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Extraction Properties of *Mangifera indica* Seed Kernels: A Comprehensive Analysis of Their Industrial Potential

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Abstract

Mango (Mangifera indica) is widely regarded as one of the world's finest fruits, with a rich nutritional profile, including fiber, riboflavin, carotene, and ascorbic acid. Among its lesser-known components, the mango seed kernel offers significant nutritional and industrial value. Mango kernels are composed of protein, fat, carbohydrates, crude fiber, and ash, and contain bioactive compounds such as polyphenols, phytosterols, and tocopherols. The fat extracted from mango seed kernels has shown potential as a safe and nutritious edible oil, offering an alternative to solid fats without any toxicological concerns. Additionally, the kernel produces mango kernel butter, a solid at room temperature, known for its moisturizing properties, making it an ideal ingredient for cosmetics, particularly in lotions and lubricants. This study also examines the extraction process of mango seed kernel oil and butter, highlighting key parameters such as temperature, extraction time, and yield efficiency. Using the Kjeldahl method, the protein content of agro-seed cakes was measured, providing insights into the nutrient composition of seed cakes. Extraction efficiency, as determined by the extraction mass transfer model, demonstrated a decrease in oil yield when the extraction temperature exceeded 55°C for extended periods, with variable yields observed across different mango seed varieties. The findings underscore the untapped potential of mango seed kernels as a valuable resource in both the nutritional and cosmetic industries. Further research into optimization of extraction conditions could enhance the viability of mango kernels as a sustainable, renewable raw material for diverse applications, contributing to environmental and economic benefits.

Keywords: *Magnefeira indica*, kernel, remediation, oil production, extraction, analysis

INTRODUCTION

Mango (*Mangifera indica*), a member of the Anacardiaceae family, belongs to the genus Mangifera. Research suggests that *Mangifera indica* originated in the tropical and subtropical regions of Asia and Africa. It is a perennial, evergreen tree that can grow between 5 to 20 meters tall, with branches from which both fruits and leaves emerge. Over the past few decades, numerous mango varieties, such as Golers Chokanah MA224 and Masmuda MA204, have been cultivated. One of the most widely available varieties in local markets is *Mangifera indica* Malt2, which produces medium-sized fruits weighing between 100 to 300 grams. The fruit is visually appealing, with an attractive orange color and a firm, fresh texture, often with a green tint. Mangoes are considered one of the world's finest fruits. Both the green and yellow varieties are excellent sources of fiber, riboflavin, carotene, ascorbic acid, and also provide notable amounts of calcium and iron [1–3].

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Mango seed kernels, depending on the variety, typically contain an average of 6.0% protein, 11% fat, 77% carbohydrates, 2.0% crude fiber, and 20% ash on a dry weight basis. Studies have shown that mango seed kernels are a rich source of polyphenols, phytosterols such as campesterol and β-sitosterol, and tocopherols. When total lipids are extracted and fractionated from the Alphonso mango kernel, they make up 11.6% of the dry kernel, with 96.1% being neutral lipids and 3.9% polar lipids, including 2.9% glycolipids and 10% phospholipids. Nutritional and toxicological studies suggest that mango seed kernel fat is a promising and safe source of edible oil, being both nutritious and non-toxic. This makes it a viable alternative to solid fats without any adverse effects [4–6].

Mango kernel extracts, often overlooked, have significant potential. When cold-pressed, the kernel produces mango kernel butter, not oil. This butter is highly valued and can serve as a substitute for cocoa or shea butter. Rich in essential fatty acids, minerals, and vitamins, mango kernel butter offers excellent moisturizing properties, making it ideal for use in skin lotions and lubricants [7]. It is solid at room temperature, has a sweet and nutty aroma in its pure form, and has a smooth, creamy color. The fragrance is mild, similar to olive oil with a slight nutty undertone.

Semi-solid mango kernel oil is produced during the refining process of mango kernel butter. This soft yellow oil has a stronger scent than the butter and a melting point of around 23°C to 27°C, meaning it melts upon contact with the skin. On average, a mango kernel contains about 8% to 15% extractable butter and oil. Often discarded, the seed is an excellent resource for cosmetics and beauty products. Its shelf life is 3 to 4 years when stored in a cool environment. Most mango oils are refined, which can alter their therapeutic properties [8, 9].

The search for renewable raw materials and solutions to environmental pollution has driven research into plant-based materials, especially for their nutritional and potential industrial applications. The avocado seed, along with other plant oils, is also part of this growing interest [10].

METHODOLOGY

Determination of Nitrogen Content of Three Varieties of Agro-Seed Cake

Food proteins are made up of amino acids that contain various functional groups. The Kjeldahl method is one of the most effective techniques for directly estimating protein content.

Principle (Micro Kjeldahl)

The Kjeldahl method involves the wet combustion of the sample, achieved by heating it with concentrated sulfuric acid in the presence of metallic and other catalysts. This reaction reduces the organic nitrogen in the sample to ammonia, which is then retained in solution as ammonium sulfate. After the digestion, the solution is made alkaline, and the ammonia is released through steam or distillation. The released ammonia is then trapped and titrated.

Reagents/Apparatus

Procedure

To determine the nitrogen content of three varieties of agro-seed cake, begin by measuring 0.5 g of the seed cake into a No. 1 Watchman filter paper and place it in a Kjeldahl digestion flask. Add 3 g of sodium sulfate (Na_2SO_4) and 3 g of copper sulfate ($CuSO_4$) as catalysts, followed by 12 mL of concentrated sulfuric acid (H_2SO_4). Heat the flask in an inclined position in a fume cupboard until frothing stops. Continue boiling briskly until the solution becomes clear. Once the solution is clear, allow it to cool for 10 minutes, then dilute it to 100 ml with distilled water using a measuring cylinder. Next, transfer 20 m_l of the digest to a 500 mL distillation flask, add 20 mL of 40% sodium hydroxide solution, and perform simple distillation to obtain a distilled alkaline-ammonia solution. To this distilled ammonia solution, add 10 mL of boric acid in a 200 mL conical flask and shake thoroughly. Collect 150 mL of the ammonia-alkaline solution in a beaker and titrate it against 0.1 N HCl (Table 1).

Table 1. Applying the experimental data of C_s against extraction time.

$C_{s\,(g)}$	T (min)	*In* C_s
150	40	5.011
142	50	4.956
132	60	4.883
128	70	4.852
123	80	4.812
118	90	4.771

Method 1

Applying the extraction mass transfer equation

$$C = C_s \left[1 - exp\left[-\frac{KA}{Vb}\right] t\right] \tag{1}$$

e – Exponential
t – Extraction time
A – Area of extract = 3.4159 × L^2
L – Length of cylinder containing the extract (30 mm)
V – Volume of extract
b – Thickness of extract
C_S – Initial concentration of feed (g)
K – Diffusion coefficient = 1.12 × 10^{-8} m^2

Taking the natural logarithm of Equation (1)

$$In\ C = In\left[C_s\left(1 - e - \frac{KAt}{Vb}\right)\right]$$

$$In\ C = In\ C_s + In\left(1 - e - \frac{KAt}{VL}\right)$$

$$In\ C = In\ C_s + In\ 1 - In\ e - \frac{KAt}{VL} \tag{2}$$

But $In\ 1 = 0$
Equation (2) yields

$$In\ C = In\ C_s - In\ e - \frac{KAt}{Vb} \tag{3}$$

Mathematical analysis of Equation (3) gives

$$In\ C = In\ C_s + \frac{KAt}{Vb} \tag{4}$$

Upon variable separation or re-arrangement of Equation (4)

$$In\ C_s = In\ C - \frac{KAt}{Vb} \tag{5}$$

Therefore, a plot of *In* C_s against t using Equation (5) gives a straight line of intercept in *In* C_s and equation In C and the slope of the plot equals $-\frac{KAt}{Vb}$

Method 2

Applying the extraction mass transfer equation

$$C = C_s \left[1 - exp\left[-\frac{KA}{Vb}\right] t\right] \tag{6}$$

e – Exponential
t – Extraction time

A – Area of extract = 3.4159 × L^2
L – Length of cylinder containing the extract (30 mm)
V – Volume of extract
b – Thickness of extract
C_S – Initial concentration of feed (g)
K – Diffusion coefficient = 1.12×10^{-8} m^2
Taking the natural logarithm of Equation (1)

$$In\ C = In\left[C_s\left(1 - e - \frac{KAt}{Vb}\right)\right]$$

$$In\ C = In\ C_s + In\left(1 - e - \frac{KAt}{VL}\right)$$

$$In\ C = In\ C_s + In\ 1 - In\ e - \frac{KAt}{VL} \quad (7)$$

But $In\ 1 = 0$
Equation (2) yields

$$In\ C = In\ C_s - In\ e - \frac{KAt}{Vb} \quad (8)$$

Mathematical analysis of Equation (8) gives

$$In\ C = In\ C_s + \frac{KAt}{Vb} \quad (9)$$

Upon variable separation or rearrangement of Equation (9)

$$In\ C_s = In\ C - \frac{KAt}{Vb} \quad (10)$$

Therefore, a plot of *In* C_s against *t* using Equation (10) gives a straight line of intercept in *In* C_s and equation In C and the slope of the plot equals $-\frac{KAt}{Vb}$

From the plot of *In* C_s against time (*t*)
The slope $(8) = -0.0047$
Thus, $5 = -\frac{KA}{Vb} = -0.0047$
Also, *In C*$= 5.18928$

$C = e\ 5.18928$

$C = Exp(5.18920) C = 179.339$

From the plot of *In* C_s against time (t)
The slope $(8) = -0.0047$
Thus, $5 = -\frac{KA}{Vb} = -0.0047$
Also, *In C* $= 5.18928$

$C = e\ 5.18928$

$C = Exp(5.18920)$

$C = 179.339$

RESULTS AND DISCUSSION

The study revealed optimal mango kernel oil extraction below 55°C, with yields declining at higher temperatures. Extraction efficiency varied across samples, highlighting potential for cosmetics and nutritional industries.

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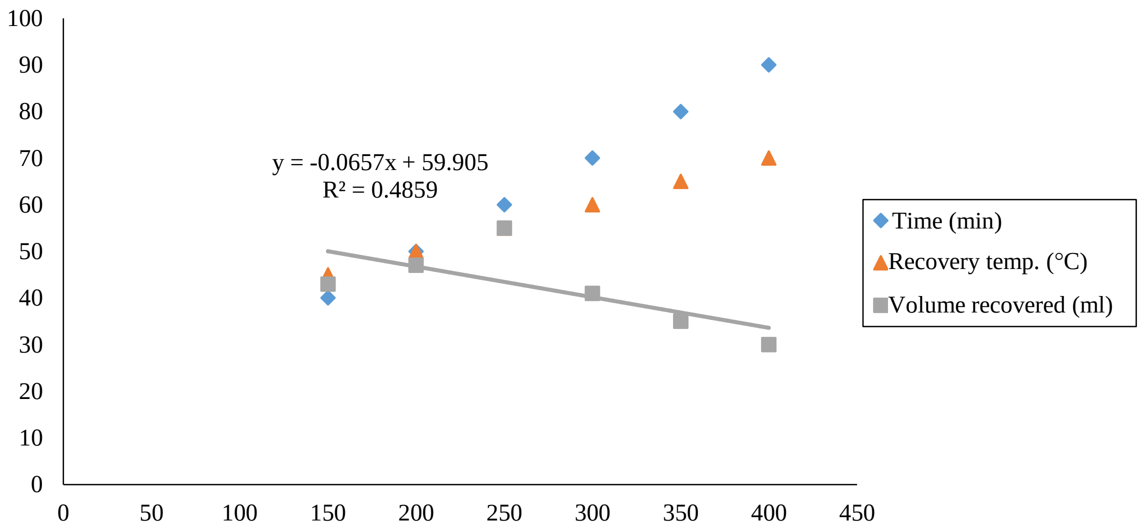

Figure 1. Comparison of recovery temperature, volume, and time (Sample 1).

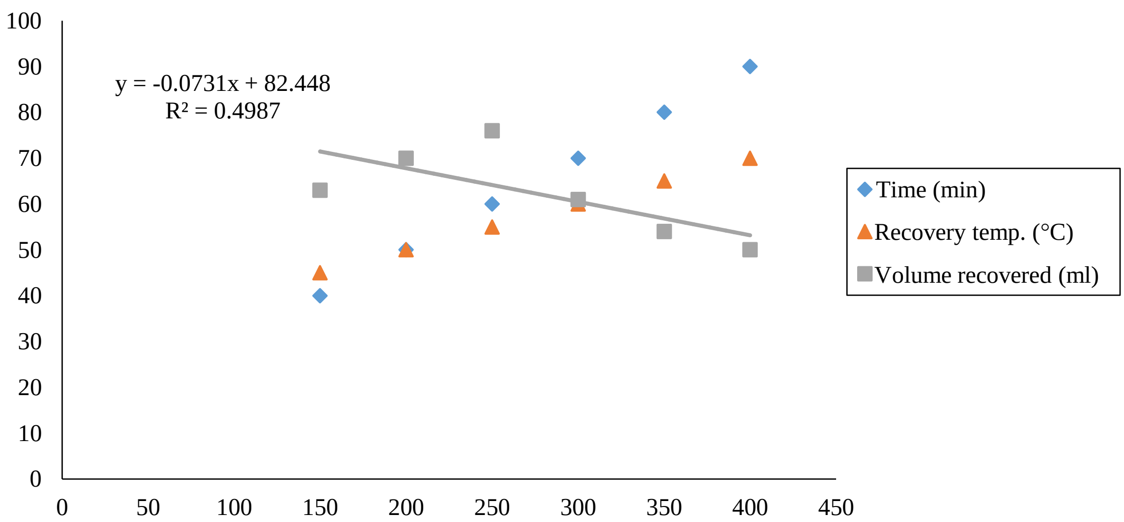

Figure 2. Comparison of recovery temperature, volume, and time (Sample 2).

The result of Figure 1 shows lower coefficient of determination (R^2) number of 0.4859, and with a yield deterministic model expression as $y = –0.0657x + 59.905$. This result still shows the effect of temperature and time on the volume of extracted oil, with a pseudopodal decrease of the oil over increase in temperature above 55°C and 60 min. sing the linear model for yield determination of the system, the yields at variant temperatures of 45°C, 50°C, 55°C, 60°C, 65°C, and 70°C are 56.9485, 56.62, 56.2915, 55.963, 55.6345 and 55.306, respectively.

Figure 2 shows a decrease in the extracted oil volume gotten from alligator pear seed (Reed species) withing the increase in recovery temperature above 55°C which lies within 60 min extraction time. The result also shows that the coefficient of determination (R^2) of the extraction system is 0.4987, which defines that the process accessible variables of the system lies below fitting level.

Finally, from the plot, it resulted that the yield of the system at variant operating temperatures (x) of the system using the linearity model: $y = –0.0731x + 82.448$, are 79.1585, 78.793, 78.4275, 78.062, 77.6965 and 77.331, respectively, with respect to the following degree change in temperature; 45°C, 50°C, 55°C, 60°C, 65°C, and 70°C.

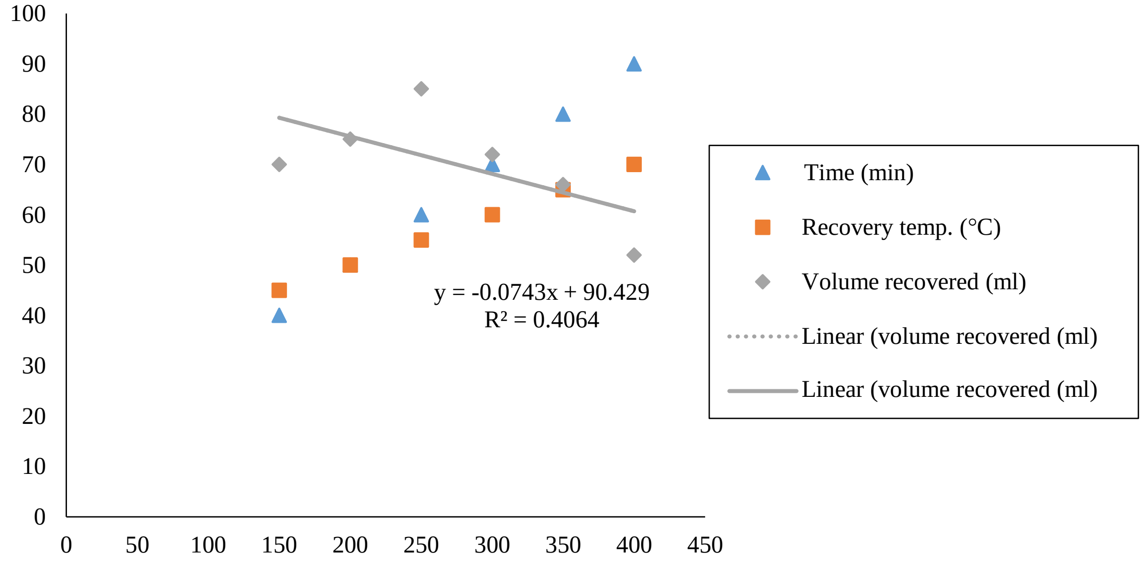

Figure 3. Comparison of recovery temperature, volume, and time (Sample 3).

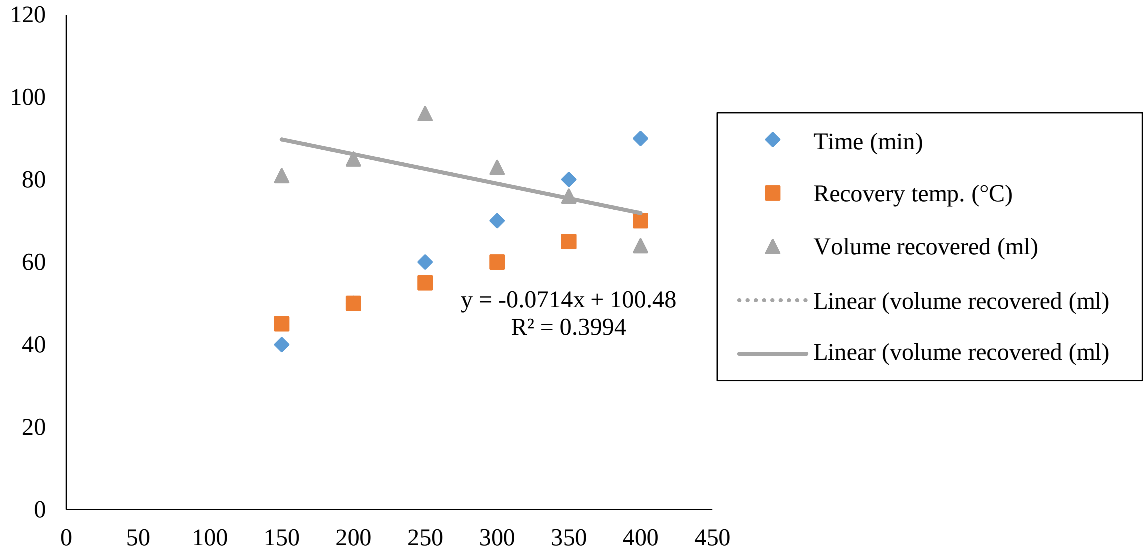

Figure 4. Comparison of recovery temperature, volume, and time (Sample 4).

Figure 3 shows decrease in extracted oil volume is also observed in this plot at a point above 55°C recovery temperature, but with a coefficient of determination (R^2) number of 0.4064, with the yield determined using the deterministic model: $y = –0.0743x + 90.429$. The yield of the system over degree increase in temperature is; 87.0855, 86.714, 86.3425, 85.971, 85.5995 and 85.228, respectively, at 45°C, 50°C, 55°C, 60°C, 65°C, and 70°C.

In Figure 4, the volume of oil extracted is also affected by increase in temperature above 55°C, the feed masses above 250 g experiences a greater loss of recovered oil, which promotes the exponential fall of the plot curve line. The result also shows that the coefficient of determination (R^2) of the extraction system is 0.3994, which defines that the process accessible variables of the system lie below fitting level. Finally, from the plot, it is resulted that the yield of the system at variant operating temperatures (x) of the system using the linearity model: $y = –0.0714x + 100.48$, are 97.267, 96.91, 96.553, 96.196, 95.839 and 95.482, respectively, with respect to the following degree change in temperature 45°C, 50°C, 55°C, 60°C, 65°C, and 70°C.

CONCLUSION

This research also involves the determination of physical properties of the oil from the nine species of the three agro-seeds such as refractive index, density, and viscosity. Also, the chemical properties such as iodine value, peroxide value, acid value, saponification and free fatty acid of the oil. These physiochemical characteristics of the oil constitute useful reference point as being used as quality standard in chemical and food processing industries.

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