CHAPTER 2 FOOD AREA

MICROENCAPSULATION OF NANCE (*BYRSONIMA CRASSIFOLIA* L.) EXTRACT BY SPRAY DRYING

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Abstract

This study aimed to evaluate the effect of spray drying parameters on the antioxidant and physicochemical properties of a microencapsulated extract of *Byrsonima crassifolia* (Nance) fruit. An aqueous extract of nance pulp was analyzed for total phenolics, flavonoids, and antioxidant capacity before and after the spray-drying microencapsulation process. The microencapsulation was carried out using a spray dryer by varying the drying temperature (110-134 °C) and maltodextrin concentration (3-17%). The results showed that the nance extract contained 185.06 μg of gallic acid/mL and 18.38 μg of quercetin/mL in terms of total phenolics and flavonoids, respectively. The antioxidant capacity as a percentage inhibition of the extract was 30.11%, and that of the microencapsulates ranged from 9.25 to 45.64%. Conversely, microencapsulated total phenolics ranged from 173.11 to 4.75 μg/mL gallic acid. The yields for the microencapsulation process ranged from 80 to 90%, obtaining powders with moisture contents lower than 2.63%. The results indicate a strong interaction between drying temperature and maltodextrin concentration. High maltodextrin concentrations and high drying temperatures hurt the bioactive properties. The powders obtained in the different formulations show microparticles between 10 and 20 μm sizes, with smooth, collapsed, and rough surfaces.

Keywords: microencapsulation, nance, phenols, flavonoids, antioxidant capacity.

1. Introduction

Byrsonima crassifolia L., commonly known nance or changunga, is a fruit native to the tropical Americas and is distributed in different regions of Central and South America and in the southeastern part of Mexico. In Mexico, the main nance producing states are: Campeche, Chiapas, Guerrero, Jalisco, Michoacán, Morelos, Nayarit, Oaxaca, Sinaloa, Veracruz and Yucatán, with an annual production of 7,713.13 tons [1]. Nance is a rounded drupe that is produced in pendulous infructescences of 10 to 15 cm in length. When ripe, they are about 1.7 to 2 cm in diameter, slightly orange-yellow in color, with abundant sweet and sour flesh surrounding a large, hard stone [2]. The main bioactive compounds contained in the nance fruit are gallic acid and quercetin [3, 4]. It also contains trace amounts of catechin, epicatechin, rutin and kaempferol [5]. Several studies have demonstrated the antioxidant activity of nance leaves, fruits, and seeds. It is also reported to have anti-inflammatory, antiproliferative, and antihyperglycemic properties [6 - 8]. In addition, extracts of *Byrsonima crassifolia* L. have bactericidal, fungicidal, and topical anti-inflammatory activities [9]. This extract has been used medicinally since pre-Hispanic times, mainly for the treatment of gastrointestinal disorders and gynecological inflammation [10]. Nance is also highly valued as a dietary supplement due to its high vitamin and mineral content (thiamine, riboflavin, and niacin); it is also an excellent source of dietary fiber [11, 12].

Microencapsulation is a process that improves the properties of the spray-dried core, taking into account the matrices used and the operating conditions of the equipment. In addition, it facilitates the handling of the bioactive compounds, improves their solubility and stability, protects against the degradation of the cores, controls the release of the compounds and masks unpleasant tastes and odors. The type and characterization of the coating agent used for encapsulation determines the final properties of microencapsulated materials, such as efficiency and microcapsule size. Due to its low cost and its encapsulation efficiency of hydrophilic core materials such as anthocyanins and gallic acid, maltodextrin is the most used wall material in microencapsulation technology [13].

There has been an increase in interest in the use of raw materials for the development of products that are rich in bioactive compounds for use as health-promoting agents in the food, pharmaceutical and cosmetics industries. Thus, the nance fruit is considered as a feasible raw material for the application and development of products with functional properties, due to the growing

demand for foods with natural antioxidants and nutritional potential. Therefore, the objective of the present research was focused on the quantification and evaluation of bioactive compounds and antioxidant capacity of nance extract microencapsulates.

2. Materials and Methods

2.1. *Materials*

The nance fruits were procured from the local market in the city of Pátzcuaro, Michoacán. Prior to use, the fruits were subjected to a washing process and disinfected in a 0.1% solution of sodium hypochlorite. The size of the fruits was selected based on considerations of mechanical damage. Subsequent to this, the pulp was extracted and stored in a freezer at -20 °C until use.

2.2. *Preparation of the extracts*

For the extract preparation, 100 milliliters of distilled water was combined with 10 grams of nance pulp, which was then stirred for a period of 40 minutes at a temperature of 40 °C. After that, vacuum filtration was conducted. The extract was subsequently stored under refrigeration until required for use.

2.3. *Determination of Total Phenolic Contents (TFC)*

Total phenolic contents were determined by using the Folin–Ciocalteu method, according to the methodology reported by Robert et al., [13]. The nance extract (500 μL) was add to Folin–Ciocalteu reagent (1:10- diluted) and sodium carbonate (2 mL/7.5%). Then the mixture was kept for 60 minutes at room temperature. Following the incubation period, the absorbance was measured at 760 nm using a UV–Visible spectrophotometer (Perkin Elmer Lambda XLS, UK).

2.4. *Determination of Flavonoid Contents*

The flavonoid content of the aqueous extract was quantified using the method described by Chang et al. [14]. The results were expressed as μg/mL of quercetin. A standard curve was generated over the range of 0 to 50 μg/μL. A total of 500 μL of the aqueous extract was taken and subsequently combined with 1.5 mL of methanol, 100 μL of a 10% aluminum chloride solution, 100 μL of a 1M potassium acetate solution, and 2.8 mL of distilled water. Absorbance readings

were obtained at 415 nm using a UV–Visible spectrophotometer (Perkin Elmer Lambda XLS, UK).

2.5. *ABTS$^{\bullet+}$ radical cation scavenging activity*

The antioxidant capacity was determined according to the methodology developed by Kuskoski et al. [15], with some modifications. Then, 20 μL of the aqueous extract was taken and 2 mL of the ABTS^{+} radical dilution was added, after which the absorbance (Abs) was taken. The results are expressed as percentage inhibition, which is calculated by the following equation:

$$inhibition(\%) = \frac{Initial\ absorbance\ of\ ABTS\text{-}Absorbance\ of\ the\ sample\ after\ 6\ min}{Initial\ absorbance\ of\ ABTS} \times 100$$

2.6. *Production of microcapsules*

Maltodextrin was dispersed in the aqueous extract of nance at different concentrations (Table **1**) by magnetic stirring for 30 minutes. The drying process was carried out in a Büchi mini spray-dryer B-290 (Flawil, Switzerland). The parameters were selected based on preliminary tests: a suction flow rate of 35 m^3/h and a solution volume flow of 2.61 mL/min. Central Composite Design (CCD) was used to evaluate the spray drying conditions (Design Expert 7.0v, USA). Furthermore, the hygroscopicity and moisture content of the microencapsulates obtained were evaluated.

Experiment	Maltodextrin concentration (%)	Inlet temperature °(C)	Key
1	10	120	MD10120
2	10	106	MD10106
3	10	120	MD10121
4	15	130	MD15130
5	5	110	MD05110
6	10	120	MD10122
7	10	120	MD10123
8	3	120	MD03120
9	15	110	MD15110
10	10	120	MD10124
11	5	130	MD05130
12	10	134	MD10134
13	17	120	MD17120

Table 1. Experimental design of microencapsulation.

2.7. *Characterization of the microcapsules*

2.7.1. Moisture content

The moisture content of the powder was determined gravimetrically according to AOAC method [16].

2.7.2. Hygroscopicity

The hygroscopicity was performed using the methodology described by Cai and Corke [17] with minor modifications. One gram of microcapsules was placed in a desiccator containing a saturated sodium chloride solution (85%) After seven days the samples were weighed and their hygroscopicity expressed as a percentage (%) of adsorbed moisture.

2.7.3. Drying yield

The drying yield for spray-drying was evaluated based on the percentage between the total mass of the product recovered upon its exit from the equipment and the mass of the extract fed into the system, according to Eq. (dry basis):

$$Y\,\% = \frac{Mass\ off\ \ microcapules\ (g)}{Total\ mass\ of\ \ extract\ fed\ into\ the\ system\ (g)} \times 100$$

2.8. *Total phenolic content (TFC) and surface phenolic content (SPC)*

Total phenolic content was determined by releasing the phenolic compounds from the microcapsules, according to the methodology described by Robert et al. [13], and Tolun et al., [18]. A total of 200 mg of microcapsules were weighed and added to 2 mL of a methanol-acetic acid-water mixture in a 50:8:42 ratio, respectively. Subsequently, the samples were centrifuged at 4,000 rpm for 15 minutes. Then, the sample was filtered and decanted, after which the Folin-Ciocalteu method was employed to determine the TFC.

To determine the surface phenolic content (SPC) of the microcapsules, 24 mg of microcapsules were washed with 3 mL of an ethanol: methanol mixture (1:1, v/v) for 5 minutes and then filtered through a microfilter (0.45 μm) [18].

2.9. *Total flavonoid content*

Total flavonoid content (TFC) in the microcapsules was determined using the methodology described by Robert et al.,[13] and Fuentes et al., [19]. A total of 200 mg of the microcapsules was taken and mixed with 2 mL of a methanol-ethanol solution (1:1, v/v). Subsequently, the solution was subjected to centrifugation at 4,000 rpm for a period of 15 minutes. Finally, a 500 μL sample was taken for the TFC using the aluminum chloride procedure. The TFC was calculated using a calibration curve with quercetin as the standard and expressed in milligrams of quercetin equivalent per gram of dry weight of the sample. Absorbance was then measured at 420 nm using a UV–Visible spectrophotometer (PerkinElmer Lambda XLS, UK).

2.10. *Antioxidant capacity in microcapsules*

The antioxidant capacity of the microcapsules was determined with brief modifications [13]. For that, 200 mg of the microcapsules were mixed with 2 mL of a methanol-ethanol solution (1:1) and vortexed for 1 min, then the solution was centrifuged at 4000 rpm for 15 min. Then, 20 μL of the aqueous extract was taken and mixed with 2 mL of the ABTS+ radical dilution following the methodology described in 2.5 The results are expressed in percentage inhibition, which is calculated by the following equation:

$$inhibition(\%) = \frac{Initial\ absorbance\ of\ ABTS\text{-}Absorbance\ of\ the\ sample\ after\ 6\ min}{Initial\ absorbance\ of\ ABTS} \times 100$$

2.11. *Encapsulation efficiency*

The encapsulation efficiency (%EE) is determined by the results of the % SPC according to Robert et al. (2010), which are expressed using the following equation:

$$\%EE = 100\% - \%SPC$$

Where SPC is: % surface phenolic content.

2.12. *Total phenolic content*

Total phenolic content was determined by releasing the phenolic compounds from the microcapsules by destroying the coating material, according to a modified form of the methodology described by Tolun et al., [18]. The tests

were carried out in triplicate and the efficiency of encapsulation of the bioactive compounds was determined using the equation:

$$\% PCS = \frac{Phenolic\ compounds\ on\ the\ surface}{Initial\ phenolic\ compounds} \times 100$$

2.13. *Morphological analysis of microcapsule*

A scanning electron microscope was employed to evaluate the particle morphologies of microcapsules produced with different coating material concentrations and drying temperatures. The particle morphologies of the microcapsules produced with coating material concentrations and drying temperatures were evaluated by employing a scanning electron microscope (SEM). A small quantity of each powder was attached to a double-sided adhesive tape fixed to stubs, coated with gold, and examined with 5 kV in a JEOL JSM 7800F scanning electron microscope.

3. Results

3.1. *Total phenols and flavonoids in the aqueous extract*

The results for total phenols and flavonoids were 185.06 μg gallic acid/mL and 18.38 μg quercetin/mL, respectively (Table **2**). Values of 174.15 mg gallic acid/100 g fresh weight and 159.9 mg gallic acid/100 g total phenols, respectively [20, 21]. As reported by Barrett et al. [22], the content of phenols and flavonoids is highly influenced by fruit maturity. These compounds are found in higher proportion in an immature state than when the fruit is fully ripe. Miletić et al. [23] conducted a study on an endemic plum species finding a decrease in the quantity of total phenols during fruit ripening.

Titratable Acidity	0.034% 0.003	
Total phenolic content	185.06 0.53 μg gallic acid/mL	
Flavonoids	18.38 0.01μg quercetin/mL	
Antioxidant Capacity	Nance juice (untreated)	95.860.35 % Inhibition
	Aqueous extract	30.11 2.19 % Inhibition

Table 2. Characterization of the aqueous extract of nance

3.2. *Antioxidant Capacity*

The results of the antioxidant capacity of the aqueous extract shown in Table **2**, demonstrated a percentage inhibition of $ABTS^{+}$ radicals of 30.11%, whereas the fruit juice, which was not subjected to any processing, exhibited an antioxidant capacity inhibition of 95.86%. López-Vidaña et al. [24] indicated that the antioxidant activity is influenced by the temperature and the time of application, particularly during heating that may result in an oxidative process. In their study, Karaaslan et al. [25] reported that the use of high temperatures, ranging from 50-80°C, can result in a reduction of up to 65% in the phenolic compounds present in the extract. Similarly, Akowah et al. [26] found that the temperature at which the extraction is conducted has an impact on the stability of the phenolics and in the antioxidant capacity of the extract.

3.3. *Characterization of the microcapsules*

Response surfaces were produced to understand the behavior of physicochemical properties relevant to encapsulation concerning process temperature and concentration of encapsulating material encapsulating material. Figures 1a, 1b, and 1c show the effects of temperature and maltodextrin concentration on encapsulation yield, moisture, and hygroscopicity, respectively.

Table **3** shows the recovery performance results. The yield ranged from 82.84-94. 89%, with MD05110 and MD15110 showing the lowest and highest values, respectively. The results show (Figure 1a) that increases in maltodextrin concentration and temperature improve the recovery yield. Similar results have been reported by Millinia et al. [27], who observed an increase in the yield of anthocyanin encapsulates from roselle (*Hibiscus sabdariffa* L.). Thanh et al. [28] also observed this behavior by microencapsulating noni juice in maltodextrin-gum Arabic mixtures at temperatures from 140 to 180 °C. Karrar et al. [29] reported a microencapsulation yield between 85.25 and 92.80 % using the spray drying technique.

Furthermore, Bhusari and Kumar [30] mentioned that the increase in powder recovery yield is due to the reduction of stickiness and deposition of powder particles on the walls of the drying chamber. On the other hand, Quek et al. [31] found that maltodextrin could increase the total solids content and reduce the moisture content of the product, since it can alter the surface area of adhesion of low molecular weight sugars, such as glucose, sucrose, fructose and organic acids, facilitating drying and decreasing the stickiness of the product.

Nance microcapsules showed a moisture content ranging from 0.15 to 2.63 % (Table 3). These results agree with Rodrigues Pereira et al. [32] and Porras-Saavedra et al. [33] who reported values of 2.21 and 4.38 (% dry base, d. b.) in microencapsulated powders with maltodextrin and gum Arabic. According to Bhandari [34], the moisture content in powders should be less than 5%, and Baudelaire [35] mentions that microcapsules with moisture values between 2 and 8% can be stable for a period of 12 to 24 months. Moisture and hygroscopicity are relevant properties in spray-dried powders, which can directly affect the stability and storage properties of the powder [36].

Figure 1b shows that moisture decreases with increasing maltodextrin concentration and drying air temperature. This behavior was observed by Queck et al. [31], who reported that at a constant flow rate, the moisture content of the encapsulates decreases with increasing temperature. On the other hand, Kha et al. [37] found that increasing the quantity of solids in the feed solution decreases the initial total moisture to evaporate. Goula and Adamopoulos [38] mentioned that the increase in maltodextrin concentration could hinder the diffusion of water molecules, causing an increase in moisture content. Also, very low moisture contents can decrease the glass transition temperature, causing stickiness and hardening of the microcapsules [39].

Table 3 shows the formulations with the lowest hygroscopicity value (MD10106 and MD15110) and the highest hygroscopicity (MD05110 and MD03120). The results showed significant differences between treatments ($p = 0.05$), particularly with increasing encapsulant concentration. Figure 1c shows that low hygroscopicity occurs with low maltodextrin concentrations and drying temperatures. This behavior is also observed by Rodriguez-Hernandez et al. [40], Cai and Corke [17], and Laureanti et. al. [36]. They mentioned that hygroscopicity is affected by the concentration of the encapsulating agent and this can be inversely proportional to moisture content.

On the other hand, Tonon et al. [41] report that maltodextrin is a material with low hygroscopicity, which confirms its efficiency as an encapsulating agent. Other authors have also documented a reduction in hygroscopicity with increasing maltodextrin concentration [17, 40]. This is due to the fact that maltodextrin has the capacity to absorb water, thereby forming a moisture protection barrier on the surface of the hygroscopic particles. Furthermore, it increases the glass transition temperature, which stabilizes the carbohydrates and improves the stability of the microencapsulates [42, 43]. The highest hygroscopicity found in nance microencapsulates was 18.81g water/100g encapsulate (Figure 1c). This

can be attributed to the concentration of carbohydrates in the nance. The results also show that the temperature contributes positively to the hygroscopicity, since the higher the temperature, the higher the hygroscopicity of the microcapsules. Ferrari et al. [39] and Tonon et al. [41] reported that hygroscopicity is inversely proportional to moisture content. That is, encapsulates are more hygroscopic if their moisture content is low, which, tend to possess a better capacity to absorb water from the environment according to Akhavan. et al. [44].

Key	Inlet Temperature (°C)	Maltodextrin (%)	Yield (%)	Moisture (%)	Hygroscopicity (g of water/100 g of encapsulate)
MD10120	120	10	84.53 0.85	2.63 0.06	15.47 0.85
MD10106	106	10	90.29 2.99	1.47 0.07	13.49 0.13
MD10121	120	10	85.73 2.97	2.21 0.07	15.07 0.06
MD15130	130	15	90.76 1.56	1.07 0.14	15.04 1.34
MD05110	110	5	82.84 1.16	2.40 0.21	18.81 1.43
MD10122	120	10	89.82 1.19	2.15 0.53	15.23 1.09
MD10123	120	10	82.84 2.89	2.57 0.52	15.84 2.72
MD03120	120	3	86.39 2.74	0.90 0.05	18.21 0.18
MD15110	110	15	94.89 2.87	1.42 0.30	14.24 0.45
MD10124	120	10	85.82 2.04	1.79 0.09	14.79 0.72
MD05130	130	5	83.96 1.10	1.41 0.09	17.22 0.07
MD10134	134	10	89.78 1.38	0.15 0.09	15.30 0.16
MD17120	120	17	88.76 1.85	0.84 0.10	14.66 0.12

Table 3. Yields of the encapsulation process of the aqueous extract of nance.

3.4. *Total phenolic content*

Table 4 shows the total phenol content, and Figure 3d shows the behavior with respect to microencapsulation temperature. The highest phenol content was observed at 120 °C and above this temperature the concentration decreases. Additionally, phenolic compounds are heat-sensitive substances, and their biological properties may be affected by high [45, 46]. Mishra et al. [46] reported that above 175°C, microencapsulations with maltodextin exhibit an increase in the quantity of phenols. This behavior may be attributed to the fact that as the temperature increases, polymerization or synthesis of phenolic compounds may occur. On the other hand, Kha et al. [37], and Ferrari et al. [39] mentioned that

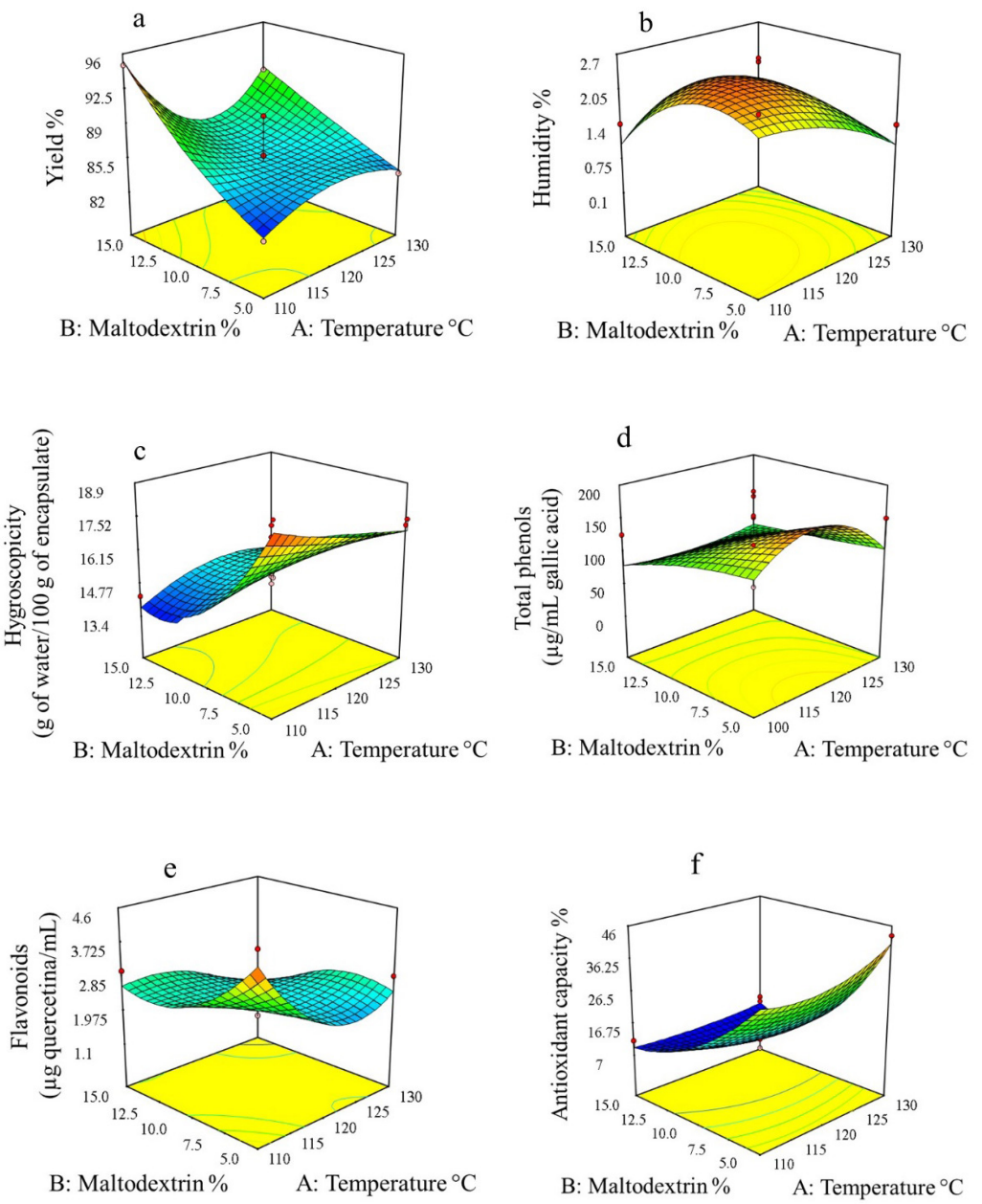

Figure 1. Responses surfaces of microcapsules a) yield; b) moisture; c) hygroscopicity; d) total phenols; e) Flavonoids and f) Antioxidant capacity (% inhibition).

the temperature negatively affects the content of phenolic compounds since there is a degradation and oxidation caused by high temperatures. Kha et al. [37] showed that the encapsulates with higher moisture content have more loss of components; however, when the encapsulates have a higher percentage of moisture they can form agglomerates which would give them greater protection by reducing the contact of the microencapsulates with the environment. In the case of the nance microencapsulates, the content of total phenols was higher in those obtained with high moisture content.

On the other hand, the behavior of the microencapsulation efficiency of phenolic compounds is shown in Figure 1a. It can be observed that the microencapsulation efficiency improves with high maltodextrin concentrations and low drying temperatures. Robert et al. [13], argue that the quantification of phenols may be affected since it is possible that a complete extraction of the compounds has not been performed due to the complexity of the matrix formed and the different polarity and solubility that phenolic compounds present. Queck et al. [31] also mentioned, that one of the disadvantages of using high concentrations of maltodextrin is that it can cause the phenolic components to be inaccurately quantified.

3.5. *The total flavonoid content*

As show in Figure 1f, the flavonoid concentration exhibits a positive correlation with decreasing temperature and maltodextrin concentration. A reduction in flavonoid concentration (MD15130) was observed when the drying temperature was elevated (130 °C), whereas the formulation MD05110 exhibited the highest flavonoid concentration. In this regard, Krishnaiah et al. [47], obtain a similar effect in *Morinda citrifolia* L. encapsulates, and Shahidi and Naczk [48], mention that phenolic compounds and flavonoids can form complexes with polysaccharides and the affinity of phenolics to polysaccharides depends on water solubility, molecular size, conformational mobility and shape of the polyphenol. Yousefi et al., [49] mention that maltodextrin ratio and core/coating ratio are the factors that most affect encapsulation efficiency.

3.6. *Antioxidant Capacity*

Table 4 shows that lower maltodextrin concentrations increase the antioxidant capacity of the microcapsules because the matrix formed by the maltodextrin releases the compounds more efficiently. The formulations that showed the

highest antioxidant capacity were MD03120, MD05130 and MD05110. It was also observed that the formulations MD10120, MD17120 and MD15110 show a decrease in antioxidant capacity when the maltodextrin concentration decreases. Likewise, those microencapsulates that obtained higher percentages of antioxidant capacity were MD05110, MD05130 and MD03120, which showed a high content of total phenols, total surface phenols and flavonoids. It has been observed that the determination of antioxidant capacity is negatively affected by the increase in maltodextrin concentration. Ahmed et al. [50], mentioned that antioxidant capacity is negatively affected by increasing maltodextrin concentration. Also, Mishra et al. [46] reported that the antioxidant capacity decreases when the temperature increases from 125 to 200 °C. Thus, exposure to high temperatures affects the structures of phenolic compounds causing their degradation and inducing the loss of their antioxidant capacity. Kha et al. [37] reported that the antioxidant capacity of microencapsulates decreases with increasing maltodextrin concentration at temperatures higher than 120 to 200 °C causing degradation of antioxidant compounds. High temperatures can lead to the synthesis or polymerization of phenolic compounds [46].

Key	Inlet Temperature (°C)	Total phenols (μg/mL gallic acid)	Flavonoids (μg Quercetin/mL)	Antioxidant capacity (% Inhibition)
MD10120	120	83.59 1.98	2.64 0.16	9.25 0.56
MD10106	106	48.35 1.25	2.60 0.37	18.12 0.22
MD10121	120	151.88 0.57	1.86 0.08	13.12 0.82
MD15130	130	131.22 0.33	1.53 0.32	12.42 0.36
MD05110	110	173.11 2.06	4.59 0.32	36.51 2.53
MD10122	120	153.98 1.54	2.41 0.08	13.42 0.33
MD10123	120	190.52 4.81	2.60 0.14	13.32 0.46
MD03120	120	138.79 1.13	1.86 0.21	45.64 9.70
MD15110	110	125.74 0.45	3.01 0.14	11.52 0.51
MD10124	120	45.91 3.92	2.18 0.24	12.02 1.79
MD05130	130	150.89 1.28	2.88 0.24	43.05 0.99
MD10134	134	22.87 0.87	2.32 0.14	11.97 0.79
MD17120	120	4.75 1.06	2.13 0.45	11.02 0.29

Table 4. Total phenols, Antioxidant capacity and flavonoids of the encapsulation process of the aqueous extract of nance

3.7. *Morphological analysis of microcapsule*

Figure 2 shows the micrographs of the microcapsules obtained by SEM for the different formulations and operating conditions of the spray drying process. The micrographs show the presence of irregular spherical particles with sizes ranging from 8 to 20 μm. The microcapsules with lower maltodextrin concentration presented particles smaller than 10μm. However, at low maltodextrin concentrations there was presence of agglomerates as seen in the microcapsules of MD03120. On the other hand, formulations MD10106, MD15110 and MD05110, obtained at low temperature presented smooth surfaces. The microcapsules of formulation MD10134 showed collapsed surfaces, which can be attributed to the temperature changes suffered by the particles inside the drying chamber. Rosenberg et al. [51] mention that high drying temperatures and fine spray leads to rapid water removal, causing collapsed microcapsules. On the other hand, formulations with higher maltodextrin concentrations (MD15110, MD15130 and MD17120) have larger particle sizes (10 - 20 μm). Rajabi et al. [52] observed this same behavior and attribute it to increased solids in the feed.

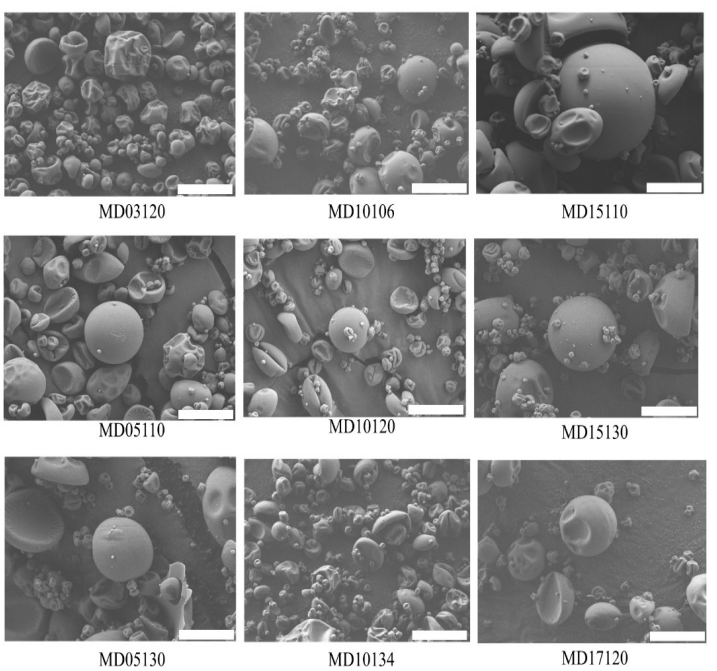

Figure 2. Micrographs of microcapsules of spray dried nance extract powder 2500 X magnification, 5 KV at 10 μm.

Alamilla-Beltrán et al. [53] reported that at low drying temperatures there is a better degree of particle shrinkage. Likewise, particle size tends to be smaller at low temperatures. On the other hand, Dolinsky [54], found that when particles are obtained by spray drying, they begin to dry at temperatures lower than those of the drying air, shrinking once the boiling point of the liquid phase is reached, thus, the particles inflate. This explains the behavior of the particles of the nance microcapsules, with collapsed particles MD05110. In addition, it is observed that the microcapsules MD10134 show deformation due to the high temperatures. Paramita et al. [55] reported that the smaller particles are compressed or roughened which may be due to shrinkage during the drying cycle. However, Tonon et al. [41] mention that at high temperatures particles with smooth surfaces are produced and at low temperatures particles with a rougher structure. This behavior is the opposite of that of the particles of the nance encapsulates.

4. Conclusions

In this study, the effect of spray drying conditions on microcapsules obtained from nance extract were investigated for the first time. It was found that different concentration maltodextrin and inlet temperature have significant effect on the yield, moisture, hygroscopicity and total phenolic content. With a temperature of 130 ° and a maltodextrin concentration of 5%, the highest antioxidant activity was achieved. Particle size is also directly affected by the quantity of solids contained in the feed solution and the drying temperature.

Acknowledgments

The authors would like to thank CONAHCyT, the Instituto Politécnico Nacional, Mexico, the Nanosciences Network of the IPN and the research projects (Proyectos SIP 20240729) that led to this book chapter. As well as the financial support granted by CONAHCyT to Project 2542765 of the Postdoctoral Stay Academic Modality 2022.

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