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# Postoperative *Cinnamomum camphora* aromatherapy enhances haematology and supports hepatic and renal function in live-donor nephrectomy: A murine model

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**Abstract**

The increased demand for kidney transplants arising from kidney failure and intricacies with dead-donor organ nephrectomy has led to increased focus on live-donor nephrectomy. As with all procedures, postoperative care is critical to physiologic recovery and mental health support in live donors. This study explored the clinical potential of *Cinnamomum camphora* (camphor) aromatherapy to improve haematology and biochemical parameters following unilateral nephrectomy in the Wistar rat model. Eighteen male Wistar rats (mean weight 217 ± 12 g) were randomized into three groups (n = 6): Group I (unilaterally nephrectomised) was subjected to *Cinnamomum camphora* inhalation exposure for 10 days post-surgery. Group II (unilaterally nephrectomised) and group III (sham-operated) were not exposed to camphor. *Cinnamomum camphora* exposure was an adjunct to routine post-operative care. Hematologic and serum biochemical indices were assessed on day 10 post-surgery. The results showed the red cell indices slightly enhanced and total WBC significantly ($p < 0.05$) lowered in group I compared to group II, with a reduced neutrophil-to-lymphocyte ratio. Serum creatinine was lower in group I compared to group II, while bilirubin significantly ($p < 0.05$) reduced in Group I compared to control, with serum fibrinogen lowest in Group II. This study has shown that Cinnamomum *camphora* aromatherapy potentially improved recovery in live-donor nephrectomy, with most homeostatic indices studied being enhanced, although not all reached statistical significance. The trend provides preliminary evidence for a safe adjunct to conventional postoperative care that ameliorates stress, reduces drug reliance, and promotes homeostatic stability. The findings lay a good groundwork for future studies.

*Keywords*: Aromatherapy, *Cinnamomum camphora*, Live-donor, Nephrectomy, Post-operative

**Introduction**

The kidneys are critical organs that carry out essential functions to achieve and maintain homeostasis in humans and animals. They filter blood, excrete metabolic wastes and regulate fluid and electrolyte balance throughout the body, making them indispensable to life. While complete nephrectomy is incompatible with life, live-donors (following unilateral nephrectomy) can be managed to live physiologically stable and normal lives. Unilateral nephrectomy is recommended when one kidney is irreparably damaged, or for donation purposes in live-donors during renal transplantation (Goldfarb, 2008). Medical and non-medical support, starting with adequate post-operative care, is necessary to provide ideal conditions for the unilaterally nephrectomized individuals to heal properly, adapt to their new status and lead a normal life.

The kidney of rats is a commonly accepted model in biomedical researches for studying renal physiologies and pathologies since they exhibit significant anatomical and physiological similarities to that of humans (Kovács *et al.,* 2015).

Aromatherapy, a complementary therapy involving inhalation of medicants, has been revered over the years by practitioners for its potential in alleviating various health conditions (NCCIH, 2021). Central to conventional aromatherapy are essential oils; each possessing unique chemical properties that confer specific therapeutic effects on patients (Dhifi *et al*., 2016). Among these, camphor, a compound derived from camphor tree (*Cinnamomum camphora*), has been celebrated for its analgesic, anti-inflammatory, anti-neoplastic and antimicrobial properties (Lin *et al.,* 2007).

Camphor is colourless, transparent and crystalline in nature (Jaber & Mahinoud, 1984), and is used in the formulation of liniments, expectorants, carminatives and anti-aphrodisiacs (Hamidpour *et al.,* 2013). For many years, it has been used traditionally in the treatment of skin, eye, nerve and cerebral disorders and for gastric discomforts like diarrhea, and for inflammations of the liver (Khan, 2018), bladder and kidney (Unamba-Oparah *et al.,* 2025). In a study involving controlled inhalation exposure of wounded rats, *Cinnamomum camphora* was found not to interfere with wound healing but appeared to promote systemic conditions necessary for improved healing process (Didehdar *et al.,* 2022). Can *Cinnamomum camphora's* diverse bioactivity and therapeutic potential be useful as support therapy in live-donors following unilateral nephrectomy? Could its antioxidant and anti-inflammatory activities be employed to enhance the compensatory function of the remaining kidney, while its antiseptic (Unamba-Oparah *et al.,* 2025), antifungal (Fazmiya *et al.,* 2022) and antibacterial (Poudel *et al.,* 2021) activities also facilitate healing after surgery, thereby enhancing renal function and recovery post-nephrectomy. This study sought to evaluate the post-operative application of *Cinnamomum camphora* aromatherapy on live-donor male Wistar rats.

**Materials and Methods**

*Experimental animals*

A total of 18 twenty week-old male Wistar rats with a mean body weight of 217.47±11.92 g used for this study were obtained from the Laboratory Unit of the Department of Veterinary Biochemistry, College of Veterinary Medicine, Michael Okpara University of Agriculture, Umudike. The rats were housed individually in stainless steel cages at ambient temperature, fed conventional rat chow (Chikun® Grower Feed, Nigeria) and water *ad libitum* throughout the course of the study. They were allowed 2 weeks to acclimatize before the commencement of the experiment. Ethical approval was obtained from the Institution's Research Ethics Committee with ethical number MOUAU/CVM/REC/202419.

The rats were randomly assigned to three groups of six (6) rats each and treated as follows:

Group I - Unilaterally nephrectomized, exposed to *Cinnamomum camphora* (Donor I)

Group II - Unilaterally nephrectomized, unexposed to *Cinnamomum camphora* (Donor II)

Group III - Sham-operated, unexposed to *Cinnamomum camphora* (Control).

*Exposure to Cinnamomum camphora aromatherapy*

Group I rats were exposed to *Cinnamomum camphora* aromatherapy for 10 days post-surgery via 8 h inhalation at 12 mg/m³ (ACGIH 2005). The volatile camphor balls were weighed out and placed evenly inside the cages and within the enclosed environment of the animal house.

*Surgery*

*Animal preparation and anaesthesia*

The rats were sedated with Xylazine (VMD, Arendonk-Belgium) at 5 mg/kg body weight intramuscularly, followed by ketamine hydrochloride (Swiss Parenteral Ltd, India) at 35 mg/kg body weight intramuscularly five minutes later. Each rat was positioned in right lateral recumbency and the left flank was clipped and disinfected using chlorhexidine solution (Purit®, Nigeria).

*Surgical technique*

The left kidney was removed in groups I and II by adapting the paracostal surgical approach as described by Fossum (2013). A skin incision of approximately 1.5 cm was made parallel to the last rib. The incision was extended through the abdominal muscles into the abdominal cavity and the left kidney was gently exteriorized. The renal blood vessels and ureter were isolated, ligated with 5/0 vicryl suture material and transected caudal to the ligatures and the kidney was removed. The abdominal muscles were then closed with 3/0 chromic catgut in a simple continuous pattern and the skin was routinely closed. Group III was sham-operated (laparotomy was performed but the left kidney was not removed). The day of surgery was considered as postsurgical day (PSD) 0.

*Post-operative care*

Each animal was given post-operative antibiotic treatment with ampicillin sodium (22 mg/kg, IM) for 7 days (Seifi *et al*., 2011).

*Data collection*

On PSD 10, the rats were weighed and euthanized using cardiac exsanguination following inhalation anaesthesia in a gas chamber (Hickman & Johnson, 2011). The blood collected were used for the following assays:

*Assays for kidney functionality*

Creatinine was measured by the Jaffe method (Henry, 1974), and urea was determined by the enzymatic colourimetric method (Tietz, 1983) using Randox® kits (Randox® Laboratories Ltd., UK). Sodium and Potassium assays (Tietz, 1983) and Chloride test (Young, 2001) were carried out with Teco test kits (Teco Diagnostics®, U.S.A).

*Assays for liver integrity*

Alanine aminotransferase (ALT), Aspartate aminotransferase (AST), Total Protein and Bilirubin tests were carried out using Randox® kits (Randox® Laboratories Ltd., UK), while Alkaline phosphatase (ALP) was done using Teco test kits (Teco Diagnostics®, U.S.A). The serum ALT was determined by the Colorimetric method (Reitman & Frankel 1957). The Colorimetric method of Reitman & Frankel (1957) was adopted for the aspartate aminotransferase (AST) assay. For Alkaline phosphatase (ALP), the method of Kachmar & Moss (1976) was used. The Biuret method described by Tietz (1995) was used for Total protein (TP) assay. The Jendrassik colorimetric method as described by Garber (1981) was adopted for Total bilirubin assay. Fibrinogen assay was carried out using the heat precipitation method as described by Stockham & Scott (2008).

*Haematology*

The Packed cell volume (PCV) was carried out using the microhematocrit method as described by Coles (1986). Hemoglobin concentration (Hb) was done with the Cyanomethemoglobin method, as described by Kachmar (1970). To assay total white blood cell (tWBC), the haemocytometer method was used while for Differential WBC Counts, the Leishman technique (Schalm *et al*., 1975) was employed.

*Data analysis*

Statistical analysis was performed using SPSS software® (Version 20). The data were analysed using one way analysis of variance (ANOVA) and variant means were separated with least significant difference (LSD) post hoc test. Significance was accepted at $p < 0.05$. The results were presented as mean ± standard deviation (SD) in figures and tables.

**Results**

*Effect of Cinnamomum camphora Aromatherapy on Kidney Functionality*

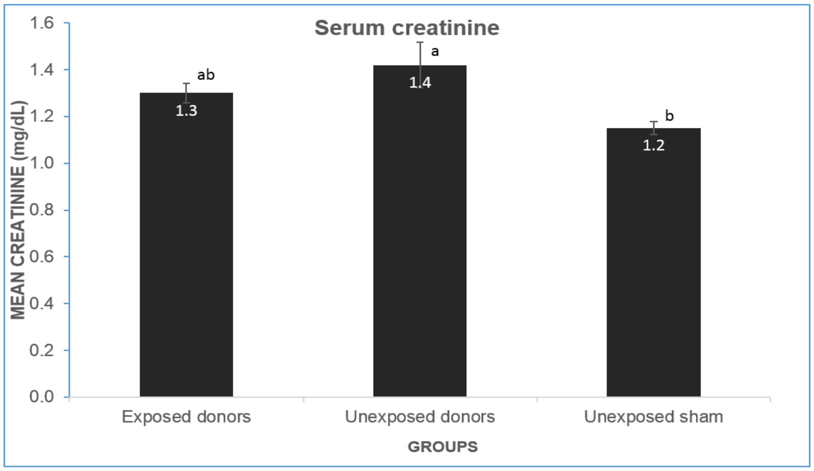
Serum creatinine levels in the Cinnamomum camphora-exposed 'donor' group I were comparable to those of the control ($p>0.05$). However, the unexposed 'donor' group II rats exhibited significantly higher creatinine levels compared to controls ($p<0.05$; Figure 1). Serum urea levels did not differ significantly across groups ($p>0.05$; Figure 2). The urea-to-creatinine ratio remained stable across all groups, though it showed a downward trend in group II (Figure 3). Similarly, the sodium-to-chloride ratio was slightly reduced in the unexposed rats (Figure 4).

*Effect of Cinnamomum camphora Aromatherapy on Liver Integrity*

Liver integrity markers, including AST, ALT, ALP, and total protein, showed no significant differences between the groups ($p>0.05$; Table 1). However, serum bilirubin levels in both donor groups were lower than in the control group. However, this difference was significant ($p<0.05$) in the exposed donor group I rats; it was not significant ($p>0.05$) in the exposed donor group II rats. Serum fibrinogen was also lower in unexposed group II compared to both exposed group I and the sham group III, though the difference was not significant (p>0.05; Figure 5).

*Effect of Cinnamomum camphora Aromatherapy on Haematology*
Packed cell volume (PCV) and haemoglobin of exposed donor rats were slightly higher than in unexposed donors, though not significantly (p>0.05) (Table 2). Total white blood cell counts (tWBC), of the unexposed donor rats exhibited significantly higher (p<0.05) values compared to exposed donor rats. Neutrophil counts showed no significant variation across groups, though donor group I values were consistently lower than both the donor group II and control rats. Lymphocyte counts were also statistically comparable across the groups, but with the values for the exposed donor group being slightly higher than both unexposed groups of rats. The neutrophil-to-lymphocyte ratio was slightly lower in exposed donor group relative to both unexposed donor and control groups (Figure 6).

**Discussion**
Haematology indices, electrolyte balance, as well as liver and kidney markers are widely used parameters that assess systemic homeostasis in subjects. In this study, 10 days of postoperative *Cinnamomum camphora* aromatherapy appeared to support adaptive stability of the remaining kidney in the live donor nephrectomised rats. Elevated serum creatinine and urea levels among donor rats may not be unexpected considering the absence of a paired organ. Higher creatinine in particular in the unexposed donor rats, despite relatively stable urea and urea-to-creatinine ratios, suggested on-going physiological stress on the sole kidney. As creatinine and urea, products of muscle and protein



*Values with different superscripts are significantly (p < 0.05) different

**Figure 1:** Serum creatinine levels of *Cinnamomum camphora* aromatherapy–exposed and unexposed live-donor nephrectomized male Wistar rats

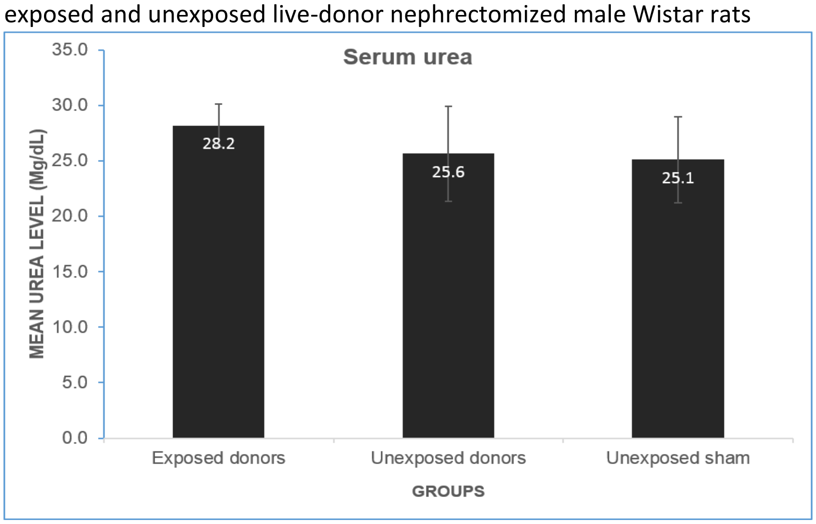



**Figure 2:** Serum urea level of *Cinnamomum camphora* aromatherapy–exposed and unexposed live-donor nephrectomized male Wistar rats

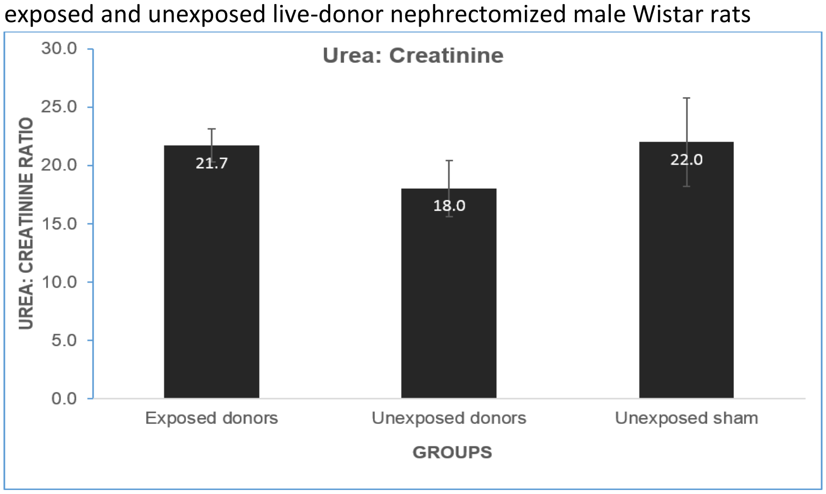



**Figure 3:** Serum urea: creatinine ratio of *Cinnamomum camphora* aromatherapy–exposed and unexposed live-donor nephrectomized male Wistar rats

metabolism, respectively, are exclusively excreted by the kidney, their levels are used to assess renal clearance capacity. The maintenance of lower creatinine level in exposed donor rats, alongside a sodium-to-chloride balance comparable to the control, indicated that camphor aromatherapy may have ameliorated any physiologic stress due to functional compensation on the remaining kidney.

Liver function in both donor groups was not adversely affected by unilateral nephrectomy, and remain largely functional following the procedure. However, while the exposed group I donors maintained serum fibrinogen values comparable to the sham-control, the unexposed group II donors demonstrated a possible decrease in healing capacity, as evidenced by the relative decline in their serum fibrinogen levels. Fibrinogen, produced by the liver, plays a critical role in tissue repair and coagulation (Laurens *et al.*, 2006), so a downward trend, as seen in the unexposed group II donors, may imply prolonged clotting time (Neerman-Arbez & Casini, 2018) in this group. Again, the significantly reduced serum bilirubin, an indication of enhanced bilirubin modulation (Kalakonda *et al.,* 2022), further highlights the greater hepatic efficiency of the exposed donor group.

In terms of haematology, exposed donor group I demonstrating relatively improved red cell indices, including hemoglobin and PCV, compared to unexposed group II suggests a beneficial effect of *Cinnamomum camphora* aromatherapy on red cell recovery after surgical blood loss. Conversely, higher total WBC counts in unexposed rat groups

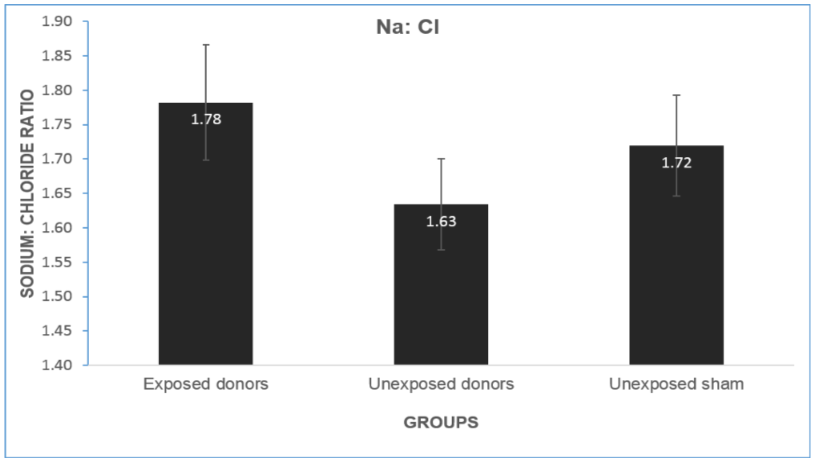



**Figure 4:** Serum sodium: chloride ratio of *Cinnamomum camphora* aromatherapy–exposed and unexposed live-donor nephrectomized male Wistar rats

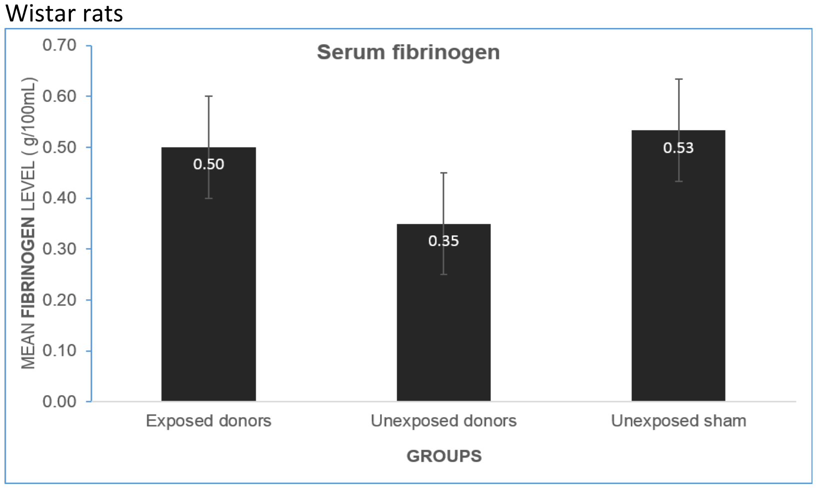



**Figure 5:** Serum fibrinogen level of *Cinnamomum camphora* aromatherapy–exposed and unexposed live-donor nephrectomized male Wistar rats

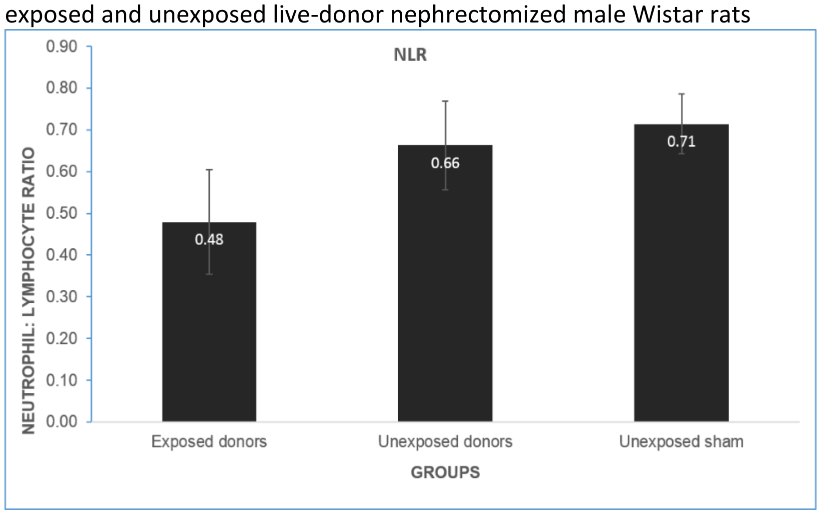



**Figure 6:** Serum neutrophil: lymphocyte ratio of *Cinnamomum camphora* aromatherapy–exposed and unexposed live-donor nephrectomized male Wistar rats

**Table 1:** Effect of Camphor (*Cinnamomum camphora*) aromatherapy on Liver integrity assays of unilaterally nephrectomized male Wistar rats

| Parameters | Exposed donor | Unexposed donor | Unexposed Sham |
|---|---|---|---|
| AST (U/L) | 10.00±4.58 | 11.48±1.30 | 12.00±1.41 |
| ALT (U/L) | 12.00±5.57 | 14.44±2.54 | 11.25±3.86 |
| ALP (U/L) | 116.48±5.74 | 123.98±23.21 | 116.65±38.02 |
| TB (mg/dL) | 0.20±0.00[a] | 0.22±0.04[ab] | 0.26±0.05[b] |
| TP (g/dl) | 7.60±0.61 | 7.58±0.66 | 7.58±0.54[a, b] |

Different alphabetical superscript in a row indicates significant difference between the means ($p<0.05$).
ALT = Alanine aminotransferase; AST = Aspartate aminotransferase; ALP = Alkaline phosphatase; TB = Total Bilirubin; TP = Total Protein.

**Table 2:** Effect of camphor (*Cinnamomum camphora)* aromatherapy on the haematology of unilaterally nephrectomized male Wistar rats

| Parameters | Exposed donor | Unexposed donor | Unexposed Sham |
|---|---|---|---|
| PCV (%) | 41.00±0.82 | 39.80±3.77 | 43.70±3.21 |
| Hb (g/dL) | 12.60±0.24[ab] | 12.20±1.18[a] | 13.50±1.23[b] |
| tWBC ($10^3$/µL) | 12.50±0.71[a] | 17.00±2.21[b] | 14.70±1.61[ab] |
| Neutrophil (%) | 31.00±6.08 | 36.60±8.99 | 38.30±6.11 |
| Lymphocyte (%) | 65.30±3.79 | 58.40±11.19 | 56.74±7.77 |
| Eosinophil (%) | 1.00±0.82 | 1.17±1.17 | 1.00±0.82 |
| Monocyte (%) | 3.00±1.41 | 3.17±1.33 | 2.75±1.71 |
| Basophil (%) | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 |

[a, b] Different alphabetical superscript in a row indicates significant difference between the means ($p<0.05$)
PCV = Packed cell volume; Hb = Hemoglobin concentration; tWBC = total white blood cell.

likely reflected immunologic or inflammatory responses, potentially due to secondary infections or stress considering the non-pathogen-free setting. Elevated neutrophils count in unexposed groups reinforces this and aligns with prior reports of the anti-inflammatory activity of *Cinnamomum camphora* (Chen *et al.,* 2020). The lower neutrophil-to-lymphocyte ratio in exposed group also indicates reduced physiological stress, consistent with its established role as a biomarker of systemic/physiologic distress (Zahorec, 2021).

In general, although not all findings in this study were statistically significant, the consistent trend points toward beneficial effects of camphor aromatherapy on postoperative recovery in live-donors. The improvements observed across renal, hepatic, and hematologic parameters in an established surgical model highlight its promise as a simple, low-risk non-pharmacological adjunct to conventional postoperative management. These findings also hold potential psychological boost for live-donors, especially as there is still need for a multifaceted approach to address the cultural and psychological complexities of organ donation (Pai *et al.*, 2025).

In conclusion, postoperative *Cinnamomum camphora* aromatherapy demonstrated favourable trends in supporting haematology balance, kidney adaptability, and liver function following unilateral nephrectomy in live-donor rats. While some improvements did not reach statistical significance, the overall findings suggest that camphor aromatherapy may serve as a safe, complementary approach to conventional care by reducing physiological stress, enhancing recovery, and promoting systemic stability.

These results provide preliminary but meaningful evidence supporting the integration of aromatherapy into postoperative protocols in donor subjects. They also underscore the importance of considering both statistical outcomes and biological trends when evaluating novel adjuncts, thereby paving the way for further research into aromatherapy's role in enhancing postoperative well-being. Future studies with larger cohorts and mechanistic investigations are warranted to validate these findings and further explore the translational potential in both human and veterinary surgical care.

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**Conflict of Interest**
The authors declare that there is no conflict of interest.

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