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# Effects of microwave and steaming pre-treatments on oil yield and quality of Neem seed

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**Abstract**
Neem, scientifically known as *Azadirachta indica*, belongs to the family Meliaceae. It is famous worldwide for its many uses and bioactive compounds present in neem seed oil, which contain many triterpenes, such as azadirachtin. This study explored the impact of microwave and steaming pretreatment techniques on neem seed oil extraction, focusing on oil yield and quality analysis. Microwave treatments were applied at different power levels (300, 450, and 600 W) for 120 and 180 s, whereas steaming treatments were conducted at a constant pressure of 1.5 kg/cm² and a temperature of 121 °C for various times (5, 10, and 15 min). The results showed that higher microwave power levels and longer treatment times significantly increased the oil yield, with the highest yield of 42.18% being achieved at 450 W for 180 s. In terms of quality parameters, increased acid value, free fatty acid content, and peroxide value were observed. Steaming pretreatment resulted in a 4.42% increase in oil yield in comparison with the untreated sample (31.51%), with the highest yield of 35.97% observed after 15 min. Steaming slightly reduced the acid and free fatty acid content, although it increased the peroxide value.

**Keywords:** Neem oil, microwave pre-treatment, steaming, oil yield and quality

## 1. Introduction
Neem (*Azadirachta indica*), a plant in the *Meliaceae* family, is well known and important worldwide because of its many uses and bioactive substances. In India, approximately 25 million neem trees are distributed across the country, with the largest number of trees found in Uttar Pradesh (55.7%), followed by Tamil Nadu (17.8%), and Karnataka (5.5%). India is the world's leading producer of neem seeds, producing approximately 4,42,300 tons of neem seeds annually. This production yields approximately 88,400 tons of neem oil and 3,53,800 tons of de-oiled cakes (Girish *et al*., 2008) [8]. Its prominence has grown over the years, particularly because of its bioactive compounds, such as azadirachtin, which possess potential insecticidal properties. Azadirachtin extracted from the seeds of neem leaves and fruits plays a vital role in pest management across agricultural and domestic sectors (Ezin & Chabi, 2023) [6]. The oil contains over 100 biologically active components, including terpenoids, limonoids, and volatile sulfur compounds. Azadirachtin is a major constituent, and its crude neem oil content can vary widely, influencing its application and effectiveness (Melwita *et al*., 2010) [13].
Neem seeds are primarily used for oil extraction. Yield plays a crucial role in neem seed oil production, affecting its market availability and commercial value. Enhancing the oxidative stability and functional components of oils can extend their shelf life and increase their market potential. The extraction of oil from neem seeds involves multiple techniques, including solvent extraction, mechanical pressing, supercritical fluid extraction, and hybrid methods that combine mechanical and solvent extraction (Oyinlola & Adekoya, 2004) [14]. Mechanical pressing, although simpler and safer, has certain limitations compared to solvent extraction. Pretreatment methods applied to neem seeds prior to oil extraction can significantly affect the efficiency of oil extraction and quality of the final product. Changes in the physical and chemical properties of oil seeds, such as the use of heat or microwaves, can help release more oil (Mazubert *et al*., 2014) [12]. Pretreatment with steam promotes the breakdown of cell walls, denatures proteins, and inactivates enzymes, thereby facilitating

better oil extraction (Zhang *et al*., 2023) [22]. These pretreatment methods are not only beneficial in releasing oil from oil seeds but also in increasing oil stability and extraction of bioactive compounds (Suri *et al*., 2020) [18]. Despite the effectiveness of solvent extraction, its industrial application faces challenges, such as plant security issues, volatile organic compound emissions, and high operational costs. Therefore, mechanical pressing is more suitable for oil extraction, is an easy and simple method, and prevents the deterioration of oil due to its lower extraction temperature compared to solvent extraction.

The oil from neem seeds has many medical uses, including fighting inflammation, arthritis, fever, high blood sugar, constipation, sperm infections, fungal growth, bacterial infections, viral infections, and psoriasis. This study focused on examining the impact of various pretreatment techniques on the yield and quality of oil extracted from neem seeds. By addressing these complexities, this study aims to optimize the oil production process, thereby improving the overall efficiency and market value of neem seed oil.

## 2. Materials and Methods

### 2.1 Raw Materials

Fresh neem seed kernels were purchased from the local market in Raipur (Chhattisgarh). The kernels were sun-dried for two days, in order to remove excess moisture and prevent spoilage. Subsequently, kernels were manually cleaned using appropriately sized sieves to eliminate foreign materials, such as dirt, dust, stones, and any broken or damaged kernels. The cleaned and graded samples were stored in tightly sealed polyethylene bags at room temperature until further use.

### 2.2 Physico-chemical properties

The physical properties of the neem seed kernel, including axial dimensions (length, breadth, and thickness), geometric mean diameter, arithmetic mean diameter, sphericity, aspect ratio, volume, thousand kernel weight, bulk density, true density, porosity, angle of repose, and static coefficient of friction, were meticulously determined using the methods described by Sahay and Singh (1994) [16].

Quality parameters, including acid value, free fatty acid content, and peroxide value, were determined using the methods described by the Food Safety and Standards Authority of India.

### 2.3 Microwave pre-treatment

Neem kernels were pretreated using a microwave oven (Samsung, model CQ138S). For each treatment, 200 g of neem kernels were uniformly spread on the tray and subjected to microwave treatments at power levels of 300, 450, and 600 W for durations of 120 and 180 s at a 2450 MHz frequency (Uquiche *et al*. 2008, Karrar *et al*. 2020) [21, 9]. After treatment, oil was extracted from both treated and untreated (control) neem kernels using a single screw-type mini oil expeller. Each experiment was performed in triplicate.

### 2.4 Steaming pre-treatment

A 200 grams sample of neem kernels was steamed in an autoclave for 5, 10, and 15 min at a fixed temperature of 121°C and 1.5 kg/cm$^2$ respectively (Zhang *et al*. 2013) [22]. The autoclave was preheated for 10 min to achieve the desired temperature and pressure. After preheating, 200 g of neem kernels was wrapped in cotton cloth and placed inside the autoclave. The samples were allowed to cool to room temperature after steaming and the oil was extracted. The extracted oil samples were stored in cool and dry places in dark-colored bottles to prevent deterioration before quality analysis.

### 2.5 Oil extraction

Oil was extracted using a mini screw oil press, and the oil yield and recovery were calculated as follows (Thilakaratna *et al*., 2023) [20]:

$$\text{Oil yield (\%)} = \frac{W_E}{W_I} \times 100$$

$$\text{Oil recovery\%} = \frac{O_M}{O_S} \times 100$$

Where, $W_E$ is the weight of extracted oil (g), $W_I$ is the initial weight of sample (g), $O_M$ is the oil yield from mechanically extraction (%) and $O_S$ is the oil yield from Soxhlet extraction (%)

## 3. Results and discussion

### 3.1 Physical properties of neem kernels

The physical characteristics of neem kernels were measured in replicates. The mean dimensions of neem kernels were 9.52±0.94 mm in length, 5.01±0.65 mm in breadth, and 4.07±0.54 mm in thickness. Moreover, the sphericity was 0.61±0.05, aspect ratio was 0.53±0.07, and thousand kernel weight was 106.55±2.19 g. The bulk density, true density, and porosity were 569.18±16.43 kg/m$^3$, 1199.75±25.53 kg/m$^3$, and 52.56±0.81%, respectively. The angle of repose was 30.39±0.81 °. The static coefficient of friction measured using galvanized steel, stainless steel, and mild steel were 0.39±0.01, 0.30±0.01 and 0.66±0.01, respectively. Similar findings have been reported by Balami *et al*. (2014) [5] and Kishore *et al*. (2022) [10].

**Table 1:** Physical properties of neem kernels

| S. No. | Parameters | Mean ± SD |
|---|---|---|
| 1. | Dimensions, (mm) | |
| 1.1 | Length | 9.52±0.94 |
| 1.2 | Breadth | 5.01±0.65 |
| 1.3 | Thickness | 4.07±0.54 |
| 2. | Arithmetic mean diameter, (mm) | 6.20±0.52 |
| 3. | Geometric mean diameter diameter, (mm) | 5.77±0.51 |
| 4. | Sphericity | 0.61±0.05 |
| 5. | Aspect ratio | 0.53±0.07 |
| 6. | 1000 kernels weight, (g) | 106.55±2.19 |
| 7. | Bulk density, (kg/m$^3$) | 569.18±16.43 |
| 8. | True density, (kg/m$^3$) | 1199.75±25.53 |
| 9. | Porosity, (%) | 52.56±0.94 |
| 10. | Angle of repose (degree) | 30.39±0.81 |
| 11 | Static coefficient of friction | |
| 11.1 | Galvanized steel | 0.39±0.01 |
| 11.2 | Stainless steel | 0.30±0.01 |
| 11.3 | Mild steel | 0.66±0.01 |
| *****All the values are in Mean ± SD | | |

### 3.2 Effect of microwave pre-treatment on the yield of oil

The results demonstrated a direct relationship between microwave power and time, and the efficiency of oil extraction from neem seeds. As shown in Fig. 1, longer durations resulted in higher oil yields than shorter durations.

Additionally, higher power levels (450 and 600 W) produced greater oil yields than the 300 W power level. The highest oil yield was found to be 42.18% at 450 W with a treatment time of 180 s, whereas the lowest oil yield was 33.31% observed at 300 W for 120 s. It was found that microwave pretreatment increased the oil yield by 10.67% compared with the control sample. Similar results were observed by Karrar *et al*. (2020) and Takagi *et al*. (1999). Similar results were reported by Azadmard-Damirchi *et al*. (2010), who concluded that microwave radiation can increase extraction yields by rupturing cell membranes and creating permanent pores, which allow the oil to pass through the permeable cell walls and enhance oil recovery, improve nutraceutical content, and extend shelf life.

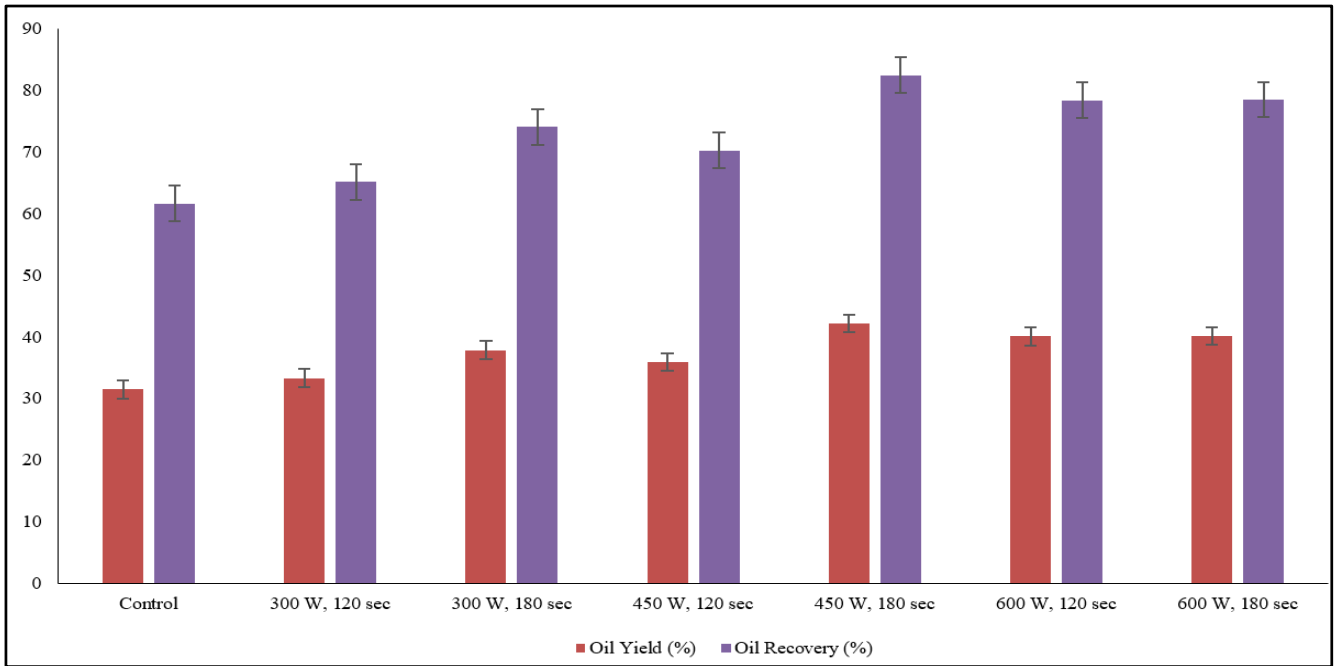


Fig 1: Effect of MW pre-treatment on the yield of neem kernel oil

### 3.3 Effect of microwave pre-treatment on the acid value

Fig. 2 illustrates that higher microwave power levels and longer treatment times increased the acid value. The control sample had an acid value of 6.61 mg KOH/g of oil. In comparison, the treated samples showed a range of values from 6.55 mg KOH/g to 7.87 mg KOH/g. Longer treatment times and higher microwave powers may accelerate the hydrolysis and thermal destruction of triglycerides. Similar results were found by Karrar *et al*. (2020) [9] for gurum seed oil and Bakhshabadi *et al*. (2017) [4] for black cumin seed oil, thereby elevating the acid value of neem oil. The difference in acid values between the control and microwave-treated samples was minimal. This result indicates that microwave treatment had a relatively minor effect on the acid value of the oil, which is consistent with the findings of Uquiche *et al*. (2008) [21] for hazelnut seed oil.

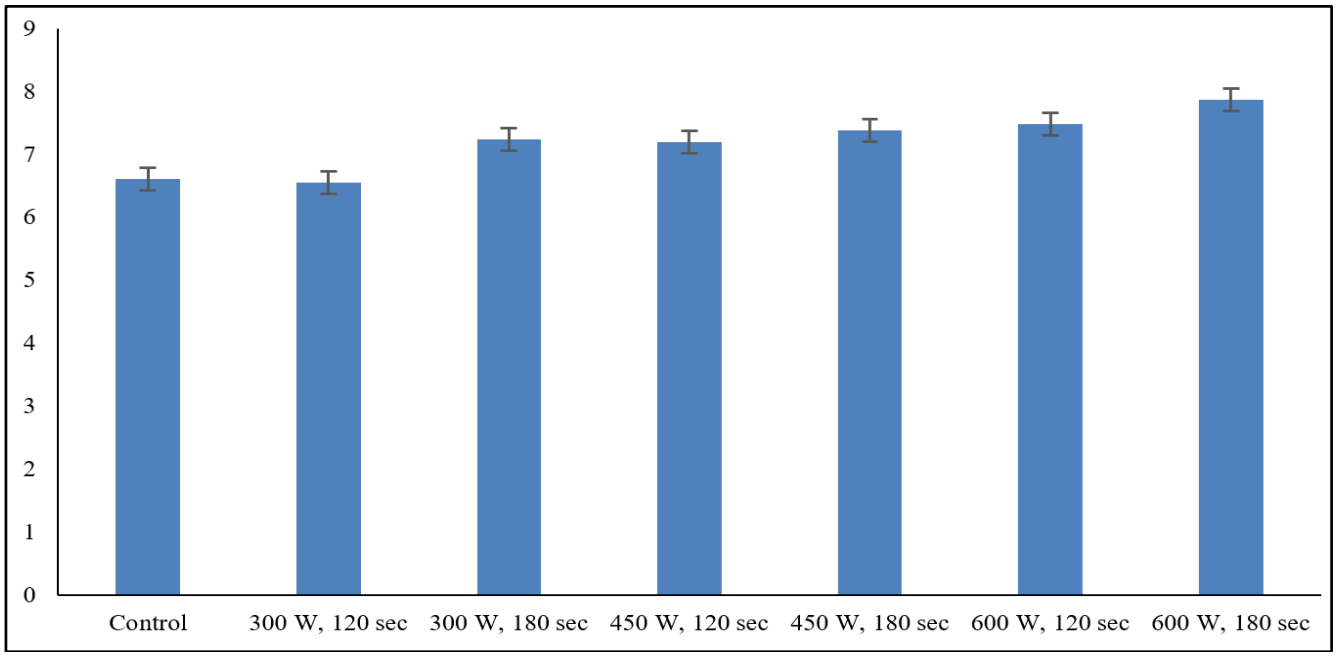


**Fig 2:** Effect of MW pre-treatment on acid value (mg KOH/g) of neem kernel oil

### 3.4 Effect of microwave pre-treatment on the free fatty acid (as oleic,%)

As shown in Fig. 3, the lowest free fatty acid content (3.29%) was observed at 300 W with 120 s of treatment, whereas the highest (3.95%) occurred at 450 W with 180 s of treatment. This indicates that a higher microwave power and extended exposure promote the release of free fatty acids in the oil; this finding is consistent with that of Karrar *et al*. (2020) [9].

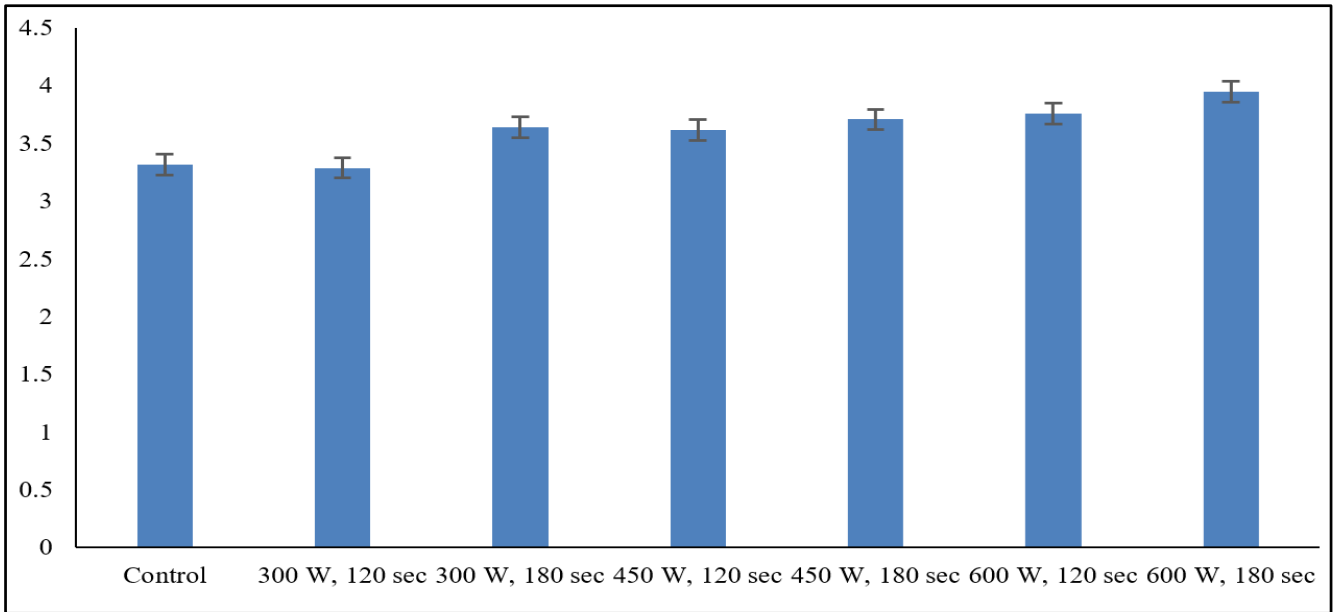


**Fig 3:** Effect of MW pre-treatment on the free fatty (as oleic acid,%) acid content of oil

### 3.5 Effect of microwave pre-treatment on the peroxide value

The lowest peroxide value was found to be 1.70 meq/kg oil at 300 W for a treatment time of 120 s, and 2.97 meq/kg oil was the highest peroxide value was found at 600 W for a treatment time of 180 s, as shown in fig. 4. The increase in peroxide value is attributed to enhanced oxidative reactions facilitated by higher power and longer exposure times, which promote the formation of peroxides and free radicals in the oil. Similar results were reported by Farag *et al*. (1992) [7], who found that the acceleration of cottonseed oil oxidation during microwave heating was observed by an increase in PV due to the presence of reactive radicals that might be formed by exposure to microwaves. Similar behavior was observed by Albi *et al*. (1997) [1] for olive and sunflower oils, respectively.

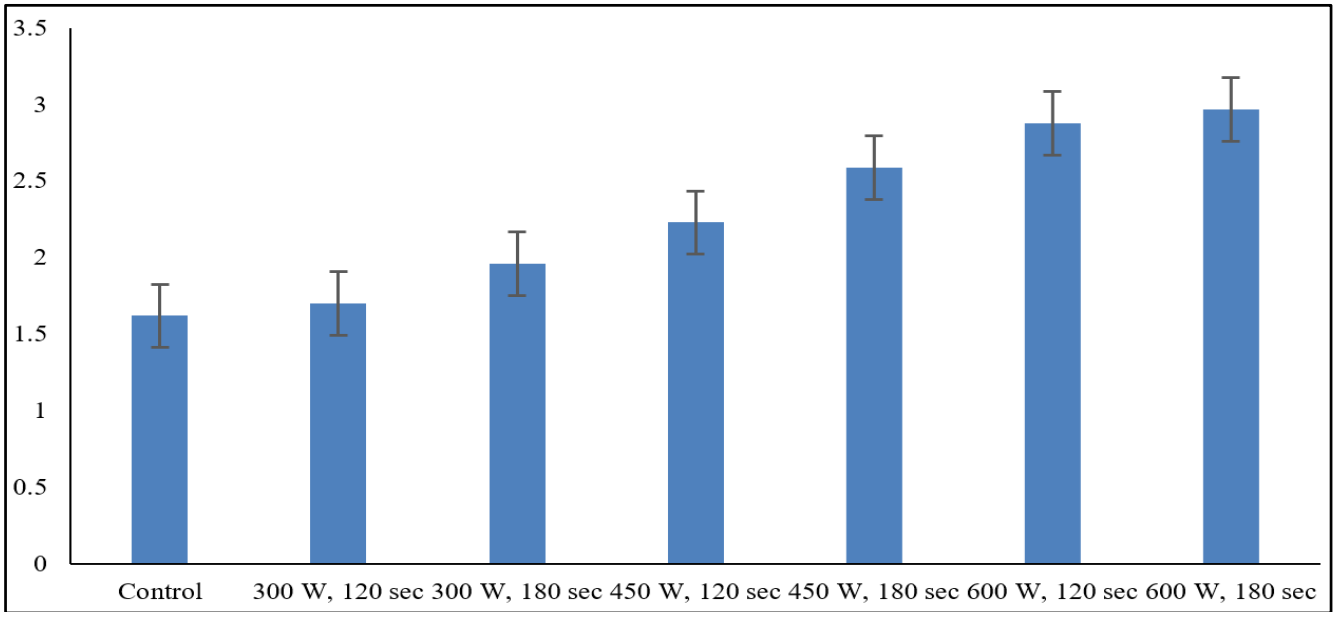


**Fig 4:** Effect of MW pre-treatment on the peroxide value (meq/kg) of neem kernel oil

### 3.6 Effect of steaming pre-treatment on the oil yield

As shown in Fig. 5, an optimal steaming time of 15 min might maximize the oil yield, potentially owing to the effective breakdown of cell structures that facilitate oil extraction. Although longer treatment times beyond 15 min might result in decreasing trends, similar findings were found by Zhang *et al*. (2023) [22], who observed that the increased oil production results from steam pretreatment, which breaks down the cellular structure of the matrix and lowers the viscosity of the oil, making it easier to press the

oil out of the cellular structure. Similar results were also observed by Lee *et al*. (2021) [20], who found that steam treatment enhanced perilla seed oil yield by almost 2.5 times when compared to untreated seeds.

The oil yield of the control sample was found to be 31.51%. results showed that the highest oil yield of 35.93% was achieved at 15 min, which was 4.42% increased by steaming pre-treatment compared to the control sample. The difference between the results of the treatment conditions at 10, 15, and 20 min was minimal, and treatment times beyond 15 min might result in decreasing returns. This may be because the steaming process reached the saturation point of the kernels; beyond this point, the extraction efficiency decreased as the neem kernels became saturated and less oil was available for extraction.

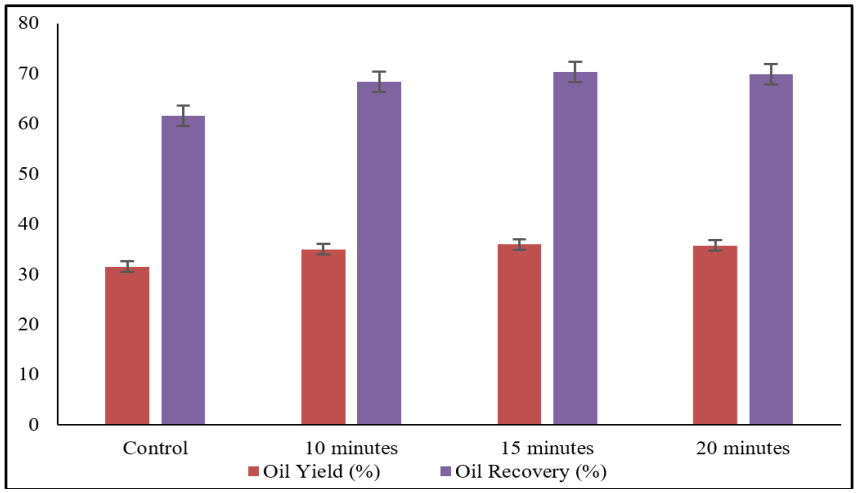


**Fig 5:** Effect of steaming pre-treatment on the yield of neem kernel oil

### 3.7 Effect of the steaming pre-treatment on the acid value

The acid value of the control sample was found 6.61 mg KOH/g oil. Fig. 6 shows that steaming pre-treatment significantly decreased the acid value of neem kernel oil compared to the control sample. The acid value decreased as treatment time increased. The lowest acid value 5.47 mg KOH/g oil was found at treatment time 20 min and the highest acid value 6.38 mg KOH/g oil was found at the treatment time 10 min similar findings were found by Zhang *et al*. (2023) [22] who stated that steam pre-treatment of tiger nut prior to oil extraction could reduce the acid value of the oil, the decrease in acid value could be attributed to the inactivation of lipase.

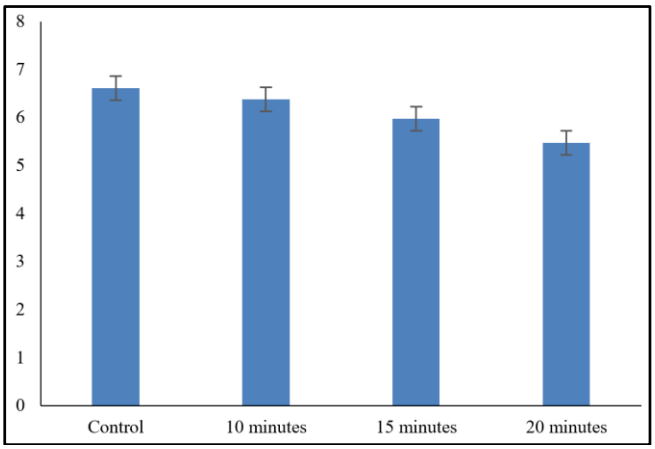


**Fig 6:** Effect of steaming pre-treatment on the acid value (mg KOH/g) of neem kernel oil

### 3.8 Effect of the steaming pre-treatment on the free fatty acid (as oleic,%)

As the results shown in Fig. 7 indicate that at a treatment time of 10 min, the free fatty acid content was 3.21%, which decreased to 3% after 15 min, and further dropped to 2.75% after 20 min. This indicated that longer treatment times may facilitate chemical reactions that lower the free fatty acid concentration in the oil. Similar findings were reported by Sarungallo *et al*. (2020) [17], who found that heat treatment of red fruit Drupa using an autoclave at 120 °C for 20 min reduced the free fatty acid content. This decrease could be due to extended heating at high temperatures, which may denature the lipase and cause it to become inactive. As a result, hydrolysis reactions are inhibited, leading to a reduction in free fatty acid levels.

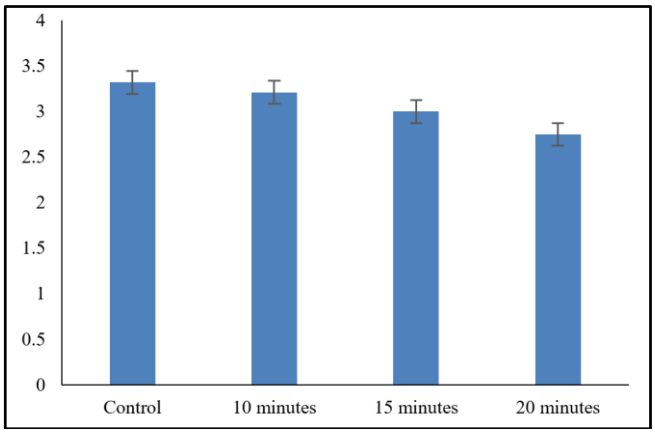


**Fig 7:** Effect of steaming pre-treatment on the free fatty acid (as oleic, %) content

### 3.9 Effect of the steaming pre-treatment on the peroxide value

The Effect of steaming pre-treatment on the peroxide value is shown in Fig. 8, which indicates that the treatment time significantly increased the peroxide value of neem kernel oil. The peroxide value of the control sample was found to be 1.62 meq/kg oil. The lowest peroxide value of neem kernel oil was found to be 3.60 meq/kg oil with a treatment

time of 10 minutes, while the highest value was found to be 4.74 meq/kg oil with a treatment time of 20 minutes. This increase in peroxide value was due to the greater oxidation of the neem kernels with longer steaming times and could be Prolonged exposure to heat during steaming could accelerate the formation of peroxides in the oil, leading to higher peroxide values. Similar findings were found by Xu *et al*. (2018) [23], who reported that pre-treatment of rapeseed with steam heating resulted in rapeseed oil with a 3-4 times higher peroxide value compared to untreated rapeseed.

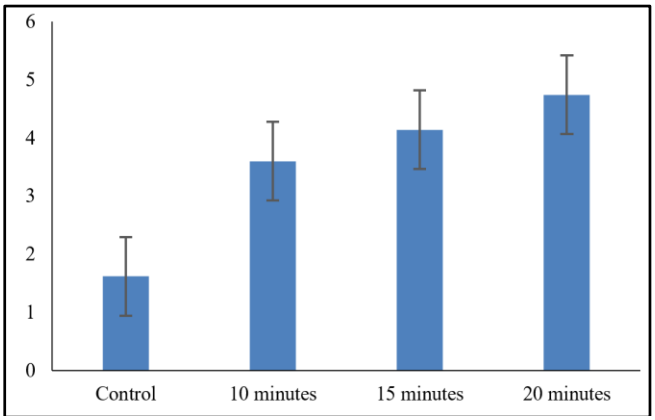


**Fig 8:** Effect of steaming pre-treatment on the peroxide value (meq/kg) of oil

## 4. Conclusion

The results of this study indicated that higher microwave power levels and longer treatment times significantly increased the oil yield. The maximum oil yield of 42.18% was achieved at 450 W for 180 seconds. Microwave (MW) pre-treatment enhanced the oil yield by 10.67% compared to the control sample. However, it was observed that the microwave pre-treatment also elevated the acid value, free fatty acid content, and peroxide value of the neem kernel oil. These findings suggest that while higher power levels and longer durations improve oil yield, they also degrade the oil's quality. Therefore, the optimal conditions for maximizing oil yield are 450 W power and a treatment time of 180 seconds. Steaming pre-treatment increased the oil yield by 4.42% compared to the control. The highest oil yield of 35.97% was achieved with a treatment time of 15 minutes. While steaming pre-treatment raised the peroxide value of the oil, it slightly reduced the acid value and free fatty acid content of neem kernel oil. Based on these findings, the optimal condition for maximizing oil yield was found to be a treatment time of 15 minutes.

## 5. Acknowledgment

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