In vitro anti-viral activity of aqueous extracts of Kenyan Carissa edulis
Prunus africana and Melia azedarach against human cytomegalovirus.

Festus M. Tolo1,7*, Geoffrey M. Rukunga 1,7, Faith W. Muli 4, John Ochora 6,7, Yoshito Eizuru2,5, Charles N. Muthaura1, Cecilia W. Kimani1, Geoffrey M. Mungai3 and Mawuli W. Kofi-Tseko1

1. Kenya Medical Research Institute, 2. Japan International Cooperation Agency (JICA). 3. The East African Herbarium, Nairobi, Kenya. 4. Kenyatta University, Nairobi, Kenya. 5. Faculty of Medicine, Kagoshima University, Kagoshima, Japan. 6. Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya. 7. Institute of Tropical Medicine and Infectious Diseases (ITROMID), Nairobi, Kenya.

* Author for correspondence: P.O. Box 54840-00200, Nairobi, Kenya., E. Mail: ftolo@kemri.org

SUMMARY
The aqueous extracts of three medicinal plants, Carissa edulis (Forssk.) Vahl (Apocynaceae), Prunus africana (Hook.f.) Kalkm (Rosaceae) and Melia azedarach L. (Meliaceae) have shown significant reduction in the replication of human cytomegalovirus (HCMV) in human embryonic lung (HEL) fibroblasts cells in vitro. Using the plaque inhibition assay for the determination of anti-viral activity, the HEL fibroblast cells cultured in 24 well plates were infected with 1 x 10^2 PFU 91S HCMV and treated with various concentrations of the extracts. The plaques formed were counted after 7 days incubation at 37°C in 5% CO2 and the percent plaques inhibited were calculated against infected untreated control. The effective concentrations inhibiting plaque formation by 50% (EC50) was found between 40 to 80 µg/ml for all the extracts. The cell cytotoxic concentrations (CC50) for each of the three extracts, by the trypan blue exclusion test, gave a safe therapeutic index. These results have demonstrated the potential anti-viral activities of the extracts of the three medicinal plants at non-cytotoxic concentrations.


Introduction
Human cytomegalovirus (HCMV), a β-herpesvirus in the family herpesviridae, is found universally throughout all geographic locations and socioeconomic groups [1]. The HCMV is the virus most frequently transmitted to a developing child before birth (0.2-2.2% of all live births) [2]. For most healthy persons who acquire HCMV after birth, there are few symptoms and no long-term health consequences. However, HCMV infection is one of the most challenging complications in persons with lowered immune states as experienced after hematopoietic stem cell transplantation (SCT) or solid organ transplantation (SOT) [3,4] and in persons with Acquired Immunodeficiency Syndrome (AIDS) [5]. In such instances, HCMV disease may occur as organ involvement such as pneumonitis or as an indirect effect such as an increased risk of opportunistic infections [6,7].

The most widely used drugs for prophylaxis and treatment of HCMV infections are foscarnet, cidofovir and ganciclovir. Unfortunately, these drugs have dose limiting renal and bone marrow toxicities. Also the long-term therapy with these drugs, necessary for management of infection, has been associated with development of clinically resistant strains of the virus [8,9,10,11]. Therefore, antiviral agents would need to be developed for the treatment and suppression of HCMV disease.

Natural products of plant origin are proving to be a valuable source for anti-viral agents [12,13,14]. We hereby report on extracts from three medicinal plants that grow in Kenya which have shown significant activity against HCMV in vitro. The plants are Carissa edulis (Forssk.) Vahl (Apocynaceae), Prunus africana (Hook.f.) Kalkm (Rosaceae) and Melia azedarach L. (Meliaceae). The three medicinal plants are widely used traditionally for treatment and management of various disease conditions by different communities in Kenya and their use in traditional medicine is well documented [15,16,17].

Materials and Methods

Medicinal plant material collection
The medicinal plants used in this study were collected with the assistance of the taxonomist, Mr. G.M. Mungai, from the East African Herbarium, Nairobi, Kenya. The plants were obtained from their natural habitats in different geographical zones of Kenya. Carissa edulis was collected from Gitoro forest, Meru District in Eastern Province.
The stem and root barks were chopped into small pieces and dried at room temperature for two weeks. The dry barks were ground into fine powder using an electric mill (Christy and Norris Ltd., England) and stored in plastic containers at room temperature ready for use.

A 100g of stem or root bark powder was boiled in 1000 ml distilled water for 45 min. The resulting extracts were filtered and lyophilised using a Modulyo Freeze Dryer (Edwards, England) producing a free flowing powder that was weighed and stored in airtight containers at room temperature until use. Each of the freeze dried material was treated as follows:- A 10 mg/ml stock solution was prepared by dissolving 100 mg of the freeze-dried powder in sterile double distilled water and made to the 10mls mark of a volumetric flask. The solution was centrifuged at 3,000 rpm for 15 min (Kubota centrifuge, Japan) to separate any undissolved matter and the supernatant collected and filtered through a 0.45 µm membrane filter. The sterile filtrate was stored at 4°C and used as a stock solution within a week.

For the in vitro experiments, a working solution of 1 mg/ml was aseptically prepared by diluting 100 µl stock with 900 µl (0.900 ml) Eagle’s Minimum Essential Medium (MEM) (GIBCO BRL, Scotland) supplemented with 2% Fetal Bovine Serum (FBS) (GIBCO BRL, Scotland).

Viruses and cells

The gancyclovir-sensitive clinical isolate of HCMV strain 91S and human embryonic lung fibroblast cells (HEL) were used in the study. The virus and cells were donated by the Kagoshima University, Kagoshima, Japan, through the Japan International Cooperation Agency (JICA). The virus was propagated in HEL cells of persurge numbers provided by the Kagoshima University, Kagoshima, Japan and who was also a JICA visiting scientist at the Kenya Medical Research Institute (KEMRI).

Reference drug gancyclovir

Gancyclovir was used as a reference drug and was a donation from Prof. Yoshito Eizuru of the Division of Persistent and Oncogenic Viruses, Centre for Chronic Viral Diseases, Faculty of Medicine, Kagoshima University, Kagoshima, Japan.
Data management

**Plaque inhibition assay**
In the plaque inhibition assay, the number of plaques in the infected untreated cells (control) and the number of plaques in the infected treated cells (test drug) was used for the calculation of the percent plaque inhibition using the formula below:

\[
\% \text{ Plaque inhibition} = 100\% - \frac{\text{No. of plaques test drug}}{\text{No. of plaques control}} \times 100\%
\]

The percent plaque inhibition at each extract concentration was then used for the graphical determination of EC\(_{50}\).

**Cytotoxicity assays**
In the cell cytotoxicity determinations, the number of viable cells was used for the calculation of percent cell viability at each tested extract concentration. This was then used for the graphical determination of the cell cytotoxic concentration (CC\(_{50}\)).

**Results**
The following results were obtained when infected and non-infected HEL cells were treated with the various concentrations of the freeze-dried plant extracts. Table 1 and Figure 1 show the results of the in vitro quantitative evaluation of anti-viral activity of the plant extracts in HEL cells infected with 91S HCMV. The following were the responses to various extract treatment as illustrated in Table 1 and Figure 1.

**Treatment with the Melia azedarach extract**
There was a rapid rise in plaque inhibition from 5% to 36% between the 10µg/ml and 20µg/ml extract concentrations (Figure 1). Thereafter plaque inhibition increased with rise in extract concentration, 50% of the plaques being inhibited at 40µg/ml (Figure 1).

**Treatment with the Carissa edulis extract**
There was no plaque inhibition between 10µg/ml and 20µg/ml concentrations. However inhibition was observed at concentrations above 20µg/ml in a dose related manner. The effective concentration inhibiting 50% of the plaques (EC\(_{50}\)) was at 74.0µg/ml (Figure 1).

Table 1: The percent plaque inhibition in HEL cells infected with HCMV at 1x10\(^2\) PFU/10µl and treated with extracts at various concentrations.

<table>
<thead>
<tr>
<th>Extract concentration (µg/ml)</th>
<th>% Plaque inhibition following treatment with:</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Melia azedarach extract</td>
<td>Carissa edulis extract</td>
<td>Prunus Africana extract</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>10</td>
<td>5.0</td>
<td>0</td>
<td>4.4</td>
</tr>
<tr>
<td>20</td>
<td>37.0</td>
<td>0</td>
<td>9.4</td>
</tr>
<tr>
<td>40</td>
<td>50.0</td>
<td>13.5</td>
<td>18.5</td>
</tr>
<tr>
<td>60</td>
<td>59.0</td>
<td>36.5</td>
<td>23.0</td>
</tr>
<tr>
<td>80</td>
<td>59.0</td>
<td>55.0</td>
<td>50.0</td>
</tr>
<tr>
<td>100</td>
<td>68.0</td>
<td>68.0</td>
<td>60.0</td>
</tr>
</tbody>
</table>

Human embryonic lung fibroblast cells (HEL) were seeded in 24 well plates and infected with 1x10\(^2\) PFU 91S HCMV. The infected cells were treated with various concentrations of the test extracts and incubated for 7 days. The numbers of plaques were counted and the percent plaque inhibition at each concentration calculated against uninfected control

**Treatment with the Prunus africana extract**
Plaque inhibition increased steadily with increase in concentration. The EC\(_{50}\) was obtained at 80µg/ml (Figure 1).
Human embryonic lung fibroblast cells (HEL) were seeded in 24 well plates and infected with $1 \times 10^2$ PFU 91S HCMV. The infected cells were treated with various concentrations of the test extracts and incubated for 7 days. The numbers of plaques were counted and the percent plaque inhibition at each concentration calculated. A plot relating percent plaque inhibition against concentration was developed and used for the determination of EC$_{50}$. 

**Cell cytotoxicity assay**

Table 2 presents the cell cytotoxic concentrations for 50% cell death (CC$_{50}$) of the extracts in non-infected HEL cells. The EC$_{50}$ values are also included in this table for comparison. The results show that the CC$_{50}$ values for all the extracts were above the EC$_{50}$. The *Melia azedarach* extract was cytotoxic at concentrations above 80µg/ml while the *Carissa edulis* and *Prunus africana* extracts were cytotoxic at concentrations above 100µg/ml.

**Table 2:** The cell cytotoxic concentrations (CC$_{50}$) and the effective concentrations for 50% plaque inhibition (EC$_{50}$) for *Carissa edulis*, *Prunus africana* and *Melia azedarach* aqueous extracts in HEL fibroblast cells in vitro.

<table>
<thead>
<tr>
<th>Medicinal plant</th>
<th>EC$_{50}$</th>
<th>CC$_{50}$</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Carissa edulis</em> (root bark)</td>
<td>74 µg/ml</td>
<td>&gt;100 µg/ml</td>
</tr>
<tr>
<td><em>Prunus africana</em> (stem bark)</td>
<td>80 µg/ml</td>
<td>&gt;100 µg/ml</td>
</tr>
<tr>
<td><em>Melia azedarach</em> (stem bark)</td>
<td>40 µg/ml</td>
<td>&gt;80 µg/ml</td>
</tr>
</tbody>
</table>

In the CC$_{50}$ determination, the HEL fibroblast cells were seeded in 24 well plates at $6 \times 10^4$ cells/well and treated with various concentrations of the extracts. The trypan blue exclusion test was used for evaluation of cell viability at each tested concentration. The concentration of extract reducing cell viability by 50% (CC$_{50}$) was determined from a curve relating percent cell viability to concentration.
Discussion
The results indicate that the HCMV strain 91S used in the study was sensitive to all the three extracts examined. However, the virus was more sensitive to the Melia azedarach extract than to the other two from Prunus africana and Carissa edulis whose activity was almost similar (the EC₅₀ for two from KEMRI, for authority and permission to publish these technical support in this study and to the Director, Cooperation Agency (JICA) for the financial and

Acknowledgments
The authors are grateful to the Japan International Cooperation Agency (JICA) for the financial and technical support in this study and to the Director, KEMRI, for authority and permission to publish these results. We also thank Mr. L. Ogutu, Ms. M. Muthoni, Ms. G. Nginya, Mr. D. Odira and Mr. N. Mwangi for their excellent technical assistance.

References
10. Alexandra Ducancelle, J’erôme Gravisse, Sophie Alaina, Anne-Marie Fillet, Françoise Petit, Marie-José Sanson Le Pors, Marie-Christine Mazeron. Phenotypic characterisation of cytomegalovirus DNA polymerase: a
method to study cytomegalovirus isolates resistant to foscarnet. *Journal of Virological Methods.* 2005; **125:** 145–151.


