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ORIGINAL ARTICLE

Physicochemical characterization of microencapsulated spice oleoresin blend using various carrier agents

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Abstract

The present study was carried out to assess the impact of various carrier agents on the physical and chemical properties of microencapsulated spice oleoresin blend. Oleoresins of turmeric, chilli, and coriander were mixed in a definite ratio to get the flavour and aroma of the generally used spice mix in south India. The blend was microencapsulated by spray drying using three different carrier agent combinations, such as gum arabic - GA, maltodextrin - MD, and sodium caseinate - SC for comparison. The use of MD: GA combination had the highest encapsulation efficiency of 77.14 ± 2.05% and an encapsulation yield of 45.92 ± 0.85%, surpassing MD: SC and MD: GA: SC combinations. Physical parameters like hygroscopicity and solubility were higher for MD: GA combination, along with better particle morphology and improved flowability. Retention of active compounds in the microencapsulated powder having MD and GA combination was observed as 98.57% for curcumin, 93.52% for capsaicin, and 95.61% for linalool. The findings obtained in the present study indicated that combining MD and GA effectively protected the oleoresin and enhanced its stability compared to the other two combinations.

Highlights

- Microencapsulation by spray drying to convert oleoresin blend into powder form to enhance stability.
- Impact of three distinct carrier agents on the physical and chemical properties of microencapsulated spice oleoresin blend.
- Comparing three combinations of wall materials for their effectiveness to encapsulate the oleoresin blend.

Keywords Spice · Oleoresin · Microencapsulation · Spray drying · Physico-chemical properties

Abbreviations

CI	Carr index
GA	Gum Arabic
GCMS	Gas chromatography mass spectrometry
HPLC	High performance liquid chromatography
HR	Hausner ratio
MD	Maltodextrin
SC	Sodium caseinate
SEM	Scanning electron microscopy
SO	Surface oleoresin
TO	Total oleoresin
WAI	Water absorption index

Introduction

Oleoresins are the liquid or semi-solid substances extracted from spices through solvent extraction. It encompasses both volatile and non-volatile components of spices, along with antioxidants, pigments, fixed oils etc. Oleoresin has a standardized taste, flavour, and aroma, serving as substitutes for original spices and herbs. This substitution mainly facilitates

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extended shelf life by minimizing the potential for bacterial contamination (Serrano et al. 2020).

Microencapsulation is the process that helps to convert the liquid oleoresin into powder form and it aids in the protection of active compounds present in it. It is carried out to protect the oleoresin from flavour loss and to enhance its solubility in food matrices. This process involves retaining sensitive compounds within another substance (such as carrier agents, capsules or coating materials) and allowing controlled release under specific conditions (Ishwarya et al. 2014). Selecting the right encapsulating agent hinges on its physicochemical attributes, the compound that must be encapsulated, the intended application, and the chosen encapsulation method. A range of commercially approved materials are used as encapsulating agents, including naturally occurring gums (gum arabic/acacia, alginates and carrageenans), proteins (soy protein, milk protein and gelatin), polysaccharides (inulin, cellulose derivatives, and maltodextrins), and lipids (emulsifiers and waxes) (Correa-Filho et al. 2019).

Choosing an appropriate carrier agent is essential for the effectiveness of microencapsulation, as it determines the physical, chemical, and morphological characteristics of the final encapsulated material. Maltodextrin (MD), composed of numerous glucose units that are connected by α-1,4 glycosidic bonds, is key in achieving high dextrose equivalence, which reduces the particle's permeability to oxygen. Higher solubility rate in water and lower viscosity in concentrated solutions of MD allow for an increase in the solids content of emulsions, helps in retaining the core during drying (Ozkan et al. 2018). Gum Arabic (GA), an extensively used natural gum helps in stabilizing and emulsifying food. Its ability to blend smoothly into processed foods and beverages, combined with its low viscosity and high solubility, makes it ideal for producing encapsulated food products. Importantly, GA does not alter the taste, flavor, aroma, or food consistency, which enhances its suitability for food product formulations. As a stabilizer, GA boosts the microencapsulation efficiency and improves the stability and acceptability of the end product. Sodium caseinate (SC) is another versatile wall material for encapsulation and is extensively utilized in food, pharmaceutical, and cosmetic industries to protect and deliver sensitive active ingredients. Derived from casein, a milk protein, and sodium hydroxide (NaOH), SC forms stable encapsulates and is renowned for its biocompatibility, making it highly preferred in various microencapsulation applications. Additionally, it has been identified as particularly effective in stabilizing emulsions and achieving small fat droplet sizes (Shivakumar et al. 2012).

Since most encapsulating compounds are in liquid form, drying techniques, particularly spray drying is commonly employed. It is a commonly used manufacturing process for the large-scale synthesis of encapsulated flavours and volatiles. Its popularity in the industry is due to several benefits, including the availability of equipment, cost efficiency, a variety of carrier solids, product stability, effective retention of volatile compounds and the capability for continuous large-scale production. The feed is transformed to droplets and introduced into a flow of heated air, producing the final product in powder form, granular, or agglomerate (Jafari et al. 2021).

Exploring the microencapsulation of various spice oleoresins through spray drying has been the focus of numerous studies. However, an untouched aspect in the existing literature pertains to the encapsulation of blend of spice oleoresins with variations in the combination of wall materials. Hence, the current study aims to fill this research gap by investigating the physicochemical behaviour of microcapsules of oleoresin blend of turmeric, chilli and coriander developed using various carrier agent combinations, namely GA, MD, and SC by spray drying technique.

Materials and methods

Oleoresins of chilli (*Capsicum anuum* L.) - PL27272, turmeric (*Curcuma longa* L.) - PL88104 and coriander (*Coriandrum sativum* L.) - PL34100 were purchased from Plant Lipids, Kochi, Kerala. Acetone was obtained from Avantor (Maharashtra, India). HPLC water, acetonitrile, orthophosphoric acid and acetonitrile from Merck (Mumbai, India), maltodextrin, gum arabic, SC and tween-80 from HiMedia (Nashik, India). Capsaicin, curcumin, and linalool (Sigma Aldrich) were used as authentic standards.

Preparation of spice oleoresin mix

Oleoresins of coriander (1.5%), chilli (20%) and turmeric (8.5%) were mixed in a definite ratio to obtain a blended spice oleoresin that resembled the flavour and aroma of sambar, one of the most preferred south Indian cuisines. Based on the ratio of the active ingredients in the oleoresin, the oleoresin blend was finalized.

Production of microcapsules through spray drying

Three combinations of MD, GA and SC prepared were, MD: GA, MD: SC and MD: GA: SC by the proportion of 1:1, 1:1 and 2:1:1 respectively to make a total of 40 g of wall material in each combination. It was then mixed into distilled water and adjusted to a final volume of 100 ml. 10 ml of oleoresin blend was added to it along with 1 ml of tween-80 which aids to emulsification. This mixture was then homogenized in shear homogenizer (VelpScientifica, Italy, Model type- OV5) at 2000 rpm for 5 min. The slurry was filtered and spray dried using SMST-tall type sprayer dryer make by SM Scientech- Kolkata-India. The spray drying was performed under the parameters such as; inlet air temperature of 160 °C, outlet air temperature of 80 °C, a feed rate of 3 ml/min with a 3 mm nozzle diameter, flow rate for drying 0.5 l/h, and 4 bar air pressure. Airflow was adjusted to 2400 rpm. The capacity of the spray drier was 1 l/h. The microencapsulated powder was collected and packaged in laminated pouches for further analysis.

Encapsulation efficiency

The microencapsulation efficiency was measured using (Eq. 1) the following approach outlined by Carneiro et al. (2013).

$$\%\,Encapsulation\ efficiency = \left(\frac{TO - SO}{TO}\right) \times 100 \quad (1)$$

Where, TO represents total initial oleoresin content added, and SO represents surface oleoresin content obtained through extraction.

Encapsulation yield

Encapsulation yield was measured by taking the ratio of weight of the powder obtained after drying to the total weight of solids added before drying (Eq. 2). % yield was calculated as;

$$\%\,Yield = \frac{Amount\ of\ powder\ obtained\ after\ spray\ drying\ (g)}{Total\ weight\ of\ solids,\ g} \times 100 \quad (2)$$

Moisture content

AOAC standard method was followed to assess the moisture content of the spray-dried powder (AOAC 2003). 5 g powder was taken in a petri dish and it was kept in oven for 5 h, weighed every 30 min until constant weight is obtained.

$$\%\,Moisture\ content = \frac{W_1 - W_2}{W_3} \times 100$$

Where;

W_1 = weight of the petri dish + initial weight of the powder.

W_2 = Weight of petri dish + final weight of the powder.

W_3 = Initial weight of the powder.

Bulk density

Bulk density was assessed using the modified procedure outlined by Balci-Torun and Ozdemir (2021). 2 g powder was taken in a measuring cylinder and the volume occupied by the powder was noted. Bulk density was calculated by taking the ratio between weight of the powder to the volume it occupied in the cylinder.

$$Bulk\ density = \frac{weight\ of\ powder\ (g)}{volume\ occupied\ (cm^3)} \quad (3)$$

Tapped density

Tapped density was studied by the procedure outlined by Goula and Adamopoulos (2008). 2 g powder was taken and placed in a measuring cylinder and tapped on a flat surface 100 times. The tapped density was calculated by the ratio of weight of the powder and the newly occupied volume.

$$Tapped\ density = \frac{weight\ of\ powder\ (g)}{volume\ occupied\ (cm^3)} \quad (4)$$

Flowability and cohesiveness

Flow properties such as flowability and cohesiveness were assessed in terms of Carr's index (CI) and the Hausner's ratio (HR), respectively (Reddy et al., 2014).

$$Carr's\ index = \frac{Tapped\ density\ \left(\frac{g}{cm}^3\right) - bulk\ density\ \left(g/cm^3\right)}{Tapped\ density\ \left(g/cm^3\right)} \times 100 \quad (5)$$

$$Hausner\ ratio = \frac{Tapped\ density\ \left(g/cm^3\right)}{bulk\ density\ \left(g/cm^3\right)} \quad (6)$$

Classification of the flowability and cohesiveness of the powder based on the CI and HR values are presented below:

Classification of powder flowability based on Carr index (CI).

CI value	Flowability
< 15	Very good
15–20	Good
20–35	Fair
35–45	Bad
> 45	Very bad

Classification of powder cohesiveness based on Hausner ratio (HR).

HR	Cohesiveness
< 1.2	Low
1.2–1.4	Intermediate
> 1.4	High

Hygroscopicity

Hygroscopicity was done by the method described by Nishad et al. (2019). In a petri dish, 5 g powder was taken and kept in a desiccator with 75% relative humidity maintained by a saturated NaCl solution for 5–7 days. It was measured by the rate of absorbed moister per 100 g of spray dried powder.

$$Hygroscopicity,\ \% = \frac{weight\ increased\ (g) + Moisture\ conetnt\ (g)}{Initial\ weight\ of\ sample\ (g) - Moisture\ content\ (g)} \times 100 \tag{7}$$

Wettability

Wettability was studied by the method explained by Gong et al. (2008). 1 g of powder was sprinkled onto the surface of water taken in a beaker (100 ml). Wettability was reported as the time taken for the powder become fully wet and completely sink in to the water.

Solubility and water absorption index (WAI)

Solubility and WAI was studied by following the modified procedure described by Goula and Adamopoulos (2008). In a pre-weighted centrifuge, 2.5 g powder was taken and 30 ml of distilled water was poured. This mixture was stirred frequently for 30 min and then centrifuged for 10 min at 3000 rpm. The supernatant was transferred to a petri dish and dried until its weight remained constant. To calculate WAI, the weight of the sediment was recorded and expressed as the ratio between weight of the wet sediment and the weight of the powder.

$$Solubility,\ \% = \frac{(weight\ of\ petri\ plate\ with\ dry\ supernatant - weight\ of\ empty\ petri\ plate),\ \ g}{initial\ weight\ of\ sample\ ,\ g} \times 100 \tag{8}$$

$$Water\ absorption\ index = \frac{wet\ sediment\ settled\ in\ the\ centrifuge\ tube,\ g}{initial\ mass\ of\ dry\ sample,\ g} \tag{9}$$

Colour analysis

Colour parameters were measured using a Hunter Lab colorimeter (ColorFlex EZ) with CIE Lab scale parameters, including lightness (L*), red-green axis (a*), and yellow-blue axis (b*) values. Before measuring the colour, the instrument was calibrated. The calibration was done by using standard black and white reflector plate. Chroma (Eq. 3) and hue (Eq. 4) were subsequently calculated based on the primary data.

$$Chroma\ (c^*) = \left(a^{*2} + b^{*2}\right)^{1/2} \tag{10}$$

$$Hue\ angle\ (h^*) = 180 + tan - 1\,(b^*/a^*) \tag{11}$$

Morphological characterization of micro particles

The morphological characters of the microencapsulated powder was carried out using SEM (Zeis sigma 300 high-resolution scanning electron microscope). The powder sample was affixed on the stub with double-sided tape followed by a gold-palladium coating applied via plasma deposition technique. The scanning was performed at a voltage of 2 kV and 800x magnification.

Analysis of major active compounds

Determination of capsaicin and curcumin content by HPLC

The examination of non-volatile compounds like capsaicin and curcumin in the spice oleoresin blend was performed using a Shimadzu LC-20 Preparative HPLC system with a PDA detector (Shimadzu, Kyoto, Japan). Separation was done with a C18 column measuring 150 × 4.6 mm and 5 µm (Merck, Germany). Samples were prepared in methanol (HPLC-grade) at a concentration of 100 milligrams per milliliter, were injected and the resulting chromatogram was analyzed using Shimadzu LC Solution 3.6 software. The quantification of these compounds was based on the evaluation of the peak area of the standards.

For the analysis of capsaicin content, column temperature set was 30 °C with 1.5 ml/min flow rate. Mobile phase was acetonitrile along with 1% acetic acid in water (70:30) with detector wavelength at 280 nm. The volume injected was 20 µL.

Curcumin content was quantified using a mobile phase consisting of 60:40 ratio of acetonitrile and orthophosphoric acid of 0.1%. Flow rate was set at 1 ml/min, with wavelength of the detector set to 425 nm, and 20 µL injection volume.

Determination of linalool content by GCMS

The linalool content in the spice oleoresin blend was assessed by Gas chromatography (Shimadzu GC-2010) coupled with a MS (QP 2010). RTX–5 column of 30 m length and 0.25 mm inner diameter was utilized. The carrier gas was Helium with 1 ml/min flow rate, split ratio of 1:40 and an ionization energy of 70 eV. Injection port temperature was set to 260 °C, and the temperature in the detector was 250 °C. Samples were prepared in hexane at 50 mg/mL concentration, were filtered using a 0.2 µm filter before injection into the GC-MS system. Sample volume of 20 µl was injected, and the percentage composition of linalool was determined using area normalization. Components in the powder samples were identified with the mass spectral data from National Institute of Standards and Technology (NIST) and Wiley library databases.

Sensory evaluation

The sensory evaluation of the sambar prepared using microencapsulated oleoresin blend was performed using nine-point hedonic scale with a panel of trained members.

Statistical evaluation

The analysis was conducted in three replicates, results are presented as mean ± SD. R software (Version 13) was used to carry out the statistical analysis.

Result and discussion

The encapsulation yield was 40.6% for the combination MD: GA: SC, 45.92% for MD: GA and 42.9% for MD: SC combination. Ie, highest yield was obtained when MD and GA were combined in 1:1 ratio. Encapsulation efficiency ranged from 64.99 ± 2.95 to 77.14 ± 2.05 for the developed microcapsules (Table 1).

Physical properties of microencapsulated spice oleoresin blend

Microencapsulated oleoresin blend was compared with respect to various physical properties and is shown in Table 1.

Moisture content

According to the present study, moisture content of the encapsulated powder ranged from 4.3 ± 0.1 to 4.55 ± 0.05%. The change in wall material combination had significant effect ($p \leq 0.05$) on the moisture content of the encapsulated powder. The lower moisture content may be due to the higher concentration of MD used for encapsulation. The research conducted by Chen et al. (2023) regarding the microencapsulation of blueberry juice found that the concentration of carrier agents significantly impacted the moisture content. The authors observed that microencapsulation with lower concentration of MD resulted in an encapsulated powder with a moisture content of 8–10%, which is relatively high and this observation agrees with the results obtained in the present study.

Table 1 Physical parameters of MD: GA: SC, MD: GA and MD: SC combinations

Combination		MD: SC: GA	MD: GA	MD: SC
Parameter	Moisture content (%)*	4.5 ± 0.1^{a}	4.3 ± 0.1^{b}	4.55 ± 0.05^{a}
	Encapsulation yield (%)*	40.6 ± 2.58^{c}	45.92 ± 0.85^{a}	42.91 ± 1.01^{b}
	Encapsulation efficiency (%)*	65.91 ± 2.09^{b}	77.14 ± 2.05^{a}	64.99 ± 2.95^{b}
	Bulk density (g/ml)*	0.27 ± 0.008^{c}	0.36 ± 0.005^{a}	0.30 ± 0.002^{b}
	Tapped density (g/ml)*	0.38 ± 0.015^{b}	0.45 ± 0.00^{a}	0.36 ± 0.00^{c}
	Solubility (%)*	92.16 ± 1.4^{b}	94.06 ± 0.66^{a}	91.3 ± 0.5^{b}
	Hygroscopicity (%)*	9.22 ± 0.15^{b}	8.18 ± 0.22^{c}	10.08 ± 0.12^{a}
	Carr index*	29.13 ± 3.48^{a}	20.92 ± 0.76^{b}	21.42 ± 0.00^{b}
	Hausner's ratio*	1.41 ± 0.06^{a}	1.26 ± 0.012^{b}	1.21 ± 0.00^{b}
	Wettability (sec)*	3020 ± 18.87^{a}	2990 ± 35.0^{a}	2970 ± 26.45^{a}
	Water absorption index (WAI)*	0.18 ± 0.011^{a}	0.17 ± 0.017^{a}	0.19 ± 0.029^{a}

*Values are expressed as Mean ± S.D ($n = 3$). Means in rows with different letters (a-c) are significantly different

Bulk and tapped density

Bulk density was lower for MD: GA: SC (0.27 ± 0.008 g/ml) and higher for MD: GA (0.36 ± 0.005 g/ml) combination. Whereas, tapped density was lower for MD: SC (0.36 ± 0.0 g/ml) and higher for MD: GA (0.45 ± 0.00 g/ml). Both bulk and tapped density was significantly affected ($p \leq 0.05$) by the change in combination of wall materials. Chew et al. (2018) studied that the presence of SC contributed to the spongy texture of microencapsulated powder, which negatively affected the bulk and tapped density. Also, increased solid content in the carbohydrate-based wall material resulted in the high bulk density and tapped density. Along with MD, GA also contributed to the density of the microencapsulated powder. Similarly, Ferrari et al. (2013) stated that the use of MD along with GA as wall material resulted in the increase in bulk density of the spray dried powder. Because, wall materials with higher weight will fill the interstitial spaces between particles more effectively, thereby reducing overall volume and leading to increased bulk density values. Moisture content is another factor that contributes to higher bulk and tapped density. Chegini and Ghobadian (2005) explained that encapsulated powder with high moisture exhibited increased bulk density due to the denser nature of water compared to dry solids. The results obtained in the present study are in agreement with this relationship. I.e., as the encapsulated oleoresin blend prepared with a blend of MD and GA showed high moisture content, it resulted in increased bulk density values for this combination.

Flow properties

Flowability and cohesiveness are the two critical characteristics to select the appropriate packaging material for encapsulated powder and are represented by CI and HR, respectively. CI denotes the compressibility and HR denotes the cohesiveness of the powder. Better desirable flowability were achieved with a lower CI, while a higher HR indicates higher cohesiveness (Jinapong et al. 2008). The present study results showed that the MD: GA combination exhibited superior flowability with a lesser CI value (20.92 ± 0.76). Cohesiveness was high for MD: GA: SC combination (1.41 ± 0.06) while the other two combinations had intermediate cohesiveness that ranged from 1.21 to 1.26. The study carried out by Quispe-Condori et al. (2011) reported a high CI value in the range of 33.7–48.7 in the encapsulates of oil from flax seed which resulted in the poor flowability of the same. Reineccius (2004) and Chew et al. (2018,) explained that the addition of GA and MD while spray drying enhanced the flowability of powder due to the high density of these wall materials when compared to SC. These results supported the high flowability and low CI value obtained in the MD: GA combination in the present study. Similarly, flow properties of the powders are also affected by geometry of the particle as the particles in spherical shape and those with high surface area resists the flow as they have high contact surface and cohesive force.

Hygroscopicity

hygroscopicity varied significantly from 8.18 ± 0.22 to 10.02 ± 0.12% for the microencapsulated powder ($p \leq 0.05$) (Table 1). Tonon et al. (2008) mentioned that with the increase in moisture content, hygroscopicity values increased, signifying that powder with lower moisture contents corresponded to lower hygroscopicity. As in the case of moisture content, concentration of wall material also altered the hygroscopicity. According to the study, with an increase in MD concentration in the powder, the hygroscopicity decreased owing to the relatively low hygroscopic nature of MD used for microencapsulation.

Wettability

According to Cynthia et al. (2015), wettability is the ability of the powder to absorb liquid, which is influenced by capillary forces. Wettability of a substance exhibits an inverse correlation with particle size, with larger particles featuring increased interstitial spaces, rendering them more susceptible to water penetration. GA, with its smaller particles and hydrophilic hydroxyl groups, provides a larger surface area for interaction with water, enhancing wettability. This contributes to variations in wettability from powder to powder. The wettability values obtained for the microencapsulated oleoresin blend in the present study ranged from 2970 ± 26.45 to 3020 ± 18.87 s (Table 1). Encapsulated powder with a wettability falling within the range of 30 to 60 s are considered suitable for the proper mixing in water (Naik et al. 2004). The variation in the results obtained in the previous literatures and the observations in the present study could be because of the insoluble and hydrophobic behaviour of the core material used and it was confirmed by Kim et al. (2002).

Solubility

The solubility of encapsulated spice oleoresin blend using various combinations of wall material is shown in Table 1. Solubility was 92.16 ± 1.4% for MD: GA: SC, 94.06 ± 0.66% for MD: GA and 91.3 ± 0.5% for MD: SC combination. The study conducted by Phoungchandang & Sertwasana (2019) in spray dried ginger juice reported that the use of wall material like MD which is amorphous and

Table 2 Colour parameters of MD: GA: SC, MD: GA and MD: SC combinations

Combinations	Parameters				
	L*	a*	b*	Chroma (c*)	Hue angle (h*)
MD: GA: SC	78.2 ± 0.07^a	8.79 ± 0.08^c	66.49 ± 1.16^a	67.06 ± 1.07^a	187.53 ± 0.12^c
MD: GA	75.23 ± 0.08^b	10.67 ± 0.04^b	53.04 ± 0.66^c	54.10 ± 0.45^c	197.50 ± 0.26^a
MD: SC	76.65 ± 0.06^b	13.46 ± 0.04^a	63.22 ± 0.94^b	64.63 ± 0.46^b	192.17 ± 1.03^b

*Values are expressed as Mean ± S.D (*n* = 3). Means in columns with different letters (a-c) are significantly different

Fig. 1 Images of microencapsulated spice oleoresin blend powder, (**a**) MD: SC: GA, (**b**) MD: GA and (**c**) MD: SC

non-crystalline in nature can lead to a powder that has better solubility. According to Krishnan et al. (2005), GA demonstrated solubility values ranging from 80 to 90%. These studies suggested that higher concentrations of GA contribute to improved powder solubility. The study by Nishad et al. (2019) reported that powder with high protein content can lead to reduced solubility because of the formation of insoluble matter during protein denaturation. These findings aligned with the observations from the present study because, solubility values obtained for powders containing SC as carrier agent was low compared to the values obtained for the powder that lack SC. Also, the presence of MD and GA also could make the powder more soluble in water which contribute to the high solubility values of powder samples.

Water absorption index (WAI)

WAI is a quick measure of how well a powder can rehydrate in water under controlled conditions. For effective rehydration, the powder should absorb moisture thoroughly and settle, rather than remaining floated. According to the present study, WAI ranged from 0.17 ± 0.017 to 0.19 ± 0.029 for the three combinations. This result agreed with the study conducted by Ahmed et al. (2010), which indicated that particles leading to increased WAI tend to result in a subsequent reduction in water solubility of the powder, and vice versa.

Colour analysis

Table 2 shows the colour parameters L*, a*, b*, as well as the hue and chroma angle for the microencapsulated powder. All the powders developed using various combinations of wall materials had yellow colour (Fig. 1). Change in combinations of the wall materials had significant affect ($p \leq 0.05$) in the colour parameters of the powder. The L* values were measured in the range of 75.23 ± 0.08–78.2 ± 0.07, a* and b* values in the range of 8.79 ± 0.08–13.46 ± 0.04 and 53.04 ± 0.66–66.49 ± 1.16 respectively. The chroma values (c*) were recorded in the range of 54.10 ± 0.45–67.06 ± 1.07 and hue angle (h*) were between 187.53 ± 0.12° and 197.50 ± 0.26°.

Particle morphology

Microencapsulates prepared by spray drying of spice oleoresin blend using various combinations of GA, MD and SC were studied for its size and shape on SEM (Fig. 2). The encapsulates prepared using MD and GA had more spherical and smoother surface while the other two combinations had wrinkles on it. The encapsulates developed by using MD: GA, MD: GA: SC and MD: SC had maximum size range of 11 µm, 17 µm and 19.6 µm respectively. Comparable morphological attributes (spherical and smooth) were identified in the microencapsulated powder of turmeric oleoresin utilizing gum GA as wall material, as reported by Kshirsagar et al. (2009).

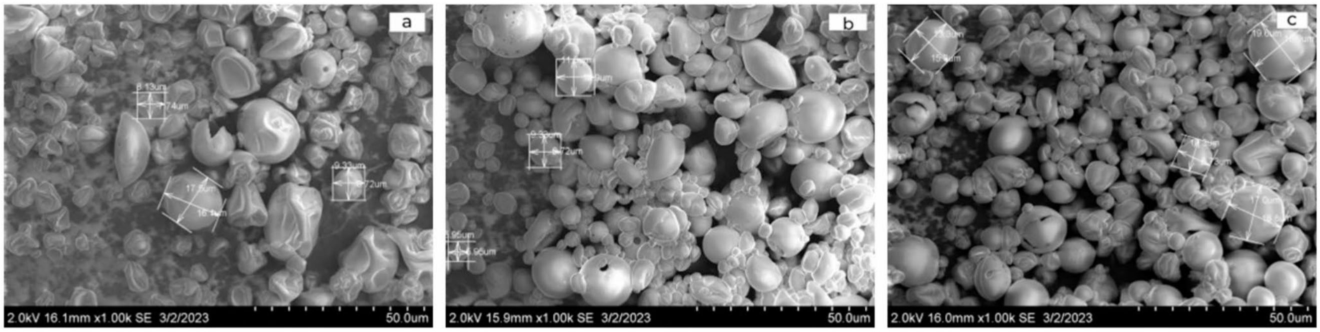

Fig. 2 SEM images of microparticles of (**a**) MD: GA: SC, (**b**) MD: GA and (**c**) MD: SC

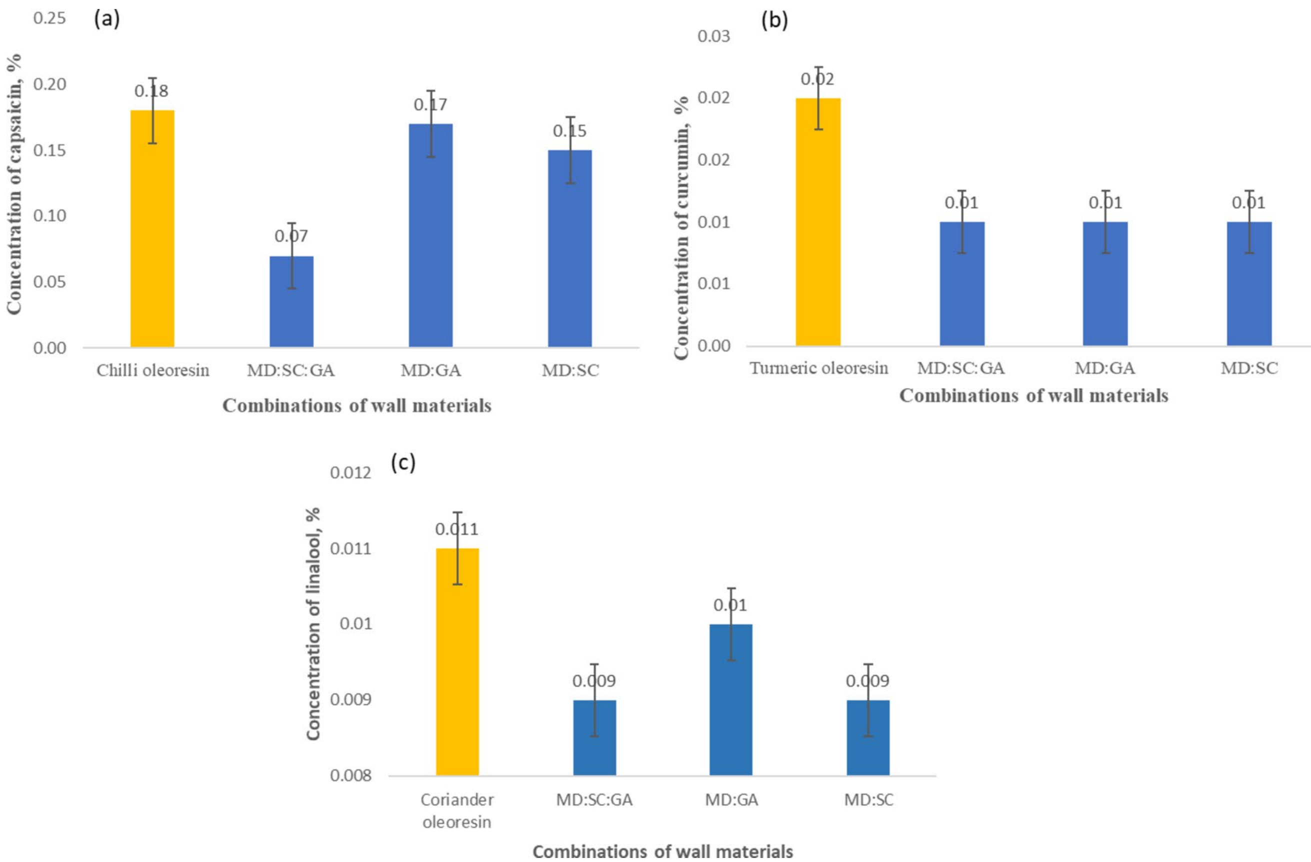

Fig. 3 **a** Capsaicin; **b** curcumin; **c** linalool content in microencapsulated spice oleoresin blends with various combinations of wall materials

Retention of major active compounds

Curcumin and capsaicin in the microencapsulated powder were quantified using the standards of these active compounds in an HPLC system containing a Photo Diode Array (PDA) detector. Concentrations of the active compounds were compared to the concentration present in the commercial oleoresins of turmeric and chilli. Capsaicin content in the purchased oleoresin was 0.18% and capsaicin content in the microencapsulated oleoresin blend was 0.07% in MD: SC: GA, 0.17% in MD: GA and 0.15% in MD: SC combination (Fig. 3). Curcumin content was recorded as 0.02% in the purchased turmeric oleoresin and it was 0.01% for MD: SC: GA, MD: GA and MD: SC combinations. The findings showed that, when a blend of MD and GA was used as carrier agents, it effectively protected capsaicin in the microcapsules ($p \leq 0.05$). However, variations in the combination did not affect the presence of curcumin in the encapsulated spice oleoresin blend ($p \geq 0.05$). The results obtained in the present study are in agreement with those of Meena et al. (2021) in spray-dried curcumin, where the authors reported that curcumin content was highest when MD and GA, supplemented with whey protein, were used as the wall materials. Presence of linalool, major active compound present in coriander was quantified by GCMS. Purchased coriander oleoresin contained 0.011% linalool and it was 0.009% in MD: SC: GA and MD: SC, 0.010% in MD: GA ($p \geq 0.05$). As in the case of curcumin, the linalool content also remained consistent regardless of the carrier agents used for encapsulation. Bertolini et al. (2001) investigated the encapsulation of various monoterpenes (including linalool) using GA as the wall material and reported that high concentration of the wall material led to the degradation of linalool content. Variation in the result in the present study could be because of the use of combination of wall materials for encapsulation rather than using individual carrier agents.

Sensory evaluation

Sambar prepared with microencapsulated oleoresin blend was evaluated to study the organoleptic properties like colour, flavour, taste, appearance and overall acceptability. Sambar was acceptable among the panel members and it had an overall acceptability of 8.5 ± 0.5.

Conclusion

This study intended to investigate a better combination of encapsulating agents for encapsulating spice oleoresin blend. It was found that the 1:1 ratio of GA and MD combination was the most effective among the three combinations explored. This combination achieved a maximum encapsulation yield of $45.92 \pm 0.85\%$ and an encapsulation efficiency of $77.14 \pm 2.05\%$. Notably, observations related to hygroscopicity, solubility, and flow properties, crucial aspects for an encapsulated product, showed promising outcomes for the microcapsules produced with this specific combination. Also, the active compounds such as curcumin, capsaicin and linalool were retained without degradation within the microcapsules. In summary, the utilization of GA and MD blend as carrier agent in the spray drying of spice oleoresin blend emerges as a promising technology for preserving oleoresin. The potential adoption of this technology opens new market opportunities within the food industry.

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Code availability Not applicable.

Declarations

Ethics approval Not applicable.

Consent to participate Not applicable.

Consent for publication I hereby declare that the present work described has not been published before and it is not under consideration for publication elsewhere, its submission to JFST publication has been approved by all authors as well as the responsible authorities tacitly or explicitly at the institute where the work has been carried out, if accepted, it will not be published elsewhere in the same form, in English or in any other language, including electronically without the written consent of the copyright holder, and JFST will not be held legally responsible should there be any claims for compensation or dispute on authorship.

Conflict of interest The authors declare that there is no conflict of interest.

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