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Variables Affecting the Yield of Oil from Tobacco Seed

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In this study, a parametric study was implemented for the purpose of optimization of the efficient oil extraction for a continuous oil production plant. The parameters affecting oil extraction from the tobacco seed oil in the study were chosen as temperatures and seeds-to-solvent ratio, grinding size (mm) of tobacco seed, stirring rate and duration. Mass based seeds-to-solvent ratio, stirring rate and grinded seed size were found to be effective on oil extraction. It was reached maximum oil extraction in the conditions of 40 ºC, 600 rpm stirring rate, 0.4 mm grinding size and 1 to 3 seeds-to-solvent ratio. The amount of oil was extracted from the tobacco seed oil was measured as 45 %. This is the highest amount of extracted oil from the tobacco seed oil up to day in the open literature.

Key Words: Tobacco seed oil, Solvent extraction, *n*-Hexane, Physical properties, Fatty acid composition.

INTRODUCTION

Tobacco plant has capsules which contains numerous very small seeds. The average mass of 1000 seeds is in the range of 0.08-0.09 g. In literatures, it is reported that the seed yield is determined as 617 kg (± 142 kg) per hectare area of tobacco plant. When it is considered figures in a published report in 2002, potential tobacco seed oil reserves is estimated as 48,566,044 kg in Turkey[1]. The estimated income will be reach about $ 100,000,000 when the waste tobacco seeds is evaluated for the purpose of producing biodiesel. The seeds can be stored in dry conditions at ordinary temperatures and can resistant to high humidity. The tobacco seeds endosperm contains thin walled cells which are rich in terms of oil[2]. In literature, it is given various amount of oil which can be extracted from the tobacco seed ranging from 33 to 41 % in weight basis[3,4].

Tobacco seed oil is free of nicotine and comparable to other edible oils[5]. Although it is considered to be non-edible[6]. Refined tobacco seed oil is also used as salad oil in some countries[2,7]. Because tobacco seed oil has low proportion of saturated fatty acids it can be considered nutritionally appropriate in compared to high saturated fat vegetable oils[8,9]. The nutritional value of tobacco seed oil is better than groundnut and cotton seed oil. The remaining part consists of protein, crude fiber, carbohydrate

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and inorganic material. Since tobacco seed cake is rich in nitrogen (around 6 %)[5] and it can be used for the aim of animal food and fertilizer[9].

Tobacco seed is also used in soap production and as a solvent in paint and varnish industries[10]. The specific composition of fatty acids of vegetable oil which contains straight-chain differs depending upon the origin of the oil. The major fatty acids in tobacco seed oil are the linoleic, oleic, palmitic and stearic acids and among these fatty acids the major one is linoleic acid[11,12]. Hence, the tobacco seed oil is classified as a linoleic acid, which falls in the category of semi-drying oil[6]. Tobacco seed oil has been found rich in unsaturated fatty acids and this high degree of unsaturated acids suggests potential use of tobacco seed oil in food and cooating industries[13]. The properties like gloss, adhesion, hardness, drying time, water and acid resistance of tobacco oil-modified alkyd resin make it particularly suitable for the manufacture of architechtural coatings, industrial product finishes, traffic paints and high gloss ofset printing inks[9].

As tobacco plant is high ecological tolerance, tobacco plant farming can be realized on 5 different climatic regions in Turkey[14]. Furthermore, as the campaign to reduce the number of tobacco smokers continues worldwide, the utilization of the seed oil may be a way of encouraging tobacco farmers to focus on the production of seeds rather than leaves. The production of seeds will add more economic value to tobacco plantations since the economic value of the leaves may likely decline with the continued campaign against the smoking of tobacco[10].

In present, researchers make an effort to develop alternative usages of tobacco seed oil in biodiesel production. As tobacco seed oil are renewable, non-toxic and biodegradable and have low emission profiles and has a potential alternative fuel for compression ignition engines[2,4]. Organic seed oils are better than diesel fuel in terms of sulphur content, flash point, aromatic content and biodegradability[15]. Table-1 gives comparisons the properties of tobacco seed oil and other vegetable oils with European requirement of automotive diesel fuels.

TABLE-1
COMPARISON OF THE PROPERTIES OF TOBACCO SEED OIL AND OTHER VEGETABLE OILS WITH EUROPEAN REQUIREMENT OF AUTOMOTIVE DIESEL FUELS [Ref. 2]

Vegetable oil	Kinematic viscosity 40ºC (mm^2/s)	Cetane number	Energy content (MJ/kg)	Cloud point (ºC)	Pour point (ºC)	Flash point (ºC)	Sulfur (wt. %)
Corn	34.9	37.6	39.5	-1.1	-40.0	277	0.010
Cottonseed	33.5	41.8	39.5	1.7	-15.0	234	0.010
Peanut	39.6	41.8	39.8	12.8	-6.7	271	0.010
Rapeseed	37.0	37.6	39.7	-3.9	-31.7	246	0.010
Sesame	35.5	40.2	39.3	-3.9	-9.4	260	0.010
Soya bean	32.6	37.9	39.6	-3.9	-12.2	254	0.010
Sunflower	33.9	37.1	39.6	7.2	-15.0	274	0.010
Tobacco oil	27.7	38.7	39.4	-7.8	-14.0	220	0.006
European reqr. (Diesel Fuel)	2-4.5	51 (min)	-	-	-	56 (min)	0.035 (max)

The parameters affecting oil extraction from tobacco seeds are important. Main parameters affecting on the yield of tobacco seed oil are the extraction temperature, the seeds-to-solvent ratio, the type of solvent, reaction time and grinding size of tobacco seeds[16] reported that the oil yield is much higher if the seeds were ground before extraction and the oil yield increased with increasing the extraction temperature and with decreasing the seeds-to-solvent ratio.

Solvent kinds are also one of the most important parameter on the yield of oil. Some researchers used *n*-hexane[2,4,5,9], diethyl-ether[14] and petroleum ether[2,8] as extracting solvents in their studies. However, it is reported that *n*-hexane was somewhat more efficient in the oil extraction than petroleum ether and diethyl ether[8]. Quite recently, the ultrasound-assisted extraction[16,17] using *n*-hexane and petroleum ether has also been applied for the oil extraction from the seeds of a semi-oriental tobacco.

There is no detailed parametric study affecting the yield of oil from tobacco seeds in open literature yet. In this study, it is performed a parametric study which maximize the oil yield from tobacco seeds. The parameters considered in the study are grinding size of tobacco seeds, the extraction temperature, the seeds-to-solvent ratio in mass base, stirring rate and extraction times. *n*-Hexane is used in the extraction process as it is more efficient solvent for the extraction of the oil from tobacco seeds.

EXPERIMENTAL

The seeds (original Saribaglar-407) used in the study were provided with Aegean Agricultural Research Institute, Menemen districts of Izmir city in Turkey. After tobacco seeds were dried for 1 h at 120 ºC, they were ground to fine powders by an electrical mill which has the feature of grinding the seeds to various particulate sizes. Then the ground seeds were sieved through a set of standard sieves of 0.4, 0.5, 0.55 and 0.6 mm. The original size of TS is measured as about 0.7 mm.

The parameters considered in the study are grinding size of tobacco seeds, the extraction temperature, the seeds-to-solvent ratio. The cost of extraction oil from the tobacco seeds is important factor for a continuous oil production plant, the effects of extraction time and stirring rate are also considered. The other driving force in using stirring rate, it may contribute to the amount of extracted oil from tobacco seeds. *n*-Hexane is used in the extraction process as it is reported that it is the best solvent for the extraction of the oil from tobacco seeds.

Tobacco seed oil was extracted using hexane solvent and the oil was separated from the solvent using a rotary vacuum evaporator. The mixtures of oil-solvent poured in rotary flask were immersed into the water bath of rotary vacuum evaporator. During the extraction period, the seed to solvent ratios were chosen as 1:1, 1:2 and 1:3 in weight bases. The extraction temperatures for each the seed to solvent ratios were defined as 30, 40 and 50 ºC, respectively. Upper limit of extraction temperature was defined considering the boiling temperature of *n*-hexane. It is chosen about 10 ºC lower than that of *n*-hexane. Same procedures were performed for the stirring rate of 300, 600 and 900 rpm in the time periods of 1, 2 and 3 h, respectively. In total, 81 parametric studies were evaluated. After the extraction time is completed, the oil rich solvent was distilled off under reduced pressure to remove the bulk of the solvent. The small particles suspended in oil were separated *via* centrifugal machine at the speed of 4000 rpm and 3600 RFC (Relative Centrifugal Force) for 15 min. This process was highly shortened the time consuming of separation period compared to the separation process with a filter. The separation is conducted with NUVE mark NF400 type centrifugal machine.

Determination of fatty acid composition: Fatty acid composition of tobacco seed oil was determined by GC analysis. A Hewlett-Packard 5890 series II gas chromatograph, with a SP2340 type column 30 m long and split-splitless injector, was used. The inside diameter was 0.53 mm and film thickness was 1.0 µm. The detector was a FID. An automatic sampler was attached to the HP 5890 GC to automate sample introduction. The sample (tobacco seed oil) amount injected was 0.5 mL/min. The temperature of GC injector was 250 °C. Helium was used as a carrier gas. Split ratio was 1:50. The flame ionization detector temperature was 260 °C. The oven temperature was kept at 150 °C for 3 min. After that, the oven was heated with heat ratio 10 °C/min to 225 °C. The oven temperature was constant for 15 min. The fatty acids of tobacco seed oil were identified and quantified using the AOAC 963.33 and AOAC 963.22 methods. Gas chromatogram of tobacco seed oil and fatty acid composition of tobacco seed oil are shown in Fig.1 and Table-2, respectively.

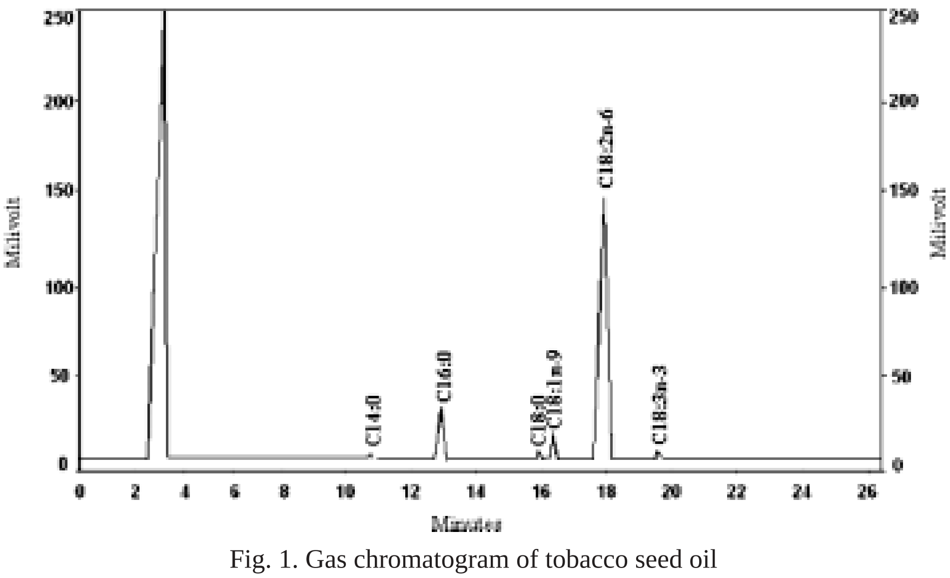

Fig. 1. Gas chromatogram of tobacco seed oil

The total saturated and unsaturated fatty acids in tobacco seed oil were found to be 11.92 and 87.96 %, respectively as shown in Table-2. Major parts of unsaturated fatty acids were linoleic acid (75.58 %) and oleic acid (11.24 %), while palmitic acid was most abundant (8.72 %) among saturated fatty acids (Table-2). The amounts of unsaturated and saturated fatty acids as reported in the present work are close to those reported by Giannelos *et al.*[2] (85.2 and14.8 %), Mukhtar *et al.*[9] (87.36 and 12.64 %) and Baydar *et al.*[7] (84.35 and 12.53 %). The slight difference in the amounts of different fatty acids as shown in Table-2 may be due to different species of tobacco (*Nicotiana*) used in the studies or due to different environmental or geographical conditions.

TABLE-2
FATTY ACID COMPOSITION OF TOBACCO SEED OIL

Fatty acids	Present study	Giannelos *et al.*[2]	Yazicioglu *et al.*[19]	Baydar *et al.*[7]	Mukhtar *et al.*[9]
Myristic acid (C14:0)	0.14	0.09	-	0.17	1.13
Palmitic acid (C16:0)	8.46	10.96	8.82	8.87	8.72
Stearic asid (18:0)	3.38	3.34	-	3.49	2.64
Oleic acid (C18:1)	11.24	14.54	13.72	12.40	13.46
Linoleic acid (C18:2)	75.58	69.49	75.30	67.75	71.63
Linolenic (C18:3)	1.14	0.69	1.59	4.20	0.93
Acid value	1.20 %	–	–	–	–

RESULTS AND DISCUSSION

In this study, it is performed a parametric study which affects on the oil yield from tobacco seeds. The parameters considered in the study are grinding size, the extraction temperature, the seeds-to-solvent ratio, stirring rate and extraction times are considered as parameters which may affects oil yield. *n*-Hexane is used in the extraction process as it is more efficient solvent for the extraction of the oil from tobacco seeds[8].

Fig. 2a-c show the effect of the parameters on the oil yield from tobacco seeds for various stirring rates. During the study, the amount of oil extracted is given as mass rate per 100 g tobacco seeds for 0.5 mm grinding size of tobacco seeds.

It is shown from the figure that the most important parameters affecting oil extraction were found as extraction time and seeds-to-solvent ratio. Although maximum amount of oil extracted is 18.1 % for 1 h extraction time in cases of 1:3 seeds-to-solvent ratio, 40 ºC and 300 rpm stirring rate, the amount oil yield is reached to 37.5 % for 2 h and 39.5 % for 3 h at the same conditions as shown in Fig. 2a.

Stirring rate especially affects the amount of oil extraction for short extraction time (Fig. 2a-c). Maximum oil yields were 18.1 % at 300 rpm, 23.1 % at 600 rpm and 29.1 % at 900 rpm for 40 ºC and 1:3 seeds-to-solvent ratio. However, when the extraction time is increased to 2 and 3 h, respectively, the effect of the stirring rate on oil yield was comparatively low.

There are two conditions for obtaining maximum oil yield of 41.5 % for 0.5 mm tobacco seeds grinding size. One of them was the conditions of 600 rpm stirring rate, 2 h of extraction time, 1:3 seeds-to-solvent ratio and 40 ºC reaction temperature.

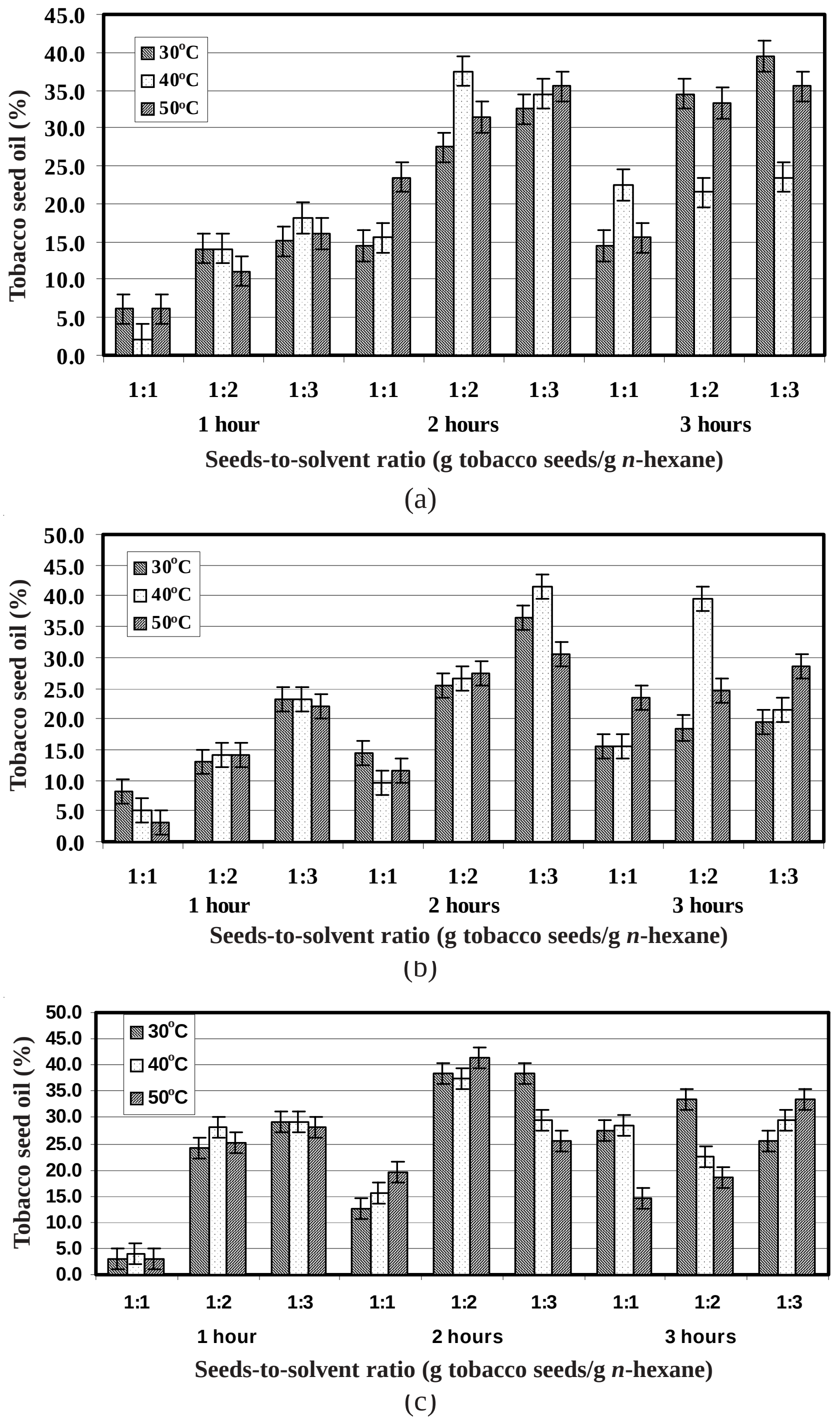

Fig. 2. Yield of tobacco seed oil extracted from tobacco seeds at stirring rates for (a) 300, (b) 600 and (c) 900 rpm

The second high quantity of oil yield was attained in the cases of 900 rpm stirring rate, 2 h of extraction time, 1:2 seeds-to-solvent ratio and 40 ºC reaction temperature for the same tobacco seeds size.

The effect of grinding size of tobacco seeds on oil yield was also studied (Fig. 3). It was observed that the most important stage is to grind the tobacco seeds for maximizing oil yield before the extraction process starts. While the oil yield from the native or not grinded tobacco seeds was only about 5 % in weight base by using *n*-hexane, the oil yield from tobacco seeds reached to 45 % for 0.4 mm when the tobacco seeds is grinded. The higher yield of oil from the ground tobacco seeds could be explained by the anatomy of tobacco seeds[16]. The main amount of oil is located in the thin-wall cells of the endosperm and some of the oil is accumulated in the embryo. However, there is no oil in the protective seed coat[18]. The oil yields obtained by some other researchers were 38.8 and 33.4 % using *n*-hexane and petroleum ether[2,6], respectively, as well as 38 ± 2 % using diethyl ether[15]. The amount of oil attained in present study seems to be the highest oil yield reported in the literature.

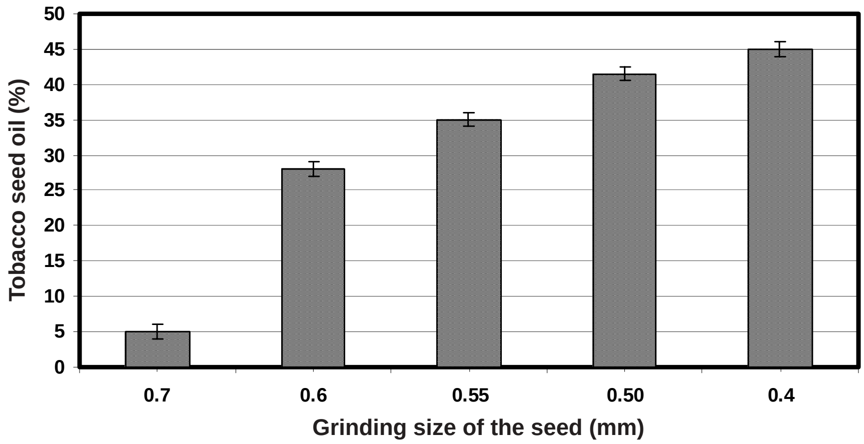

Fig. 3. Yield of tobacco seed oil per 100 g tobacco seeds depending on grinding size (mm) (600 rpm, 1:3 Seeds-to-solvent ratio (g tobacco seeds/g *n*-hexane), 2 h and 40 ºC extraction temperature)

Conclusion

The oil yield from the tobacco seeds depended on the grinding size of the seeds, the seeds-to-solvent ratio, stirring rate, the extraction temperature and time. It is shown that the most important parameters affecting oil extraction were found as seeds-to-solvent ratio, grinding size and extraction time, respectively. The oil extraction yield of tobacco seed was found as 45 % (± 2 %) in weight basis with *n*-hexane as a solvent. Compared to the no grinded seeds, the oil yield from the ground ones was much higher. This was attributed to destroying both the protective seed coat and the cells from the interior of seeds by comminution thus enabling more oil to be dissolved. The increase of the stirring rate greatly affected the oil yield from tobacco seeds especially in short extraction times. The effect of the seed-to-solvent ratio on oil yield also depends on stirring rate and time. In general, the extraction time and stirring rate shows combined effect on oil yield. In the study, two conditions which give maximum oil yield is obtained for 0.5 mm seed grinding size. When stirring rate increased from 600 to 900 rpm, maximum oil yield obtained with the 1:2 seeds-to-solvent ratio. It was not possible the tobacco seeds to grind beyond the size of 0.4 mm as the seeds turn to dough.

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