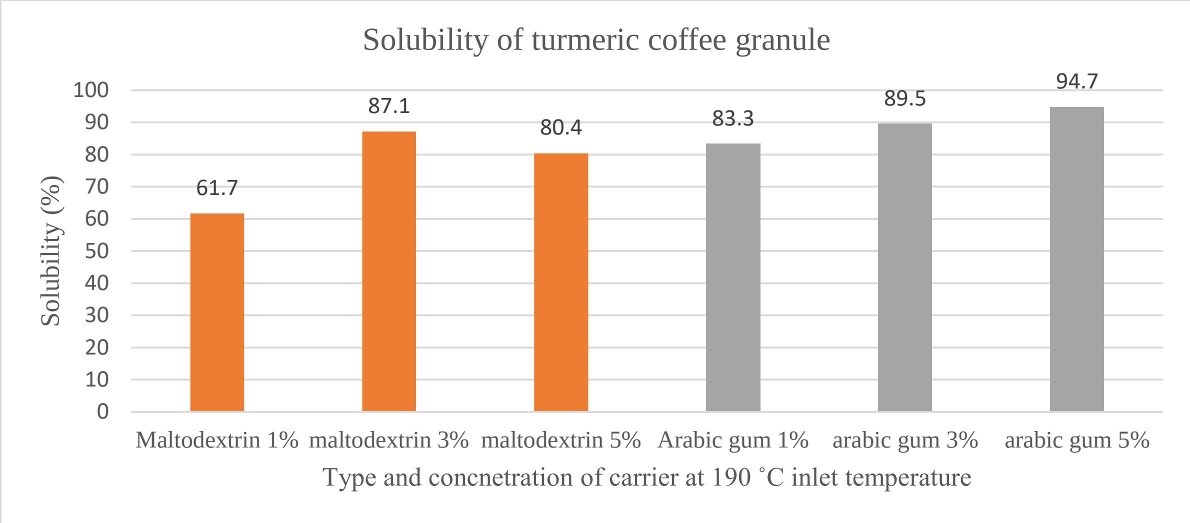


Figure 5: The solubility of turmeric coffee after spray dry at a different type and concentration of carriers at inlet temperature of 190 °C

3.3.4 Colour

Table 2 shows the colour value of turmeric coffee granules obtained after spray dried of the different carriers (maltodextrin and arabic gum) and concentrations (1.00 %, 3.00 % and 5.00%). From Table 1, the addition of the carriers makes the L* value decrease from 27.32 to 15.34 and 21.45 for 1.00 % maltodextrin and 1.00 % arabic gum respectively. This indicates that the powder become darker when the carrier was added but at different concentrations of the carrier, the L* value increase significantly, making the powder become more brightness at the higher concentration of carrier. The 5.00 % arabic gum gives the highest L* value (46.53) meanwhile 1.00 % maltodextrin gives the lowest L* value (15.34). The higher the concentration of the carriers, the lower the a* and b* value are, the higher the L* value for maltodextrin meanwhile for arabic gum, the lower the a* value, the higher the b* and L* value at a high concentration that makes the powder more yellowish and brighter.

This can be supported by previous study in the study of spray-dried mountain tea, the addition of the carrier and increasing the concentration resulted in lower the a* and b* values, but higher L* values for the powders [6]. The observation from the data can be compared visually with Figure 6 and Figure 7 which the higher the concentration of the carriers, the brighter and yellowish the powder is. From the result, the concentration of the carriers gives a significant effect on the colour of the turmeric coffee powder which makes the 5.00 % arabic gum produces brighter colour of turmeric coffee powder. The previous study has reported that the enhanced brightness at higher carrier concentrations was most likely because of the white colour impact of carrier, which resulted in the powder becoming white [15].

Figure 6: The colour of turmeric powder at 190 °C inlet temperature with different concentrations of maltodextrin carrier

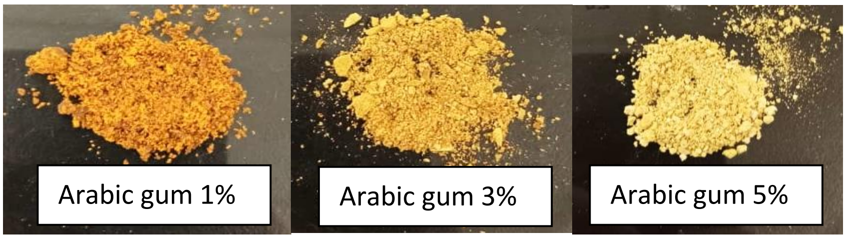


Figure 7: The colour of turmeric powder at 190 °C inlet temperature with different concentrations of arabic gum carrier

3.4 Determination of the Total Phenolic Content (TPC)

Table 3 shows the total phenolic content in turmeric coffee before and after spray-dried process. The colour of Folin-ciocalteu reagent used in TPC analysis changed from yellow to blue in the presence of the phenolic compound of the turmeric coffee sample as shown in Figure 8 and Figure 9. Gallic acid was used as a reference for determining the total phenolic content in this study.

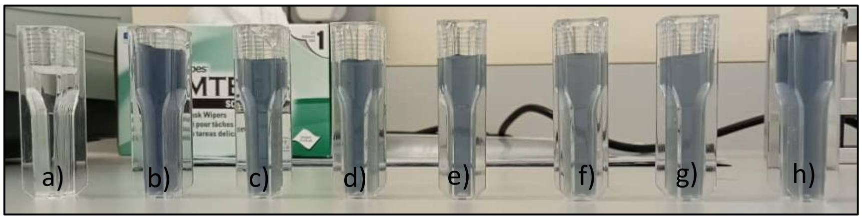


Figure 8: Analysis of the phenolic content of turmeric coffee granules before spray-dry process. a) methanol as control, b) sample without carrier, c) sample with 1% MD, d) sample with 3% MD, e) sample with 5% MD, f) sample with 1% AG, g) sample with 3% AG, h) sample with 5% AG

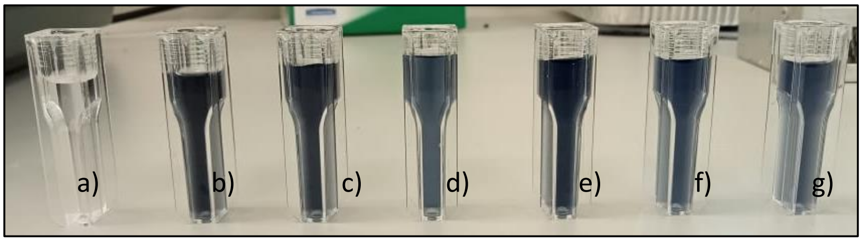


Figure 9: Analysis of the phenolic content of turmeric coffee granules after spray-dry process. a) methanol as control, b) sample without carrier at 190˚C inlet temperature, c) sample without carrier at 200˚C inlet temperature, d) sample without carrier at 210˚C inlet temperature, e) sample with 1% MD, f) sample with 3% MD, g) sample with 5% MD

From Figure 8, sample without carrier (b) was the darkest indicating the highest total phenolic content. Comparison between Figure 10 and Figure 11 shows that without a carrier the spray-dried sample has the highest total phenolic content. The total phenolic content after spray dry was significantly decreases as the inlet temperature of spray-dried increases based on Figure 10. This can be supported by a previous study that stated, the total phenolic content in mountain tea extract was lower as the high inlet temperature of spray-dried [6]. The temperature of the inlet spray dryer has a substantial impact on total phenolic content retention as this can be observed from Figure 10 which sample without a carrier at 210 °C of inlet temperature of spray dry has the lowest total phenolic content. Thus, the phenolic compounds have limited extreme temperature even though the phenolic compounds are thermally stable before the compound degradation and alter the molecular structure that leads to the low reactivity of the compound.

Table 3: Total phenolic content of turmeric coffee before and after spray drying

Qualitative analysis		Total phenolic compound (GAE mg/mg)	
		Before spray-dried (at ambient temperature)	After spray dried
Inlet air temperature of spray dry	190 ˚C	2.66	18.67
	200 ˚C	2.66	6.16
	210 ˚C	2.66	4.40
Maltodextrin concentration at 190˚C	1%	1.98	8.70
	3%	2.03	6.67
	5%	1.79	5.91
Arabic gum Concentration at 190˚C	1%	1.63	6.44
	3%	1.70	6.18
	5%	2.49	4.77

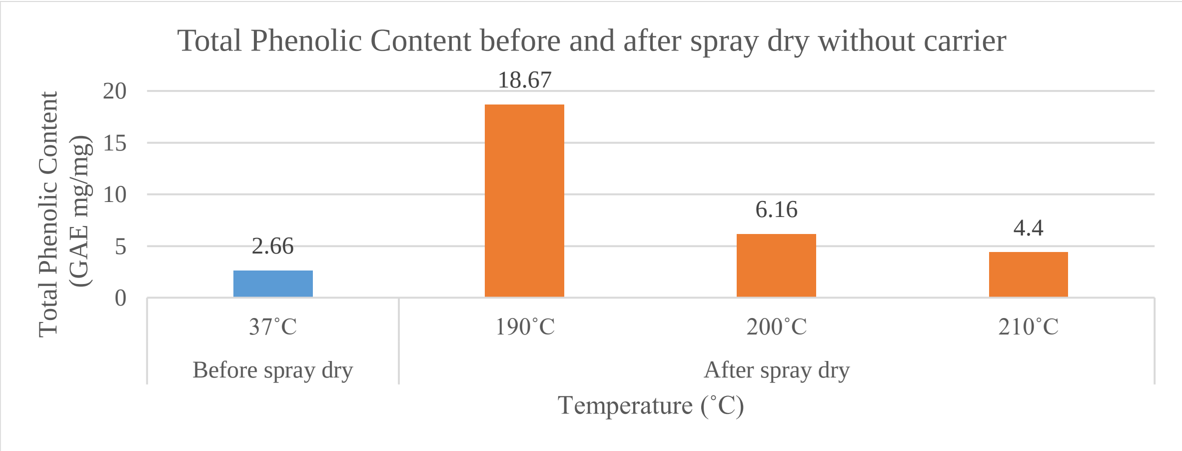
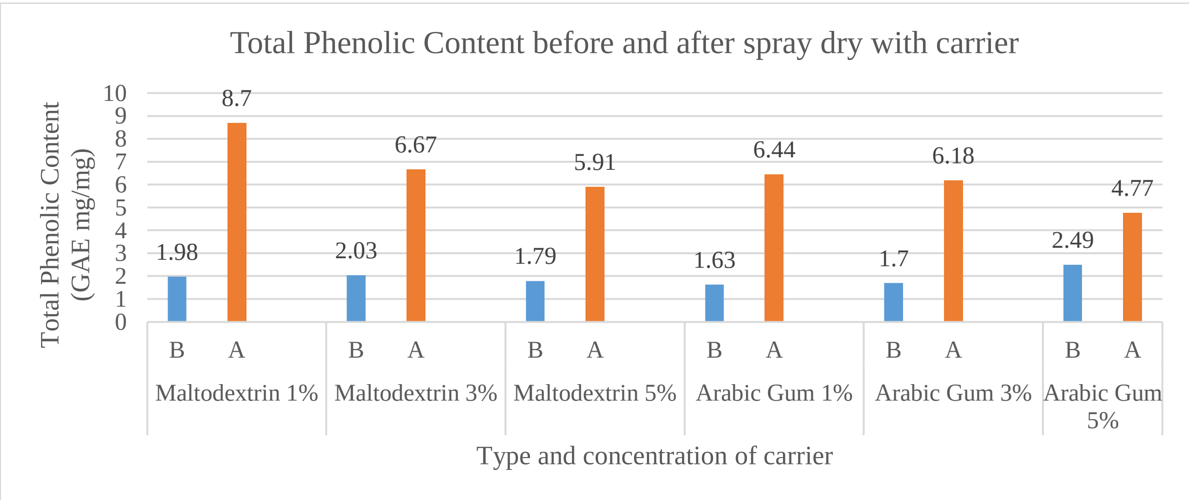


Figure 10: The total phenolic content of turmeric coffee before and after spray-dried at different temperature without carrier



Key: B = Before spray dry and A = After spray dry

Figure 11: The total phenolic content of turmeric coffee before and after spray-dried at 190˚C inlet temperature with different type and concentration of carrier

After spray drying, the concentration of the carrier increases and that makes the total phenolic compound decrease as shown in Figure 11. The trend of the total phenolic compound against concentration in this study has a similar trend with a previous study which also reported that the total phenolic compound of the spray-dried mountain tea extract decreases as the concentration of the carriers increases [6]. This is due to the dilution of the mountain tea extract in the final product with the addition of more carrier material.

Figure 10 shows that the total phenolic content of turmeric coffee after spray dried is higher compared to before spray dried which means that the temperature is increased as before spray dried, the temperature is at ambient temperature (37 °C) while after spray-dried the inlet temperature is 190 °C, 200 °C and 210 °C. The current study (turmeric coffee) findings are compatible with those of previous research on the spray drying of apricot juice, purple sweet potato pulp, and sapodilla powder [16]. It was mentioned that the faster the drying process is at higher temperatures, the shorter the heat exposure duration and the less heat degradation for heat-sensitive compounds [16]. Furthermore, the rise in TPC with increasing temperature might be attributable to polymerization and the release of bound polyphenols as temperatures were raised to 200 °C [16]. The finding shows that the inlet temperature is the vital parameter to retain the phenolic compound in turmeric coffee after spray-dried while the presence of carrier and concentration of carrier does not significantly affect the total phenolic compound before and after spray drying as shown in Figure 10 and Figure 11 respectively.

3.5 Determination of the Total Antioxidant Activity (TAA)

Analysis of the total antioxidant activity of turmeric coffee before and after spray dried is shown in Table 3, Figure 14 and Figure 15 respectively. When using the DPPH assay the reagent turned colour from purple to yellow in the presence of antioxidant activity in the turmeric coffee sample as shown in Figure 12 and Figure 13.

Table 4: Total antioxidant activity of turmeric coffee before and after spray drying

Qualitative analysis		**Total antioxidant activity (%)**	
		Before spray-dried (at ambient temperature)	**After spray dried**
Inlet air temperature of spray dry	190 °C	44.23	72.89
	200 °C	44.23	72.73
	210 °C	44.23	70.33
Maltodextrin concentration at 190°C	1%	47.85	49.76
	3%	55.98	39.63
	5%	27.83	32.70
Arabic gum Concentration at 190°C	1%	69.78	44.66
	3%	65.23	11.88
	5%	60.37	4.70

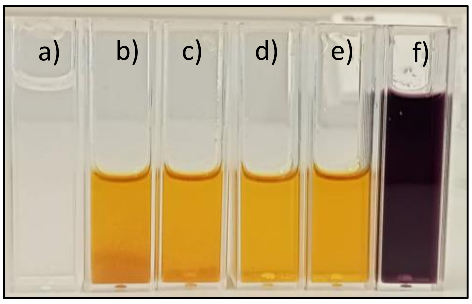


Figure 12: Analysis of the total antioxidant activity of turmeric coffee granules before spray dry process. a) methanol as blank, b) sample without carrier, c) sample with 1.00 % MD, d) sample with 3.00 % MD, e) sample with 5.00 % MD, f) DPPH as control

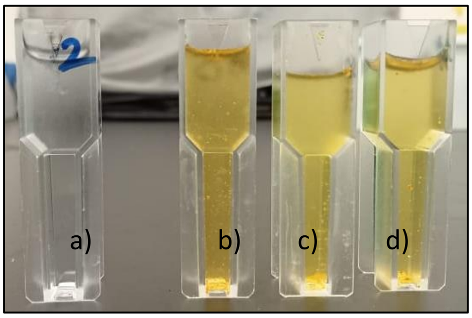


Figure 13: Analysis of the total antioxidant activity of turmeric coffee granules after spray dry process. a) methanol as blank, b) sample without carrier at 190 °C inlet temperature, c) sample without carrier at 200 °C inlet temperature, d) sample without carrier at 210 °C inlet temperature

The highest total antioxidant activity after spray dried was at 190˚C inlet temperature without carrier and the lowest total antioxidant activity was 5% Arabic gum at 190˚C inlet temperature. Figure 14 shows that after spray dry the total antioxidant activity slightly decreases when the inlet temperature increase. The observation was similar to the previous study that stated the total antioxidant activity for date powder was reduced when the inlet temperature is high because the antioxidant activity is vulnerable under thermal treatment [17]. The higher the concentration of the carrier, the lower the total antioxidant activity in turmeric coffee after spray dried as shown in Figure 15.

The observation was different from other studies that stated the carrier does not influence the total antioxidant activity [17]. The total antioxidant activity without carrier after spray dried is higher compared to before spray dried as shown in Figure 14. This observation shows that processing of turmeric coffee by thermal does not cause a drastic loss in the antioxidant value. According to a previous study, it shows that heating improves the antioxidant activity in fruits and vegetables by enhancing the antioxidant characteristics of naturally existing molecules or forming new compounds with antioxidant activity, such as Maillard reaction products [18].

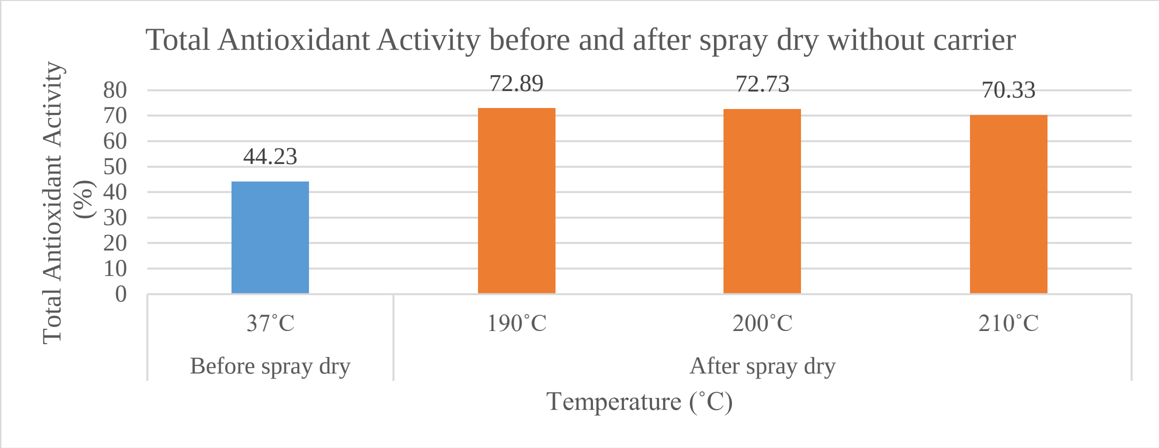
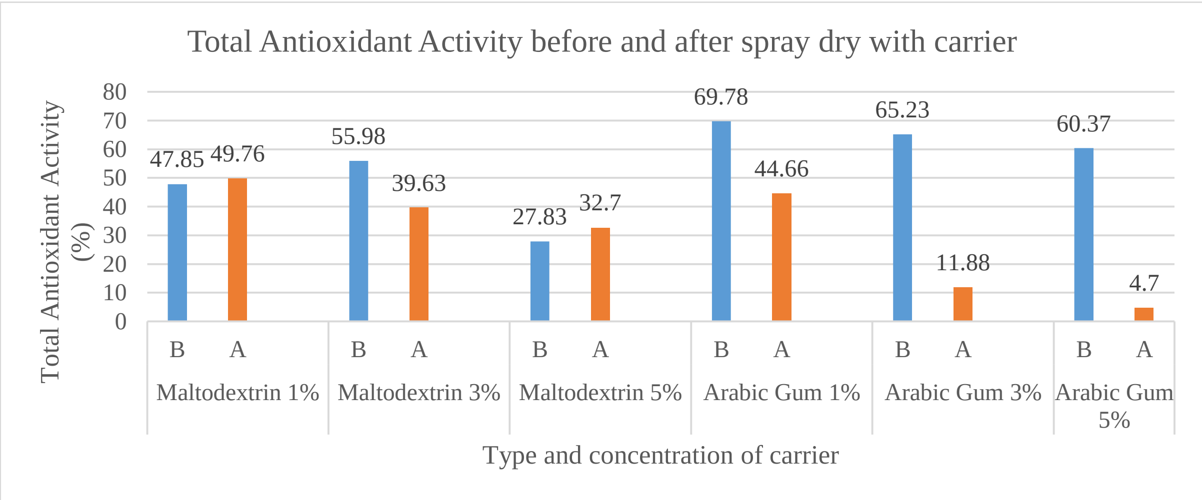


Figure 14: The total antioxidant activity of turmeric coffee before and after spray-dried at different temperature without carrier



Key: B = Before spray dry and A = After spray dry

Figure 15: The total antioxidant activity of turmeric coffee before and after spray-dried at 190˚C inlet temperature with different type and concentration of carrier

The trend between TAA and temperature without a carrier for before and after is in contrast with the trend of TAA and concentration of carrier before and after as shown in Figure 14 and Figure 15. Both types of the carrier (maltodextrin and arabic gum) shows that the total antioxidant before spray dried is higher compared to after spray drying. This finding is similar to previous studies that before spray dried, the mixture of *Morindacitrifolia L.* and *Beta vulgaris L.* fruit extract's total antioxidant activity is higher compared to after spray drying process [19]. Between fruit extract (sole as well as mixed) and spray dried powder, there was a significant loss in antioxidant activity [19]. This is due to the spray-dried high temperature (140 °C), which might cause all of the bioactive components to be volatilized [19].

This is in agreement with others who stated that the kind of additives used and the intake drying temperature had a major impact on the retention of volatile components in durian fruit [19]. This is also in agreement with some who believe that lowering the temperature in the spray drying process might reduce the loss of bioactive components [19]. The finding for this study shows that the inlet temperature has a greater impact to enhance the total antioxidant activity at limited extreme temperatures. The type of carriers and concentration of carriers such as arabic gum give a big effect on the total antioxidant activity of turmeric coffee before and after spray drying.

4. Conclusion

The study has achieved its objectives. The bioactive ingredients of turmeric (*Curcuma Longa*) has been successfully extracted by using subcritical water extraction (SWE), with the new formulation for turmeric coffee have been developed using ingredients such as 16.0 g coffee, 48.2 g coconut milk, 29.2 g coconut sugar, 9.6 g turmeric and 1000 ml mineral water. Secondly, the best inlet temperature for the spray drying process is determined to be at 190 °C with the highest yield of 0.87 %. Thirdly, the best carrier is identified to be arabic gum with concentration of 5.00 % to give product of highest yield (2.85 %) and solubility (94.70 %), and lowest moisture content (4.17 %). Finally, the total phenolic compound (TPC) of turmeric coffee powder increased (18.67 GAE mg/mg) due to heat treatment from spray drying. The total antioxidant activity (TAA) of turmeric coffee also increased (72.89 %) after the spray drying process but the TAA decreased (44.66 %) when arabic gum was used as the carrier.

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References

[1] S. J. Stohs, O. Chen, S. D. Ray, J. Ji, L. R. Bucci, and H. G. Preuss, “Highly bioavailable forms of curcumin and promising avenues for curcumin-based research and application: A review,” *Molecules*, vol. 25, no. 6. MDPI AG, 2020. doi: 10.3390/molecules25061397.

[2] S. Prasad and B. B. Aggarwal, “Turmeric, the golden spice: From traditional medicine to modern medicine,” in *Herbal Medicine: Biomolecular and Clinical Aspects: Second Edition*, CRC Press, 2011, pp. 263–288. Accessed: Jun. 16, 2021. [Online]. Available: https://www.ncbi.nlm.nih.gov/books/NBK92752/

[3] J. v. Higdon and B. Frei, “Coffee and health: A review of recent human research,” *Critical Reviews in Food Science and Nutrition*, vol. 46, no. 2, pp. 101–123, Mar. 2006, doi: 10.1080/10408390500400009.

[4] J. Kubala, “Almond Milk vs. Cow’s Milk vs. Soy Milk vs. Rice Milk,” *hea*, 2020. https://www.healthline.com/health/milk-almond-cow-soy-rice#cows-milk (accessed Jun. 16, 2021).

[5] M. Valizadeh Kiamahalleh, G. Najafpour-Darzi, M. Rahimnejad, A. A. Moghadamnia, and M. Valizadeh Kiamahalleh, “High performance curcumin subcritical water extraction from turmeric (Curcuma longa L.),” *Journal of Chromatography B: Analytical Technologies in the Biomedical and Life Sciences*, vol. 1022, pp. 191–198, Jun. 2016, doi: 10.1016/j.jchromb.2016.04.021.

[6] H. Şahin Nadeem, M. Torun, and F. Özdemir, “Spray drying of the mountain tea (Sideritis stricta) water extract by using different hydrocolloid carriers,” *LWT - Food Science and Technology*, vol. 44, no. 7, pp. 1626–1635, Sep. 2011, doi: 10.1016/j.lwt.2011.02.009.

[7] P. Susantikarn and * Donlao, “Optimization of green tea extracts spray drying as affected by temperature and maltodextrin content,” 2016.

[8] M. F. Razali, N. A. M. Fauzi, A. Sulaiman, and N. A. A. Rahman, “Effect of high-pressure processing (Hpp) on antioxidant, diastase activity and colour for kelulut (stingless bee) honey,” *Jurnal Teknologi*, vol. 81, no. 3, pp. 91–98, May 2019, doi: 10.11113/jt.v81.13105.

[9] M. F. N. Akhmazillah, M. M. Farid, and F. V. M. Silva, “High pressure processing (HPP) of honey for the improvement of nutritional value,” *Innovative Food Science and Emerging Technologies*, vol. 20, pp. 59–63, Oct. 2013, doi: 10.1016/j.ifset.2013.06.012.

[10] B. Panchal, “Turmeric Coffee Recipe (Easy & Tasty) | Holland & Barrett,” *Holland & Barrett*, Apr. 2019. https://www.hollandandbarrett.com/the-health-hub/food-drink/drinks/coffee/turmeric-coffee-recipe/ (accessed Jan. 11, 2022).

[11] J. Thym, “Taste-off: The best -- and worst -- coconut milk,” *The Mercury News*, Mar. 20, 2017. https://www.mercurynews.com/2017/03/20/taste-off-the-best-coconut-milk-and-the-murky-mistakes/ (accessed Jan. 11, 2022).

[12] G. R. Chegini and B. Ghobadian, “Spray Dryer Parameters for Fruit Juice Drying,” *World Journal of Agricultural Sciences*, vol. 3, no. 2, pp. 230–236, 2007.

[13] S. Y. Quek, N. K. Chok, and P. Swedlund, “The physicochemical properties of spray-dried watermelon powders,” *Chemical Engineering and Processing: Process Intensification*, vol. 46, no. 5, pp. 386–392, May 2007, doi: 10.1016/j.cep.2006.06.020.

[14] J. K. M. Lee, F. S. Taip, and H. Z. Abdulla, “Effectiveness of additives in spray drying performance: a review,” *Food Research*, vol. 2, no. 6, pp. 486–499, Dec. 2018, doi: 10.26656/fr.2017.2(6).134.

[15] S. Y. Chong and * Wong, “Effect of spray dryer inlet temperature and maltodextrin concentration on colour profile and total phenolic content of Sapodilla (Manilkara zapota) powder,” 2017.

[16] H. T. T. Do and H. V. H. Nguyen, “Effects of spray-drying temperatures and ratios of gum arabic to microcrystalline cellulose on antioxidant and physical properties of mulberry juice powder,” *Beverages*, vol. 4, no. 4, Dec. 2018, doi: 10.3390/beverages4040101.

[17] A. Manickavasagan *et al.*, “Physicochemical Characteristics of Date Powder Produced in a Pilot-Scale Spray Dryer,” *Drying Technology*, vol. 33, no. 9, pp. 1114–1123, Jul. 2015, doi: 10.1080/07373937.2015.1014045.

[18] K. Samborska *et al.*, “The Effect of Low-Temperature Spray Drying with Dehumidified Air on Phenolic Compounds, Antioxidant Activity, and Aroma Compounds of Rapeseed Honey Powders,” *Food and Bioprocess Technology*, 2019, doi: 10.1007/s11947-019-02260-8.

[19] D. Krishnaiah, K. B. Hiaw, R. Sarbatly, S. M. Anisuzzaman, and R. Nithyanandam, “Spray Drying of Morinda Citrifolia L. and Beta Vulgaris L. Fruit Extract and Its Synergistic Effect,” *International Journal of Chemical Engineering and Applications*, 2012, doi: 10.7763/ijcea.2012.v3.223.