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Microencapsulation of lemon oil by spray drying and its application in flavour tea

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ABSTRACT

The aim of this research paper is to develop cost effective coating material for encapsulating lemon oil (as a flavour) without compromising encapsulating efficiency. The three coating materials, namely gum arabic (GA), maltodextrin (MD) and modified starch (MS) and their binary and ternary blends were used to encapsulate lemon oil using spray drying technique. Their properties such as viscosity, emulsion stability, surface oil, total oil, encapsulation efficiency, entrapment efficiency, bulk density and particle size have been investigated. The blend of GA: MS in ratio of 50:50 gave highest encapsulation efficiency. As the percentage of maltodextrin in coating material was increased, the properties of encapsulated material were affected. The encapsulated lemon oil showed better results in instant ice tea premix for beverage with a stability of 6 months.

Keywords: Microencapsulation, Lemon oil, Spray drying, Gum Arabic, Modified Starch, Sensory analysis

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INTRODUCTION

Flavour is an incontrovertibly one of the most-important attributes of the food. Flavours are chemical sensations elicited by a vast number of molecules released by food during eating. Flavour is difficult to define without recourse to the human sensing apparatus. Consumers consider flavour, appearance and texture in selection, acceptance and ingestion of a particular food. “Flavour is nothing but the complex sensation comprising taste, odour, roughness or smoothness, hotness or coldness and pungency. Of these qualities, odour and taste are main components of flavour and are primarily responsible for its discrimination” It is also defined as a “sensation produced by material taken in the mouth, perceived principally by the sense of taste and smell, and also by general pain, tactile and temperature receptors in the mouth “The trigeminal senses” detects chemical irritants in the mouth and throat. Temperature and texture are also very important to the overall flavour perception. The flavour of the food as such can be altered with natural or artificial flavourants, which affect these senses. Flavourant is defined as a substance that gives another substance flavour, altering the characteristics of the solute, causing it to become sweet, sour, tangy, etc.

The flavours can be natural, natural identical and synthetic, basically, three main sources of flavours –
i. Essential oils and natural extracts (Natural)
ii. Aroma chemicals (Synthetic)
iii. Formulated flavors and fragrances (Nature Identical)

Nowadays, flavours derived from essential oils are highly used due to their bioavailability nonhazardous functionality.

Citrus (Lemon, Orange oil etc.) has been the source of distinctive essential oils that have been esteemed by people throughout the world for centuries [1]. There is hardly any product in food, beverage, soap, cosmetics and perfume industries which do not contain at least a small quantity of the delightfully scented, refreshing citrus oils.

Citrus oils have unique composition profiles depending on the cultivar, processing conditions and storage conditions. There are more than 200 different compounds identified in citrus oils. The reactivity and volatility of citrus oils require strict quality control protocols. The quality of citrus oils determines their function and market value [1].

Lemon oil (*Citrus Limonum)*, the most important of the citrus oils, has sharp, fresh smell. It is mainly due to limonene. β-pinene and terpinene-4-ol are responsible for the green peely odour that associates with lemon oil [2]. The high amounts of unsaturated and oxygen-functionalized compounds in these oils are very susceptible to oxidation. The resulting changes in peel oil constituents have long been known to responsible for deteriorative changes during storage. Oxidation has been known to be influenced by temperature, UV irradiation and presence of metal.

Microencapsulation is one of the most effective techniques for protecting volatile compounds against evaporation, oxidation and thermal degradation. Microencapsulation is defined as technology of packing of specific (core) substances (solids, liquids or gases) in miniature, sealed capsules (microcapsules of diameters from 1 to 800 μm) with a matrix material (carrier) in order to protect their special properties during storage, distribution or applications [3, 4].

Microencapsulation has also become an attractive approach for transforming liquid flavourings into stable, free flowing powders which are easy to handle and incorporate into dry mix. It can add an extra zing, mask the taste or odours of undesirable components, alleviate processing problems and extend the shelf life of the products. Microencapsulation technology provides those and other benefits by providing a controlled, sustained and/or timed release of the encased materials through a wide range of rupture mechanisms.

As the name indicates microencapsulation is the encapsulation around microscopic particles having sizes in the order of microns in which the active material forms the core, surrounded by a protective sheath of wall material [5]. Microencapsulation may be achieved by a myriad of techniques, with several proposes in mind. The most remarkable techniques are spray drying, spray chilling and spray cooling, extrusion, coacervation, inclusion in cyclodextrins, air suspension coating, centrifugal extrusion, centrifugal suspension-separation, alginate beads and freeze drying [6, 7]. Among all these methods, spray drying is currently dominating flavour encapsulation technique, offers a potential means of producing unique flavour-loaded microcapsules [8].

Gum arabic (gum acacia) has been the standard of excellence as a flavour encapsulating material for many years. It is an excellent emulsifier, bland in flavour and provides good retention properties for the volatiles during the drying process. The gum also has the advantage of being considered natural in most countries [9, 10]. While in the past years cost and availability of gum arabic have been an important concern, these issues are less important due to a systematic cultivation. The blends of gum arabic with maltodextrin and/or modified starch may represent an encapsulating matrix with improved properties regarding flavour retention, emulsion stability and protection against oxidation. Although previous researchers have already investigated blends of gum arabic with maltodextrin and/or modified starches [11, 12], none of them undertook a systematic, statistically rigorous approach in order to define optimum combination among the blends.

The objective of the present study is to optimize microencapsulation of lemon oil (essential oil) with gum arabic, maltodextrin, modified starch and their binary and ternary blends using spray drying technique. The encapsulation efficiency was checked for all the carrier materials and their stability and sensory analysis were done to investigate their application efficiency.

MATERIALS AND METHODS

1.1. Raw materials

1.1.1.Core Material

Ginger oil, Lemon oil and Cardamom oil were the gifted samples obtained from Synthite Industries Ltd, Kochin. The essential oils, oleoresins and other plant extracts contribute to the largest category of flavourings. Most of the liquid food flavourings are volatile and chemically unstable due to the presence of air, light, moisture and high temperatures. Similar is the case with essential oils like Ginger oil, Lemon oil and Cardamom oil. Hence, these essential oils were selected for the encapsulation.

1.1.2.Wall Material

- Gum arabic (gum acacia) was a gifted sample obtained from Silver Oak Innovations.
- Maltodextrin was a gifted sample obtained from Silver Oak Innovations.
- Modified starch was a gifted sample obtained from National starch.

All chemicals used were of AR grade.

1.2. Methods

1.2.1.Emulsion Preparation

Wall materials were separately rehydrated for overnight and then gently heated at 60°C in a water bath to allow complete dissolution. Blends of wall materials, described in the experimental design figure 1, were prepared by directly mixing the components at the corresponding concentrations. Solutions were allowed to cool to room temperature before storing under refrigeration (4°C) until emulsion preparation. 30gm of wall materials (gum arabic and modified starch) were individually dispersed in distilled water and final volume made to 100ml. It was rehydrated overnight at 10°C in a refrigerator, after which 3gm (10% of the carrier used) of respective essential oil was added to the mixture. The mixture is emulsified in shear homogenizer for 10min at 3000 rpm until complete dispersion of the essential oil was obtained.

1.2.2.Spray Drying

The slurry of the carrier material, water and essential oils (Ginger oil, Lemon oil, Cardamom oil) were spray dried in a JISL, LSD-48 model mini spray drier. The pressure of the compressed air for concurrent the flow of spray was adjusted to 2 bars. The inlet and outlet temperatures were maintained to 175±5°C and 95±5°C respectively. Aspirator was adjusted to 40 % and Peristaltic pump was used to feed the slurry into nozzle at 22% efficiency. The microcapsules so prepared were collected from the collecting chamber; these powders were filled in airtight, self-sealable polyethylene pouches and stored in desiccators containing calcium chloride at 25°C to prevent moisture absorption and lump formation until further studies.

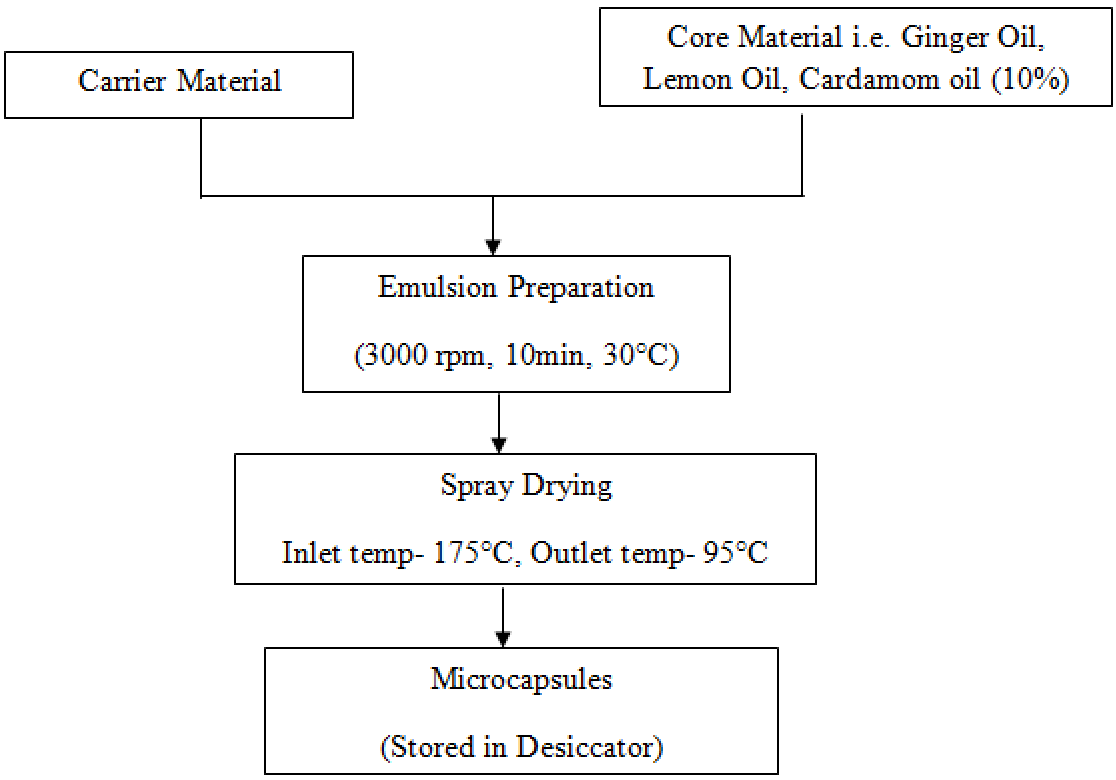

Figure 1. Flow sheet for spray drying of essential oil

1.2.3.Design of wall material of microencapsulation

The experimental design of wall material for microencapsulation is given in table 1.

Table 1. Experimental design of wall material

Sr. No.	Carrier Material	Gum Arabic (%)	Maltodextrin (%)	Modified Starch (%)
1	Gum Arabic	100	0	0
2	Maltodextrin	0	100	0
3	Modified Starch	0	0	100
4	GA:MD[a]	75	25	0
5	GA:MD	50	50	0
6	GA:MD	25	75	0
7	GA:MS[b]	75	0	25
8	GA:MS	50	0	50
9	GA:MS	25	0	75

[a] *GA:MD = Gum Arabic: Maltodextrin*
[b] *GA:MS = Gum Arabic: Modified Starch*

Furthermore, blending of gum arabic, maltodextrin and modified starch was undertaken. Blends of these three wall materials may represent an encapsulating matrix with improved properties regarding essential oil retention, emulsion stability and protection against oxidation. Hence, further permutations and combinations were performed to develop centroid mixture design to evaluate the blends of gum acacia, maltodextrin and modified starch as encapsulating materials. The design for an experiment is given in table 2.

Table 2. Design for ternary blending gum arabic, maltodextrin and modified starch for effective encapsulation

Co-ordinates (GA/MD/MS)	Gum Arabic %	Maltodextrin (%)	Modified Starch (%)
(1/3, 1/3, 1/3)	33.33	33.33	33.33
(4/6, 1/6, 1/6)	66.66	16.66	16.66
(1/6, 1/6, 4/6)	16.66	16.66	66.66
(1/6, 4/6, 1/6)	16.66	66.66	16.66

RESULTS AND DISCUSSION

1.3. Determination of optimal process conditions
The optimal process conditions were determined by using lemon oil as a core material and pure gum arabic as carrier (wall) material. The carrier concentration was 30% for all the formulations. The spray drying process was carried out at four different temperatures i.e. 150°C, 160°C, 175°C, 180°C for different oil loadings (10%, 20% and 30%) and checked for their encapsulation efficiency. Figure 2 summarises the data.

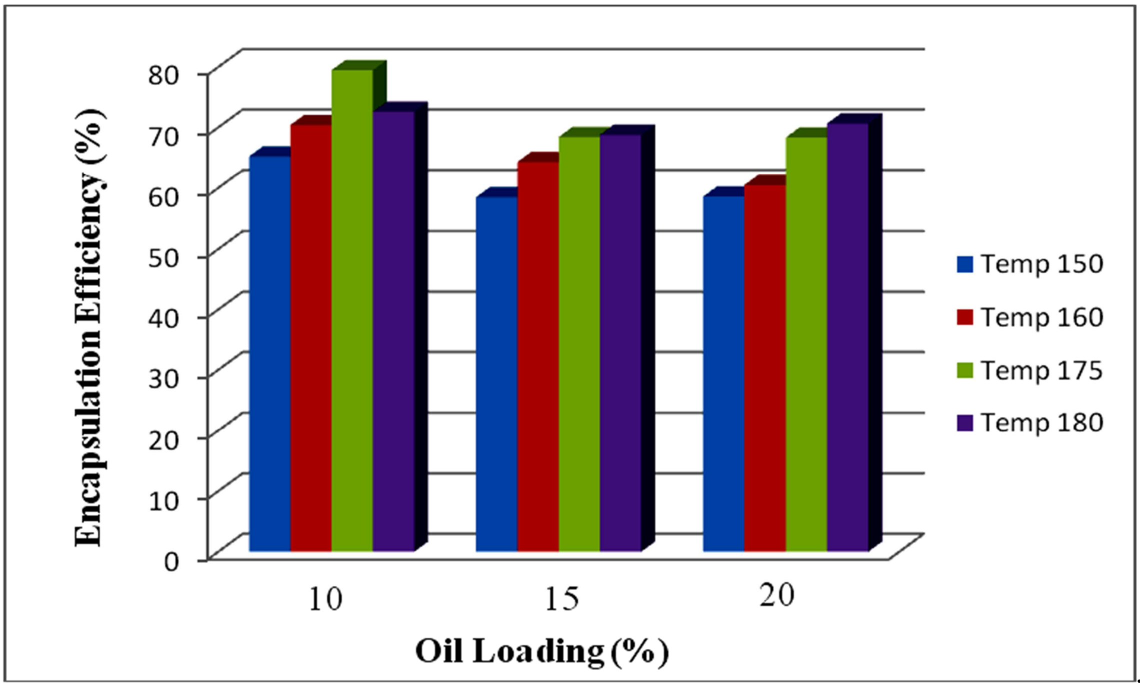

Figure 2. Process optimization parameters for microencapsulation

It can easily be said that 10% oil loading gives effective encapsulation for all the temperatures. The optimum temperature to achieve significant encapsulation efficiency is 175^{o}C. It gives maximum efficiency (77.50%) for 10% oil loading at 175^{o}C. These results conclude that the flavour retention increases with an increase in inlet air temperature. The higher inlet air temperatures produce a more rapid drying which thereby results in a shorter time until the formation of high solids 'skin' around the droplets. Higher inlet temperatures also increase the duration for internal mixing and thus enhances oil retention. Also, microencapsulation efficiency was found to be decreased with increase in oil: wall ratio. Therefore, the optimum conditions for effective spray drying encapsulation are summarized in Table 3.

Table 3. Optimum conditions for effective spray drying microencapsulation

Variable	Optimal Value
Inlet air temperature	175±5^{o}C
Outlet air temperature	95±5^{o}C
Carrier material concentration	30%
Optimal retention efficiency	77.50
Oil loading (%)	10%

1.4. Emulsion viscosity and stability index before spray drying

Viscosity of all the emulsions before spray drying was determined by using *Brookfield Viscometer* at 25°C.

Emulsion stability index (ESI) study was carried out by standing the prepared emulsion in a graduated cylinder for overnight and the reading was noted in ml. The emulsion stability index was evaluated using the formula shown below equation 1.

$$Emulsion\ Stability\ Index = \frac{Total\ Volume\ of\ Separated\ Oil}{Total\ Volume\ of\ Oil\ in\ Emulsion} \qquad (1)$$

Table 4. Viscosity and emulsion stability index (esi) of homogenized emulsion before spray drying

Carrier Materials	Viscosity (cps)	Emulsion Stability Index (ESI)
GA (100%)	115	1.0
MD (100%)	40	0.34
MS (100%)	70	1.0
GA:MD (75:25)	105	1.0
GA:MD (50:50)	85	0.41
GA:MD (25:75)	65	0.38
GA:MS (75:25)	110	1.0
GA:MS (50:50)	95	1.0
GA:MS (25:75)	72	1.0
GA/MD/MS		
1/3,1/3,1/3	90	1.0
4/6,1/6,1/6	108	1.0
1/6,4/6,1/6	75	1.0
1/6,1/6,4/6	55	1.0

Table 4 showed the viscosities and emulsion stability index of homogenized emulsions before spray drying. Viscosity of emulsion is important, since this parameter affects the size of microcapsules and thickness of their walls. Gum Arabic (115 Cps) was found to give maximum viscosity among all the carrier materials. Maltodextrin (40 Cps) showed least viscosity. Viscosity of modified starch (70 Cps) was more than maltodextrin. Also, it was observed that when all materials were used in combinations, the viscosity got decreased.

The emulsion stability index [ESI] of all 13 batches was also referred in table 4. The data clearly indicates that gum Arabic and modified starch was excellent emulsifier for lemon oil. Poor emulsifying properties of maltodextrin were evident to the fact that maltodextrin in the blend lowers the emulsion stability. Except for the maltodextrin, all the emulsions formed were stable. The data portrays that GA (1.00) and MS (1.00) have good ESI as compared to MD (0.34). The ESI of 1 indicates that emulsion was highly stable and there was no separation of oil in 24 hours.

1.5. Spray drying analysis

The spray dried powder was analysed for its total oil, surface oil, encapsulation and entrapment efficiencies, bulk density and powder particle size.

1.5.1.Total Oil Determination

Total oil in the spray dried powders was determined by *Clevenger distillation.* A 500 ml flat-bottomed flask was used to dissolve 5gm of powder (±0.04 gm) in 150ml of distilled water. Each flask was stoppered and manually shaken for approximately 1 min in order to break lumps and facilitate dissolution. Boiling chips were added. The Clevenger apparatus was fitted to the flask with an ice-water cooled condenser on top of it. The solution was distilled for 3 hrs. The volume of oil read directly from the oil collection arm, was converted to gm of the oil by multiplying by the density of the oil system. Samples were run in duplicate. The results are shown in Table 5.

1.5.2.Surface Oil Determination

Surface oil was determined by *solvent extraction.* This involves placing the encapsulated product in a flask and adding organic solvent (hexane). The flask was then shaken for several minutes. The powder was filtered from the solvent and then solvent was removed by using *Rotavac* unit. The residue or surface oil was determined by weighing the residue. The data is summarized in Table 5.

1.5.3.Encapsulation Efficiency

The encapsulation efficiency was determined using the following equation 2. –

$$Encapsulation\ Efficiency\ (\%) = \frac{Total\ oil\ experimental\ loading\ \left(\frac{g}{g}\right)powder}{Theoretical\ loading\ \left(\frac{g}{g}\right)powder}\ X\ 100 \qquad (2)$$

The encapsulation efficiency for all carriers and their blends is given in Table 5.

1.5.4.Entrapment Efficiency

The entrapment efficiency was calculated using the formula equation 3 –

$$Entrapment\ Efficiency\ (\%) = \frac{Total\ oil\ \left(\frac{g}{g}\right)powder - Surface\ oil\ \left(\frac{g}{g}\right)powder}{Total\ oil\ \left(\frac{g}{g}\right)powder}\ X\ 100 \qquad (3)$$

The encapsulation efficiency for all carriers and their blends is mentioned in Table 5.

Table 5. Effect of gum arabic, maltodextrin and modified starch, their binary and ternary blends as the carrier material on surface oil, total oil, encapsulation efficiency and entrapment efficiency

Carrier Material	Surface oil (g/g powder)	Total oil (g/g powder)	Encapsulation efficiency (%)	Entrapment efficiency (%)
Gum Arabic (100%)	0.0025	0.0712	77.50	95.85
Maltodextrin (100%)	0.0028	0.0459	50.52	94.30
Modified Starch (100%)	0.0026	0.0608	66.88	95.71
GA:MD (75:25)	0.0007	0.0672	73.92	98.95
GA:MD (50:50)	0.0016	0.0656	72.16	97.55
GA:MD (25:75)	0.0043	0.0624	68.68	93.10
GA:MS (75:25)	0.0036	0.0616	67.76	94.14
GA:MS (50:50)	0.0028	0.0760	83.60	96.31
GA:MS (25:75)	0.0009	0.0689	75.86	98.69
1/3,1/3,1/3	0.0015	0.0707	77.79	97.87
4/6,1/6,1/6	0.0031	0.0672	73.92	95.37
1/6,4/6,1/6	0.0010	0.0640	70.40	98.43
1/6,1/6,4/6	0.0023	0.0633	69.70	96.36

NOTE: The error was ranging from 0.05% to 0.1%

Table 5 gives encapsulation and entrapment efficiency of pure gum Arabic, maltodextrin and modified starch, their binary and ternary blends. The table also gives the data about effect of the carrier material on the surface and total oil. The data showed that surface oil is minimum for GA than MD and MS. The GA gives microcapsules containing minimum surface oil 0.0024g as compared to MD 0.0026g and MS 0.0026g, but the total oil is comparatively higher for GA i.e. 0.0712g than 0.0608g for MS and 0.0459g for MD. Hence, the encapsulation efficiency of GA was higher i.e. 77.50% followed by MS (66.88) and MD (50.52). This shows that highest encapsulation efficiency found in GA microcapsules was may due to larger particle size of GA microcapsules which retain maximum oil amongst the carrier material studied.

The data also showed the effect of a blend of carrier materials on surface oil and encapsulation efficiency. In GA:MD blends, the combined blend of GA and MD (25:75) gives less encapsulation efficiency as compared to the individual carrier material i.e. 68.64%. These results clearly indicate that as the percentage of gum arabic decreases in blends, encapsulation and entrapment efficiency decreases consequently. Higher percentage of maltodextrin was not recommended because of a dramatic drop in oil retention. Further, gum arabic and modified starch blends gave better results than the blends prepared by using gum arabic and maltodextrin, suggesting gum arabic and modified starch as better combination for lemon oil retention. Highest encapsulation efficiency among all the blends was found in the blend having GA and MS in 50:50 ratio. It was found to be 83.60%.

Highest encapsulation efficiency for ternary blends was found in the blend having ratio 1/3,1/3,1/3. The best ternary blend obtained contains GA/MD/MS in ratio of 1/3,1/3,1/3 was found to be best for microencapsulation of lemon oil giving low surface oil i.e. 0.0015g and maximum encapsulation efficiency i.e. 77.79% which is greater than other ternary blends while the entrapment efficiency was found to be 97.87%. In this blend, an excellent emulsifying, film forming and binding properties of gums can be obtained.

There was a clear trend from above data that oil retention increases with an increase in modified starch and decrease in maltodextrin as wall material. These results confirmed the reported data in the literature, which regarded modified starches as excellent carriers for volatile retention and characterize maltodextrin as having a marginal retention of lemon oil. Hence, in general, encapsulation efficiency is better for GA which is followed by MS and then MD. In the present study, the blend of 50% GA and 50 % MS gave excellent results in terms of encapsulation efficiency and found to be best among 13 batches hence further used for the encapsulation of Orange, Ginger and Cardamom oils.

1.5.5.Bulk Density

Bulk density was determined by tapping method. 10 gm of a powder was loosely weighed in100 ml graduated cylinder. Cylinder with the powder was tapped on soft surface. The final volume was recorded. Bulk density was calculated by dividing the sample weight by the volume.

$$Bulk\ Density = \frac{Weight\ of\ spray\ powder}{Volume\ of\ spray\ powder} \tag{4}$$

1.5.6.Powder Particle Size

Particle size analysis of the spray dried powder was done using Beckman Coulter LS 230 Laser Diffraction Particle Size Analyzer.

It measures the size of particles (powders, suspensions and emulsions) using the diffraction and diffusion of a laser beam.

Both bulk density and particle size analysis data is summarized in Table 6.

Table 6. Bulk density and particle size of a spray dried lemon powder

Carrier material	Bulk density (g/ml)	Particle size (µm)
GA (100%)	0.385	10.24
MD (100%)	0.466	13.55
MS (100%)	0.435	10.88
GA:MD (75:25)	0.378	11.56
GA:MD (50:50)	0.377	11.80
GA:MD (25:75)	0.384	12.47
GA:MS (75:25)	0.392	10.77
GA:MS (50:50)	0.408	11.66
GA:MS (25:75)	0.466	10.82
1/3,1/3,1/3	0.408	10.33
4/6,1/6,1/6	0.377	12.30
1/6,4/6,1/6	0.378	10.07
1/6,1/6,4/6	0.4	10.44

Bulk densities were determined by tapping method for all 13 powders. They were ranging from 0.377 to 0.466. From a theoretical point of view, particles with smaller diameter contribute to a tighter packing and thus, leads to an increase in bulk density. The bulk density of gum Arabic was found to be 0.385 as compared to maltodextrin (0.466) and modified starch (0.435). Bulk density of a combination of GA:MS (50:50) was found to be 0.408.

The table also showed the particle size of the microcapsules. The particle size of microcapsules was in the range of 10.07µm (GA, MD, MS – 1/6,4/6,1/6) to 13.55µm (MD-100%). The particle size of pure GA, MD and MS was found to be 10.24, 13.55 and 10.88 µm, respectively. The fine capsules were obtained in 100% GA. Particle size of a combination of GA: MS (50:50) was found to be 11.80 µm.

1.6. Stability and sensory analysis of encapsulated flavour

1.6.1.Stability Studies

In this study, the microcapsules stability helped to determine the formula compatibility. The microcapsules were incorporated in the lemon drink (ice tea) at 1% levels and stability was studied at various temperatures. Testing includes storage of the drinks under ambient conditions and 45°C in an ordinary oven. Also, the sample was kept under refrigeration temperature (4°C) for 3 weeks that corresponds to stability study for six months (especially for the food products). The stability results are given in Table 7.

1.6.2.Sensory Analysis

The samples kept for stability studies were studied for its sensory characteristics. *Hedonic* and *Intensity Scale* ratings were used to evaluate the sensory attributes of the lemon ice tea premix by expert panel members. These data is summarized in Table 7.

1.6.2.1. Hedonic Scale

A measure of the degree of acceptance of the product was obtained by the use of the hedonic scale. Panellists were asked to their degree of likes or dislikes in terms which best describes their perception about the product. The term may be given numerical values to enable the results to be scored. Rating of the product according to hedonic scale is as follows (Table 7)-

Table 7. Tabular form of Hadonic scale

Sr. No.	Hedonic Scale	Score
01	Dislike Completely	1
02	Dislike Somewhat	2
03	Dislike a Little	3
04	Neither Like nor Dislike	4
05	Like a Little	5
06	Like Somewhat	6
07	Like Completely	7

1.6.2.2. Intensity Scale

Intensity scale measures the odour strength of the product. Panellists were asked to rate the odour strength of the lemon ice tea on the basis of 10-point scale.

Rating of the product is as follows (Table 8)-

Table 8. Tabular form of intensity scale

Sr. No.	Intensity Scale	Score
01	None, No Odour	0
02	Threshold Odour	1
03	Very Slight Odour	2
04	Slight Odour	3
05	Slight to moderate Odour	4
06	Moderate Odour	5
07	Slightly Strong Odour	6
08	Moderately Strong Odour	7
09	Strong Odour	8
10	Very Strong Odour	9
11	Extremely Strong Odour	10

Table 9. Stability study and sensory analysis of spray dried lemon flavour in instant ice tea premix

Panel Number	Room Temperature (28°C)			Accelerated Temperature (45°C)			Refrigerated Temperature (4°C)
	No of days			No of days			no of days
	7	15	25	7	15	25	25
	Hedonic Scale Rating						
P_1	4	5	5	5	4	5	6
P_2	4	4	6	4	6	6	7
P_3	5	6	5	5	5	5	7
P_4	4	6	5	5	6	5	6
P_5	5	4	4	4	5	5	6
P_6	5	5	4	6	4	5	7
P_7	4	5	5	4	5	5	6
	Intensity Scale Rating						
P1	5	6	7	5	6	7	5
P2	6	6	7	6	7	8	6
P3	5	6	6	7	8	7	6
P4	6	7	7	6	7	8	5
P5	5	6	7	5	6	7	6
P6	6	5	7	6	7	8	6
P7	6	6	7	5	6	8	5
Appearance	No change			No change			No change
Odour profile	Citrusy, lemon note reminiscent of the peel with slight bitter undertone						

Table 9 indicates the stability study and sensory analysis of the spray dried lemon powder at 1% concentration in Lemon Ice Tea premix. It was observed that there is no significant change in appearance of the drink and it gives good odour profile of lemon even after 3 weeks of application. It was also observed that the microcapsules give slight turbidity and settlement in the drink during the stability studies.

The results show that on hedonic scale, the sample kept at refrigerated temperature gave better results than samples kept at ambient and accelerated temperatures. The scores given by panel to refrigerated temperature samples were between 6 and 7. It was then followed by samples kept at accelerated temperatures and ambient temperature.

On the *intensity* scale rating, the samples kept at accelerated temperature showed good results as compared to the refrigeration and ambient temperatures. The score reached a maximum of 8 (i.e. strong odour), while some panellists gave score of 7 (i.e. moderately strong odour). The results so obtained could be due to the fact that release rates were higher at accelerated temperatures. The microcapsule gave controlled release of the lemon flavour over a period of time.

Hence, it was observed that lemon drinks were stable for 3 weeks, with no change in appearance and a good odour/taste profile at 45°C, which would be equivalent to 1-year stability at ambient temperature.

1.7. Overall sensory analysis of spray dried microencapsulated lemon oil.
All the batches of spray drying were optimized to get maximum encapsulation efficiency, total oil content, minimum surface oil. The most efficient batch was carried forward for the application in ice tea premix.

The blends of powdered sugar, tea extract powder and acids were made by making permutations combinations in order to get proper sugar-acid ratio in the final product. The appropriate percentage of powdered sugar, tea extract powder, citric acid, malic acid were 97%, 1.8%, 0.15% and 0.1%, respectively. Further optimization of flavour dosage was performed by using three different concentrations of spray dried lemon flavour (1%, 1.5% and 2%). The ice tea was served by diluting ice tea premix with ice water in the ratio of 1:10.

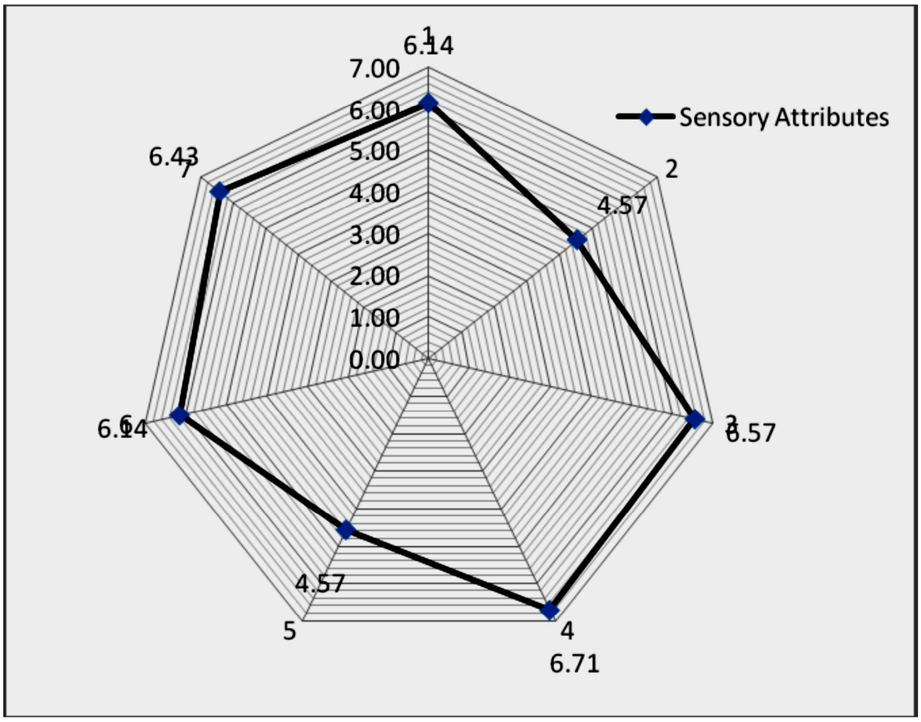

Figure 3. Spider chart for sensory attributes of lemon ice tea

The sensory evaluations of all the three batches were carried out on 7 point Hedonic scale by seven expert panel members. The best batch was found to be 1.5% concentrated spray dried lemon flavoured ice tea. The results for this batch are shown in tabular (Table 10) as well as in spider chart form (figure 3).

Table 10. Sensory analysis of lemon ice tea

No	Attributes	Ratings by R1	Ratings by R2	Ratings by R3	Ratings by R4	Ratings by R5	Ratings by R6	Ratings by R7	Mean
1	Flavour	6	5	7	6	6	7	6	6.14
2	Aroma	5	4	5	5	4	4	5	4.57
3	Body	7	7	6	6	7	6	7	6.57
4	Colour	7	7	6	7	6	7	7	6.71
5	After taste	5	4	5	4	4	5	5	4.57
6	Clarity	5	6	7	6	7	6	6	6.14
7	Overall rating	6	6	7	7	6	7	6	6.43

Table 10 and Figure 3 indicate the sensory analysis of Lemon ice tea conducted by 7 panel members. Data shows that overall acceptability of the product is 6.64 out of 7. Out of the all attributes used for sensory analysis colour got highest rating and after taste got the lowest rating.

CONCLUSION

The microencapsulation of lemon oil with three carrier materials i.e. gum arabic, maltodextrin, modified starch and their binary and ternary blends was successfully carried out using spray drying. The parameters such as carrier concentration (30%), core material concentration (10%), inlet temperature (175^{o}C) and outlet temperature were found to be effective for maximum encapsulation efficiency. The experimental results are concluded as follows:
Though maltodextrin forms least viscous solution than gum Arabic and modified starch, it gives minimum emulsion stability. In blends of carriers too, as a percentage of maltodextrin in blend increases, emulsion stability goes down. The blend of Gum Arabic and modified starch gives most stable emulsion.

Due to large particle size, gum Arabic gives maximum encapsulation efficiency than others. It gives minimum surface oil concentration but maximum total oil concentration which is highly recommended for any carrier material. These materials could be put in the following order depending on their efficiency: GA> MS> MD.But to make encapsulated material cost-effective, gum Arabic was blended maltodextrin and modified starch. It is investigated that GA:MS at 50:50 combination gives highest encapsulation efficiency (82.60%). Even ternary blend (GA/MD/MS) in combination of (1/3,1/3,1/3) does not give such high efficiency.

Encapsulated lemon oil showed better results in instant ice tea premix for beverage with a stability of 6 months. Further, the effective dosages of the encapsulated lemon oil are found to be 1.5% in the instant ice tea premix.

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