Effect of Various Process Conditions on Efficiency and Colour Properties of *Pistacia terebinthus* oil Encapsulated by Spray Drying

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***Abstract*—In the present study, determination of colour properties of encapsulated material and encapsulation effecieny of Pistacia terebinthus spp. terebenthus oil were aimed by using spraying drying. Drying operations were carried out in the spray dryer at different temperatures (170-180-190 ℃) and different wall materials (gum arabic, inulin, maltodextrin (DE18) and the yields of the resulting encapsulated menengic oils were calculated. Literature studies and preliminary tests have shown that 14% wall material is encapsulated with 14% oil. By wall the Pistacia terebinthus oil with different wall materials at different temperatures, the best encapsulation efficiency was obtained and the highest L* value was determined inulin at 170 ℃. The lowest encapsulation yields at different temperatures were found in maltodextrin wall material. As temperature increases, a* values in all wall materials increase in gum arabic, but decrease in inulin and maltodextrin.**

***Index Terms*—pistacia *terebinthus*, spray dryer, encapsulation, maltodextrin, inulin, gum arabic**

I. Introduction

The genus *Pistacia* belonging to the family of *Anacardiaceae*, is noteworthy for its numerous species and varieties of wild-growing plants. Many of these species are endemic of the Mediterranean area. As it is a source of several bioactive molecules, this genus has an economic value [1]. The plant is locally called “menengic”. It is the source of market products such as dried whole fruit, gummy extract and a special soap, known as “menengiç soap” or “bıttım soap”, which contains a different proportion of terebinth oil [2]. In various regions of the world, different organs of turpentine tree are collected for several purposes. Its fresh shoots and fruits are used for human nutrition. The fruits have been regarded as an appetizer in Southern Turkey for several thousand years. The fruits are also used in the baking of a speciality village bread and as a coffee substituent [3]. *P. terebinthus* has been reported to be composed of approximately 40 % of oil, which is rich in unsaturated fatty acids and carotenoids [4]. Meanwhile, *P. terebinthus* fruit is known to contain high levels of phenolic compounds and tocopherols with its high oil and phytochemicals contents, *P. terebinthus* can be considered as a good natural model to investigate the effect of roasting on phytochemicals in extracted oil [5].

In previous studies various properties of this plant and products obtained from it were studied. Topcu *et al*. [6] investigated the total phenolic and flavonoid composition of extracts of *Pistacia terebinthus* fruit obtained by conventional extraction using acetone and methanol, and the antioxidant and antimicrobial activities of these extracts were investigated. Antioxidant activity determination was determined using the DPPH (1,1-diphenyl-2-picryl-hydrazyl) method. Ozcan *et al*. [3] investigated the composition of essential oils obtained by hydrodistillation method from the fruits of *Pistacia terebinthus* plant which grow wild in 15 different locations in Turkey. GC-MS (gas chromatography/mass spectrometry) technique was used in the examination of the essential oil composition. Dhifi *et al*. [1] carried out a survey with essential oil belonging to *Pistacia terebinthus* seeds growing in Tunisia. In this study, the composition of essential oils obtained by hydrodistillation using Clevenger was examined by GC-FID (gas chromatography/flame ionization detector) and GC-MS, and the antimicrobial activities of these oils were determined. Durmaz and Gokmen [5] examined the oxidative stability, antioxidant activity and phytochemical composition of oils obtained from solvent extraction (n-hexane) from *Pistacia terebinthus* fruits prepared under different roasting conditions (0-40 min/180C). DPPH and ABTS (2,20-azino-bis-(3-ethylbenzthiazoline-6-sulphonic acid) methods were used to determine antioxidant activity. Kıvçak *et al*. [7] reported that essential oil contains 61 essential volatile flavor compounds, which have been analyzed using GC-MS technique for the composition of essential oils from leaves of *Pistacia terebinthus* plant, grown in Turkey. Duru *et al*. [8] used GC-MS technique to determine the composition of essential oils obtained from the leaves of *Pistacia terebinthus* collected from the Fethiye region. Antifungal properties of fats obtained from leaves were also studied.

Insufficient information is available on microencapsulation of *Pistacia terebinthus* oil and none

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of the published works reported the influence of different types of wall materials on the encapsulation efficiency of this oil. The objective of this work was to evaluate colour properties of encapsulated material and encapsulation effecieny of *Pistacia terebinthus* oil were aimed by using spraying drying. Encapsulation was performed with various wall material (DE(dextrose equivalent) 18 maltodextrine, inulin and gum arabic) and inlet temperatures (170, 180 and 190^{o}C).

II. Materials and Methods

A. Materials

The oil of *Pistacia terebinthus* were purchased from a company that manufactures the fruits grown in Siirt region by cold-pressing technique, Turkey in October 2015. Inulin, maltodextrine and gum Arabic were obtained from Integro Food (Izmit, Turkey). Lecithine and Tween 20 were purchased from Merck (Darmstdat, Germany).

B. Preparation of Emulsions

The wall materials (gum arabic, inulin, maltodextrin (DE18) were dissolved in distilled water in an ultrasonic water bath. A homogeneous structure was obtained by treating in a shaking water bath at 10-12 °C for 12 hours. Before delivering the spray dryer, *Pistacia terebinthus spp. Terebenthus* (Menengiç) oil and a few drops of Tween 20 (emulsifier). As a result of the experiments, Tween 20 showed better emulsifier than lecithin. The homogenizer (Heidolph Silentcrusher M, Germany) was homogenized for 5 min at 15000 rpm.

C. Spray Drying

Spray drying process was performed in a laboratory scale spray dryer Buchi B290 (Huddersfield, England), with a nozzle atomization system with 1.0 µm diameter nozzle. The emulsions were fed into the main chamber through a peristaltic pump and the feed flow rate was controlled by the pump rotation speed. The main parameters important for the spray drying phase are: Inlet air temperature, outlet air temperature, nozzle diameter. Compressor air pressure was 0.04 MPa. Inlet air temperature were 170 °C, 180 °C and 190 °C, and outlet air temperature were 105 °C. Feed flow rate was 12±2 mL/min. Each encapsulation were performed triplicate (n=27) (Table I).

D. Encapsulation Efficiency Analysis

Encapsulation efficiency (EE) was determined according to the method described by Carneiro *et al* [9]. Fifteen milliliters of hexane were added to 1.5 g of powder in a glass jar with a lid, which was shaken by hand for the extraction of free oil, during 2 min, at room temperature. The solvent mixture was filtered through a Whatman filter paper no 1 and the powder collected on the filter was rinsed three times with 20 mL of hexane. Then, the solvent was left to evaporate at room temperature and after at 60 °C, until constant weight. The non-encapsulated oil (surface oil) was determined by mass difference between the initial clean flask and that containing the extracted oil residue [9]. Total oil was assumed to be equal to the initial oil, since preliminary tests revealed that all the initial oil was retained, which was expected, since *Pistacia terebinthus* oil is not volatile. Encapsulation efficiency (EE) was calculated from Eq. (1).

$$EE = \left(\frac{TO - SO}{TO}\right) \times 100 \tag{1}$$

where TO is the total oil content and SO is the surface oil content.

E. Colour Measurement

The colour of *Pistacia terebinthus* oil powder sample was determined using a Minolta Chroma Meter calibrated with a white standard tile. The results were expressed as Hunter colour values of L*, a*, and b*, where L* was used to denote lightness, a* redness and greenness, and b* yellowness and blueness. Prior to measurement, the powder samples were packed into a polyethylene pouch and measured. Hunter values of the samples for each treatment method were measured in triplicate.

F. Statistical Analysis

Experiments were preformed in triplicate. All data were reported as means ± standard deviation of samples.

TABLE I. Levels and Factors used in Experiment Design

Factor name	Level 1	Level 2	Level 3
Spray Dryer Inlet Temperature(^{o}C)	190	180	170
Wall Material	Maltodextrin	Inulin	Gum arabic

TABLE II. Encapsulation Efficiency of Pistacia Terebinthus Oil

Wall Material	Spray Dryer Inlet Temperature(°C)	Wall Material Rate (g/100 g, in wet basis)	Oil Rate (g/100 g, in wet basis)	Efficiency (%)
	170	14	14	41.63±0.20
Gum Arabic	180	14	14	43.44±1.42
	190	14	14	43.08±1.03
	170	14	14	56.25±2.13
Inulin	180	14	14	54.08±5.68
	190	14	14	53.42±0.39
	170	14	14	15.58±2.57
Maltodextrin	180	14	14	31.41±1.99
	190	14	14	32.12±0.65

III. Results and Discussion

A. Encapsulation Efficiency

Drying experiments were carried out on the spray dryer with one nozzle type, different temperature (170-180-190 ℃) and different wall materials (gum Arabic, inulin, maltodextrin (DE18) and the obtained encapsulation efficiencies were calculated.

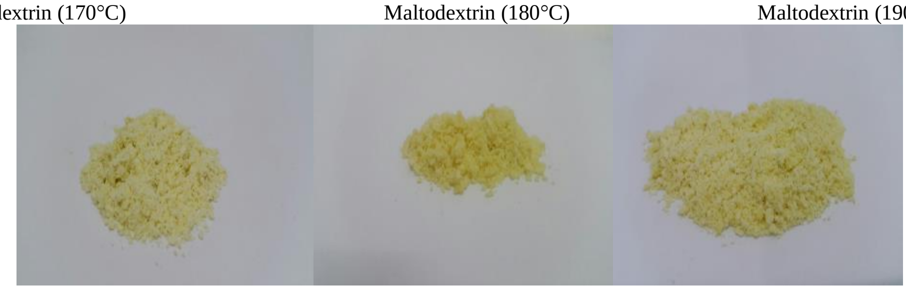
Literature studies and preliminary tests have shown that 14% wall material is encapsulated with 14% oil, in wet basis.

The *Pistacia terebinthus* oil encapsulation efficiency, encapsulated in the spray drier, was calculated by the equation given above and is shown in Table II.

TABLE III. Colour Properties of *Pistacia Terebinthus* Oil

Wall material	Spray dryer inlet temperature (°C)	L*	a*	b*
Gum Arabic	170	83.05±1.15	-0.15±0.21	19.32±0.31
	180	83.72±0.47	0.11±0.17	18.76±0.97
	190	82.93±0.42	0.31±0.04	19.79±0.44
Inulin	170	89.96±2.64	-5.55±2.06	25.75±0.98
	180	87.68±0.45	-5.50±2.13	26.70±0.33
	190	87.07±3.11	-6.46±0.25	28.78±2.90
Maltodextrin	170	80.43±1.88	-6.99±0.48	34.33±5.49
	180	83.80±2.13	-6.50±0.35	28.65±2.43
	190	78.60±0.84	-7.19±0.34	34.71±3.66

Maltodextrin (170°C) Maltodextrin (180°C) Maltodextrin (190°C)



Inulin (170°C) Inulin (180°C) Inulin (190°C)

Gum Arabic (170°C) Gum Arabic (180°C) Gum Arabic (190°C)

Figure 1. Encapsulated *Pistacia terebinthus* oil samples

The results of the experiment the highest encapsulation efficiency was determined by the inlet temperature at 170 ℃ using inulin wall material. It has been observed that the lowest encapsulation efficiency occurs when the maltodextrin wall material is used at a temperature of 170 ℃.

The reason for this is that the temperature is not enough for the drying and that high levels of adhesion to the wall and the extract can not be collected in the collection chamber. In practice maltodextrin encapsulation efficiency increases as the temperature increases.

Previous studies have also shown that gum Arabic maltodextrin or modified starch their combinations are more effective than single use [10], [11].

B. Colour Properties

The color characteristics of the encapsulated The *Pistacia terebinthus* oil are shown in Table III. According to this, highest L* values of the wall material is determined in inulin. a* values decrease in gum arabic, inulin and maltodextrin, respectively. b* values are increased in gum Arabic, inulin and maltodextrin, respectively, as opposed to a*.

The highest L* value is found in the spray dryer inlet temperature at 170 ℃ and the lowest L* value at 190 ℃ in maltodextrin. a* value of 190 ℃ was found in the sample using gum Arabic wall material and in the case of using the maltodextrin wall material at 190 ℃ at the lowest. b* value was found at the highest 170 ℃ maltodextrin and lowest 180 ℃ gum Arabic wall material.

The images of the encapsulated *Pistacia terebinthus* oil samples are shown in Fig. 1. As it can be seen in the pictures, the brightest examples are those in which the inulin wall material is used.

IV. Conclusion

The results obtained in the present study indicate that inulin is a better wall material for the encapsulation of *Pistacia terebinthus* oil compared to other wall materials when encapsulation efficiency is taken into consideration.

In this work it was possible to evaluate the performance of different wall materials combinations in the *Pistacia terebinthus* oil microencapsulation by spray drying.

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