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## 1 Introduction

The liver is an essential metabolic organ that is unique to vertebrates and is involved in many biological functions. It produces proteins, detoxifies the body, and synthesizes a variety of biochemicals necessary for development and digestion<sup>1</sup>. Over two million deaths worldwide are attributed to liver disease each year, making up 4% of all fatalities (1 in 25). Of them, females account for one in three liver-related fatalities. The number of fatalities from liver cancer alone ranges from 600,000 to 900,000<sup>2</sup>.

# Effectiveness of Crude Drug Extract of *Moringa oleifera* on Hepato Carcinoma: A Cell Line Study

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## Abstract

Hepatocellular carcinoma (HCC), one of the most prevalent forms of liver cancer, remains a significant global health challenge due to its aggressive nature and limited treatment options. This study explores the potential anticancer properties of crude extracts derived from *Moringa oleifera* a plant known for its rich phytochemical profile and medicinal properties on HepG2 liver cancer cells. The investigation employed in vitro assays, including MTT and cell migration assays, to evaluate cytotoxic and anti-metastatic effects. The MTT assay revealed a dose-dependent reduction in cell viability, with an IC<sub>50</sub> value of 464 µg/mL, indicating cytotoxic potential of the crude extract. Additionally, the cell migration assay demonstrated that *Moringa oleifera* significantly inhibited cell migration, a key process in cancer metastasis. These findings suggest that crude *Moringa oleifera* extract exhibits promising anticancer activity against hepatocellular carcinoma through inhibition of cell proliferation and migration, supporting its potential use as a natural therapeutic agent. Further studies involving purified constituents and in vivo models are warranted to validate and optimize its efficacy.

**Keywords:** *Moringa oleifera*, Hepatocellular carcinoma, HepG2 cells, MTT assay, Cell migration

The hepatoprotective properties of *Moringa oleifera* (commonly known as the drumstick tree) have been widely researched due to its bioactive compounds. This plant is a rich source of antioxidants, vitamins, minerals, and phytochemicals, all of which play a role in its liver-protective effects<sup>3</sup>.

The liver is highly susceptible to damage from various factors, including infections, excessive alcohol consumption, drug toxicity, and metabolic disorders, leading to conditions collectively known as liver diseases. These disorders, ranging from mild hepatic dysfunction to severe conditions like

cirrhosis, hepatocellular carcinoma, and liver failure, hepatitis pose significant global health concerns<sup>4, 5</sup>.

The ability of a substance (drug, herbal extract, or molecule) to either prevent liver damage or aid in the liver's recovery from injury is known as hepatoprotective action. Alcohol, drugs, illnesses, and pollutants can all have an impact on the liver, which is essential for digestion, metabolism, and detoxification<sup>6</sup>.

## Drug Profile

**Name** – *Moringa Oleifera*

**Kingdom** – *Plantae*

**Sub kingdom** – *Tracheobionta*

**Super Division** – *Spermatophyta*

**Division** – *Magnoliophyta*

**Class** – *Magnoliopsida*

**Sub class** – *Dilleniidae*

**Order** – *Capparales*

**Family** – *Moringaceae*

**Genus** – *Moringa*

**Species** – *oleifera*

Aqueous and alcoholic extracts (methanolic & ethanolic) of leaves and roots of *Moringa oleifera* exhibit strong in-vitro antioxidant and radical scavenging activity<sup>7</sup>. Aqueous extract of *Moringa oleifera* leaves shows anti-diabetic activity and controls diabetes and thus exhibit glycemic control<sup>8</sup>. Ethanolic extract of *Moringa oleifera* leaves showed prominent anti-hypertensive or hypotensive activity<sup>9</sup>. Ethanolic extracts of leaves and seeds of *Moringa oleifera* shows potent anti-tumor activity<sup>10</sup>. The in-vitro anti-urolithiatic activity was performed in aqueous and alcoholic extract of bark of *Moringa oleifera*. It showed reduction in weight of stone produced using ethylene glycol induced urolithiasis. It also possesses both preventive and curative property<sup>11</sup>. Leaves, roots, bark and seeds of *Moringa oleifera* show anti-microbial activity against bacteria and fungi<sup>12</sup>. Methanolic and aqueous extract of root and bark, methanolic extract of leaves and flowers and ethanolic extract of seeds of *Moringa oleifera* possess anti-inflammatory activity<sup>13</sup>. *Moringa oleifera* leaves extract restores mono amine levels of brain, which may be useful in Alzheimer's disease<sup>14</sup>.

**Table 1: Phytoconstituents test**

Phytoconstituent	Test	Procedure	Observation
Nitrile glycosides	Sodium Nitroprusside Test	Add a few drops of sodium nitroprusside ( $\text{Na}_2[\text{Fe}(\text{CN})_5\text{NO}]$ ) solution to the sample.  Add dilute sodium hydroxide (NaOH) solution.	A red or violet color indicates the presence of a nitrile group.
	Copper Acetate Test	Dissolve the sample in water and add copper (II) acetate solution.	Formation of a blue or greenish-blue complex indicates a nitrile group.
Benzyl Isothiocyanate	Mercuric Chloride Test	Add $\text{HgCl}_2$ (mercuric chloride) solution to the sample.  Heat gently.	Formation of a yellow to orange precipitate indicates the presence of an isothiocyanate ( $-\text{N}=\text{C}=\text{S}$ ) group.
	Lead Acetate Test	Add lead acetate solution to the sample.	Formation of a black precipitate (lead sulfide) due to BITC degradation.
Niaziminin A	Sodium Nitroprusside Test	Add sodium nitroprusside ( $\text{Na}_2[\text{Fe}(\text{CN})_5\text{NO}]$ ) solution to the sample.  Add dilute sodium hydroxide (NaOH) solution.	Formation of a red or violet color confirms the presence of a nitrile ( $-\text{C}\equiv\text{N}$ ) functional group in Niaziminin A
	Ferric Chloride ( $\text{FeCl}_3$ ) Test	Add $\text{FeCl}_3$ solution to the sample.	A blue-green or purple color indicates the presence of phenolic or glycosidic hydroxyl groups.
Pyrrole alkaloid	Mayer's Test	Add Mayer's reagent to the solution of the test substance.	Formation of a cream-colored precipitate indicates the presence of alkaloids.
	Dragendorff's Test	Add Dragendorff's reagent to the solution of the test substance.	Formation of an orange or reddish-brown precipitate suggests the presence of alkaloids.

## 1.1 Aim and Objectives

**Aim:** Effectiveness of crude drug of *Moringa oliefera* in Hepato carcinoma.

### Objectives:

1. Prepare extract of crude drug *Moringa oliefera*.
2. Prepare culture of HEPG2 cell line.
3. Evaluation of crude drug extract of *Moringa oliefera* using MTT assay.
4. Evaluation of crude drug extract of *Moringa oliefera* using Cell migration assay.

## 2 Materials and Methods

### 2.1 Cell lines

It is a population of cells that can be cultured and maintained in lab for an extended period often indefinitely under controlled conditions. Cell lines are derived from various sources including normal tissues, tumors, stem cell and they are commonly used in biological and medical research<sup>15</sup>.

#### 2.1.1 HepG2 Cell line

Hep G2 is an immortal cell line that was derived in 1975 from the liver tissue of a 15-year-old Caucasian male from Argentina with a well-differentiated hepatocellular carcinoma. These cells are epithelial in morphology, have a modal chromosome number of 55, and are not tumorigenic in nude mice<sup>16</sup>. HepG2 cells, a human hepatoma cell line, are used in research as in vitro model for studying liver-related functions, including drug metabolism, hepatotoxicity, and liver cancer, as well as viral infections and tissue engineering<sup>17</sup>.

### 2.2 MTT Assay Experimental Procedures

#### 2.2.1 Preparation for Test Material

All Test Samples were filter sterilized using 0.22 $\mu$  filters and diluted by double dilution method in MEM with FBS<sup>18</sup>.

#### 2.2.2 Chemicals & Materials

1. Cell Culture Plates: 96 well microtiter plates (Corning)
2. Cell culture flasks: T25 Flasks (Falcon)
3. Trypsin/EDTA: 0.25% Trypsin and 0.02% EDTA in Dulbecco's Phosphate Buffered Saline (GibcoThermo Fisher)
4. DMSO: Dimethyl sulfoxide (Sigma)
5. Cell culture Medium: D-Modified Eagle Medium (DMEM) containing 10% (v/v) Fetal Bovine Serum
6. Cell Line: HepG2

7. Culture Conditions: 37°C with 5% CO<sub>2</sub>

#### 2.2.3 Procedure

##### • Preparation of Cells

HepG2 cells were cultured in D-Modified Eagle Medium (DMEM) with NEAA media supplemented with 10% (v/v) fetal bovine serum. Cells were cultured at 37°C and 5% CO<sub>2</sub>; the complete medium was changed every 2 to 3 days<sup>19</sup>.

##### • MTT Assay Procedure

- Cells were seeded in 96-well plates at 1,00,000 cells per well (100  $\mu$ l). The plates were incubated at 37°C and 5% CO<sub>2</sub> atmosphere for 24 hr.
- After the incubation period cells were observed for half confluent monolayers.
- Culture medium was removed, and cells were treated with 9 different test item concentrations.
- Cells in cell culture medium without any Test Item incubated for 24 hr under the same condition served as Control.
- Plates were incubated at 37°C in a 5% CO<sub>2</sub> incubator for 24 hr.
- After 24 hr, cells were observed under an inverted microscope for any changes in morphology or death.
- After observation, the culture medium was removed, and 100  $\mu$ l of fresh medium was added along with 10  $\mu$ l of MTT reagent in each well.
- Plates were incubated for 4 hr at 37°C in 5% CO<sub>2</sub> incubator.
- 100 $\mu$ l of the Solubilization solution was added into each well.
- Plate was allowed to stand for 1 hr at 37°C in 5% CO<sub>2</sub> incubator.
- After checking for complete solubilization of the purple formazan crystals, absorbance was measured at 570 nm using a microplate reader.
- IC50 values were calculated by plotting a log graph for the concentration of the test items vs. % cell survival<sup>20</sup>.
- Percentage Cell Survival was calculated using the formula:

$$\text{Percentage Cell Survival (\%)} = \frac{\text{Absorbance of Test}}{\text{Absorbance of Control}} \times 100$$

## 2.3 Cell Migration Assay Experimental Procedures

### 2.3.1 Preparation for Test Material

All Test Samples were filter sterilized using 0.22 $\mu$  filters and diluted by double dilution method in MEM with FBS.

### 2.3.2 Chemicals & Materials

1. Cell Culture Plates: 96 well microtiter plates (Corning)
2. Cell culture flasks: T25 Flasks (Falcon)
3. Trypsin/EDTA: 0.25% Trypsin and 0.02% EDTA in Dulbecco's Phosphate Buffered Saline (GibcoThermo Fisher)
4. DMSO: Dimethyl sulfoxide (Sigma)
5. Cell culture Medium: D-Modified Eagle Medium (DMEM) containing 10% (v/v) Fetal Bovine Serum.
6. Cell Line: HepG2
7. Culture Conditions: 37°C with 5% CO<sub>2</sub>

### 2.3.3 Procedure

#### 1. Cell Seeding

1. Seed cells into a 6-well plate (or other suitable plates) at a density where they form a confluent monolayer after 24 hours.
2. Incubate the cells overnight at 37°C in a CO<sub>2</sub> incubator.

#### 2. Create the Scratch

1. After the cells are confluent, use a sterile pipette tip or a mechanical scratching tool to create a single, straight scratch (or wound) across the cell monolayer.
2. The width of the scratch should be uniform, but it's typically about 0.5 to 1 mm wide.
3. Be gentle while scratching to avoid damaging the bottom of the well.

#### 3. Wash and Replace Media

1. Gently wash the cells with sterile PBS to remove detached cells and debris.
2. Add fresh culture medium (with or without serum depending on your experimental needs). If you want to assess migration in a controlled environment, you can use serum-free media.

#### 4. Imaging (Initial Timepoint)

1. Take the initial image of the scratch area under a microscope to document the starting point (time 0).
2. Ensure you capture the entire scratch area for later comparison.

#### 5. Incubation

1. Place the plate back in the incubator and allow the cells to migrate into the scratch area.
2. Depending on your experiment, you can continue to observe the cells over a set period (e.g., 12, 24, or 48 hours).

#### 6. Monitor and Take Images

1. At regular time intervals, take images of the scratch area under the microscope to monitor cell migration.
2. Ensure that you are capturing the same area each time for consistency.

#### 7. Data Analysis

1. Measure the gap (scratch area) using imaging software (e.g., ImageJ, CellSens, etc.) at each time point.
2. Compare the width of the gap at different time points to assess the rate of cell migration.
3. Migration is often quantified by calculating the percentage closure of the gap<sup>21</sup>.

## 3 Results and Discussions

### 3.1 MTT Assay

The MTT assay is a colorimetric assay for assessing cell metabolic activity. NADPH-dependent cellular oxidoreductase enzymes may, under defined conditions, reflect the number of viable cells present. These enzymes are capable of reducing the tetrazolium dye MTT, which is chemically 3-(4,5-dimethylthiazol-2-yl) 2,5-diphenyltetrazolium bromide, to its insoluble formazan, which has a purple colour. The result of MTT Assay is given below<sup>22</sup>.

### 3.2 MTT Result

Table 2 shows the morphological changes in HepG2 cells treated with different concentrations of *Moringa oleifera* powder ranging from 5  $\mu$ g/ml to 250  $\mu$ g/ml over a 24-hour period.

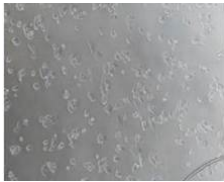
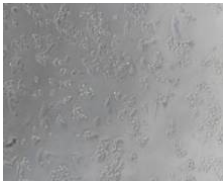
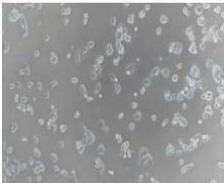



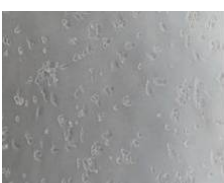
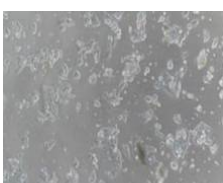

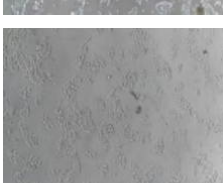

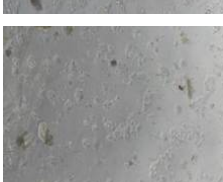
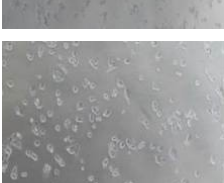
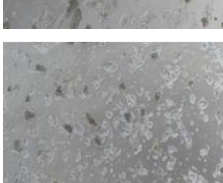
The table includes images of the HepG2 cells at 0 hours and 24 hours for each concentration. The images help visualize the shape, size, and colour of the cells, which are indicators of cell viability and health.

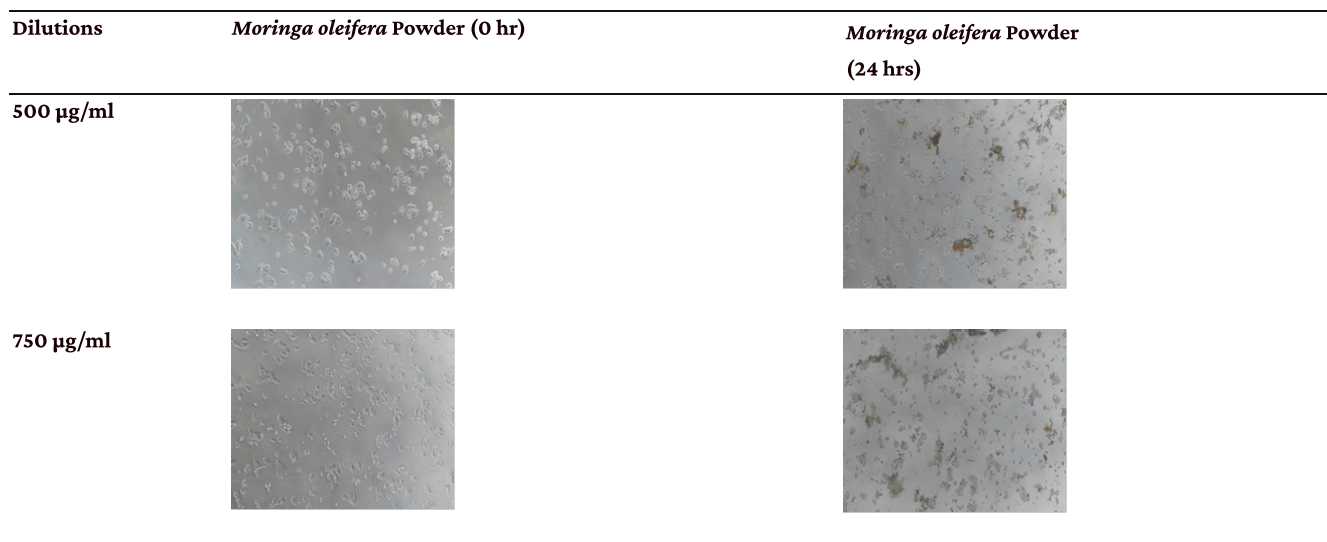
**Control:** Shows healthy, viable cells with no treatment.

**Treated Cells:** As the concentration of *Moringa oleifera* increases, the number of viable cells decreases, and cell morphology changes (e.g., cells may appear shrunken or fragmented), indicating cytotoxicity.

Table 3 provides quantitative data from the MTT assay, including absorbance values, average % cell survival, and the IC50 value.

**Table 2: Morphological Observations of *Moringa oleifera* Powder**

Dilutions	<i>Moringa oleifera</i> Powder (0 hr)	<i>Moringa oleifera</i> Powder (24 hrs)
controlled		
5µg/ml		
10µg/ml		
25µg/ml		
50µg/ml		
100µg/ml		
250 µg/ml		



**Table 3: MTT Results: *Moringa oleifera* powder**

Concentration (µg/ml)	Absorbance		Average		% Cell Survival			Average % Cell Survival
CTRL	0.9	0.881	0.879	0.887	101.5	99.4	99.1	100.0
5	1.057	0.749	0.781	0.862	119.2	84.5	88.1	97.3
10	0.726	0.836	0.731	0.764	81.9	94.3	82.4	86.2
25	0.681	0.884	0.599	0.721	76.8	99.7	67.6	81.4
50	0.834	0.798	0.657	0.763	94.1	90.0	74.1	86.1
100	1.002	0.607	0.605	0.738	113.0	68.5	68.2	83.2
250	0.887	0.832	0.661	0.793	100.0	93.8	74.5	89.5
500	0.798	0.681	0.879	0.786	51.4	45.3	43.1	46.6
750	0.781	0.742	0.654	0.725	41.4	38.4	36.2	38.6
<b>IC50 VALUE</b>	<b>464 µg/ml</b>							

**Concentration (µg/ml):** The concentrations tested range from 5 µg/ml to 250 µg/ml.

**Absorbance:** The absorbance values at 570 nm are recorded for each concentration, reflecting the amount of formazan produced by viable cells.

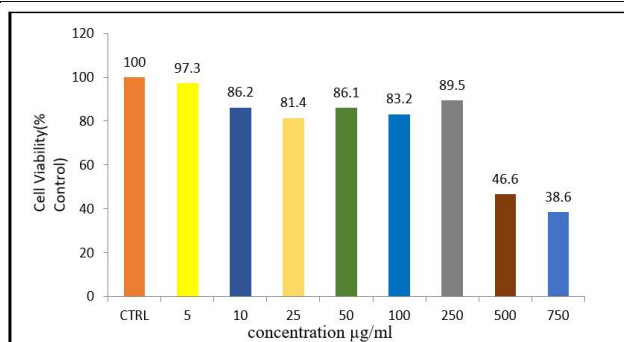
**% Cell Survival:** The percentage of cell survival is calculated by comparing the absorbance of treated cells to the control (untreated cells).

**IC50 Value:** The IC50 value (464 µg/ml) is the concentration at which 50% of the cells are killed. This value indicates the potency of *Moringa oleifera* in inhibiting HepG2 cell growth.

Fig. 1 is a column chart that further illustrates the % cell viability at different concentrations of *Moringa oleifera*.

The X-axis represents the concentrations (Control to 250 µg/ml), and the Y-axis represents the % cell viability.

The chart shows a clear trend of decreasing cell viability with increasing concentrations of *Moringa oleifera*, supporting the cytotoxic effect of the extract on HepG2 cells.



**Fig. 1: Graph of conc. vs. % cell Viability**

### 3.3 Cell Migration Assay

Cell migration is a central process in the development and maintenance of multicellular organisms. Tissue formation during embryonic development, wound healing and immune responses all require the orchestrated movement of cells in particular directions to specific locations. Cells often migrate in response to specific external signals, including chemical signals and mechanical signals. The result of Cell Migration Assay is given below<sup>23</sup>.

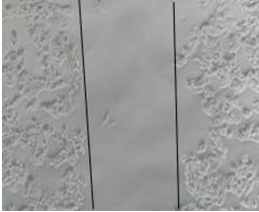
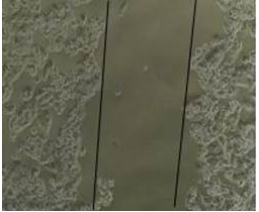

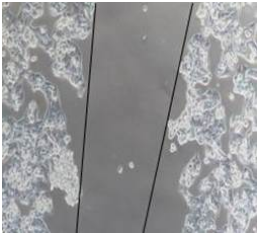














### 3.3.1 Cell Migration Result

Table 4 shows the wound healing process (cell migration) in HepG2 cells treated with *Moringa oleifera* powder at concentrations ranging from 10 µg/ml to 50 µg/ml.

The table includes images of the HepG2 cells at 0 hours, 8 hours, and 24 hours for each concentration.

**Control:** Shows the natural wound healing process over time.

**Table 4: Morphological Observations of *Moringa oleifera* Powder Treated Wells**

Dilutions	<i>Moringa oleifera</i> Powder (0 hr)	<i>Moringa oleifera</i> Powder (8 hrs)	<i>Moringa oleifera</i> Powder (24 hrs)
Control			
10µg/ml			
20µg/ml			
30µg/ml			
40µg/ml			
50 µg/ml			

**Table 5: Cell migration Results: *Moringa oleifera* powder**

Concentration ( $\mu\text{g/ml}$ )	Time	Area	Mean	Min	Max
Control	0 hr	680129	156.197	108	223
	8 hr	542320	36.252	19	186
	24 hr	688365	72.654	51	164
10	0 hr	658139	128.476	92	246
	8 hr	731880	50.375	31	115
	24 hr	705554	53.959	14	85
20	0 hr	764233	126.638	89	249
	8 hr	635508	30.803	14	134
	24 hr	760459	66.973	23	107
30	0 hr	713394	141.182	98	240
	8 hr	584251	50.592	28	152
	24 hr	539227	56.458	29	95
40	0 hr	854407	156.818	105	217
	8 hr	456760	110.283	45	161
	24 hr	616535	70.042	25	121
50	0 hr	691697	119.729	77	251
	8 hr	371565	93.68	31	143
	24 hr	614890	83.386	22	128

**Treated Cells:** The images show how *Moringa oleifera* affects the migration of HepG2 cells into the scratch area. As the concentration increases, the rate of cell migration decreases, indicating that *Moringa oleifera* inhibits cell migration, which is a critical factor in cancer metastasis.

**Table. 5** provides quantitative data from the cell migration assay, including the area covered by migrating cells, mean values and minimum/maximum areas.

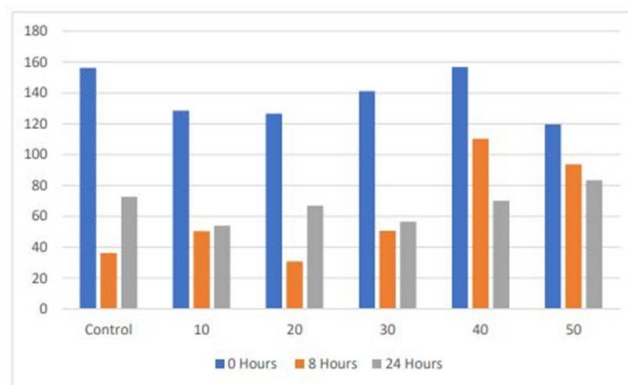
**Concentration ( $\mu\text{g/ml}$ ):** The concentrations tested range from 10  $\mu\text{g/ml}$  to 50  $\mu\text{g/ml}$ .

**Time:** The observations are recorded at 0 hours, 8 hours, and 24 hours.

**Area:** The area covered by migrating cells is measured at each time point.

**Mean, Min, Max:** These values provide a statistical summary of the cell migration data, showing the variability in cell migration at different concentrations and time points.

The data shows that as the concentration of *Moringa oleifera* increases, the area covered by migrating cells decreases, indicating that *Moringa oleifera* inhibits cell migration.

**Fig. 2: Migration mean of *Moringa oleifera* Powder**

**Fig. 2** is a graphical representation of the cell migration data. It shows the mean area covered by migrating cells at different concentrations of *Moringa oleifera* over time.

The X-axis represents the concentrations (Control to 50  $\mu\text{g/ml}$ ), and the Y-axis represents the mean area covered by migrating cells.

The graph shows a clear trend of decreasing cell migration with increasing concentrations of *Moringa oleifera*, supporting the anti-migratory effect of the extract on HepG2 cells.

## 4 Conclusion

The results demonstrate that *Moringa oleifera* has a cytotoxic effect on HepG2 cells, with an IC50 value of 464 µg/ml. The morphological images and graphs show a dose-dependent decrease in cell viability, indicating that *Moringa oleifera* can inhibit the growth of liver cancer cells. IC50 value of pure extract of *Moringa oleifera* drug is  $10 \pm 1 \mu\text{g/ml}$  but as we have used crude form of *Moringa oleifera* the IC50 value was found to be 464µg/ml.

The results show that *Moringa oleifera* inhibits the migration of HepG2 cells, which is a critical factor in cancer metastasis. The concentration of 30µg/ml showing the constant decrease in Area and Mean both. The images and graphs demonstrate that higher concentrations of *Moringa oleifera* significantly reduce cell migration, suggesting its potential as an anti-metastatic agent.

These findings suggest that *Moringa oleifera* has potential therapeutic effects against liver cancer by inhibiting cell proliferation and migration, making it a promising candidate for further research.

## References

- Tortora GJ, Derrickson BH. *Principles of Anatomy and Physiology*. 12th ed. Hoboken (NJ): John Wiley & Sons; 2008. p. 945.
- Asrani SK, Devarbhavi H, Eaton J, Kamath PS. Burden of liver diseases in the world. *Journal of Hepatology*. 2019;70(1):151-171. Available from: [10.1016/j.jhep.2018.09.014](https://doi.org/10.1016/j.jhep.2018.09.014)
- Anwar F, Latif S, Ashraf M, Gilani AH. *Moringa oleifera*: a food plant with multiple medicinal uses. *Phytotherapy Research*. 2007;21(1):17-25. Available from: [10.1002/ptr.2023](https://doi.org/10.1002/ptr.2023)
- World Health Organization (WHO). *Hepatitis: Questions and answers*. [cited 2025 Mar 06].
- Centers for Disease Control and Prevention (CDC). (2025, January 31). *Hepatitis A Basics*.
- International Journal of Pharmaceutical Sciences and Research (IJPSR). A review on hepatoprotective activity [cited 2025 Mar 06].
- Sharma VR, Paliwal R, Sharma S. Phytochemical analysis and evaluation of antioxidant activities of hydro-ethanolic extract of *Moringa oleifera* Lam. pods. *J Pharm Res*. 2011;4(2):554-7.
- Ndong M, Uehara M, Katsumata S, Suzuki K. Effects of oral administration of *Moringa oleifera* Lam on glucose tolerance in Gotokakizaki and Wistar rats. *Journal of Clinical Biochemistry and Nutrition*. 2007;40(3):229-233. Available from: [10.3164/jcbs.40.229](https://doi.org/10.3164/jcbs.40.229)
- Gilani AH, Aftab K, Suria A, Siddiqui S, Salem R, Siddiqui BS, *et al.* Pharmacological studies on hypotensive and spasmolytic activities of pure compounds from *Moringa oleifera*. *Phytotherapy Research*. 1994;8(2):87-91. Available from: [10.1002/ptr.2650080207](https://doi.org/10.1002/ptr.2650080207)
- Nadkarni KM. *Indian Materia Medica*. Mumbai: Popular Prakashan; 1994. p. 1319.
- Fahad J, Vijayalakshmi, Satish Kumar MC, Sanjeeva, Kodancha GP, Adarsh B, *et al.* Antiulcer activity of aqueous extract of bark of *Moringa oleifera* (Lam.) in rats. *Health*. 2010;02(04):352-355. Available from: [10.4236/health.2010.24053](https://doi.org/10.4236/health.2010.24053)
- Caceres A, Cabrera O, Morales O, Mollinedo P, Mendia P. Pharmacological properties of *Moringa oleifera*: preliminary screening for antimicrobial activity. *Journal of Ethnopharmacology*. 1991;33(3):213-216. Available from: [10.1016/0378-8741\(91\)90078-r](https://doi.org/10.1016/0378-8741(91)90078-r)
- Caceres A, Saravia A, Rizzo S, Zabala L, Leon ED, Nave F. Pharmacological properties of *Moringa oleifera*: screening for antispasmodic, anti-inflammatory, and diuretic activity. *Journal of Ethnopharmacology*. 1992;36(3):233-237. Available from: [10.1016/0378-8741\(92\)90049-6](https://doi.org/10.1016/0378-8741(92)90049-6)
- Talhaliani P, Kar A. Role of *Moringa oleifera* leaf extract in the regulation of thyroid hormone status in adult male and female rats. *Pharmacological Research*. 2000;41(3):319-323. Available from: [10.1006/phrs.1999.0587](https://doi.org/10.1006/phrs.1999.0587)
- Freshney RI. *Culture of Animal Cells: A Manual of Basic Technique and Specialized Applications*. 7th ed. Hoboken: Wiley-Blackwell; 2016.
- Knowles BB, Howe CC, Aden DP. Human hepatocellular carcinoma cell lines secrete the major plasma proteins and hepatitis B surface antigen. *Science*. 1980;209(4455):497-499. Available from: [10.1126/science.6248960](https://doi.org/10.1126/science.6248960)
- Wilkening S, Stahl F, Bader A. Comparison of primary human hepatocytes and hepatoma cell line HepG2 with regard to their biotransformation properties. *Drug Metabolism and Disposition*. 2003;31(8):1035-1042. Available from: [10.1124/dmd.31.8.1035](https://doi.org/10.1124/dmd.31.8.1035)
- Costantini S, Di Bernardo G, Cammarota M, Castello G, Colonna G. Gene expression signature of human HepG2 cell line. *Gene*. 2013;518(2):335-345. Available from: [10.1016/j.gene.2012.12.106](https://doi.org/10.1016/j.gene.2012.12.106)
- Başoğlu-Ünal F, Becer E, Ensarioğlu HK, Güzeldemirci NU, Kuran ED, Vatansever HS. A newly synthesized thiosemicarbazide derivative trigger apoptosis rather than necroptosis on HEPG2 cell line. *Chemical Biology & Drug Design*. 2024;103(1):e14355. Available from: [10.1111/cbdd.14355](https://doi.org/10.1111/cbdd.14355)
- Lingfa L, Tirumala A, Ankanagari S. *In Vitro* Cytotoxicity of Reproductive Stage *Withania somnifera* Leaf and Stem on HepG2 Cell Line. *Evidence-Based Complementary and Alternative Medicine*. 2023;2023(1). Available from: [10.1155/2023/8832166](https://doi.org/10.1155/2023/8832166)
- Betallu MA, Bhalara SR, Sapnar KB, Tadke VB, Meena K, Srivastava A, *et al.* Hybrid Inorganic Complexes as Cancer Therapeutic Agents: In-vitro Validation. *Nanotheranostics*. 2023;7(3):270-280. Available from: [10.7150/ntno.81557](https://doi.org/10.7150/ntno.81557)
- Mosmann T. Rapid colorimetric assay for cellular growth and survival: Application to proliferation and cytotoxicity assays. *Journal of Immunological Methods*. 1983;65(1-2):55-63. Available from: [10.1016/0022-1759\(83\)90303-4](https://doi.org/10.1016/0022-1759(83)90303-4)
- Ridley AJ, Schwartz MA, Burridge K, Firtel RA, Ginsberg MH, Borisy G, *et al.* Cell Migration: Integrating Signals from Front to Back. *Science*. 2003;302(5651):1704-1709. Available from: [10.1126/science.1092053](https://doi.org/10.1126/science.1092053)