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RETENTION OF ORANGE PEEL OIL DURING MICROENCAPSULATION: INFLUENCE PROCESS AND WALL MATERIAL

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ABSTRACT

Microencapsulation is one of the quality preservation techniques of sensitive substances and a method for production of materials with new valuable properties, e.g .in food and pharamaceutial industries. Orange peel oil was encapsulated with Arabic gum (GA), maltodextrin (MD), and modified starch (MS) by spray drying using inlet and exit air temperature 200^{0}C and100 ^{0}C respectively. The encapsulation process developed the quality of orange oil which was clear from the increments of total oxygenated components of orange oil to reach 5.91%, 13.4% and 4.51% for oil carried on GA, MS or MD carriers, respectively compared 0.80% fresh orange oil.

The results showed that MS had the high volatile retention (91%) over GA (89%) or MD (57%) alone

Different ratio of GA and MD were used as wall materials for orange peel oil encapsulation by spray drying 100:0, 30:70, 40:60, 50:50, 60:40, 70:30 and 0,100. Encapsulation in 70:30 GA: MD gave the best retention of orange peel oil (92%)

It is obvious that the retention of volatiles was decreased with the increase of the proportion MD increased. The MS alone gave flavor retention that inferior to 70:30 blends of GA and MD. The blend consisted of 70:30 of GA to MD yield flavor stability almost equivalent that of pure GA as the carrier. The use of MD decreases the cost of the carrier and allows spray drying at higher infeed solids because of the lower viscosity of the emulsion.

INTRODUCTION

Flavor plays an important role in consumer satisfaction and influences further consumption of foods. Most available aroma compounds are produced via chemical synthesis or extraction. Foodstuffs containing synthetic flavor are often avoided, because the consumers suspect that these compounds are toxic or harmful to their health (Teixeira *et al.*, 2004).

Flavor stability in different foods has been of increasing interest because of its relationship with the quality and acceptability of foods, but it is difficult to control. Manufacturing and storage processes, packaging materials and ingredients in foods often cause modifications in overall flavor by reducing aroma compound intensity or producing off-flavor components (Lubbers *et al.*, 1998). Flavors form very complex systems because there are many variables. Some are more stable in carbohydrates which are water soluble and some are more stable in lipid-based coating. Many factors linked to aroma affect the overall quality of the food; examples are physico-chemical properties, concentration and interactions of volatile aroma molecules with food components (Landy *et al.*, 1995). To limit aroma degradation and loss

during processing and storage, it is beneficial to encapsulate volatile ingredients prior to use in foods or beverages.

Orange oil is of a great economic importance in food industry; its volatile components are highly sensitive to the oxidation by effect of temperature, light and oxygen presence (Matthews and Braddock, 1987). Natural flavor encapsulation is a field of relatively recent study (Bangs and Reineccius, 1990; Kim, and Morr, 1996; Bertolini, 2001), which needs to be explored to fortify this important science and technology area.

Encapsulation is especially widely used in dry flavor production, while the vast majority of flavor compounds used in industries are in the form of liquids at room temperature. For food products and beverages such as cake and soup mixes, jelly crystals, dry beverage mixes, and instant breakfast drinks, the use of liquid flavoring is not technologically acceptable. Therefore, it is necessary to present the flavoring components in the form of a dry, free-flowing powder. This can be achieved by encapsulation technology

Although several encapsulation methods have been reported (Dziezak, 1988; Chen *et al.*, 1988), the spray drying is one of the most economical and flexible process. This technique allows obtaining high volatile retention efficiencies and it produces powders with a satisfactory stability (Reineccius, 1991).Some factors affecting retention are chemical and physical properties of the core and wall materials (Rulkens and Thijssen, 1972; Reineccius 1988; Sheu and Rosenberg.1995), properties of the feed, atomization and drying conditions.

Successful microencapsulation depends on the right choice of wall material and understanding of how the core material is organized and protected within the microcapsules.

In the present work, the influence of the type of wall material (Arabic gum modified starch and maltodextrin) on the retention of orange peel oil has been studied during spray drying

MATERIALS AND METHODS

Materials

Orange peel oil was obtained from Kato aromatic Co., Gizza, Egypt. characteristics Arabic gum (acacia gum) was obtained from PRS Panreac (Espania) ,modified starch (N-Lok) was obtained from (National Starch and Chemical Co., U.S.A) and Maltodextrin DE-20 was obtained from (National Co. Maiza Product Cairo, Egypt) . , were used as encapsulant agents.

Methods

Emulsion Preparation and Spray Drying

Solutions of Arabic gum, modified starch and maltodextrin each containing 25,30,35,40 percent (w/w) solids dispersed in deionized water were gently heated (60^0C) over a steam bath to facilitate solubilization). The solutions were allowed to cool to room temperature before storing under refrigeration overnight (4^0C). The orange oil (20% w/w of solids) was added and homogenized vigorously (10 000 rpm for 5 min) with an Ultra Turrax M-45 homogenizer at ambient temperature (22°C). The obtained emulsion was maintained under slow agitation during spray drying.

The emulsion was spray dried in a BUCHI 190 Spray Dryer with an evaporation rate of 1.5 kg /1 hour and a chamber diameter of 10 cm, equipped with a pressurized nozzle operating at 5 atmospheres. Feed is metered into the dryer by a peristaltic pump. Drying conditions were controlled using inlet and exit air temperatures of 200 ^{o}C - and 100 ^{0}C, respectively. Powder was collected at the bottom of dryer cyclone and kept in air tight containers at 8^{0} C until analyzed

Analytical Method

Characterization of the orange oil was made in accordance with essential oils international standards (Anon, 1976). These include sensorial characteristics (appearance, color and odor), physical characteristics (specific gravity, refraction index, solubility in diluted alcohol and optical rotation) according to the method described by (Guenther, 1961) chemical characteristics determined by using Gas Chromatography technique

Separation and identification of the chemical components of essential oils:-

Gas chromatography technique was used to separate and identify the volatile chemical components under the following conditions:

A Hewlett Packard 5890 series II Instrument equipped with flame ionization detector (FID) and a carbowax fused silica column (50 m length , 0.25 mm i,d . , film thickness 0.32 micro meter) was used . The oven temperature was programmed from 60 ^{0}C to 200^{0}C at a rate of 3^{0}C/min ., Helium (1ml/min) was used as Carrier gas ; Split ratio 100:1 the temperature of injection port and detector were 150^{0}C and 250°C, respectively. Percentages of peak area were calculated with a Hewlett Packard 3396 integrator.

Determination of pH

The pH value of microencapsulant solutions was determined with a pH meter (HANNA). Bench –top

Determination of Viscosity

Viscosity of solution and emulsion was determined using Brookfield Viscometer (Brookfield DV-II+, Middleboro, MA, USA) equipped with the LV spindle

Stability of Emulsion

Physical stability of the emulsions was determined by storing 8 ml samples in a 15 x 85 mm round bottom borosilicate tubes in replicate for 10 days at 25^{o}C. The depth of the free oil layer formed was measured and when this depth was than ≥ 2 mm, the stability of the emulsion was considered broken.

Determination of Total oil

Total oil in the Spray dried powders was determined by Clevenger distillation (A.O.A.C., 1990). A 500 ml Flat – bottomed round flask. 20 g powders were dissolved in 150 ml deionized water. Each flask Stoppard and manually shaken for approximately 1 min in order to break powder clumps and facilitate dissolution. Boiling chips and approximately 0.5 ml antifoam solution (Fischer Scientific, Pittsburgh, Pa., U.S.A.) were added .The Clevenger apparatus was fitted to the top of the flask with an ice water – cooled condenser on top of it. The solution was distilled for 3h .The volume of

the oil, read directly from the oil collection arm, was converted to g oil by multiplying by the density of the oil system .0.85 g/ml

Determination of Surface Oil

A Soxhlet extraction apparatus was used for removing the surface oil from the encapsulated samples. Forty grams of powder were placed in an extraction thimble and covered with glass wool .The powder was extracted with hexane for 4 h, after which the oil retention was determined by Clevenger hydrodistillation. Differences in oil volume between solvent washed samples versus non-washed samples were attributed to surface oil on the powder (Trubiano and Lacourse, 1988)

Determination of Moisture Content

Moisture content was determined by the toluene distillation method (A.O.A.C. 1990**)**. A sample (20 g) of powder was added to 125 ml toluene in a 500 ml flask .The flask .was fitted with a bidwell-steling trap and the sample brought to boil on a hot plate. Distillation was carried out for 2 h. The distillate was allowed to cool to room temperature before the volume of water was read directly from the trap.

Bulk Density

Bulk density was determined by the tapping method. Powder (30 gm) was loosely weighed into a 100 ml graduated cylinder. Cylinder with the powder was tapped on a flat surface to a constant volume. The final volume was recorded. Bulk density was calculated by dividing the sample weigh by the volume (Bhandari *et al.*, 1992)

Emulsion Stability (Powder)

The stability of the emulsions was determined by measuring optical density of the solutions following centrifugation. A solution (0.2%) of each spray dried powder was prepared in water and the optical density read at 400 nm prepared in a Coleman spectrophotometer. A solution (0.16%) of carrier (Arabic gum) was used as a blank. This is based on a carrier to flavor ratio of 4:1. The initial optical density of each solution was read and then the solution was centrifuged in (EBA 20 Hettich Germany) centrifuge at 500 rpm for 0, 5,10,2030, and 45 min. The optical density was read after each time period (Risch and Reineccius, 1988)

RESULTS AND DISCUSSION

1-Orange Peel Oil Constituents

The data of table (1) showed that the major component of cold pressed orange peel oil is d-limonene (95.92%). Same data showed that the monoterpene hydrocarbons representing 99.19% of the identified oil components, while the oxygenated components (5 components) representing 0.80% of the identified oil components. Shaw (1979) mentioned that d-limonene of orange peel oil ranged between 83-97%.

After encapsulation orange peel oil using three carriers materials namely GA, MD and MS , the major component i.e. Limonene (95.92) suffer from loss by 6.12 , 11.13 , 3.64% with GA, MD and MS carriers, respectively

Moreover, the encapsulation process developed the quality of orange oil which was clear from the increments of total oxygenated components of

orange oil to reach 5.91%, 13.4% and 4.51% for oil carried on GA, MS or MD carriers respectively compared with 0.80% fresh orange oil.

Table (1) Chemical composition of cold pressed orange peel oil before and after encapsulation over three carriers

Retention time(min)	Major Component	Before encapsulation fresh%	After encapsulation GA	MD	MS
4.393	α - pinene	0.59	0.58	0.34	0.54
5.890	B - pinene	0.31	0.27	0.18	0.28
6.443	Camphene	0.21	0.18	0.12	0.19
6.721	Myrcene	1.96	2.74	7.12	2.78
7.916	Limonene	95.92	89.8	78.67	92.28
7.993	Cineole	0.23	0.20	0.13	0.21
4.466	γ - Terpiniene	0.03	0.03	0.02	0,03
10.184	P- cymene	0.18	0.16	0.1	0.17
14.720	Linalool	0.42	1.37	2.24	0.88
24.025	Neral	0.05	2.06	4.03	1.04
25.450	α - Terpineol	0.05	1.04	3.11	0.54
26.781	Geranial	0.05	1.44	4.03	1.05

GA: Arabic gum MD: maltodextrin MS: modified starch

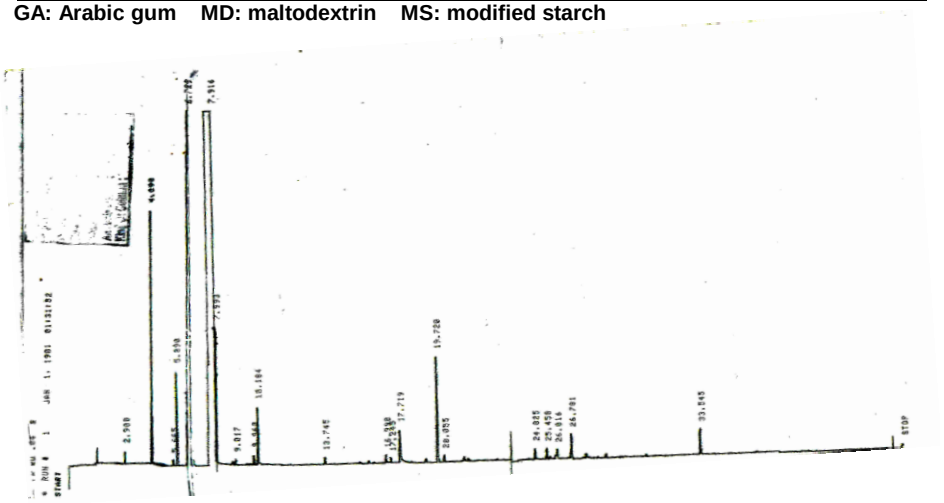

Figure (1): Chemical components of orange peel oil fractionated and identified by GC-Mass

Orange oil characterization.

The sensory and physical characteristics of orange peel oil are shown in Table 2.

The orange oil used in the present study was matching with the International Standard Determination of Viscosity behavior of wall material

The increasing of the concentration of the dissolved solids is considered to be a powerful parameter for achieving an improvement of volatiles retention. Viscosity can exert an effect on volatiles retention during drying by influencing circulation currents with the drying droplet (Re, 1998)

.However, there are restrictions because of opposing effects related to the consequential increase of the viscosity, since high viscous solution may have difficulty to pump through the atomizer of highly viscous solution can produce larger, irregular and lighter powder particles. As the drying time is longer, it cause accumulated of some under – dried particles on the chamber wall (Bhandari et al,1992) .Thus, viscosity may be increased to an optimal value to improve retention .According to Rosenberg *et al.* (1990) and Sankarikutty *et al.*(1988), Viscosity of about 70 -130 cp was very acceptable for spray drying encapsulation.

Table (2) sensory and physical characterization of Orange peel oil

Characteristics	**Parameter**	**Result**	**Reference International Standard (Anon,1976)**
Sensory attributes	Appearance	Liquid	Liquid
	Color	pale Yellow	Pale Yellow
	Odor	Characteristic	Characteristic
Physical	Refractive Index (20^0C)	1.4740	1.4730 -1.4740
	Solubility in 95% ethyl alcohol Solubility in water	Soluble in 1 ml. 95% ethyl alcohol Insoluble in water	Soluble in alcohol Insoluble in water
	Specific gravity (20^0C)	0.8451 mg/ml	o.8430 - o.8455 mg/ml
	Optical Rotention	+ 98º	+ 95º : + 99º

The viscosity of each wall material with solution of 5-10% concentration was similar (Table 3) .As the solid concentration of solution was increased, the viscosity of each wall material began to be significantly different.

Form the data showed in Table (3) it could be conclude that Maltodextrin had a very low viscosity up to 30% solids that it was not acceptable as wall material. In the contrary, GA and MS a concentration of 30% was very acceptable for spray drying.

Table (3) Effect of the concentration of some Selected Wall Materials on their Viscosity (by centipoises cp at 25^0C)

Concentration W/W %	**Viscosity of Selected Wall Materials (CP) at 25^0C**		
	MD	**MS**	**GA**
5	10.5	12.2	13
10	12.6	13.8	16
15	14	18	25.2
20	17.2	32.2	46
25	22.9	43.1	75.1
30	35.1	75	146
35	46.8	115	269
40	60	266	445

MD: Maltodextrin MS: Modified: Starch GA: Gum Arabc CP: Centipoises

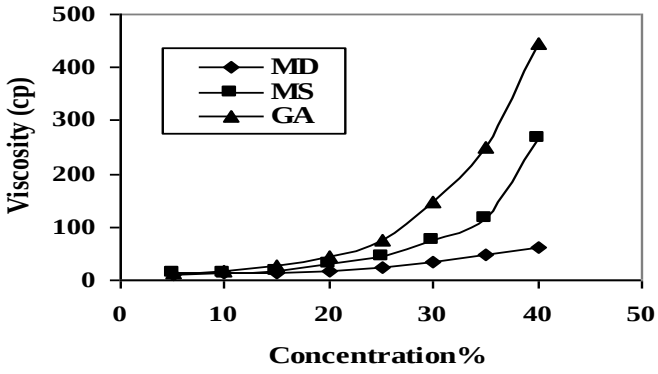

Figure (2): Viscosity of the selected wall materi

Emulsion characterization of different carriers

The characterization of three used carriers (viscosity, pH and stability) namely Maltodextrin, Modified starch and Arabic gum examined and the obtained data are table (4).

Table (4): Emulsion characterization of Maltodextrin, Modified Starch and Arabic Gum

Concentration W/W%	Viscosity (CP) 25^0C	pH	Stability days
Maltodextrin			
25	21	5	0
30	33	4.8	0
35	42	4.5	0
40	56	4.3	0
Modified starch			
25	42	4.8	4
30	70	4.6	> 10
35	106	4.3	> 10
40	260	4.1	> 10
Arabic gum			
25	75	4.3	> 10
30	144	4.2	> 10
35	262	4.0	> 10
40	445	4.0	> 10

From the data (Table 4), it could be observed that the pH of the encapsulated solutions ranged from 4 - 5 which relatively decreased with each increase in carrier concentration .The pH of Arabic gum (acacia gum) emulsion are lower than that found in modified starch (N-lok) emulsion .Viscosity of microencapsulating solution and emulsions is important, since this parameter affects the size of microencapsulated particles and the thickness of their walls. In the present study Arabic gum viscosity was higher

than modified starch (N-lok) viscosity at similar concentrations .Same table 4 had the higher stability (10 days), while maltodextrin showed negligible stability. The maltodextrin emulsion was difficult to stabilize even with continuous agitation throughout the drying process.

The relation ship between carrier concentration and the retention of different carriers after spray drying

The effect of carrier concentration before spray drying was detected (for Maltodextrin, Modified starch and Arabic gum)

From the data in table (5) it is clear that the optimum carrier concentration for all used (3 carriers) was 30% ,since the retention % were 56,91,89% for Maltodextrin, Modified starch and Arabic gum respectively.The infeed solids concentration is the most important determinant of flavor retention during drying.

Table (5): Effect of concentration MD, MS and GA as wall material on the percentage of retention

Concentration w/w%	Total oil g/100g powder	Retention %
Maltodextrin		
25	10.2	51
30	11.2	56
35	11.4	57
40	11.4	57
Modified starch		
25	17.0	85
30	18.0	91
35	18.0	91
40	18.2	91
Arabic gum		
25	17.6	88
30	17.8	89
35	17.2	86
40	-	-

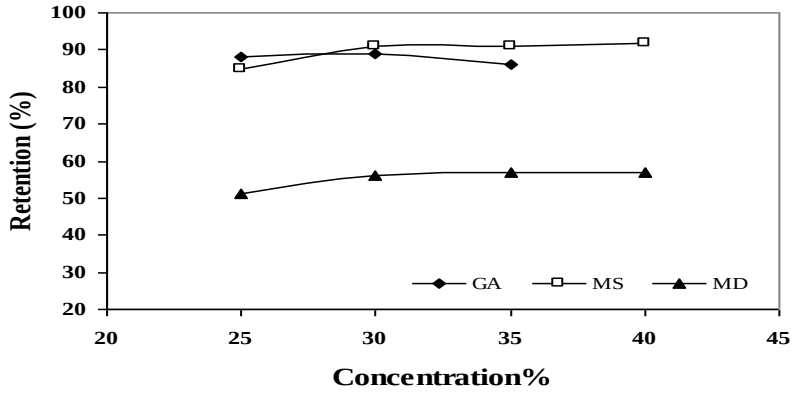

Figure (3): Effect of concentration GA, MS and MD as wall materials on the percentage of retention

The modified starch is substantially less viscous than the Arabic gum and thus can be used at higher infeed solids levels. While Arabic gum is limited to used at about than 35% infeed solids levels.

The Second concentration is the amount of flavor into the carrier

The data in table (6) showed that both ratios 9:1 (10%) and 4:1 (20%) had the highest retention but when ratio up to3:1(25%) a lower retentions were indicated with the three studied carriers .Similar results were reported by (Sankarikutty, et.al 1988, Risch 1995), who mentioned that a ratio 4:1 is usually adopted in most of published reports The 4:1 ratio has been reported optimal for encapsulating materials like gum arabic, and for other carbohydrate derivatives (Reineccius , 1988)

A decrease in volatiles total retention and an increase in volatiles retained on the surface of powder particles was also observed by (Bhandari *et al.*,1992), when the wall to oil ratio was decreased from 4:1 to 3:1 . In spite of this trend, in some specific applications higher volatile loads would also provide higher retention. For example , Sheu and Rosenberg ,(1995) obtained high ethyl caprylate retention in a whey protein / carbohydrate combined wall system for an ester load of 30% (w/w) . Corresponding to a wall: core ratio of 2.3:1.

Table (6) Effect of oil –wall ratio on the retention%

Concentration	**Retention %**		
Oil : Wall	**MD**	**MS**	**GA**
1 : 9	57	91	88
1 : 4	56	91	89
1 : 3	52	82	75

MD :Maltodextrin MS: Modified Starch GA: Arabic gum

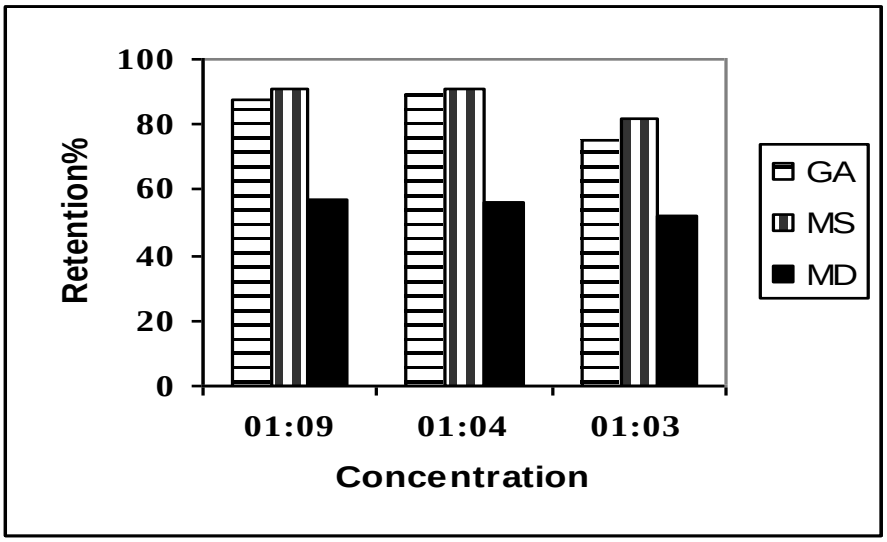

Figure (4) Effect of oil –wall ratio on the retention%

Table (7) Properties of encapsulated orange oil after spray drying (Total oil, Surface oil, and Moisture and Bulk density)

Wall material	Total oil g oil/ 100g powder	Retention oil%	Surface oil g oil /100g powder	Moisture %	Bulk density g/ml
Maltodextrin	11.2	57	0.426	4.0	0.55
Modified starch	18.2	91	0.323	3.5	0.42
Gum Arabic	17.8	89	0.975	4.6	0.46

The three carrier samples were evaluated at zero time for total oil, surface oil, moisture, and bulk density to provide back ground information for subsequent shelf life.

As for Table (7) Total oil, spray drying yields product with volatile oil contents ranging from 11.2-18.2 % w/w. Modified starch (N-lok) showed the highest volatile oil retention. Maltodextrin had the lowest volatile oil content of spray dried samples.

Moisture analysis showed that moisture range percent were 3.5-4.6. N-lok had the lowest moisture percent while Arabic gum had the highest moisture percent.

In addition the highest surface oil was that of Arabic gum 0.975 g/100g.While N-lok had the lowest surface oil 0.323 g/100g.

Influence of the combination ratio of GA to MD

As mentioned before, increasing the viscosity enhances emulsion stability by retarding the movement of the droplet; the release rate may also be reduced because of the ability of certain food ingredients to retard the movement of flavor molecules to the surface of the liquid, which may be due to enhance viscosity or due to structural hindrance(McClements,1999)

The effect of GA to MD ratio was studied using 1: 4, 1:2.3, 1:1.5, 1:1, 1:0.67, and 1:0. 43 and 1:0.25 ratio of GA: MD, respectively on the viscosity and the obtained results are shown in table (8).

Table (8) Change in viscosity of emulsion with different combination ratio of gum arabic to maltodextrin

Gum Arabic : Maltodextrin	Viscosity (CP)
2:8	79
3:7	82
4:6	85
5:5	90
6:4	92
7:3	97
8:2	99

The data of table (8) indicated that each ten proportion of carriers (GA and MD) increase in the viscosity of emulsion was increase with each Arabic gum concentration.

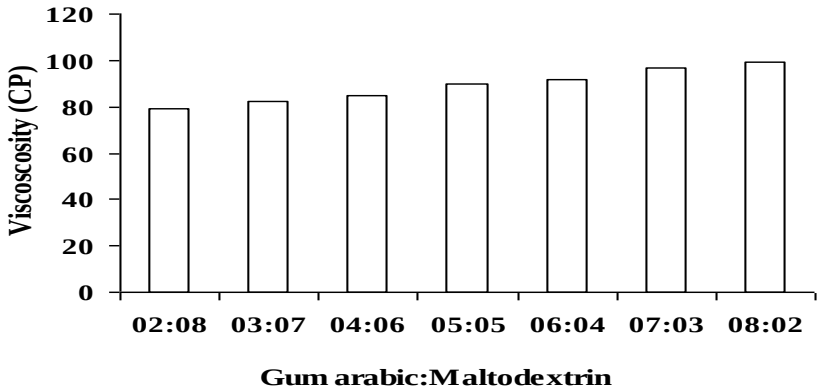

Figure (5): Change in viscosity of emulsion with different combination ratio of GA: MD

Blends of Maltodextrin with Gum arabic

Each of the starch –based encapsulation ingredients has its own strengths and weaknesses .A blend of several of these ingredients can give performance superior to using any one ingredient alone. It is possible to blend maltodextrin with either modified starch or Arabic gum and significantly reduce costs without reducing its efficiently, and sometimes improving encapsulating ability

Table (9) Effect of the ratio of blends gum Arabic to Maltodextrin on flavor Retention

blendes Maltodextrin/gum Arabic(MD:GA)	Total oil goil/100g powder	Retention%	Surface oil g/100g
100:0	11.2	56	0.4
30:70	18.4	92	0.5
40:60	17	85	1
50:50	18	90	0.6
60:40	16.6	83	1.2
70:30	12	60	0.9
0:100	17.8	89	0.8

From the data tabulated in table (9) the highest retention % was detected (30:70, 50:50) MD: GA whiles the lowest retention was detected maltodextrin alone, as for surface oil the ratio 60:40, 40:60 record 1.2 , 1 g /100g powder lowest surface oil 0.4 was record for maltodextrin alone

Emulsion stability

Emulsion stability in finished product is one of the most important criteria in carrier selection .The emulsion stability is illustrated in Figure (6). The result agreed with what could be predicated by stockes law; i,e . that a smaller particle radius yields a more stable emulsion.

$$V = 2 r^2 g(d_1 - d_2) / gn$$

Where V= velocity of rise (or fall) of droplets, r = droplet radius, g =acceleration due to gravity, d_1 and d_2 = densities of the two phases and n = viscosity of the continuous phase.

The rate of decreases in optical density was greatest in the least stable emulsions. The decrease in optical density was from the creaming phenomenon which is the orange oil rising to the top of the solution .this point is most important in beverage applications where the solution must remain stable for weeks or even month

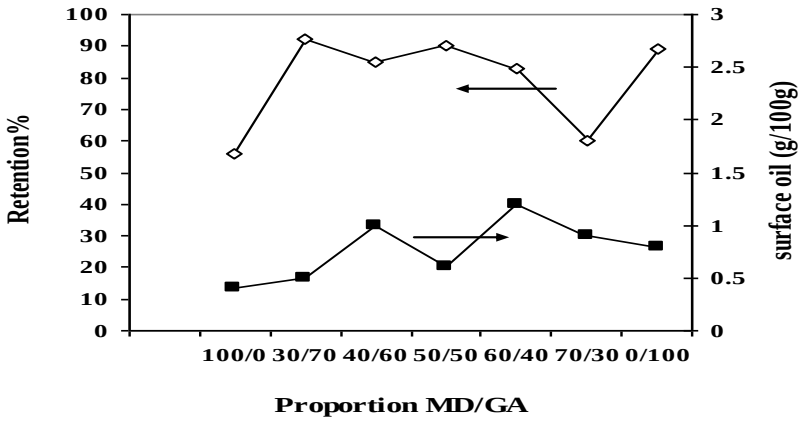

Figure (6) Effect of the ratio of blends gum Arabic to Maltodextrin on flavor Retention

Fig. (7) Shown that the modified starch is initially better (i,e.has higher absorbance) than gum acacia and continues to be during centrifugation. . The poor emulsion stabilizing abilities of maltodextrin .

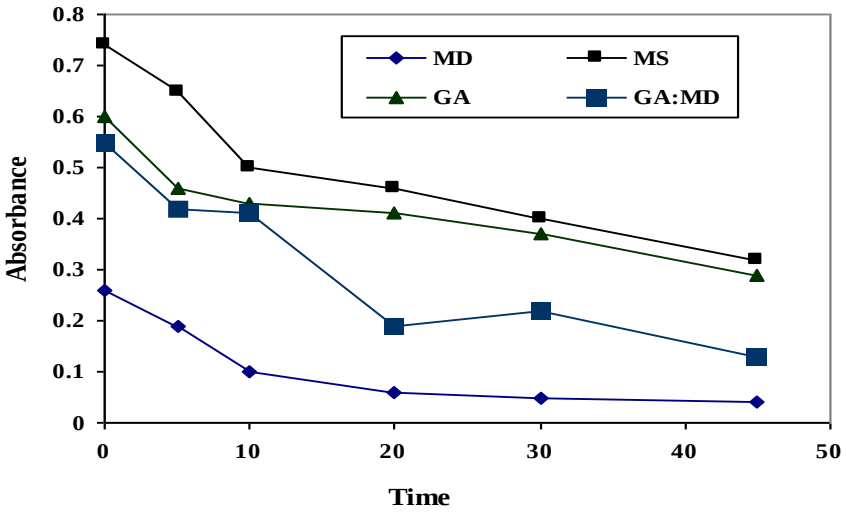

Figure (7): Emulsion Stability in different carrier

The emulsions made with modified starch are physically more stable than those made with Arabic gum. One means of doing so is to produce a small particle size (Trubiano and Lacourse,1988) compared the particle size of emulsions made with lemon oil and various encapsulation matrices,Arabic gum solutions produced an average emulsion droplet size of about 3 µ m ,maltodextrin 2-10 µ m and modified starch less than 2 µ m

Conclusion

1- Viscosity of wall materials showed very acceptable for spray drying in case of gum Arabic and modified starch at 30% concentration
2- Feed emulsion characterization examined and showed that gum Arabic and modified starch can form high stability
3- The highest retention of flavor (91%) was detected with modified starch
4- The concentration of core (orange peel oil) at 1:9 or 1:4 had the highest retention (91%) on modified starch
5- Encapsulated products were evaluated and modified starch showed high total oil (18.2%) highest retention oil (91%) ,lowest surface oil (0.323 g /100 gram powder) , and lowest moisture (3.5%).
6- Blends of Arabic gum and Maltodextrin were effect and viscosity were determined, high viscosity was noticed (99 CP) due to increase Arabic gum quantity in blends

On the other hand, flavor retention was highest with 70:30 ratio of GA: MD

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استرجاع زيت قشر البرتقال أثناء الميكروكبسلة بتاثير العملية والمواد الحاملة للكبسولة

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تعد الميكروكبسلة واحدة من التقنيات الحفظ للمواد الحساسة وهى طريقة لانتاج مواد ذات خصائص قيمة على سبيل المثال الصناعات الغذائية والدوائية. تم كبسلة زيت قشرالبرتقال بالصمغ العربى والمالتودكسترين والنشا المعدل باستخدام المجفف الرذاذى على درجة حرارة الهواء الداخل ٢٠٠°م والهواء الخارج ١٠٠ °م . ولقد وجد أن عملية الكبسلة أدت الى تحسن جودة الزيت وهذا كان واضحا من مجموع المركبات الأكسجينية لزيت قشر البرتقال المكبسل لتصل الى نسبة ٩١و٥% , ٤و١٣% , ٥١و٤% بعد التحميل على مواد التغليف وهى الصمغ العربى والنشا المعدل والمالتودكسترين على الترتيب مقارنة بـ ٨ و%فى زيت قشر البرتقال الطازج.

وأوضحت النتائج أن النشا المعدل كان لة القدرة على الاسترجاع تعادل نسبة ٩١% والتى كانت أعلى من الصمغ العربى الذى لة القدرة على الاسترجاع بنسبة ٨٩% والمالتودكسترين الذى لة القدرة على الاسترجاع بنسبة ٥٧%

ولقد تم استحدام معدلات مختلفة من الصمغ العربى والمالتودكسترين لكبسلة زيت قشر البرتقال عن طر يق المجفف الرزازى بنسب ١٠٠:صفر , ٧٠:٣٠ , ٦٠:٤٠ , ٥٠:٥٠ , ٤٠:٦٠ , ٣٠:٧٠ , صفر : ١٠٠

حيث وجد أن الخليط بنسبة ٣٠:٧٠ صمغ عربى : مالتودكسترين أعطى أفضل نسبة استرجاع لزيت قشر البرتقال بنسبة ٩٢%

كان من الواضح أيضا ان نسبة الاسترجاع قلت مع زيادة نسبة المالتودكسترين.كذلك وضح أن النشا المعدل منفردا أعطى نسبة استرجاع أدنى من الخليط ٣٠:٧٠ صمغ عربى : مالتودكسترين .كما أن الخليط ٣٠:٧٠ صمغ عربى : مالتودكسترين قد أعطى درجة ثبات للنكهة للمنتج تساوى تقريبا تلك الخاصة بالصمغ العربى كحامل منفردا. ويلاحظ أن استخدام المالتودكسترين يقلل من تكلفة مادة التغليف ويسمح بزيادة تركيز مادة التغذية للمجفف بسبب تقليل اللزوجة