Research Square

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Production of a herbal drink by spray drying of mixed purple basil extract- lemon juice; formulation, process optimization, and characterization

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Abstract

In this study, the possibility of producing mixed purple basil-lemon juice powder as an herbal drink by the spray drying was explored. The purple basil extract and lemon juice were mixed in a ratio of 65:35 (% v/v), and the process variables including inlet air temperature (110–190°C) as well as the concentrations of maltodextrin (MD) and gum Arabic (GA) as carriers were optimized. The spray dried powder was characterized in terms of the moisture content, water activity, water solubility, product yield, particle size, total monomeric anthocyanins, and volatile components. The results indicated that both air temperature and MD/AG ratio had a significant effect on final powder properties except for a_w. The optimum conditions for maximizing encapsulation efficiency and powder yield while keeping other factors in a suitable range were inlet temperature of 146°C, 9.68%, MD, and 5.32% GA. Moreover, the GC-MS data revealed that the predominant aroma components in the final powder, lemon juice, and the reconstituted product were limonene and γ-terpinene; limonene; γ-terpinene, linalool, and 1.8 cineole, respectively. Overall, these results demonstrated that spray drying using AG/MD blends was feasible, improving the consolidation of bioactive compounds of purple basil and lemon juice in powdered form.

1. Introduction

Purple basil (*Ocimum basilicum* L.) is one of the most aromatic and tasty vegetables well-known considering its numerous properties [1–3]. It is cultivated in many areas such as Asia, Africa, and Central & South America [4, 5]. In Turkey, purple basil is largely cultivated due to the appropriate climate and it is called Reyhan [6]. Special attention has recently been paid to natural bioactive compounds which have many advantages for human health, including anti-cancer, anti-inflammatory, and anti-microbial activities [7–9]. These benefits are in part related to the high level of phenolic compounds such as phenolic acids, anthocyanins, and flavonoids. Phenolics are the largest group of water-soluble pigments in fruits and vegetables. In addition, purple basil consists of a special type of anthocyanins, including cyanidin derivatives which are characterized by a high degree of acylation with coumaroyl and malonyl acids [10].

Spray dryer is one of the most important dryers used in various industries. Production of product powders from liquid foods using a spray dryer is one of the best methods of powder production, which makes the least changes in the physicochemical structure of the product [11, 12]. The spray-dried products can be dissolved in water easily. All of the effective parameters in this process are tunable, including inlet/outlet air temperature, inlet product Brix, and feed flow rate [11, 13]. The hydrophilic and thermoplastic nature of fruit and vegetable juice makes it possible to use carriers such as soy protein, natural gums, and maltodextrin to increase the stability of the materials, improve the drying process, and prevent them from adhering to the dryer wall [14–16]. Spray dryer performs the drying process when the particles are suspended in the air. Operating in a relatively short time under defined and controlled conditions ultimately results in a powder that is acceptable in terms of physicochemical properties and nutrient retention [17]. The powder produced in this way is not susceptible to microbial spoilage and oxidation, due to its low moisture content and water activity.

This study attempted to investigate the potential of producing mixed purple basil-lemon juice powder by spray drying (SD). The effect of processing conditions including inlet air temperature and the concentrations of maltodextrin (MD) and gum Arabic (GA) as the carriers on some physicochemical properties of the product, with an emphasis on total monomeric anthocyanins and determination of volatile components, was studied and the optimum condition for SD was proposed.

2. Materials And Methods

Purple basil dried leaves were obtained from Arapgir, Malatya (Turkey). Lemon was bought from a local market. Chemicals and β-cyclodextrin (BCD) were purchased from Sigma-Aldrich (USA). MD (DE = 9) and GA were supplied by Roquette (France) and Alfasol (Turkey), respectively.

2.1. Preparation of purple basil extracts

After separating the stalks, 16 g of the plant was dipped in 400 mL of distilled water in tightly closed glass jars which were then placed in an orbital shaking water bath at 80°C for 1 h. The resulting extract was filtered and subsequently added by a new 8 g portion of the plant and kept at 80°C for 1 h. The second extract was again filtered, and a new 8 g portion of the plant was added to it, then kept at 80°C for 1 h. The final extract was used for SD experiments (total soluble content = 6.0 g/100 g). The purple basil extract and lemon juice were mixed at a volume ratio of 65:35. The carrier materials (MD, GA) were added to the mixture and homogenized at 15,000 rpm (Ultra Turrax T25, Basic Ika Labortechnik, Germany) for 5 min. In addition, 1% BCD was added to each mix solution. After that, the extracts were fed into the spray dryer.

2.2. Spray drying conditions

The SD process was performed using a lab scale spray dryer (Büchi Mini Spray Dryer B-290, Switzerland) which had double-fluid nozzles (0.5 mm in diameter) operating in a co-current manner. The spray flow rate was 300 L/h, and the aspiration rate was set at 85%. After conditioning, the feed was pumped using a peristaltic pump at 30% feed rate and ambient temperature.

2.3. Product yield

The SD yield was calculated using the following equation:

$$Yield = \frac{P}{(R \times E_2)/E_1} \times 100$$

1

where *P* is the weight of the powder (g) obtained by SD, *R* denotes the total amount of the plant (g) used in each extraction, E_1 represents the total amount of the extract (g/g), and E_2 shows the amount of the spray-dried extract (g/g) [18].

2.4. Moisture content (MC) and water activity (a_w)

The MC of the powders was determined using a moisture analyzer (Kern, DBS-60, Germany). a_w measurements were taken at room temperature using the a_w meter (Aqualab 4TE, Decagon, Washington, ABD).

2.5. Particle size distribution (PSD)

The PSD of the powders was determined by the light scattering method using Mastersizer 2000 (Malvern, Worcestershire, the UK) equipped with a liquid cell (Hydro 2000S). Isopropanol was used as a dispersant for the powders. The particle size of the powders was expressed as volume mean diameter (D_{43}).

$$D43 = \frac{\sum n_i d_4^i}{\sum n_i d_3^i}$$

2

where n_i is the number of particles of diameter d_i.

2.6. Solubility of powders

The water solubility of powders was determined according to Cano-Chauca et al. [19] with some modifications. For this purpose, 0.50 g of the powder and 50 mL of water were mixed at 600 rpm in a magnetic stirrer for 5 min. The obtained solution was taken into centrifugal tubes and centrifuged at 3000 *g* for 5 min. After that, 25 mL of the supernatant was transferred to Petri dishes and kept at 70°C until reaching a constant weight. The solubility (%) was calculated from the weight difference.

2.7. Total monomeric anthocyanins (TMA)

The TMA of the powders was determined by the pH differential method [20]. The absorbance values of the samples diluted with pH = 1.0 and pH = 4.5 buffers were measured at 522 and 700 nm by a spectrophotometer (UV1800-Shimadzu Corporation, Tokyo, Japan). The TMA was calculated using the molecular weight and molecular absorptivity of cyanidin-3-glucoside.

2.8. Volatile components

Volatile component analysis was carried out using solid-phase micro-extraction (SPME) sampling with a 50/30 µm divinylbenzene/carbon/polydimethylsiloxane fiber (Supelco, Pennsylvania, the USA) by GC-MS (QP2010-Plus, Shimadzu, Kyoto, Japan) equipped with TRB-5MS (30 m × 0.25 mm × 0.25 µm) column. Helium was used as the carrier gas at 1.61 mL/min, with the ion source temperature of 200°C, and the injection port temperature of 250°C. The oven temperature was programmed as follows: held at 40°C for 3 min; then the temperature was raised to 240°C (4°C/min), and held for 10 min.

2.9. Statistical methods

The optimum conditions for SD of the purple basil extract and lemon juice mix were determined by combined optimal design (2 mixture components and 1 process variable) using Design Expert 10.0 (Stat-Ease Co. Minneapolis, USA). MD and GA concentration (total 7.5%) and inlet air temperature (110, 150, and

190°C) were considered as the independent variables (Table 1). TMA, particle size ($D_{4,3}$), and product yield were regarded as the response variables. All of the analyses were performed using the statistical software Design Expert (version 10.0.1, Stat-Ease Inc., Minneapolis, MN, USA). The optimum wall material combinations providing the maximum product yield and TMA, and the particle size in the range was estimated.

3. Results And Discussion

3.1. Moisture content and water activity

The stability of spray dried powder is a function of its physical properties such as MC and a_w which can be adjusted using different carriers, alone or in the mixture [21]. The changes in MC and a_w as a function of wall material concentrations and the temperature are illustrated in Figs. 1 and 2. The MC of produced powder ranged between 3.44 and 6.05% respectively for the samples of run 10 (MD = GA = 3.75, Temp.=190^oC) and run 1 (MD = 1.875, GA = 5.625, Temp.=110^oC), respectively (Table 1). This variation was because of the wall material characteristics, feed properties, and dryer variables including air temperature, flow rate, and airflow [22]. Generally, the spray-dried powders are described through their low MC to be in the range of 2.9–4.66% [23]. On the other hand, it is reported that if MC and a_w of food powder be < 10% and 0.6, respectively, it could be classified as a hygienic product [24]. Therefore, it can be concluded that all samples were acceptable concerning MC and a_w.

Table 1
The values of different responses for the spray-dried samples

Run	A: Maltodextrin (%)	B: Gum Arabic (%)	C: Inlet air temperature (°C)	Product yield (%)	Particle size (D_{43})	TMA (mg/kg dry matter)	Moisture content (%)	a_w
1	1.875	5.625	110	43.2855	13.247	1940.27	6.05	0.22
2	3.75	3.75	150	42.2872	13.5885	1989.21	4.1	0.13
3	7.5	0	110	48.0629	15.373	1716.08	4.42	0.17
4	3.75	3.75	150	41.5674	13.028	1983.95	3.9	0.14
5	3.75	3.75	190	34.7961	12.1013	1822.51	3.84	0.13
6	3.75	3.75	110	47.8723	13.383	1946.05	5.6	0.17
7	0	7.5	190	33.3434	11.249	1848.28	3.58	0.11
8	7.5	0	150	47.8723	15.681	1979.28	3.82	0.15
9	0	7.5	150	42.9965	12.512	1844.7	4.15	0.15
10	3.75	3.75	190	33.8014	12.4	1886.98	3.44	0.1
11	7.5	0	190	37.4397	16.1193	1717.06	3.72	0.1
12	1.875	5.625	150	32.8059	14.475	1921.42	4.4	0.18
13	5.625	1.875	150	47.5177	14.32	2004.76	3.81	0.12
14	0	7.5	110	43.695	12.343	1968.35	4.91	0.18
15	0	7.5	150	36.7855	12.9635	1841.88	4.49	0.17

As shown in Fig. 1, the MC of powders decreased at higher concentrations of MD. This decreasing trend was more pronounced in lower temperatures because in high temperatures the impact of drying air temperature on lowering the MC is more significant than the carrier type. A similar trend was observed by Ferrari et al. [25] who spray dried blackberry juice using a mixture of MD and GA. They stated that this result is because MD is more effective than GA in decreasing the MC because GA is a complex heteropolysaccharides having a ramified structure with shorter chains and hydrophilic groups. This findings were also confirmed by T.A. Tran, V.H. Nguyen [26] who used a mixture of MD and GA for SD of lemongrass leaf extract. So, it can be concluded that producing powders with high amounts of GA in the formulation might result in a more hygroscopic product that results in problems in further processing and storage systems.

It was also shown that the MC content of powder increased at lower air temperatures in the spray dryer chamber due to the lack of sufficient thermal energy to remove water from atomized droplets [26, 27]. The same trend was observed for a_w towards role-playing of temperature, in which the a_w of produced powder

decreased by increasing inlet air temperature (Table 1). The a_w of samples varied in the recommended range of 0.1–0.22, as reported by Tonon et al. [28], who claimed that the food powders are stable if their a_w was < 0.3. Similar results were reported for SD of different plant-based extracts such as saffron extract [23], blueberry extract [29], and myrtle extract [18].

The result of model fitting is also presented in Table 2. A reduced linear X quadratic model and a reduced cubic X linear model were the best models for MC and a_w, respectively. All of the statistical results showed a good fitting of the model to the experimental results (Table 2). As it is obvious from the models, the linear effects of MD and GA, the interaction of temperature and MD, temperature and GA, and also the quadratic term of temperature were significant in the model proposed for MC. For a_w, all of the mentioned terms for MC plus the term including the interaction of MD and GA multiplied by (MD – GA) was significant. The linear term of temperature was not significant in both models, while the interactions of temperature and both carriers were significant in both models.

Table 2
Results of model fitting for different responses

Response	Fitted model	Coded equation	Statistical parameters	
Moisture content	Reduced Linear x Quadratic model	$MC = 3.83A + 4.29B - 0.5346AC - 1.01BC + 0.3529C^2$	P value for model	0.0012
			Std. Dev.	0.3813
			Mean	4.28
			C.V. %	8.91
			R^2	0.8106
			Adjusted R^2	0.7349
			Predicted R^2	0.3413
			P value of Lack of fit	0.1644
a_w	Reduced Cubic x Linear model	$a_w = 0.1389A + 0.1517B - 0.0323AC - 0.0342BC - 0.3251AB(A-B)$	P value for model	< 0.0001
			Std. Dev.	0.0123
			Mean	0.1480
			C.V. %	8.34
			R^2	0.9061
			Adjusted R^2	0.8686
			Predicted R^2	0.8133
			P value of Lack of fit	0.7946
Product yield (%)	Reduced Cubic x Linear model	$Yield = 44.12A + 38.95B - 6.07AC - 6.4BC + 54.77AB(A-B)$	P value for model	0.0001
			Std. Dev.	2.35
			Mean	40.94
			C.V. %	5.75
			R^2	0.8773
			Adjusted R^2	0.8282

Response	Fitted model	Coded equation	Statistical parameters	
			Predicted R^2	0.6863
			P value of Lack of fit	0.6585
Particle size (D43)	Reduced KCV model	Particle size = 16.08A + 12.80B-3.25AB-0.8157BC-0.7012C^2	P value for model	0.0003
			Std. Dev.	0.6369
			Mean	13.52
			C.V. %	4.71
			R^2	0.8546
			Adjusted R^2	0.7964
			Predicted R^2	0.7035
			P value of Lack of fit	0.0993
TMA (mg/kg dry matter)	Reduced Quadratic x Quadratic model	TMA = 1979A + 1839.99B + 304.94AB-60.61BC-260.45AC^2 + 65.47BC^2	P value for model	< 0.0001
			Std. Dev.	19.68
			Mean	1894.05
			C.V. %	1.04
			R^2	0.9717
			Adjusted R^2	0.9560
			Predicted R^2	0.9396
			P value of Lack of fit	0.8840

3.2. Powder yield

The product yield of spray dried samples varied in the range of 31.81% (run12: MD = 1.875, GA = 5.625, Temp.=150^oC) to 48.06% (run 3: MD = 7.5, GA = 0, Temp.=110^oC). Similar results were reported by Asik et al. (2021) who asserted that the powder yield of spray dried myrtle extract by MD and GA was 40.18%. The wall material ratio and process temperature had a meaningful impact on powder yield (Table 1). As shown in Fig. 3, by increasing the ratio of GA in formulation along with decreasing temperature, the powder yield

was maximized. Other studies also reported higher MD levels decreased powder yield due to increased mixture viscosity and consequently adhering the drying solids to the dryer wall [30]. Furthermore, the MC of powder increased at lower inlet air temperature resulting in increasing the spray dried powder weight collected in the cyclone which translates into a higher rate of product yield. The negative effect of high drying temperatures on powder yield might be also due to melting and more adhesion of the powders onto the wall [31]. The product yield in SD is controlled by different factors including dryer conditions, wall material type and its combined ratio, and the nature and concentration of core material in feed [23].

The result of the model fitting of powder yield is presented in Table 2. A reduced cubic X linear model was best fitted to the experimental data with suitable statistical values. The linear effects of MD and GA, the interaction of MD and GA, temperature and MD, temperature and GA, and also the quadratic term of temperature were significant.

3.3. Particle size of final powders

One of the most important properties of powder formulations is their application including the texture of products which can be determined by the particle size [32]. The particle size variations as a function of wall material ratios and temperature are shown in Fig. 4. The PSD of samples varied between 11.249 and 16.12 µm. The lowest and highest values were obtained for run 7 (MD = 0, GA = 7.5, Temp.=190^{o}C) and run11 (MD = 7.5, GA = 0, Temp.=190^{o}C), respectively. These observations could be identified through the fact that the particle size of spray dried powder increased by boosting the viscosity of feed emulsion [27]. On the other hand, it is reported that several factors influenced PSD such as physicochemical properties and wall materials along with their ratios in feed and the spray dryer operational conditions [23].

As shown in Fig. 4. increasing the MD concentration had a more significant effect on particle size than drying temperature and led to larger particle size. Ferrari et al. [25] also reported that the PSD of powders produced with MD was significantly higher than the powders produced using GA. Increasing the temperature also led to a smaller particle size which was in accordance with the results of Tonon et al. [33] and Aghbashlo et al. [34]. Different PSDs were reported by researchers for the powder produced by the spray dryer as follows. 0.69-16.175 µm for myrtle extract powder [18], 1–15 µm for turmeric oleoresin powder [35], 5–30 µm for blue corn anthocyanins powder [36], and 0.56–99.80 µm for grape skin extract powder [37]. The PSD obtained in this study (Fig. 5) was different from the values reported by other researchers. This difference can be interpreted due to using different wall materials, ratios, the operational condition of the spray dryer as well as the nature of core materials [23].

The result of the model fitting of PSD is presented in Table 2. A reduced KCV model was best fitted to the experimental data with suitable statistical values. The linear effects of MD and GA, the interaction of temperature and MD, temperature and GA, and also the quadratic term of temperature were significant in this model.

3.4. Total monomeric anthocyanins

Anthocyanins are highly unstable and sensitive to processing conditions which are usually influenced by drying time and temperature [31]. As shown in Table 1 and Fig. 6, the TMA content of encapsulated powder significantly changed as a function of wall material ratios together with inlet air temperature. The highest and lowest TMA were recorded after run13 (MD = 5.625, GA = 1.875, Temp.=150) and run3 (MD = 7.5, GA = 0, Temp.=110^{o}C), that were 2004.76 and 1716.08 (mg/kg dry matter), respectively. It was observed that the combination of GA and MD was efficient toward encapsulation of anthocyanins better than other carriers due to the optimum interaction that occurred between these two biopolymers [38]. The formation of a protective film layer around the atomized droplets that contain GA in their formulation was facilitated due to the presence of protein residue in this biopolymer [23]. Accordingly, the lack of GA in the formulation of run3 brought about the loss of TMA during the drying process. On the other hand, the presence of AG in run13 resulted in the formation of an effective barrier layer around the core materials.

At very high inlet temperatures, loss of heat-sensitive TMA is expected due to oxidation and thermal degradation [39] while in moderate temperatures, a protective layer forms faster than those produced at a lower temperature, that likely resulted in the high retention rate of TMA in run 13. Do, Nguyen [40] also reported similar findings. They used a mixture of GA and Microcrystalline Cellulose for SD mulberry juice at different temperatures (120–160 ^{o}C) and found out the TMA of spray dried mulberry juice was highest at 140 ^{o}C and declined when higher temperatures were used. They also concluded that at higher inlet temperatures, a stable and more smooth layer was formed due to higher evaporation rates that protected the anthocyanins from thermal degradation. However, at severely high temperatures, loss of anthocyanins is observed due to thermal sensitivity. These findings were also confirmed by Tonon et al. [30, 41], Ersus, Yurdagel [42]. In contrast to our results, Asik et al. [18] reported that the optimum conditions for achieving the highest encapsulation efficiency were an inlet temperature of 120^{o}C, MD = 3.75, and GA = 11.25 g/100 mL extract. It is proved that the SD process should be conducted in a way that a balance creates between the inlet and outlet air temperature and the time of the process. This balance should design toward forming the protective film as quickly as possible in parallel to reduce the residence time of droplets in the dryer chamber [23]. Due to the differences between the nature of core material, wall material, wall material ratio, SD operating conditions, and its configuration, it is predictable that temperature/time process balance is case-exclusive.

The result of the model fitting of TMA is presented in Table 2. A reduced quadratic X quadratic model was best fitted to the experimental data with suitable statistical values. The linear effects of MD and GA, the interaction of temperature and MD, temperature and GA, and also the quadratic term of temperature multiplied by GA were significant in this model.

3.5. Optimization

Optimization was performed with the aim of all input parameters in the experimental range while maximizing the powder yield and TMA and keeping the PSD in range. Based on these criteria, two optimized solutions were proposed by the software as presented in Table 3. Among these, the first solution was preferred because of its higher desirability and also because MD is a less expensive carrier than GA;

therefore it would be more economical to use this compound in the SD process. The validation experiment was performed and a high correlation ($R^2 > 0.9$) was observed between the experimental and predicted values at the optimum point which shows the adequacy of the models to predict the experimental data.

Table 3
Optimization solutions to maximize the encapsulation yield and TMA and keep the PSD in range

Number	MD	GA	Temperature	Yield	Particle size	TMA	Desirability	
1	**5.915**	**1.585**	**138.548**	**50.057**	**14.833**	**1988.790**	**0.492**	**Selected**
2	0.000	7.500	110.000	45.352	12.911	1966.072	0.402	

3.6. Volatile components and particle size distribution at the optimum point

Aroma analysis of purple basil-lemon powder and reconstituted purple basil-lemon powder (0.5 g powder + 50 mL boiled water) at the optimum point was performed by GC-MS using the SPME method (Table 4 and Fig. 7). The amount of powder and water for the reconstituted product was determined by sensory analysis. Limonene and γ-terpinene in the final powder; limonene (for lemon juice), γ-terpinene, linalool, and 1.8 cineole were the predominant aroma components in the reconstituted product. A previous study reported that linalool and 1,8 cineole are the main volatile components of the basil leaves [43]. More aroma components were determined in the reconstituted product compared to the powder product. It is thought that this difference is due to the fact that the aroma components are encapsulated in the powder.

Table 4
GC-MS results of purple basil-lemon juice powder

Retention time	Area	Area (%)	Volatile component name
1.275	167477	1.69	*Trans*-β.-Ionon-5,6-Epoxide
1.357	61219	0.62	1-Propyne (CAS) Propyne
1.543	54152	0.55	(Z)-(1RS,2RS,3RS,4SR)-2-hydroxy-3-(7-hydroxy-2-heptenyl)cyclopentane-1,4-dithiol
1.975	16076	0.16	Butanal, 2-methyl- (CAS) 2-Methylbutanal
2.918	46275	0.47	4,5-Difluoroctane isomer
4.490	35946	0.36	4-Benzyloxy-1-bromobutane
6.140	47043	0.47	6-[(2-Oxocyclohexyl)methyl]-4-oxa-5-azaspiro[2.4]hept-5-ene
12.058	59911	0.60	2-β-Pinene
12.481	41356	0.42	2-methoxy[1]benzothieno[2,3-c]quinolin-6(5H)-one
12.947	43855	0.44	*Trans*-Sabinenehydrate
13.241	354721	3.57	l-Phellandrene
13.396	5130156	51.63	Limonene
13.490	737370	7.42	Eucalyptol (1,8-Cineole)
14.512	731027	7.36	γ.-Terpinene
15.331	3919	0.04	1,1,2-Trifluoro-2,5-bis(trifluoromethyl)hexane
15.587	122188	1.23	α-Terpinolene
15.998	1048561	10.56	Linalool
16.157	31701	0.32	Nonanal (CAS) *n*-Nonanal
16.484	21846	0.22	Cyclohexene 3-(tert-butyl)peroxide
18.068	13377	0.13	Trimethyl[o-[.α.-(p-tolylsulfonyl)phenylethyl]benzyl]silane
19.194	115572	1.16	β. Fenchyl Alcohol
19.498	18175	0.18	1-Methylbutyl nitrite
19.687	5088	0.05	Propane, 2-nitro
22.979	73686	0.74	2-Propenoic acid, 3-phenyl-, methyl ester (CAS) Cinnamic acid methyl ester
23.735	11319	0.11	2,3,4,4-Tretrapropyl-1-(trimethylsilyl)-1-(trimethylsilyloxy)-1,3-diaza-2,4-diborabutane

Retention time	Area	Area (%)	Volatile component name
25.398	495954	4.99	(Z)-3-Phenyl-2-Propenoic Acid, Methyl Ester
25.882	9096	0.09	Di-*n*-octyl disulfide
26.628	16746	0.17	β-elemene
27.046	130759	1.32	*Trans*-.α.Bergamotene
28.863	10974	0.11	1,3-Diphenyl-1-((trimethylsilyl)oxy)-1(Z)-heptene
28.967	2796	0.03	2-Methyl-N-Phenylpropanoic Acid Amide
29.146	239153	2.41	Cyclohexene, 1-methyl-4-(5-methyl-1-methylene-4-hexenyl)-, (S)-
29.255	7476	0.08	1,2(*trans*),2,3(*trans*),3,4(*trans*),-2,4-bis(p-cyanophenyl)-1,3-diphenylcyclobutane
31.836	9549	0.10	Butanoic acid, anhydride (CAS) Butyryl oxide
39.885	10834	0.11	1-(Allenylsulfonyl)-2,5,5-trimethyl-3-vinyl-2-cyclohexene
42.017	8475	0.09	*trans*-1-(phenylthio)-6-oxo-4-oxahept-1-ene

4. Conclusion

This study was carried out to produce soluble (instant) basil-lemon mixed powder as an alternative to purple basil herbal tea. The combined optimal design was implemented to optimize the SD condition and composition of wall materials. The concentrations of carriers (MD and GA) and inlet air temperature portrayed significant effects on the properties of the final powders. The optimization predicted that the application of inlet air temperature of 138.55°C, 1.58% GA, and 5.92% MD produced powders with the highest amount of TMA and product yield, while other variables varied in an acceptable range. The results of this study can be used in the production of herbal drinks in the industry.

Declarations

Ethics Approval

Not applicable.

Consent to Participate

Not applicable.

Consent for Publication

Not applicable.

Conflict of Interest

There is no conflict of interest.

Authors' contributions

Abdolsattar Avazsoofian: Performing the experiments and statistical analysis, writing original draft, **Handan Başünal Gülmez:** Performing the experiments and statistical analysis, writing original draft, **Ayhan Topuz**: Conceptualization, Reviewing and Editing, **Narjes Malekjani:** Performing statistical analysis, Writing, Reviewing and Editing, **Seid Mahdi Jafari:** Conceptualization, Reviewing and Editing.

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Figures

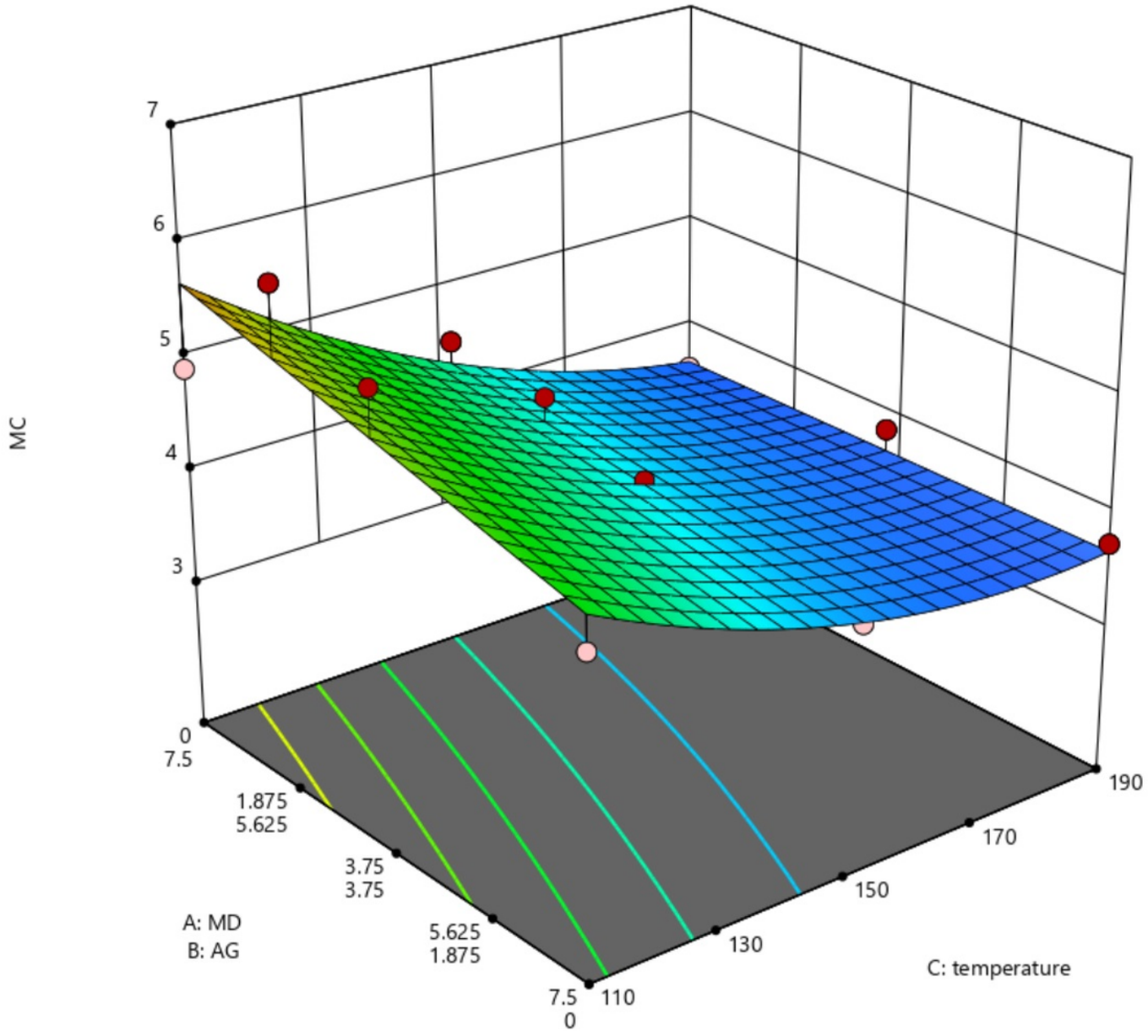


Figure 1

The effect of temperature and MD:GA ratios on MC of spray dried powders

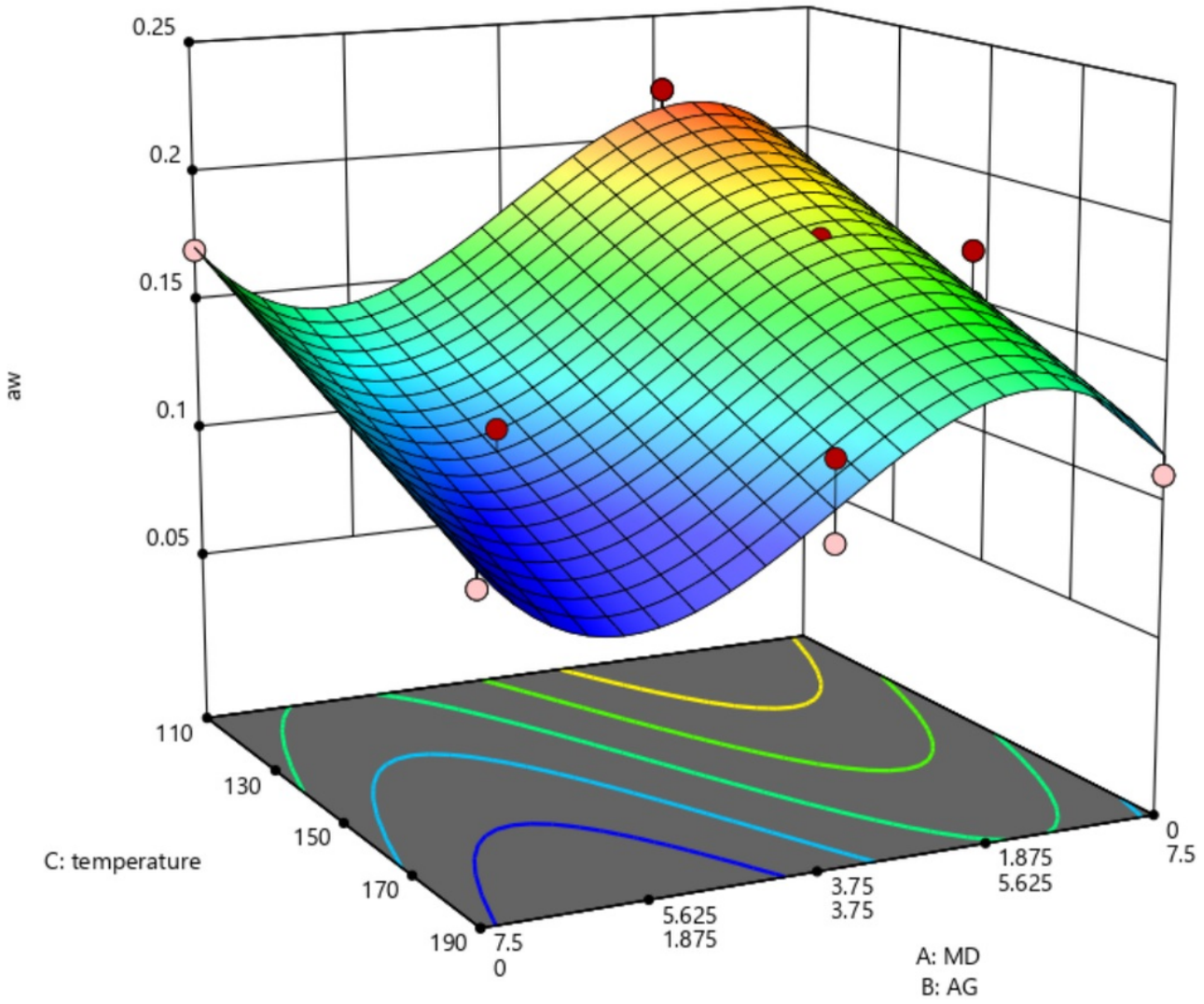


Figure 2

The effect of temperature and MD: GA ratios on a_w of spray dried powders

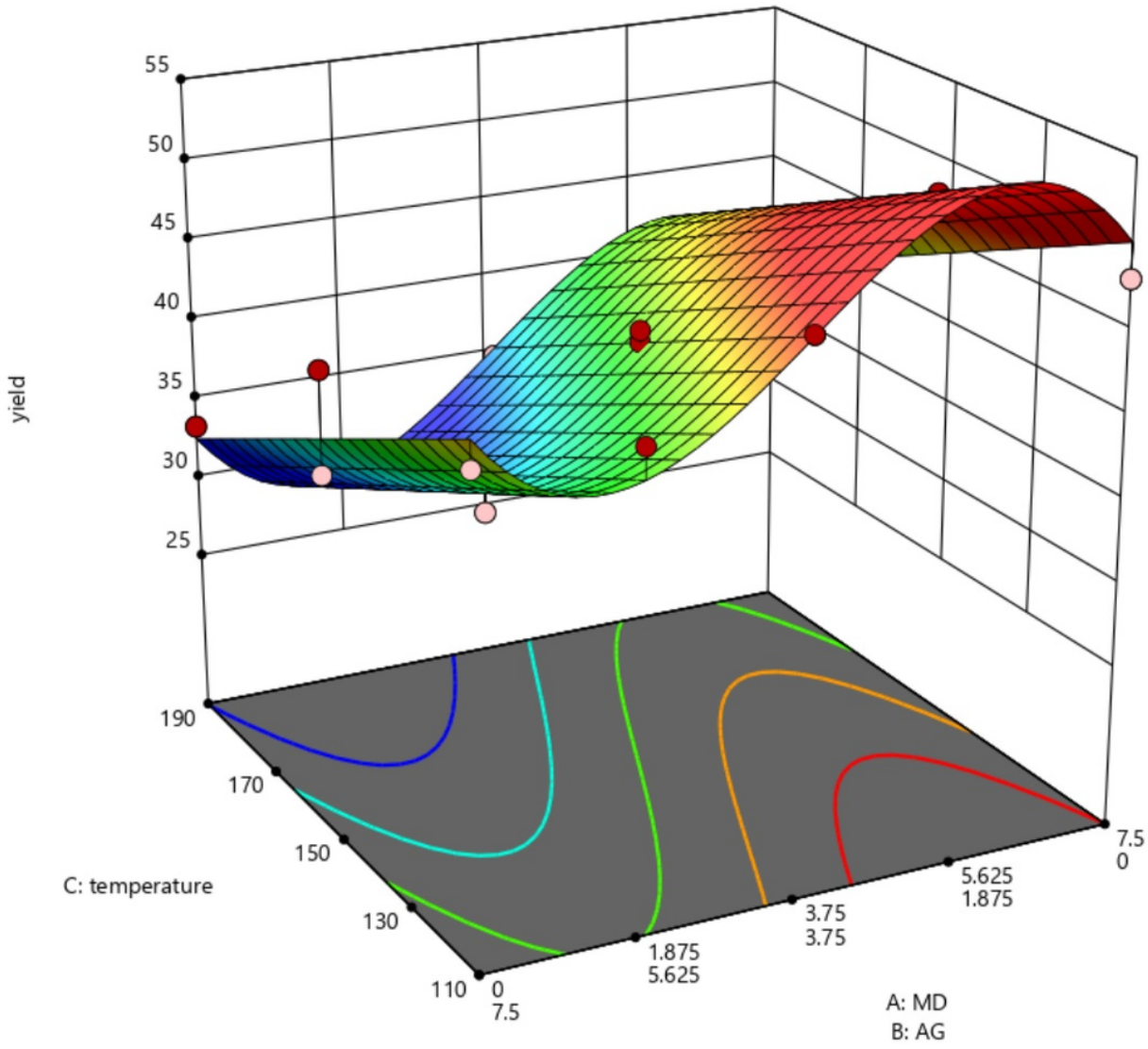


Figure 3

The effect of temperature and MD: GA ratios on powder yield of spray dried powders

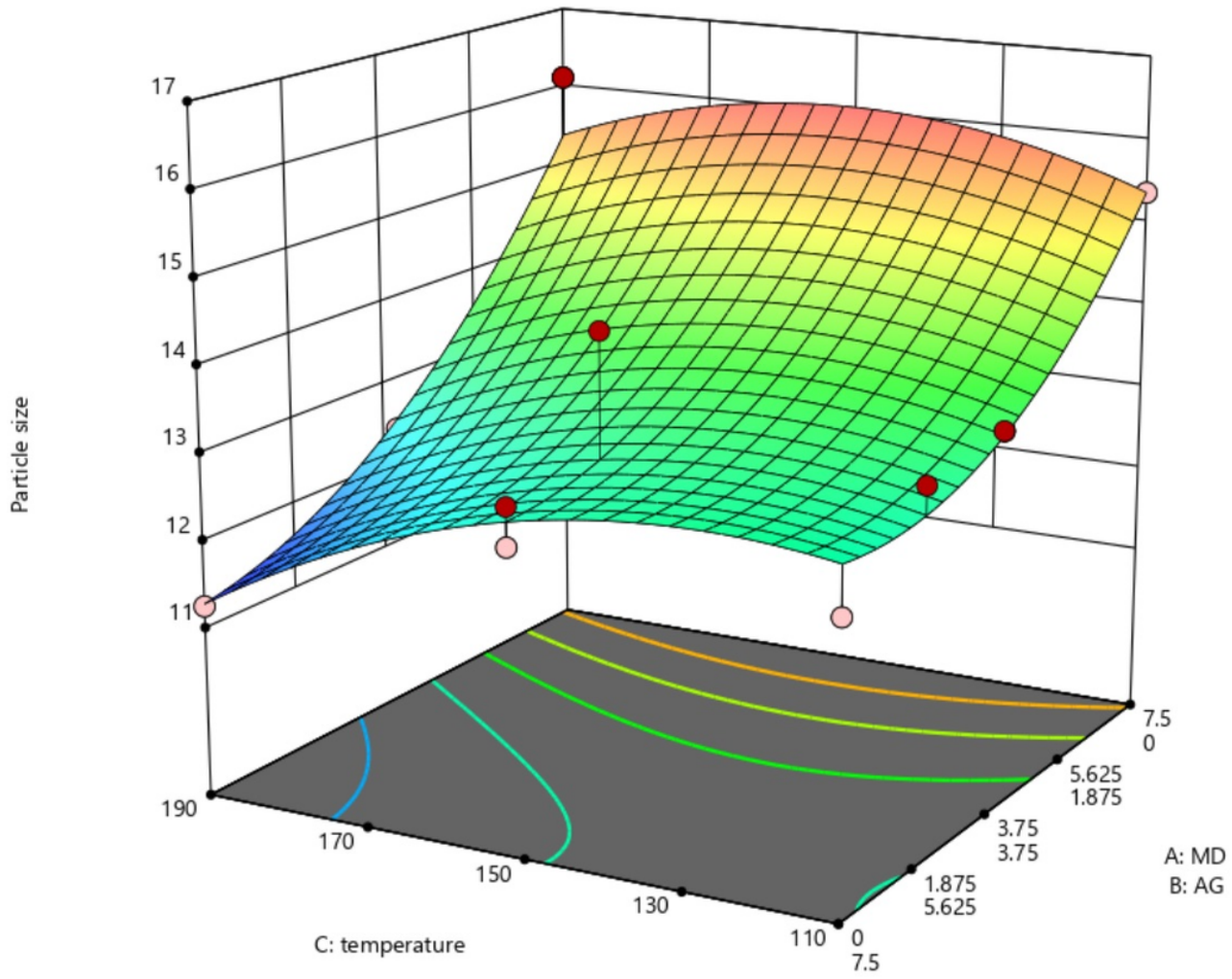


Figure 4

The effect of temperature and MD: GA ratios on the particle size of spray dried powders

Concentration:	Span :	Uniformity:	Result units:
0.0023 %Vol	1.746	0.553	Volume

Specific Surface Area:	Surface Weighted Mean D[3,2]:	Vol. Weighted Mean D[4,3]:
1.08 m²/g	5.559 um	8.458 um

d(0.1): 3.137 um **d(0.5): 7.029 um** **d(0.9): 15.413 um**

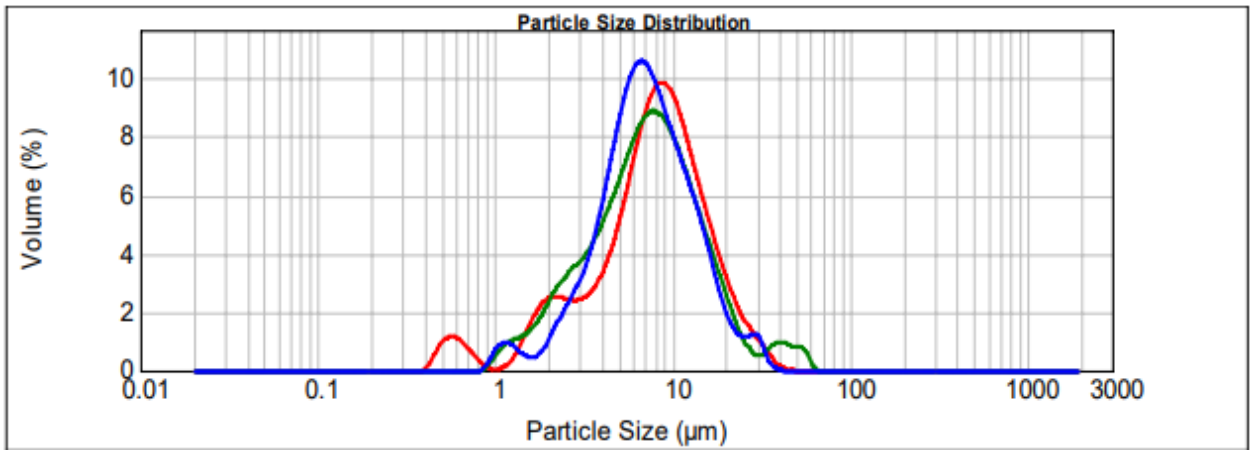


Figure 5

Particle size distribution of optimum spray dried powder.

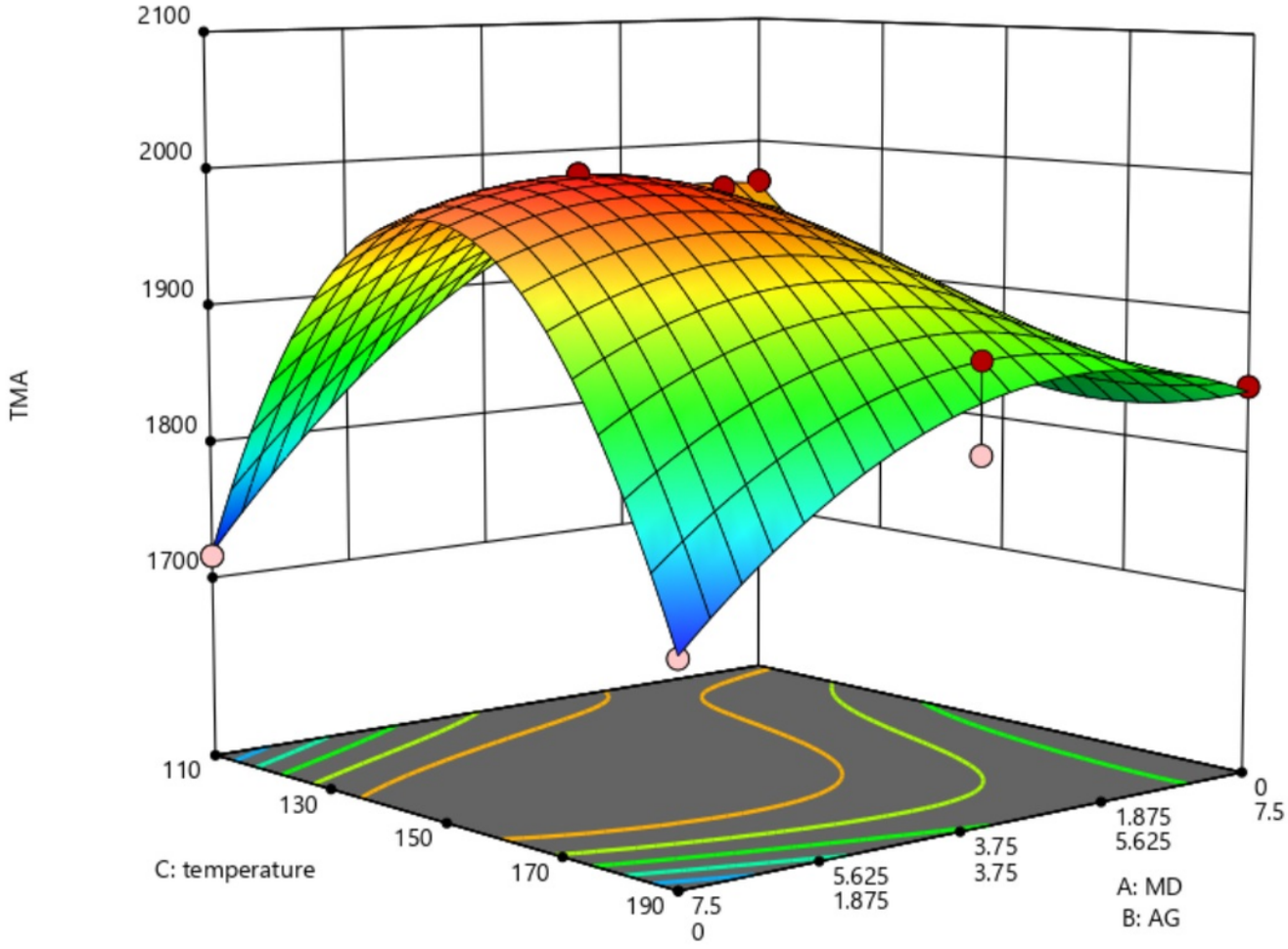


Figure 6

The effect of temperature and MD: GA ratios on TMA of spray dried powders

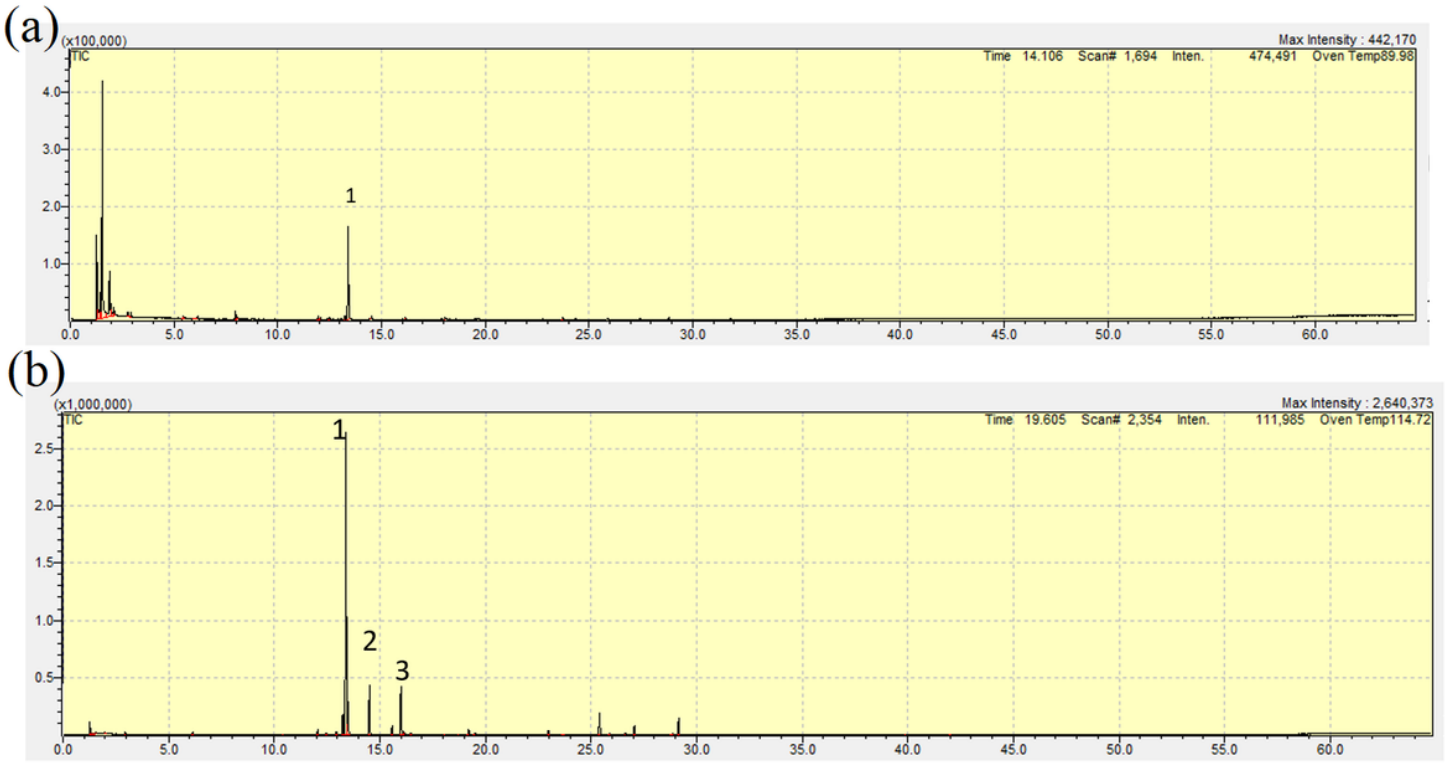


Figure 7

Spray dried samples: (a) without β-cyclodextrin, (b) with β-cyclodextrin (1:Limonene, 2: gterpinene, 3: Linalool)