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Effect of Carrier Types and Spray Drying Temperature On the Physicochemical Properties of Turmeric Tea

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Abstract: Unhealthy beverages have a variety of negative health effects, yet people continue to drink them because they taste good, so this triggered the need for a better, healthier and instant beverage as alternatives, and the quality of the resulting powder is determined by the operational variables and parameters in the spray drying process. The low glass transition temperature of the low molecular weight sugars included in such goods, primarily sucrose, glucose, and fructose, causes powder stickiness. The study was conducted to extract bioactive compound of turmeric using subcritical water extraction and formulate basis for tasty turmeric tea, to determine suitable inlet air temperature of spray dryer to produce turmeric tea granules based on the best physicochemical properties, to determine the best type of carrier agent and its concentration to produce turmeric tea granules based on the best physicochemical properties and to evaluate the total phenolic content and total antioxidants activity of the produced turmeric tea granules. The bioactive ingredients of turmeric were extracted using subcritical water extraction. The tea granules were obtained using spray drying process with the inlet temperature of 190, 200 and 210 ^{o}C. The best inlet temperature and type of carrier (Arabic gum vs. maltodextrin) were determined via optimization of yield, moisture content and solubility. The physicochemical analysis, total phenolic content (TPC) and total antioxidants activity (TAA) were also quantified. The study successfully determined the best inlet temperature at 190 ^{o}C and 6.00 % maltodextrin as the optimum carrier for highest yield (0.27 g/100g) and solubility (88.50 %). The TPC of turmeric tea increased due to heat treatment from spray drying. Meanwhile, the TAA of turmeric tea decreased 56.578 % after spray drying process but the TAA increased to 77.177 % when Arabic gum was used as the carrier. The findings of this study will shed the understanding upon the production of an alternative instant tea that is healthier and with better nutritional contents.

Keywords: Turmeric Tea, Spray Drying, Maltodextrin, Arabic Gum, Temperature

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1. Introduction

Turmeric is made from the rhizome of *Curcuma longa L.* (*Zingiberaceae*)[1]. Curcumin, demethoxycurcumin, and bisdemethoxycurcumin are three of the many physiologically active components of turmeric, the most common of which is curcumin [1]. The yellow pigment curcumin, also known as diferroyl methane, accounts for 60-70 percent of the crude turmeric extract and is the major curcuminoids studied for health promotion purposes. Many preclinical investigations have found many potential health benefits, such as the therapy of heart disease, arthritis, Alzheimer's disease, gastrointestinal illnesses, and metabolic syndrome (MetS) [1]. In this study, turmeric was the main compound that used to make the tea as the objectives of this study were to extract bioactive compound of turmeric using subcritical water extraction and formulate basis for tasty turmeric tea, to determine suitable inlet air temperature of spray dryer to produce turmeric tea granules based on the best physicochemical properties, to determine the best type of carrier agent and its concentration to produce turmeric tea granules based on the best physicochemical properties and to evaluate the total phenolic content and total antioxidants activity of the produced turmeric tea granules.

1.1 Spray drying

In comparison to vacuum and freeze drying, spray drying is the most extensively used treatment method for making the properties of liquid materials such as juices and milk very comparable to the original materials [2]. This is performed by spraying the liquid substance into a drying chamber with a hot air stream. Spray drying requires intricate interplay of process, equipment, and load characteristics, all of which influence the end product's quality [3]. The final product's physicochemical qualities are primarily determined by the input temperature, air flow rate, supply flow rate, atomizer speed, carrier, and carrier concentration [3].

1.2 Carrier

Spray drying is frequently used with additional substances known as carriers such as maltodextrin (MD) and gum Arabic (AG) to support the spray drying process because the problem of powder stickiness is primarily caused by the low glass transition temperature of the low molecular weight sugars present in such products, primarily sucrose, glucose, and fructose [3]. Maltodextrin can be used as a drying aid for difficult-to-dry materials such as hygroscopic, sticky, or viscous substances. The efficient recovery of the product reduced when maltodextrin levels decreased [4]. This is due to the bulk feed's low overall solid content and density. Because of the low density, low viscosities can result in increased radial velocities [4]. Gum Arabic is a hydrophilic colloid with a polysaccharide chain and a low protein content that overcomes stickiness and is an oxidation-sensitive component due to its strong emulsifying characteristics and low viscosity in aqueous solution [5]. According to Suhag et al. (2016)'s study on Arabic gum in honey powder, the water content of the powder dropped as the inlet temperature increased. This is due to the fast heat transfer between the product and the dry air, the significant driving force for water evaporation, and the formation of a powder with a low water content [5]. Inlet air temperature and carrier concentration had a substantial impact on product yields, but not carrier type [6].

1.3 Stability properties

The colour change caused by changes in intake air temperature is caused by non-enzymatic browning reactions such as caramelization and Maillard reactions that occur throughout the drying process [7]. Because the colour of the product changes with the amount of carrier agent and the temperature of the intake air, the powdered drink's drying conditions must be carefully designed to retain colour as one of the quality attributes [7]. Fazaeli et al. (2012) discovered that the apparent density of a powder is inversely proportional to its solubility [7]. The smaller the density and the higher the solubility, the higher the drying temperature. The temperature of the incoming air had no effect on the water content of the powder [6]. According to Nadeem et al. (2011), adding 3 g/100 g of carrier material boosted the water content by 43.00 %. This is assumed to be related to the hydrophilic colloid carrier's improved water retention capacity [6]. However, increasing the carrier material concentration from 3 to 5 g/100 g lowered the water content by 13%, which may be connected with an increase in total solid content [6]. Furthermore, it has been found that phenolic compounds are particularly temperature sensitive and readily disintegrate when heated [8]. According to Tran et al. (2018), increasing the spray drying temperature reduces the total phenol content (TPC) of the lemongrass leaf extract powder. [8]. The drying process then damages or eliminates molecules that can have a synergistic influence on antioxidant activity, contributing to a decline in the antioxidant effect of the dried product [9].

2. Materials and Methods

The methodology that is used to achieve the the objectives of this study. The flowchart is illustrated in Figure 1.

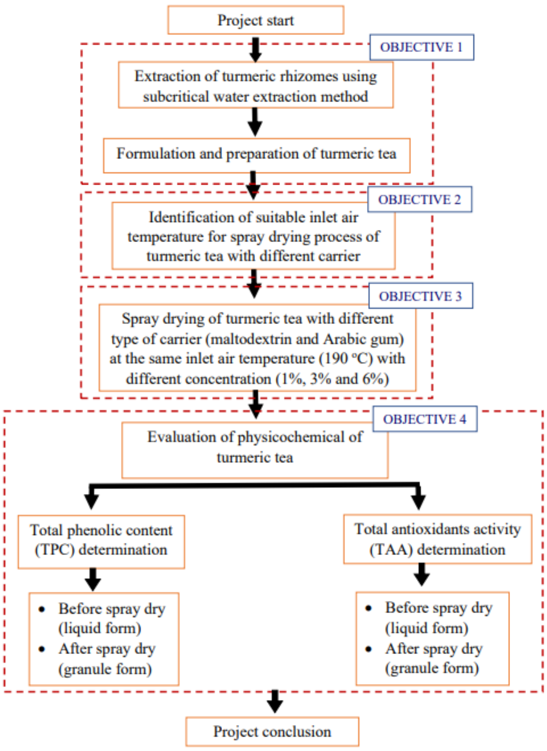

Figure 1: Process flowchart of the project

2.1 Experimental procedure

The turmeric that was extracted by subcritical water extraction and 500 mL extracted solution was mixed with 10 g coconut sugar and 2 g cinnamon powder. The solution was heated at about 50 °C and gently agitated with a magnetic stirrer before spray drying process was conducted as shown in Figure 2 [10]. Three sample solutions were prepared and used for different inlet air temperatures (190, 20 and 210 °C) of the spray dryer (TM-6000YHINO, China) in order to determine the optimum temperature prior based on its yield, moisture content, solubility and color of the produced granules. Once, the best temperature was determined, the different types of carriers (Arabic gum (Dexatama, Indonesia) and maltodextrin (Elite-indus, China)) with three different concentrations, 1, 3 and 6 g/100 g, on total solid basis were evaluated [6]. Figure 2 showed a spray drying process equipment of producing turmeric tea granules.

Figure 2: 1000 mL of sample was heated on the hot plate

Figure 3: Spray drying process of turmeric tea in the lab

2.2 Product yield

The drying yield was calculated by dividing the weight of the mass of solids recovered from the spray dryer's product collector and main chamber by the total mass of solids fed to the spray dryer as shown in Eq. 1[7].

$$\text{Product yield} = \frac{Weight\ of\ spray\ dried\ powder\ produced}{Total\ mass\ of\ feed} \times 100 \quad \ldots\ldots\ldots\ Eq.\ 1$$

2.3 Moisture content

According to AOAC (2000), the moisture content of dried samples was evaluated by oven (Therm0, US) drying at 105 °C for 24 hours (or until constant weight was attained), as described [11]. Samples weighing 0.5 – 0.6 g were weighed and dried in an oven [6]. For 2 hours, the sample was heated to 105+1 °C (as the constant weight had reached). The moisture content was calculated using Eq. 2.

Moisture content was calculated by:

$$Moisture\ content\ = \frac{W - W_1}{W_1} \times 100\% \ \ldots\ldots\ldots\ Eq.\ 2$$

where,

W is weight before drying process

W1 is weight after drying process

2.4 Solubility

1 g of the turmeric tea powder was suspended in 10 mL of water at 30 °C in a centrifuge tube [12]. The suspension was stirred continuously for 30 minutes before centrifugation (Therm0, U.S) at 9,500 rpm for 10 minutes [12] and the supernatant was poured in the conical flask while the crumb was poured on the filter paper (Fisherbrand, U.S) and weigh before drying at 105 °C until the weight was constant [12]. The weight of solids recovered after drying was used to calculate the water solubility (%). The solubility was calculated using Eq. 3.

Solubility of spray dried was calculated by:

$$\text{Solubility} = W - W_1 \times 100\% \ \ldots\ldots\ldots\ldots \ Eq.\ 3$$

Where,

W is weight before drying process,

W_1 is weight after drying process

2.5 Colour analysis

Colour analysis is performed using a tristimulus colorimeter (Therm0, U.S) equipped with a CR400 measurement head, and the colours are L* (darkness/whiteness), a* (greenness/redness), b* (blueness/yellowness) [6]. 3 g of powder was placed in the sample holder of the device above the light source (minimum height of the sample in the sample holder is about 0.5 cm) and the values for each colour were given as an average of 5 determination [6]. Prior to each measurement, the instrument was standardized for white tiles with L* = 96.96, a* = 0.08, b* = 1.83 [6].

2.6 Total phenolic content (TPC) determination

The Folin–Ciocalteu technique, as developed by prior work [13], was used to determine the total phenolic content of samples. After spray drying, 5 g of each turmeric tea sample was diluted to 50 ml with distilled water, and 2 ml of dilutes turmeric tea was combined with 2.5 ml of 0.2N Folin – Ciocalteu reagents (ACS, India) for 5 minutes before adding 2 ml of 75 mg/l sodium carbonate (Na2CO3) (ACS, India) [13]. The absorbance of the reaction mixture was measured at 760 nm against a methanol blank after 2 hours of incubation at room temperature [13]. The calibration curve was created using gallic acid (ACS, India) as the standard. Gallic acid has an excellent linearity (R2 = 0.9653) when dissolved in methanol (ACS, India) and distilled water (1:1) [13]. The total phenolic content of turmeric tea was reported in mg of gallic acid equivalents (GAE)/100 g. The procedure was repeated for the samples before spray drying.

2.7 Total antioxidants activity (TAA) determination

Antioxidant activity was measured using the 2, 2, diphenyl-2-picryl-hydrazyl (DPPH) (ACS, India) technique developed by Turkmen et al. [14]. 1 g of spray dried turmeric tea was dissolved in 5 mL of distilled water using a vortex mixer (Therm0, US) and centrifuged for 15 minutes at 5000 rpm for post spray drying samples [14]. After that, 0.5 mL of sample was combined with 1.5 mL of 0.1 mM DPPH radial in methanol [14]. The reaction mixture was then vortexed and allowed to stand in the dark at 25°C for 60 minutes. A spectrophotometer (Therm0, USA) was used to measure absorbance at 517 nm with methanol as a blank and a mixture of distilled water/aliquot of DPPH in methanol as a control [14]. Then, the process repeated for before spray drying samples. Antioxidant activity was expressed as percentage inhibition of DPPH radical and was determined by Eq. 4:

$$AA\ (\%) = (Abs_{control} - Abs_{sample}) / Abs_{control} \times 100 \ \ldots\ldots\ldots \ Eq.\ 4$$

Where,

AA (%) is the antioxidant activity in percentage,

$Abs_{control}$ is the absorbance reading of the control

Abs_{sample} is the absorbance reading of the sample

3. Results and Discussion

3.1 Determination of suitable inlet air temperature

The turmeric tea was spray-dried at temperature 190, 200 and 210 °C to know the suitable inlet air temperature for turmeric tea produced.

Table 1: Changes in physicochemical properties of spray-dried turmeric tea without carrier at different temperature

Temperature, °C	Product yield (g/100g)	Moisture content %	Solubility %	Colour		
				L*	a*	b*
190	0.27	2.22	8.49	35.71	14.32	35.44
200	0.18	56.66	0.17	39.59	15.17	33.47
210	0.23	17.19	15.41*	42.51	15.55	30.12

In Table 1 showed that at 190 °C produced highest product yield with 0.27 g/100g and at 210 °C was the lowest with 0.18 g/100g. The decreased in product yield due to increased air inlet temperature has also been reported by Chegini and Ghobadian (2007) for spray-dried orange juice powder [6]. Moisture content of turmeric tea was the best at 190 °C as it was only 2.22 % and 210 °C was the highest with 56.66 %. Conversely, the water content of spray-dried powders has been reported to decrease as the inlet and outlet air temperatures rise at a constant feed rate in Nadeem et al. (2011) study [6]. Solubility at 210 °C was the highest with 15.41 % and the lowest at 200 C with 0.17 %. But in Nadeem et al. (2011) study showed an increased in solubility was observed with an increased in the inlet air temperature from 145 °C to 155 °C, which was in agreement with the conclusions of Goula and Adamopoulos (2005, 2008), who reported the more soluble powder at high drying temperatures [6]. It can be concluded physicochemical of turmeric tea was the best at 190 °C. Spray drying turmeric tea without carriers causes the materials to adhere to the wall chamber and cyclone as shown in Figure 4 with a) was the chamber and b) was the cyclone. The results indicated that with the carriers' concentration, yield increased and the deposits on the dryer walls decreased as shown in Figure 5. Figure 6 showed the colour of turmeric tea without carrier.

Figure 4: a) Chamber and b) cyclone of spray dryer after drying turmeric tea without carrier

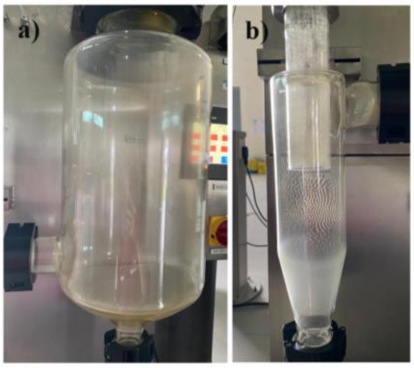

Figure 5: a) Chamber and b) cyclone of spray dryer after drying turmeric tea with carrier

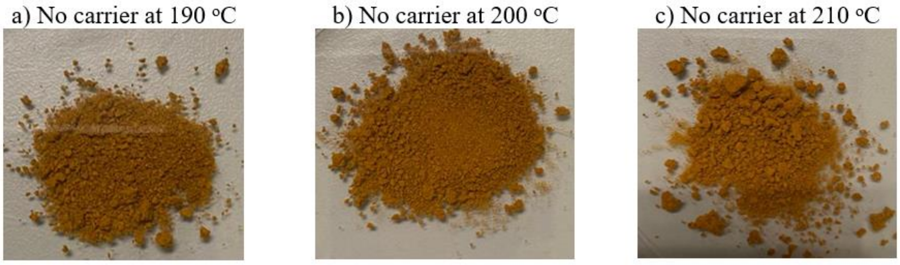

Figure 6: Colour of turmeric tea powder without carrier

3.2 Determination of the best carrier and concentration

The turmeric tea was spray-dried with maltodextrin and Arabic gum at different concentration at 190 ºC to know the best carrier for turmeric tea produced.

Table 2: Changes in physicochemical properties of spray-dried turmeric tea with carriers at different concentration at 190 ºC

Carrier	Concentration %	Product yield (g/100g)	Moisture content %	Solubility %	Colour L*	Colour a*	Colour b*
Maltodextrin	1	1.36	19.52	12.82	62.49	5.31	27.81
	3	2.63	0.84	50.00	65.12	4.02	27.81
	6	4.96	6.01	88.50	67.65	4.40	28.08
Arabic gum	1	1.28	9.70	7.47	65.69	3.78	23.34
	3	2.29	6.19	7.74	67.12	4.01	20.52
	6	4.72	6.95	11.95	69.54	4.88	19.52

In Table 2 showed that product yield was better with highest concentration of carrier with maltodextrin more effective than Arabic gum. Product yield was highest at 6.00 % maltodextrin with 4.96 g/100g and lowest at 1.00 % Arabic gum with 1.28 g/100g. Ameri and Maa (2006) point out that increasing the total solid content of the feed solution was one way of increasing the powder recovery in spray – drying operations [6]. Moisture content was the highest at 3% maltodextrin with 0.84% and the lowest at 1.00 % maltodextrin with 19.52 %. However, in Nadeem et al. (2011) study showed that further increasing the concentration of carrier material from 3 to 5g/100 g reduced the water content by 13.00 %, which may be associated with an increase in total solid content [6]. Solubility of turmeric tea was highest at 6.00 % maltodextrin with 88.50 % and lowest at 1% Arabic gum with 7.47 %. However, in the Susantikarn et al. (2016) study showed that the maltodextrin content did not significantly effect on solubility of powder while the inlet air temperature affected the solubility [11]. It also showed that solubility increased as the concentration of carrier increased. The addition of maltodextrin and Arabic gum as a carrier changed the hygroscopic and thermoplastic character of powder [6]. The a* value of turmeric tea powder with carrier were all below 10 as the addition of carrier brighten the powders as showed in Figure 8. It can be concluded that maltodextrin was the best carrier for turmeric tea at the highest concentration. Figure 8 showed the turmeric tea powder with carriers.

Figure 7: Colour of turmeric tea powder with carrier

3.3 TPC of turmeric tea granules

It has been known that turmeric contains relatively high amounts of phenolic compounds that may bring positive effects for human health. TPC of turmeric tea was evaluated for before spray drying process and after spray drying process with different concentration of carriers. Table 3 showed the results of TPC of turmeric tea with different concentration of carriers.

Table 3: Total phenolic content of turmeric tea at different concentration of carriers

Carrier	Concentration g/100g	TPC before spray dry, (GAEmg/mL)	TPC after spray dry, (GAEmg/mL)
Maltodextrin	1	5.328	5.860
	3	5.156	6.242
	6	3.079	3.107
Arabic gum	1	6.281	6.504
	3	2.704	2.756
	6	3.139	3.621

TPC of spray dried turmeric with carriers showed decrement as the concentration of carriers increase with Arabic gum 1.00 % at 190 °C was the highest and Arabic gum 6.00 % at 190 °C was the lowest. The spray dried turmeric tea with carriers also were low as they had been spray-dried at 190 °C. Moreover, TPC for spray dried turmeric tea with carriers was the highest with Arabic gum 1.00 % at 190 °C with 6.281 GAEmg/mL and lowest with Arabic gum 3% at 190 °C with 2.704 GAEmg.mL. However, in Susantikarn et al. (2016) study, the highest value was found in the powder produced from 3.00 % maltodextrin with 190 °C inlet air temperature [11]. Figure 8 showed the graph of TPC of turmeric tea before and after spray drying process.

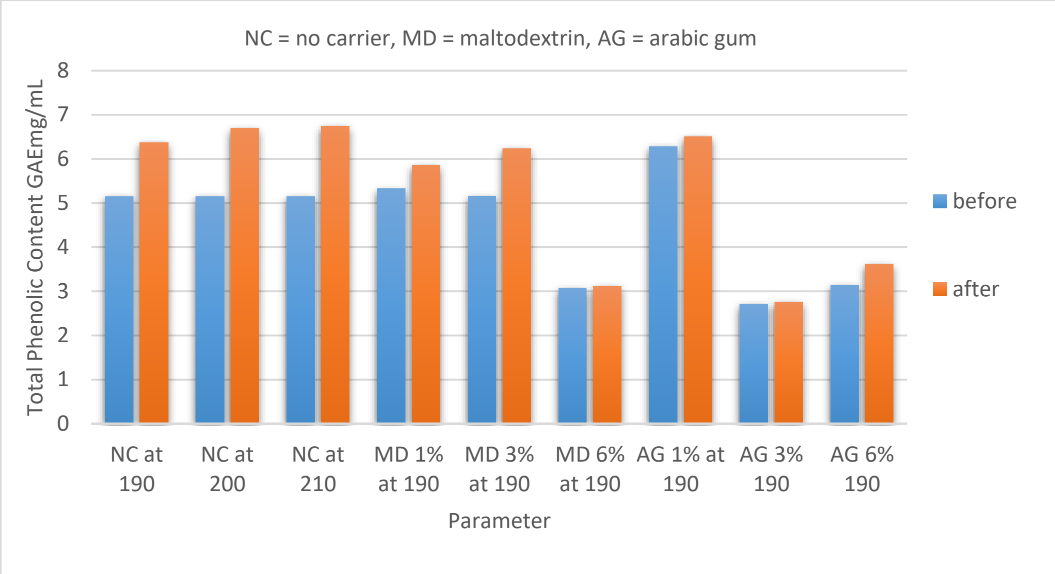

Figure 8: Graph total phenolic content of turmeric tea before and after spray drying process

As comparison for TPC of spray dried turmeric tea and before spray dry turmeric solutions, it showed that TPC of turmeric tea increases after spray drying process. It can be concluded that heat treatment due to spray drying process and no addition of carriers increased the TPC of turmeric tea. Increase in TPC after heat treatment could be due to the inactivation of polyphenol oxidase (PPO), as PPO are thermally unstable and lose activity after 60 °C[15].

3.4 TAA of turmeric tea granules

TAA of turmeric tea was evaluated for before spray drying process and after spray drying process with different concentration of carriers. Table 4 showed the results of TAA of turmeric tea with different concentration of carriers.

Table 4: Total antioxidants activity of turmeric tea at different concentration of carriers

Carrier	Concentration g/100g	TAA before spray dry, %	TAA after spray dry, %
Maltodextrin	1	87.903	51.855
	3	86.855	71.290
	6	69.355	80.242
Arabic gum	1	59.355	59.387
	3	17.903	67.339
	6	2.258	77.177

The highest reading of TAA for turmeric tea was with maltodextrin 1.00 % at 190 °C and the lowest was Arabic gum 6.00 % at 190 °C. It showed that there was a decrement for TAA of turmeric tea before spray dry as the concentration of carriers increase with maltodextrin being more effective than Arabic gum. TAA of spray dried turmeric tea increased as the concentration of carriers increased with maltodextrin was more effective than Arabic gum. The same observations show that acai powder made from maltodextrin can achieve higher antioxidant capacity than gum arabic of the same concentration when compared to studies of acai powder [8]. This result can be explained by the fact that the higher the solubility of the powder, the higher the antioxidant capacity of the powder [8]. Due to the high solubility of maltodextrin powder, when passed through a spray dryer, it tended to enclose the extract and carrier at the same time to form a matrix capable of producing microencapsulated juice [8]. Figure 9 showed the graph of TAA of turmeric tea before and after spray drying process.

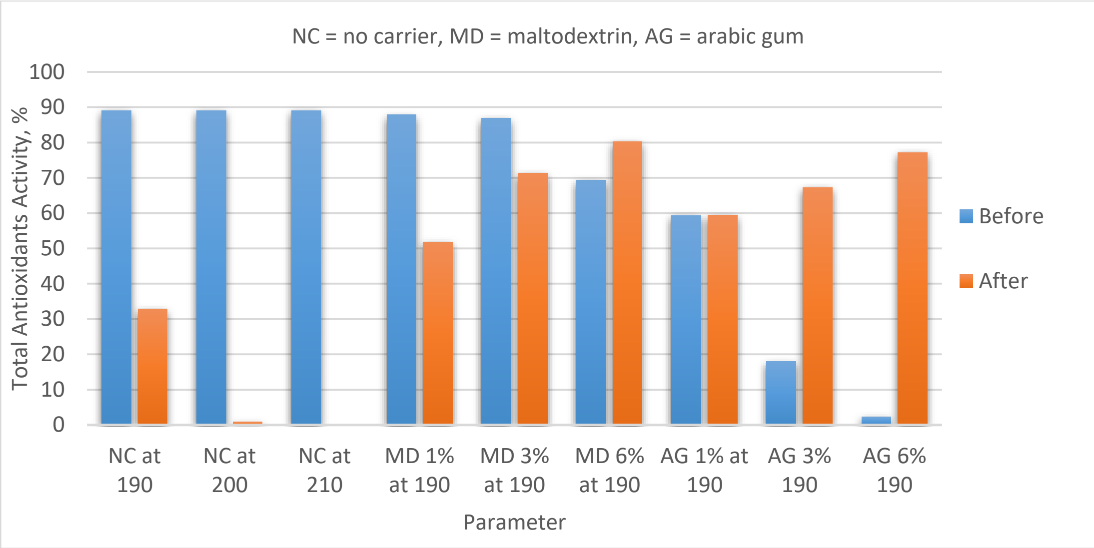

Figure 9: Graph total antioxidants activity of turmeric tea before and after spray drying process

As comparison, the spray dried turmeric tea contained lower TAA than turmeric tea solutions before spray dry. In this case, the extract was not completely encapsulated, resulting in more antioxidant decomposition during the heat treatment [8]. It can be concluded that heat treatment during spray drying process decreased the TAA of turmeric tea because excessive heat treatment led to the degradation of curcuminoids and reductions in antioxidant activity [16] but with heat treatment and addition of Arabic gum, the TAA of turmeric tea was increased because Arabic gum has been claimed to act as an antioxidant and anti-inflammatory agent in experimental studies and clinical trials [17], so it added more antioxidants in turmeric tea even after heat treatment.

4. Conclusion

Then, the physicochemical of turmeric tea evaluated was product yield, moisture content, solubility, colour, total phenolic content and total antioxidants activity. As the results, the product yield of spray dried turmeric tea with addition of higher concentration of maltodextrin can produce higher product yield and the spray dried turmeric tea with maltodextrin 3.00 % at 190 °C was the most suitable parameter for moisture content. For solubility, the higher solubility of spray dried turmeric tea was obtained with addition of higher concentration of carrier with maltodextrin been more effective than Arabic gum and the colour for spray dried turmeric tea powders obtained without carrier is brownish orange colour while spray dried turmeric tea powders with carriers were light yellowish colour. Moreover, the TPC of turmeric tea increased due to heat treatment from spray drying process and without carrier and the TAA of turmeric tea decreased due to heat treatment from spray drying process but the TAA increased when combination of heat treatment and Arabic gum used. The tests carried out with the data obtained showed the effect of carrier types and spray drying temperature on the physicochemical of turmeric tea. In conclusion, the research study objectives had achieved and according to the findings of the study, the carrier types and temperature had a significant effect on the physicochemical of turmeric tea. Additional study might be conducted to improve the results.

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