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Performance Evaluation of the Screw-Type Oil Expeller for Extracting Mee (*Madhuca longifolia*) Oil

D.M.S.P Bandara*, C.A.K Dissanayake, T.M.R Dissanayake, H.M.A.P Rathanayake, D.P Senanayake

Institute of Post Harvest Technology, Jayanthi Mawatha, Anuradhapura, Sri Lanka

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Abstract

Purpose: Mee (*Madhuca longifolia*) is an economically important tree growing throughout Sri Lanka. Its importance is mainly attributed to its oil with high nutritional and medicinal values. However, an inefficient extraction method limits its use. This study revealed the possibility of extracting oil from mee seeds by using a screw-type oil expeller. **Methods:** A popular screw-type oil expeller was used in the experiment. Extract bar clearance and speeds of the main spiral shaft were altered to increase the oil expelling efficiency of the machine. The quality of refined oil at the optimum oil yield was determined by measuring the refractive index, saponification value, iodine value, unsaponifiable matter, free fatty acid, and specific gravity. **Results:** An optimum yield of 35% oil was obtained when the machine capacity was 30 kg/h and energy consumption was 0.13 kWh/kg. This optimum machine condition was observed at an extract bar clearance of 0.5 mm and a main spiral shaft speed of 90 rpm. The refractive index, saponification value, iodine value, unsaponifiable matter, free fatty acid, and specific gravity of the oil were 1.4, 203, 59, 3.5%, 0.2%, and 0.907 g/cm3 respectively. Color of the mee oil was closer to yellow, which is revealed by the lightness value (L) of 24.93 and positive value (b) of 11.81. **Conclusion:** The screw-type oil expeller can be used for economically extracting mee oil on a commercial scale.

Keywords: *Madhuca longifolia* oil, Mee, Oil expellers, Oil extraction

Introduction

Butter cup or mahua, *Madhuca longifolia* (Koenig) (Synonyms, *Madhuca indica* Gmelin; Family, Sapotaceae), is a large, shady, deciduous tree, both wild and cultivated, common in the central Indian landscape (Mohamed et al., 2006). It is an important economic tree that grows throughout Sri Lanka. It is very popular in the districts of Anuradhapura, Kurunagala, Kegalle, and Kandy, and consumption of oil extracted from the seeds of the plant is presently confined to these areas. People in Sri Lanka call it “mee” in Sinhala and “illuppu” in Tamil. When the seeds mature and fall from the tree, they are collected and dried, and put into a “Sekku” or oil-press and ground well (Figure 1). Mee oil can also be extracted at home by a traditional method called “Peha” (Figure 1). In this method, dried mee seeds are pound to obtain the pith, which is then boiled and squeezed to extract the oil. This oil is obtained in the same manner as coconut oil and gingerly oil. The medicines obtained from the mee tree are used for both external application and consumption. Mee oil is especially effective in curing hives. According to various researches, the fruit of the mee plant is also very beneficial for the heart; those suffering from heart diseases can consume a concoction made of boiled mee fruits. Another use of mee fruits is as follows: few mee fruits are mixed with four quarts of water in a pot, and then the water is boiled to reduce it to one quart; the mixture obtained is strained for consumption. Consuming half of the quantity thus obtained in the morning, and the other half in the evening is beneficial to the body. Harmful liquors are commonly

***Corresponding author:** D.M.S.P Bandara
Tel: +94-71-802-5200; **Fax:** +94-25-222-0149
E-mail: srimapriyangika@yahoo.com

Figure 1. Mee seeds.

consumed today; in the ancient past, medicinal liquor, which is quite different from the presently used toxic liquors, was manufactured. Mee flowers are used commonly to manufacture medicinal liquor. This liquor is good for increasing appetite and has been used to eliminate stomach irregularities.

Mee syrup (the syrup of the Mee tree) is a unique medication in Ayurvedic Medicine. Well-boiled mee flowers are squeezed, and the juice is extracted and simmered to obtain the Mee syrup. This simmered Mee syrup can cure diseases of the female reproductive system (Maduranga, 2016).

The mee is a drought-resistant tree of the dry tropics and sub-tropics and is common in deciduous and dry forests. The tree is treasured for its flowers, fruits, seeds, and timber. It grows in a wide variety of soils, but prefers sandy soil. In Sri Lanka, the seeds (Figure 1) are the most commonly utilized part of the tree. It has been reported that the content of the desirable monounsaturated fatty acid (FA), namely, oleic acid in mee seed oil is greater than that in olive oil; oleic acid is a long-chain FA that is sufficiently long to be transformed into high-density lipoprotein (HDL) cholesterol but not into low-density lipoprotein (LDL) cholesterol (Kureel et al., 2009). According to Kureel et al. (2009), the unsaturated FA content, including oleic acid and linoleic acids, is higher than the saturated FA content, including palmitic and stearic acids.

Traditionally, the bark of the mee tree has been used in treatments for diabetes, rheumatism, ulcers, bleeding, and tonsillitis. The flowers, seeds, and seed oil of the mee tree have great medicinal value. Mee oil is used externally for massage to alleviate pain. The oil is a good remedy for itching, swelling, fractures, and snakebite poisoning. It is administered internally to treat diabetes and chronic tonsillitis (Mishra et al., 2013). In treating skin diseases, the juice of the flowers is rubbed for oleation. It is also beneficial as a nasal drop in diseases of the head due to sinusitis (Akshatha et al., 2013).

The extracted seed oil is applied as an ointment for curing rheumatism and for preventing cracks in the skin during winter. In addition, the oil is also used for culinary purposes, and it helps keep the skin glossy and warm. It also has insecticidal properties and can be used as a hair-wash. Further, it is also used for treating the enlargement of auxiliary grand, neurotic disorders, and

(a) Sekku (b) Peha

Figure 2. Traditional method of mee oil extraction: (a) “Sekku” and (b) “Peha”.

cough and bronchitis and as an aphrodisiac.

Although oils and fats are essential components of almost all forms of plants and animal life, relatively few life forms produce oil and fat in sufficient quantities to be of commercial importance. The continuing trend of preparation of products from vegetable oils rather than animal fats is of great significance. Presently, vegetable oils contribute approximately 85% of the visible oil or fat available for consumption. Several plants are now grown not only for food and fodder, but also for the amazing variety of products with novel industrial applications. In the search for new oil plants for nutritional, pharmaceutical, industrial, and other uses, it is necessary to check whether the plant provides a large quantity of oil or fat.

Regardless of the nutritional and medicinal values of mee oil, in Sri Lanka, consumption of the oil is limited to the residents of the localities in which mee trees grow. The main reason for this limitation is the traditional extraction method—"Peha" (Figure 2)—that does not yield sufficient quantities of oil for commercial purposes.

Hence, the development of an efficient mee oil extraction method is of vital importance. Therefore, this research aims at optimizing the operation of the screw-type oil expeller for the commercial scale extraction of mee oil whilst maintaining oil quality.

Materials and Methods

The screw press is a helical screw mount on a conical shaft supported by a bearing with a shaft rotating in a stationary cylindrical barrel. As the shaft rotates, the screw at the discharge end of the assembly moves the oil seed that is fed through the hopper to the inlet where it is pressed. In this study, mee seeds were fed into the hopper as a 4-kW motor continuously rotated the screw shaft with variable speed adjustment. In this experiment, a popular Chinese screw-type oil expeller machine was used; its screw shaft had a pitch of 25 mm, and it had an internal barrel of dimensions 75 × 315 mm (Figure 3 and Figure 4). The machine mainly consists of a pressing part, an adjustment part, and a transmission part. This machine, which is used for small- and medium-scale coconut oil extraction, was modified and tested for mee oil extraction.

Testing and modifications

Unlike the bridge presses that operate with a batch system, oil seed expellers produce oil and oil-cake continuously. The essential components of a typical small-scale expeller are shown in Figure 3. The expeller is driven by either an electric motor or a diesel engine. The main part of the machine is a powered worm shaft (screw shaft) that rotates inside a closely fitting cage. The oil

Figure 4. Screw-type oil expeller.

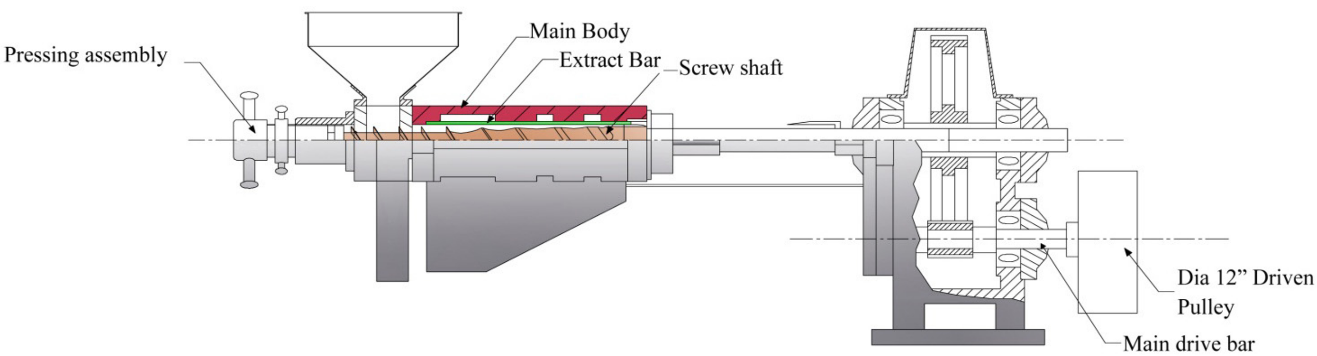

Figure 3. Sectional view of the screw-type oil expeller (Bandara et al., 2014).

Table 1. Different speed ranges of the main shaft in the oil expeller

Combination No:	Diameter of drive pulley/(mm)	Diameter of driven pulley/(mm)	Speed ratio	Speed of screw shaft/(rpm)
1	63.5	304.8	30:1	75
2	76.2	304.8	16:1	90
3	101.6	304.8	12:1	z120

expeller machine was tested under in-built conditions for the rotational speed of the shaft, extract bar clearance, and other original constructions. For preparing the raw material, mee seeds were subjected to steaming for 30 min; this is followed by sun drying for one day to reduce the moisture content to approximately 6%. In the first stage, the extract bar clearance was adjusted from 0.2 mm to 0.5 mm, and the rotational speed was set up for three different speeds using 63.5-mm, 76.2-mm, and 101.6-mm pulleys. The drive shaft diameter was 25.4 mm, and hence, the smallest pulley diameter compatible with the drive shaft was 63.5 mm. The screw speeds obtained according to the speed ratio under these conditions are listed in Table 1.

A homogeneous bulk sample of mee seed was used for the experiment. Before use, seeds were steamed for 30 min. The initial moisture content of the sample was determined by the oven method according to the AOAC (1999) standard for oil seed. According to this method, the samples were dried in the oven for 3 h at 105 ± 3°C. The final weight of the dried sample was used to calculate the moisture content on the wet basis using the following equation:

$$Mc = (W_1 - W_2)/W_1 \times 100 \quad (1)$$

where Mc is the moisture content (wet basis); W_1 is the weight (g) of the sample before drying; and W_2 is the weight (g) of the sample after drying.

The machine capacity was calculated for each combination as follows:

$$C = S/T \times 100 \quad (2)$$

where C is the machine capacity (kg/h); S is the mass of the seed fed (kg); and T is the time taken for processing (h).

The energy consumption for extraction per kilogram of oil was calculated by considering the power consumed by the machine. The electric current consumed by the machine during the extraction operation was measured by clip-on amperemeter (KYORITSU, Model 2608A). The line voltage was assumed as 415 V, and the power consumed by the machine was calculated using following equation.

$$P = VI \quad (3)$$

where P is the power (W), V is the voltage (V), and I is the ampere (A).

The energy consumption for extraction per kilogram of oil was calculated by considering the power consumed by the oil expeller as follows:

$$E = P/O \times 100 \quad (4)$$

where E is the energy consumption (kWh/kg), P is the electrical power consumed (kWh), and O is the crude oil recovered (kg).

The specific gravity of the extracted oil was calculated using the following equations:

$$SG = W_w / W_d S_v \times 100 \quad (5)$$

where SG is the specific gravity, W_w is the sample weight (kg), S_v is the sample volume (m^3), and W_d is the density of water (kg/m^3).

The refractive index, saponification value, iodine value by mass, unsaponifiable matter (percent by mass), and free FA (oleic acid; percent by mass) were analyzed by three hexane extractions following the guidelines of the Sri Lanka Standard Institute (SLS 313: 2009). The free FA profile consisting of palmitic, stearic, oleic, linoleic, and arachidic acids was analyzed using the method prescribed in ISO 5509:1978. The color of the oil samples was determined in three replicates using a chroma meter (Konica Minolta, Model CR-400). Representative oil samples were introduced in the chroma meter, and readings of L, a, and b values were taken.

Complete randomized design was used in designing the experiments. The data gathered were analyzed by using analysis of variance (ANOVA) by the Statistical Analysis System (SAS). Percentage data were transformed into arcsin values prior to analysis. Differences between treatment means were obtained via Duncan's multiple range test at 5% significance level ($p < 0.05$).

Results and Discussions

The screw-type oil expeller employed in this experiment is normally used for extracting coconut oil. The modifications made for extracting oil from mee seeds included extension of the extract bar clearance and over flow outlet. The extract bar clearance that was originally 0.1 mm was adjusted to 0.2 mm at one end and 0.5 mm at the other end. A problem encountered when extracting oil was that the cake mixed with the oil and flowed out through the pressure-releasing outlet of the cylindrical body. This affected the quality of the extracted oil. To overcome this problem, a modification was made to direct the pressed mixer to the cake outlet. After making these modifications, trials were conducted by changing the speed ratios of the machine as per the speeds listed in Table 1. Trials were conducted with three replicates. To evaluate the machine performance, the crude oil yield, machine capacity, and energy consumption at different screw shaft speeds were calculated (Table 2).

Raw mee seeds contain approximately 40% pale yellow semi-solid oil. The seed oil is commonly known as "mahua butter." The oil content of seeds varies from 33-43% of the kernel weight (Sunita and Sarojini, 2013). According to Table 2, the crude oil yield was the highest at a screw speed of 90 rpm, and the maximum oil yield of 35% was obtained under this condition. There is a significant change in the oil yield between speed levels. An oil-rich seed such as sesame seed or groundnut yields about 5% less oil by traditional methods than when a mechanical expeller is used (Maheshwari, 2015). The lowest energy consumption of 0.13 kWh/kg was recorded at speeds of 90 and 120 rpm. Considering the percentage of oil yield, machine capacity, and energy consumption during expelling, the best performance is obtained at a screw speed of 90 rpm. The maximum machine capacity of 30 kg/h was achieved at speeds of 90 and 120 rpm.

Table 2. Oil yield at different screw shaft speeds

Combination No.	Oil yield/(%) (crude oil)	Machine capacity/(kg/h)	Energy consumption/per kg (kWh/kg)
1	32^a	20^a	0.20^a
2	35^b	30^b	0.13^b
3	22^c	30^b	0.13^b

Values with the same letter in the columns for the same parameter are not significantly different at $p < 0.05$

In previous studies, the saponification value of mee oil was recorded in the range of 187-197 (Kureel et al., 2009). In this study, the value closet to this range was observed at a screw speed of 90 rpm. According to Navindgi et al. (2012), the specific gravity of mahua oil obtained from the Indian variety is approximately 0.891 g/cm^3, and test 2 of this study yields the closet value of 0.907 g/cm^3. The refractive index determines how much light is bent, or refracted, when entering a material. According to the study of Kureel et al. (2009), the refractive index of the oil obtained from the seeds of the Indian variety is approximately 1.452-1.462; the values obtained in this study were close to this range. Iodine numbers are often used to determine the degree of unsaturation of FAs. This unsaturation is attributed to double bonds, which react with iodine compounds. The higher the iodine number, the greater is the number of C=C bonds present in the fat. Kureel et al. (2009) stated that the iodine value of mee oil ranges 55-70, and the results for the iodine value in this study fell within this range; thus, the data in Table 3 are validated. According to the results, the unsaponifiable matter percentage varied between 2.3 and 3.5, while this range was reported as 1-3% in literature (Kureel et al., 2009).

Edible oil is an essential nutrient and an important source of energy, providing 9 kcal/g of energy. However, for oil to be utilized as a source of energy, it must be well

Table 3. Some quality parameters of the oil obtained at different screw shaft speeds

Combination No.	Saponification value	Specific gravity/(gcm^{-3})	Refractive index	Iodine value/(%)	Unsaponifiable matter/(%)
1	159^a	0.917^a	1.470^a	57^a	2.3^a
2	203^b	0.907^b	1.467^a	59^a	3.5^b
3	205^b	0.815^c	1.466^a	60^a	3.3^b

Values with the same letter in the columns for the same parameter are not significantly different at $p < 0.05$

Table 4. Fatty acid contents of oil obtained at different screw shaft speeds of the oil expeller

Combination No.	Fatty acid content (%)					Total saturated fatty acid content (A+B)	Total unsaturated fatty acid content (C+D+E)
	Palmitic acid (A)	Stearic acid (B)	Oleic acid (C)	Linoleic acid (D)	Arachidic acid (E)		
1	22.2	19.9	47.3	9.8	0.8	42.1[a]	57.9[a]
2	24.4	18.0	47.4	9.6	0.6	42.4[a]	57.6[a]
3	22.0	20.2	46.8	10.3	0.7	42.2[a]	57.8[a]

Values with the same letter in the columns for the same parameter are not significantly different at $p < 0.05$

Table 5. Color value of oil obtained at different screw shaft speeds of the oil expeller

Combination No.	L Value	a Value	b Value
1	26.00[a]	-1.48[a]	8.27[a]
2	24.93[b]	-2.02[b]	11.81[b]
3	23.44[c]	-0.88[c]	10.71[c]

Values with the same letter in the columns for the same parameter are not significantly different at $p < 0.05$


1 2 3

Figure 5. Mee oil obtained at different speed combinations.

digested and absorbed into the body (Tannenbaum, 1979). Oils in the diet are available to the body as FAs, which are excellent sources of dietary calorie intake. FAs are classified as saturated fatty acids (SFAs), monounsaturated fatty acids (MUFAs) and polyunsaturated fatty acids (PUFAs). The total energy intake from oils for a normal healthy adult is approximately 30% of total energy intake and that in the western diets is about 40%. High-fat diets enhance the incidence of coronary heart disease (Romon et al., 1995). The risk factors for coronary heart disease, such as elevated levels of serum total cholesterol, LDL cholesterol, serum triglycerides, and reduced levels of HDL cholesterol, are modulated by the fat content in the diet. According to the data listed in Table 4, the extracted mee oil had high unsaturated FA contents. The FA profile obtained shows that oleic acid, an unsaturated FA, was the major constituent, and palmitic acid was the main SFA present.

According to the Hunter lab L, a, and b color spaces, positive a is red, and negative a is green; positive b is yellow, and negative b is blue; and L value gives the lightness index of the sample. The data listed in Table 5 shows that all the samples complied with positive b values, confirming the yellow color of the oil. This clearly shows that the color is lighter when the machine speed decreases. These differences are shown in Figure 5.

Conclusions

The screw-type oil expeller, which is commonly used in Sri Lanka for medium- and small-scale coconut oil extraction, can be economically used for extracting mee oil on a commercial scale. The optimum machine parameters were set for obtaining the highest yield of 35% of crude mee oil at a machine capacity of 30 kg/h and energy consumption of 0.13 kWh/kg as follows: an extract bar clearance of 0.5 mm and a main spiral shaft speed of 90 rpm.

Conflict of Interest

The authors have no conflicting financial or other interests.

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