Juniper Online
Journal of Immuno Virology

Research Article
Volume 1 Issue 2 - December 2015

J O J Immuno Virology

In Silico Approach to Combat HIV Using Phytoconstituents of *Moringa oleifera Lam*.

Vikrant Chadrakant Sangar[1], Lalit Rajan Samant[1,2], Sandip Shantaram Pawar[3] and Abhay Sadashiv Chowdhary[1,2]

[1]*Department of Virology and Immunology, Haffkine Institute for Training Research and testing, India*
[2]*Systems Biomedicine Division, Haffkine Institute for Training Research and testing, India*
[3]*Department of Biochemistry, The Institute of Science, India*

Submission: October 08, 2015; **Published:** December 09, 2015

***Corresponding author:** Vikrant Chadrakant Sangar, Department of Virology and Immunology, Haffkine Institute of Training, Research and Testing, Acharya Donde Marg, Parel, Mumbai -400012, Mumbai, India, Tel: +91-222416 0947; Email: vikrant.sangar@gmail.com

Abstract

HIV/AIDS remains a persistent problem around the world. There were approximately 35 million people worldwide living with HIV/AIDS in 2013. In Sub-Saharian Africa countries use of *Moringa oleifera* Lam. along with Antiretroviral (ART) regimen among HIV positive people is high. However, there is scarcity of scientific evidences to support *M. oleifera* as anti-HIV therapy. Recent research pointed out that the G protein-coupled chemokine receptor CXCR4 is an important target, as they are specifically implicated in cancer metastasis and HIV-1 infection. In present study, attempt has been made to answer the role of *M. oleifera* in HIV treatment using CXCR4 as a target receptor. Major phytoconstituents of *M. oleifera* incorporated in virtual screening against CXCR4. Drug molecule optimization, addition of charges and hydrogen bonds was carried out using Autodock tools. Receptor optimization was carried out using Accelrys Discovery studio visualizer 4. Molecular docking study was performed on Autodock 4. The results has shown that docking energy of 2-Pyrrolidinone (-3.35 kcal/mol), Linalool oxide (-4.12 kcal/mol), Upiol (-4.15 kcal/mol), 1,2- Benzene dicarboxylic acid, bis(2-ethylhexyl) ester (-5.56 kcal/mol), Ellagic acid (-6.10 kcal/mol), Gallic acid (-4.38 kcal/mol), Ferulic acid (-4.81 kcal/mol), Vanillin (-4.23 kcal/mol), 1,2,3-Cyclopentanetriol (-4.09 kcal/mol), Astragalin (-5.69 kcal/mol), Aurantiamide acetate (-6.02 kcal/mol), Chlorogenic acid (-5.89 kcal/mol), Isoquercetin (-5.52 kcal/mol), Cryptochlorogenic acid (-4.66 kcal/mol), Kaempferol (-5.90 kcal/mol), Niaziminin (-3.96 kcal/mol). 6,6-dimethyl-5,6- dihydroimidazo [2,1-b] [1,3] thiazol-3-yl) methyl N,N' dicyclo hexylimido thio carbamate and selected phyto constituents of *Moringa oleifera*. Docking energies for (6,6-dimethyl-5,6-dihydroimidazo[2,1- b] [1,3] thiazol-3-yl) methyl N,N' dicyclo hexylimido thio carbamate was taken as a standard ligand of CXCR4 for comparative study. Ellagic acid and Aurantiamide acetate are shown as promising anti-HIV candidate. However, further *in vitro* and *in vivo* studies needed to validate their biological potential.

Keywords: HIV/AIDS, *Moringa oleifera*, CXCR4, virtual screening.

Abbreviations: AIDS: Acquired immunodeficiency syndrome; ART: Antiretroviral therapy; GPCR: Gprotein-coupled chemokine receptors: HAART: Highly Active Antiretroviral Therapy; HIV: Human Immunodeficiency Virus; LGA: Lamarckian algorithm: *M. oleifera: Moringa oleifera*, Lam: NACO: National AIDS Control Organisation; NNRTIs: Non-nucleoside reverse transcriptase inhibitors: NTRIs: Nucleoside reverse transcriptase inhibitors; PIs: Protease inhibitors.

Introduction

Human immunodeficiency virus (HIV) is a retrovirus, belongs to the family of lentiviruses. HIV types 1 and 2 (HIV-1 and HIV-2) causes Acquired immunodeficiency syndrome (AIDS). During the course of AIDS in humans, immune system begins to fail which leads to life- threatening opportunistic infections or malignancies associated with the progressive failure of the immune system [1,2]. HIV/AIDS remains a persistent problem around the world. Till 2013, 35 million people were detected worldwide living with HIV/AIDS. Sub-Saharan Africa remains most severely affected due to HIV. In Sub-Saharan Africa, 1 in every 20 adults living with HIV. This accounts for nearly 71% of the people living with HIV worldwide [3]. India is the third highest number of estimated people living with HIV in the world. According to the National AIDS Control Organization (NACO) report 2014, the estimated number of people living with HIV/AIDS in India during 2012 was 20.89 lakh [4].

At present, there are no defined vaccines or drugs available to cure HIV infected patients. Currently, nucleoside reverse transcriptase inhibitors (NRTIs), non-nucleoside reverse transcriptase inhibitors (NNRTIs) and protease inhibitors (PIs) are anti-HIV class of drugs are exercised around the world [5]. Most HIV-infected patients in resource limited settings receive a first-line triple combination of lamivudine, nevirapine,

stavudine or zidovudine. This combination antiretroviral therapy (ART) provides many benefits but it also creates more adverse events like peripheral neuropathy, hypersensitivity and life-threatening hepatotoxicity in HIV patients which hamper treatment adherence [6].

Chemokine receptors are critical regulators of cell migration in the context of immune surveillance, inflammation and development. In 2013, it is reported that G protein-coupled chemokine receptor CXCR4 is an important targets for HIV infection [7]. CXCR4 is a major co-receptor for T-cell-tropic HIV-1 [8]. Due to this, till now numerous efforts have been made to develop a new class of anti-HIV agents that target CXCR4 as an additional or alternative therapy to standard HAART. The first FDA approved CXCR4 antagonist, plerixafor/ AMD3100 is used to mobilize hematopoietic stem cells, which are collected for use in stem cell graft in patients with hematological cancers. Plerixafor was initially developed to interfere with SDF-1/CXCR4 interaction and shows promise for HIV infection, cancers and autoimmune diseases such as rheumatoid arthritis. However, this drug is expensive because of the difficulty in its total synthesis. Therefore, there is an urgent need for the discovery of new CXCR4 antagonists that are cost-effective, potent and safe [9]. Phytochemicals have been an important and safe source of lead compounds in drug discovery and development.

Moringa oleifera, Lam (*M. oleifera*) is a member of the Moringaceae family. This edible plant is also known as drumstick tree, horseradish tree and malunggay. *Moringa oleifera*, Lam is native to the sub-Himalayan tracts of India, Pakistan, Bangladesh and Afghanistan and it is consumed as food [10,11]. Phytochemical analyses have shown that *M. oleifera* leaves are particularly rich in potassium, calcium, phosphorous, iron, vitamins A and D, essential amino acids, as well as such known antioxidants such as β-carotene, vitamin C and flavonoids [12-15]. In many regions of Africa, from traditional days *M. oleifera* is widely consumed for self-medication by patients affected HIV/AIDS [16]. However, the benefit for the treatment or prevention of HIV disease or infection by using either dietary or topical administration of *M. oleifera* preparations is not quite well-known. There is room to exploit the potential *M. oleifera* in the battle against HIV. In the present study, attempt has been made to answer the role of *M. oleifera* in HIV treatment using CXCR4 as a target receptor.

Materials and Methods

Data Set

Phyto constituents and standard drug compounds could be downloaded from the database (https://pubchem.ncbi.nlm.nih.gov/search/search.cgi) and generate the small molecule compounds to identify potential CXCR4 antagonist screening. A three-dimensional structure of CXCR4 chemokine GPCR protein could be offered from the Protein Data Bank (PDB ID: 3ODU).

Receptor Optimization

Receptor was optimized using Discovery Studio version-4 Accelrys Software. The energy minimization of modeled protein was performed by SPDV and its score was obtained. Then the active sites of these proteins were obtained from online active site prediction tool. The Ramachandran plot was obtained to study the favorable regions with residues present.

Ligands Optimization

Drug molecule and phyto constituents optimization, addition of charges and hydrogen bonds was carried out using Autodock tools.

Computational Docking Studies

The docking of selected protein with three drug molecules was performed by using Auto dock 4. The docking calculations were verified using docking server [17]. Gasitier partial charges were added to ligand. Nonpolar hydrogen atoms were merged and rotatable hydrogen bonds were defined. Docking calculations were carried out on receptor. Essential hydrogen atoms, kollaman charges and savlavation parameters were added affinity (grid) maps 25 Å grid points and 0.500 Å were generated using the auto grid program. Auto dock parameters set and distance dependent dielectric functions were used in the calculation of the van der Waals and the electrostatic terms, respectively. Docking simulations were performed using Lamarckian algorithm (LGA) and Solis and Wet local search methods [18]. Initial position torsion and orientation of the drug molecules were set randomly. All rotatable torsions were released during docking. Each docking experiment was derived from 10 different runs that were set to terminate after 250000 energy calculations. The population size was set to 150. During search the translational step 0.2 Å and quaternion and torsion step 5 were applied [19].

Results

Docking is done by Auto dock 4 for CXC4 structure with control drug (6,6-dimethyl-5,6-dihydroimidazo [2,1- b] [1,3] thiazol-3-yl) methyl N,N' dicyclo hexylimidothio carbamate and selected phyto constituents of *Moringa oleifera.* Docking energies for (6,6-dimethyl-5,6-dihydroimidazo[2,1-b] [1,3] thiazol-3- yl) methyl N,N' dicyclo hexylimido thio carbamate (-9.17Kcal/mol), 2-Pyrrolidinone (-3.35 kcal/mol), Linalool oxide (-4.12 kcal/mol), Upiol (-4.15 kcal/mol),1,2- Benzene dicarboxylic acid, bis (2-ethyl hexyl) ester (-5.56 kcal/mol), Ellagic acid (-6.10 kcal/mol), Gallic acid (-4.38 kcal/mol), Ferulic acid (-4.81 kcal/mol), Vanillin (-4.23 kcal/mol), 1,2,3-Cyclopentanetriol (-4.09 kcal/mol), Astragalin (-5.69 kcal/mol), Aurantiamide acetate (-6.02 kcal/mol), Chlorogenic acid (-5.89 kcal/mol), Isoquercetin (-5.52 kcal/mol), Crypto-chlorogenic acid (-4.66 kcal/mol), Kaempferol (-5.90 kcal/mol), Niaziminin (-3.96 kcal/mol) (Table 1). Interaction tables of drug and all phyto constituents have shown the non-covalent interactions occurring between active site residues and respective drug and phyto constituents (Table 2-18). The docking study showed that Ellagic acid and Aurantiamide acetate as a promising anti-HIV candidate when they are compared with 6,6- dimethyl-5,6-dihydroimidazo [2,1-b] [1,3] thiazol-3- yl) methyl N,N' dicyclo hexylimidothio carbamate. However, further *in vitro* and *in vivo* studies of individual phyto constituents are needed to validate their biological potential. Ball and socket model of respective drug

How to cite this article: Vikrant C S, Lalit R S, Sandip S P, Abhay S C. *In Silico* Approach to Combat HIV Using Phytoconstituents of *Moringa oleifera Lam*. J O J Immuno Virology. 2015;1(2): 555558.

molecule and phyto constituents interacting with active site are shown in (Figure 1-16). In the present investigation, we found that tryptophan 94 and histidine113 from the active site of CXCR4 contributed to hydrophobic interaction with Ellagic acid and Aurantiamide acetate. The nature of amino acids present at the active site of receptor is an important to understand interaction studies with ligand. In case of Aurantiamide acetate hydrophobic interactions were contributed by histidine113 and Iso leucine 284. These three amino acids plays crucial role in the docking and non- covalent interaction and defined as the amino acids that can interact with all the selected ligands. Thus these amino acids may play important role in target function of CXCR4.

Table 1: CXCR4 chemokine GPCR inhibitors docked against 3ODU.

Sr. No	Drug molecule	Est. Free Energy of Binding (kcal/mol)	Estimated Inhibition Constant, Ki (mM)	vdW + Hbo nd + desolve Energy (kcal/mol)	Electrostatic Energy (kcal/mol)	Total Inter-molecular Energy (kcal/mol)
1	6,6-dimethyl-5,6-dihydroimidazo[2,1- b] [1,3] thiazol-3- yl) methyl N,N'-dicyclohexylimidothiocarbamate	-9.17	190.68	-8.42	-2.32	-10.74
2	2-Pyrrolidinone	-3.35	3.51	-3.33	-0.002	-3.35
3	Linalool oxide	-4.12	958.57	-5.62	-0.08	-5.69
4	Upiol	-4.15	905.78	-4.72	-0.08	-4.80
5	1,2- Benzenedicarboxylic acid, bis (2-ethylhexyl) ester	-5.56	84.15	-8.62	0	-8.62
6	Ellagic acid	-6.10	33.63	-5.63	-0.54	-6.17
7	Gallic acid	-4.38	616.49	-4.18	-0.43	-4.61
8	Ferulic acid	-4.81	299	-5.42	-0.01	-5.43
9	Vanillin	-4.23	793.80	-4.44	-0.06	-4.51
10	1,2,3-Cyclopentanetriol	-4.09	997.44	-4.14	-0.31	-4.45
11	Astragalin	-5.69	67.14	-5.59	-0.54	-6.63
12	Aurantiamide acetate	-6.02	38.98	-8.39	-0.26	-8.64
13	Chlorogenic acid	-5.89	47.86	-6.82	-0.64	-7.46
14	Isoquercetin	-5.52	63.07	-6.43	-0.50	-6.93
15	Crypto-chlorogenic acid	-4.66	384.07	-6.30	-0.27	-6.57
16	Kaempferol	-5.90	47.40	-6.16	-0.38	-6.53
17	Niaziminin	-3.96	1.25	-6.64	-0.05	-6.70

How to cite this article: Vikrant C S, Lalit R S, Sandip S P, Abhay S C. *In Silico* Approach to Combat HIV Using Phytoconstituents of *Moringa oleifera Lam*. J O J Immuno Virology. 2015;1(2): 555558.

Table 2: (6,6-dimethyl-5,6-dihydroimidazo[2,1-b][1,3] thiazol- 3-yl)methyl N,N'-dicyclohexylimidothiocarbamate interaction.

Hydrogen bonds	Polar	Hydrophobic	Other
N (2) GLU32 – [*2.95*] (CD, OE1, OE2)	H (1) GLU32 – [*1.95*] (*OE1, OE2*)	C (6) LEU41 – [*3.42*] (*CD1*)	C (17) ARG30 – [*3.88*] (*CG*)
N (4) ASP97 – [2.58] (CG,OD1)	H (3) ASP97 – [2.01] (OD1)	C (4) LEU41 – [3.81] (CD1)	H (1) GLU32 – [2.58] (CD, CG)
N (3) ASP97 – [3.03] (OD1)	H (2) ASP97 – [3.57] (OD1)	C (14) TRP94 – [3.71] (CD1, CG)	C (15) GLU32 – [3.69] (OO E1, E2)
		C (13) TRP94 – [3.43] (CD2, CE2, CZ2)	S (1) GLU32 – [3.74] (OE2)
		C (3) TRP94 – [*3.31*] (*CE3,CZ3*)	C (1) TYR45 – [*3.84*] (*OH*)
		C (4) ALA98 – [*3.84*] (*CB*)	C (3) TYR45 – [*3.23*] (*OH*)
		C (12) TRP102 – [*3.02*] (*CE3,CH2, CZ3*)	C (7) TYR45 – [*3.41*] (*OH*)
		C (14) TRP102 – [*3.89*] (*CZ3*)	C (4) TYR45 – [*3.69*] (*OH*)
		C (18) ILE185 – [*3.79*] (*CG2*)	C (13) TRP94 – [*3.60*] (*NE1*)
		C (15) ILE185 – [*3.54*] (*CD1*)	H (3) ASP97 – [*3.01*] (*CB,CG*)
		C (11) CYS186 – [*3.51*] (*CB, SG*)	C (12) ASP97 – [*3.40*] (*CB,CG,OD1*)
			C (19) ASP97 – [*2.96*] (*OD1*)
			C (21) ASP97 – [*3.72*] (*OD1*)
			C (1) ASP97 – [*3.59*] (*OD1*)

How to cite this article: Vikrant C S, Lalit R S, Sandip S P, Abhay S C. *In Silico* Approach to Combat HIV Using Phytoconstituents of *Moringa oleifera Lam*. J O J Immuno Virology. 2015;1(2): 555558.

			C (5) ASP97 – [3.63] (OD1)
			C (11) ASP97 – [3.59] (OD1)
			N (2) ILE185 – [3.75] (CD1)
			H (1) ILE185 – [3.73] (CD1)
			S (1) ILE185 – [3.53] (CD1)
			C (8) ASP187 – [3.14] (OD2)
			C (9) SER285 – [3.14] (OG)
			C (6) SER285 – [3.60] (OG)
			C (7) GLU288 – [3.47] (OE2)

Table 3: 2-Pyrrolidinone interaction.

Hydrogen bonds	Polar	Hydrophobic	Other
N () ASP97 – [2.96] (CB,CG, OD1)	H () ASP97 – [2.19] (OD1)	C () TRP94 – [3.36] (CD1,CD2,CE2,CE3,CG)	N () TRP94 – [3.78] (CD2,CG)
		C () TRP102 – [3.28] (CZ3)	O () TRP94 – [3.73] (CD2,CE3,CZ3)
		C () VAL112 – [3.55] (CG2)	C () TRP94 – [3.65] (NE1)
			C () ASP97 – [3.28] (CB,CG,OD1)
			H () ASP97 – [2.91] (CB,CG)

How to cite this article: Vikrant C S, Lalit R S, Sandip S P, Abhay S C. *In Silico* Approach to Combat HIV Using Phytoconstituents of *Moringa oleifera Lam*. J O J Immuno Virology. 2015;1(2): 555558.

Table 4: Linalool oxide interaction.

Polar	Hydrophobic	pi-pi	Other
O (2) – ASP97 (*OD1*) [*3.13*]	C (8) – TRP94 (*CD1,CG*) [*3.51*]	C (2) – HIS113 (CD2,CE1) [*3.75*]	O (2) – TRP94 (CD2, CE3) [*3.78*]
H (1) – ASP97 (*OD1*) [*2.44*]	C (4) – TRP94 (CD2,CE2,CZ2) [*3.42*]		C (4) – TRP94 (*NE1*) [*3.73*]
O (1) – HIS113 (*NE2*) [*3.16*]	C (3) – TRP94 (CH2,CZ2,CZ3) [*3.55*]		C (8) – TRP94 (*NE1*) [*3.80*]
	C (5) – TRP94 (CH2,CZ3) [*3.21*]		H (1) – ASP97 (*CB,CG*) [*3.27*]
	C (10) – TRP102 (*CE3,CZ3*) [*3.52*]		O (2) – ASP97 (*CG*) [*3.84*]
	C (8) – TRP102 (*CZ3*) [*3.52*]		C (10) – ASP97 (CG,OD1,OD2) [*3.18*]
	C (9) – TRP102 (*CZ3*) [*3.75*]		O (1) – HIS113 (*CD2,CE1*) [*3.74*]
	C (8) – VAL112 (*CG2*) [*3.75*]		C (2) – HIS113 (*NE2*) [*3.41*]
	C (6) – HIS113 (*CD2*) [*3.39*]		C (6) – HIS113 (*NE2*) [*3.76*]
	C (6) – TYR116 (CD2, CE2,CG) [*3.31*]		C (5) – GLU288 (*OE1*) [*3.68*]
	C (10) – CYS186 (*CB,SG*) [*3.34*]		
	C (9) – CYS186 (*SG*) [*3.56*]		

How to cite this article: Vikrant C S, Lalit R S, Sandip S P, Abhay S C. *In Silico* Approach to Combat HIV Using Phytoconstituents of *Moringa oleifera Lam*. J O J Immuno Virology. 2015;1(2): 555558.

Table 5: Upiol interaction.

Hydrogen bonds	Polar	Hydrophobic	cation-pi	Other
N (2) ASP97 – [3.00] (CG,OD1)	N (1) TRP94 – [3.25] (NE1)	C (6) TRP94 – [3.58] (CD2,CG)	H (3) TRP94 – [2.65] (CB, CD2,CE2, CE3,CG, CZ3)	N (1) TRP94 – [3.08] (CD1, CD2,CE2, CE3,CG, CZ2)
	H (1) TRP94 – [2.94] (NE1)	C (5) TRP94 – [3.68] (CE2,CZ2)	H (1) TRP94 – [3.16] (CD1, CD2, CE2,CG,CZ2)	N (2) TRP9 – [3.57] (CD2, CE3, CG)
	O (2) ASP97 – [3.61] (OD1)	C (1) HIS113 – [3.39] (CE1)		Br (1) TRP94 – [3.37] (CH2,CZ2)
	H (2) ASP97 – [2.19] (OD1)	C (3) HIS113 – [3.24] (CE1)		O (2) ASP97 – [3.50] (CB,CG)
	H (3) ASP97 – [3.74] (OD1)	C (3) CYS186 – [3.23] (CB,SG)		H (2) ASP97 – [2.97] (CB,CG)
	O (1) HIS113 – [3.78] (ND1)			C (6) ASP97 – [3.70] (OD1)
				O (2) TRP102 – [3.27] (CZ3)
				H (1) VAL112 – [3.40] (CB,CG2)
				O (1) VAL112 – [3.36] (CG2)
				O (1) HIS113 – [3.75] (CE1)
				C (1) HIS113 – [3.46] (NE2)
				C (3) HIS113 – [3.86] (NE2)

How to cite this article: Vikrant C S, Lalit R S, Sandip S P, Abhay S C. *In Silico* Approach to Combat HIV Using Phytoconstituents of *Moringa oleifera Lam*. J O J Immuno Virology. 2015;1(2): 555558.

Table 6: 1,2-Benzenedicarboxylic acid, bis (2-ethylhexyl) ester interaction.

Hydrogen bonds	Polar	Hydrophobic	Other
O(4) HIS113 - [3.33] (CE1,NE2)	O(3) ASP97 - [3.65] (OD1)	C(16) LEU41 - [3.60] (CD1)	C(11) TYR45 - [2.96] (OH)
	O(1) ASP97 - [3.60] (OD1)	C(13) TRP94 - [3.57] (CD1,CD2,CG)	C(16) TYR45 - [3.09] (OH)
	O(4) ASP187 - [3.06] (OD1)	C(4) TRP94 - [3.59] (CE2, CZ2)	C(20) ASP97 - [3.86] (OD1)
		C(8) TRP94 - [3.53] (CZ2)	C(21) ASP97 - [3.27] (OD1)
		C(12) TRP94 - [3.46] (CH2, CZ2)	C(18) ASP97 - [3.48] (OD1)
		C(11) TRP94 - [3.68] (CZ3)	C(9) HIS113 - [3.61] (NE2)
		C(6) TRP102 - [3.36] (CZ3)	C(8) HIS113 - [3.84] (NE2)
		C(13) TRP102 - [3.85] (CZ3)	C(15) HIS113 - [3.53] (NE2)
		C(1) VAL112 - [3.64] (CG2)	C(22) ASP187 - [3.31] (CG, OD2)
		C(6) VAL112 - [3.88] (CG2)	C(17) ASP187 - [3.47] (CG, OD1)
		C(15) HIS113 - [3.45] (CD2)	O(4) ASP187 - [3.61] (CG)
		C(9) HIS113 - [3.12] (CE1)	C(24) ASP187 - [3.88] (OD2)
		C(1) HIS113 - [3.69] (CE1)	C(16) SER285 - [3.28] (CB,OG)
		C(8) HIS113 - [3.89] (CE1)	C(5) GLU288 - [3.85] (OE1, OE2)
		C(9) CYS186 - [3.63] (SG)	C(3) GLU288 - [3.31] (OE2)
			C(7) GLU288 - [3.64] (OE2)
			C(11) GLU288 - [3.20] (OE2)

How to cite this article: Vikrant C S, Lalit R S, Sandip S P, Abhay S C. *In Silico* Approach to Combat HIV Using Phytoconstituents of *Moringa oleifera Lam*. J O J Immuno Virology. 2015;1(2): 555558.

Table 7: Ellagic acid interaction.

Hydrogen bonds	Polar	pi-pi	Cation-pi	Other
				O(5) VAL112 - [3.73] (CG2)
				O(3) HIS113 - [3.77] (CE1)
				H(2) SER285 - [3.14] (CB)
				C(14) GLU288 - [2.92] (CD, OE2)
				O(6) GLU288 - [3.89] (CD)
				H(4) GLU288 - [3.05] (CD)
				C(10) GLU288 - [3.35] (OE1, OE2)
				C(7) GLU288 - [3.39] (OE2)

Table 8: Gallic acid interaction.

Polar	Hydrophobic	pi-pi	Other
O(2) ASP97 - [3.03] (OD1)	C(7) TRP94 - [3.44] (CH2, CZ2)	C(3) TRP94 - [3.62] (CD2,CE3)	O(2) TRP94 - [3.76] (CD2, CG)
H(2) ASP97 - [2.14] (OD1)	C(7) HIS113 - [3.89] (CD2)	C(5) TRP94 - [3.45] (CD2,CE2, CH2,CZ2)	O(4) TRP94 - [3.45] (CE2,CZ2)
O(1) ASP97 - [2.96] (OD1)		C(1) TRP94 - [3.38] (CE2,CH2, CZ2,CZ3)	O(2) ASP97 - [3.61] (CB,CG)
H(1) ASP97 - [2.01] (OD1)		C(2) TRP94 - [3.75] (CE3,CZ3)	H(2) ASP97 - [2.88] (CB,CG)
O(5) HIS113 - [3.53] (NE2)		C(4) TRP94 - [3.68] (CZ3)	H(1) ASP97 - [3.21] (CG)
		C(6) TRP94 - [3.51] (CH2,CZ3)	C(2) ASP97 - [3.72] (OD1)
			C(3) ASP97 - [3.75] (OD1)
			O(4) VAL112 - [3.87] (CG2)

How to cite this article: Vikrant C S, Lalit R S, Sandip S P, Abhay S C. *In Silico* Approach to Combat HIV Using Phytoconstituents of *Moringa oleifera Lam*. J O J Immuno Virology. 2015;1(2): 555558.

			O(5) HIS113 - [3.33] (CD2,CG)
			C(7) HIS113 - [3.87] (NE2)
			O(4) TYR116 - [3.76] (CB)
			O(5) TYR116 - [3.78] (CD2,CG)

Table 9: Aurantiamide acetate interaction.

Polar	Hydrophobic	pi-pi	cation-pi	Other
O (2) HIS113 – [3.17] (NE2)	C (25) LEU41 – [3.71] (CD1)	C (27) TYR45 – [3.67] (CE2)	H(2) TRP94 – [3.78] (CZ3)	C(27) TYR45 – [3.40] (OH)
O(2) ARG188 – [3.79] (NH1)	C(27) LEU41 – [3.76] (CD1)	C(26) TYR45 – [3.53] (CE2)		C(26) TYR45 – [3.44] (OH)
O(4) ARG188 – [3.41] (NH1,NH2)	C(27) ALA98 – [3.24] (CB)	C(17) TRP94 – [3.30] (CD1, CD2, CE2,CG,CZ2)		C(17) TRP94 – [3.25] (NE1)
	C(26) ALA98 – [3.74] (CB)	C(20) TRP94 – [3.58] (CD1,CG)		C(20) TRP94 – [3.76] (NE1)
	C(17) VAL112 – [3.52] (CG2)	C(23) TRP94 – [3.84] (CE3)		C(18) ASP97 – [3.51] (CB,CG,OD1)
	C(20) VAL112 – [3.74] (CG2)	C(18) TRP102 – [3.19] (CE3,CZ3)		C(13) ASP97 – [3.31] (CG,OD1)
	C(4) HIS113 – [3.35] (CE1)	C(20) TRP102 – [3.73] (CZ3)		C(11) ASP97 – [3.65] (OD1)
	C(9) ILE284 – [3.78] (CG2)	C(19) HIS281 – [3.75] (CE1)		C(16) ASP97 – [3.35] (OD1)
	C(14) ILE284 – [3.16] (CG2)			C(26) ASP97 – [3.65] (OD1)
				C(23) ASP97 – [3.02] (OD1)
				O(2) HIS113 – [3.81] (CD2)
				C(4) HIS113 – [3.52] (NE2)
				C(19) SER285 – [3.04] (OG)

How to cite this article: Vikrant C S, Lalit R S, Sandip S P, Abhay S C. *In Silico* Approach to Combat HIV Using Phytoconstituents of *Moringa oleifera Lam*. J O J Immuno Virology. 2015;1(2): 555558.

				C(15) SER285 – [2.82] (OG)
				C(10) SER285 – [3.86] (OG)

Table 10: Chlorogenic acid interaction.

Polar	Hydrophobic	pi-pi	cation-pi	Other
O(8) ASP97 – [2.95] (OD1)	C(9) TRP94 – [3.86] (CH2)	C(15) TRP94 – [3.50] (CD2, CE2,	H(5) TRP102 – [3.83] (CZ3)	C(15) TRP94 – [3.57] (NE1)
H(4) ASP97 – [2.06] (OD1,OD2)	C(10) TRP94 – [3.89] (CH2)	C(13) TRP94 – [3.25] (CE2, CH2, CZ2)		C(13) TRP94 – [3.78] (NE1)
O(9) ASP97 – [3.37] (OD1)	C(15) VAL112 – [3.61] (CG2)	C(11) TRP94 – [3.84] (CH2,CZ2)		H(4) ASP97 – [2.89] (CB,CG)
H(5) SP97 – [2.41] (OD1,OD2)	C(10) HIS113 – [3.79] (CD2)	C(11) HIS113 – [3.90] (CE1)		O(9) ASP97 – [3.58] (CB,CG)
O(1) TYR116 – [3.54] (OH)	C(8) TYR116 – [3.58] (CE2)			H(5) ASP97 – [2.74] (CB,CG)
O(7) ARG188 – [3.17] (CZ, NH1,NH2)				O(8) ASP97 – [3.77] (CG)
O(2) GLN200 – [2.98] (NE2,OE1)				O(9) RP102 – [3.40] (CZ3)
H(1) GLN200 – [2.20] (NE2,OE1)				C(10) HIS113 – [3.63] (NE2)
O(5) GLN200 – [3.17] (OE1)				C(11) HIS113 – [3.78] (NE2)
O(2) TYR255 – [2.91] (OH)				O(7) TYR116 – [3.63] (CD2,CE2)

How to cite this article: Vikrant C S, Lalit R S, Sandip S P, Abhay S C. *In Silico* Approach to Combat HIV Using Phytoconstituents of *Moringa oleifera Lam*. J O J Immuno Virology. 2015;1(2): 555558.

H(1) TYR255 – [3.71] (OH)				O(1) TYR116 – [3.51] (CE2,CZ)
O(1) GLU288 – [3.29] (OE1)				O(2) GLN200 – [3.75] (CD)
O(3) GLU288 – [2.92] (OE1,OE2)				H(1) GLN200 – [3.15] (CD)
H(2) GLU288 – [2.01] (OE1,OE2)				C(1) TYR255 – [3.48] (OH)
H(3) GLU288 – [2.60] (OE1,OE2)				C(3) TYR255 – [3.81] (OH)
O(4) GLU288 – [3.49] (OE2)				C(4) TYR255 – [3.19] (OH)
				O(4) ILE284 – [3.08] (CG2)
				H(3) ILE284 – [3.72] (CG2)
				C(5) GLU288 – [2.97] (CD,OE1,OE2)
				O(3) GLU288 – [3.41] (CD)
				H(2) GLU288 – [2.70] (CD)
				H(3) GLU288 – [3.21] (CD)
				C(2) GLU288 – [3.70] (OE1)

How to cite this article: Vikrant C S, Lalit R S, Sandip S P, Abhay S C. *In Silico* Approach to Combat HIV Using Phytoconstituents of *Moringa oleifera Lam*. J O J Immuno Virology. 2015;1(2): 555558.

Table 11: Isoquercetin interaction.

Hydrogen bonds	Polar	Hydrophobic	pi-pi	cation-pi	Other
O (10) TYR255 – [2.79] (CE1, CZ, OH)	H (3) TYR45 – [3.87] (OH)	C (13) ILE284 – [3.72] (CG2)	C (20) TRP94 – [3.66] (CH2, CZ2)	HIS113 (CB, H8 () – CD2,[3.08] CE1,CG)	O (5) LEU41 – [3.86] (CD1)
O (8) SER285 – [3.07] (OG)	O (1) ASP97 – [3.35] (OD1)	C (17) ILE284 – [3.05] (CG2)	C (16) TRP94 – [3.36] (CH2,CZ2)	H (6) TYR255 – [2.95] (CE1,CZ)	O (6) ASP97 – [3.48] (CG)
O (9) SER285 – [2.96] (CB,OG)	O (6) ASP97 – [3.06] (OD1,OD2)		C (8) TRP94 – [3.87] (CZ3)		H (4) ASP97 – [2.59] (CG)
	H (4) ASP97 – [2.24] (OD1,OD2)		C (12) TRP94 – [3.60] (CH2,CZ3)		C (4) ASP97 – [3.47] (OD1)
	H (2) ASP97 – [3.85] (OD1)		C (20) HIS113 – [3.85] (CD2)		C (2) ASP97 – [3.06] (OD1)
	O (12) HIS113 – [3.22] (ND1,NE2)		C (21) HIS113 – [3.57] (CE1)		C (1) ASP97 – [3.88] (OD1)
	H (8) HIS113 – [2.92] (ND1,NE2)				C (3) ASP97 – [3.84] (OD1)
	H (2) ARG183 – [3.38] (CZ,NH1,NH2)				C (6) ASP97 – [3.49] (OD1)
	O (6) ARG183 – [3.64] (NH1)				O (3) ALA98 – [3.85] (CB)
	H (4) ARG183 – [3.43] (NH1)				H (7) VAL112 – [3.63] (CG2)
	H (6) TYR255 – [2.20] (OH)				O (12) VAL112 – [3.15] (CG2)
	H (3) SER285 – [3.57] (OG)				H (8) VAL112 – [3.34] (CG2)
	H (5) SER285 – [2.30] (OG)				O (12) HIS113 – [3.22] (CE1,CG)
	O (7) – GLU288				C (21) – HIS113

How to cite this article: Vikrant C S, Lalit R S, Sandip S P, Abhay S C. *In Silico* Approach to Combat HIV Using Phytoconstituents of *Moringa oleifera Lam*. J O J Immuno Virology. 2015;1(2): 555558.

Hydrogen bonds	Polar	Hydrophobic	pi-pi	cation-pi	Other
	[*3.61*] (*OE1*)				[*3.67*] (*NE2*)
	O (8) – [*3.74*] GLU288 (*OE2*)				C (20) – [*3.70*] HIS113 (*NE2*)
	H (5) – [*3.62*] GLU288 (*OE2*)				H (2) – [*3.70*] ILE185 (*CD1*)
					C (18) – [*3.69*] TYR255 (*OH*)
					O (10) – [*3.81*] ILE259 (*CD1*)
					H (6) – [*3.13*] ILE259 (*CD1*)
					O (9) – [*3.43*] ILE284 (*CG2*)
					H (6) – [*3.73*] ILE284 (*CG2*)
					H (5) – [*3.22*] SER285 (*CB*)
					C (10) – [*3.10*] GLU288 (*CD,OE2*)
					C (11) – [*3.43*] GLU288 (*CD,OE1,OE2*)
					C (14) – [*3.52*] GLU288 (*OE1*)
					C (7) – [*3.86*] GLU288 (*OE2*)
					C (9) – [*3.32*] GLU288 (*OE2*)
					C (13) – [*3.47*] GLU288 (*OE2*)

How to cite this article: Vikrant C S, Lalit R S, Sandip S P, Abhay S C. *In Silico* Approach to Combat HIV Using Phytoconstituents of *Moringa oleifera Lam*. J O J Immuno Virology. 2015;1(2): 555558.

Table 12: Crypto-chlorogenic acid interaction.

Polar	Hydrophobic	pi-pi	cation-pi	Other
O (4) – [3.71] GLU32 (OE2)	C (3) – [3.31] ALA98 (CB)	C (16) – [3.89] TRP94 (CZ2)	H (4) – [3.42] TRP94 (CE2,CZ2)	O (5) – [*3.77*] GLU32 (*CB*)
O (8) – [*3.73*] TRP94 (*NE1*)		C (15) – [3.78] HIS113 (CD2,CE1)	H (5) – [2.99] HIS113 (CB,CD2, CE1, CG)	O (4) – [*3.90*] GLU32 (*CD*)
H (4) – [*3.40*] TRP94 (*NE1*)		C (16) – [*3.73*] HIS113 (*CE1*)	H (5) – [3.75] TYR116 (CB,CG)	C (4) – [*3.66*] GLU32 (*OE2*)
O (1) – [*3.69*] ASP97 (*OD1*)				C (6) – [*3.64*] GLU32 (*OE2*)
O (7) – [*3.57*] ASP97 (*OD1*)				O (2) – [*3.42*] LYS38 (*CE*)
O (3) – [*3.28*] ASP97 (*OD1*)				H (1) – [*3.43*] LYS38 (*CE*)
H (2) – [*2.48*] ASP97 (*OD1*)				O (8) – [3.63] TRP94 (CE2,CZ2)
H (5) – [3.32] HIS113 (ND1,NE2)				O (9) – [*3.49*] TRP94 (*CZ2*)
O (6) – [*3.82*] SER285 (*OG*)				H (2) – [3.27] ASP97 (CB,CG)
				C (2) – [*3.56*] ASP97 (*OD1*)
				C (8) – [*3.24*] ASP97 (*OD1*)
				C (9) – [*2.97*] ASP97 (*OD1*)
				O (3) – [*3.26*] ALA98 (*CB*)
				H (2) – [*3.26*] ALA98 (*CB*)
				H (4) – [3.24] VAL112 (CB,CG2)
				O (8) – [*3.54*] VAL112 (*CG2*)
				O (9) – [*3.81*] HIS113 (*CD2*)

How to cite this article: Vikrant C S, Lalit R S, Sandip S P, Abhay S C. *In Silico* Approach to Combat HIV Using Phytoconstituents of *Moringa oleifera Lam*. J O J Immuno Virology. 2015;1(2): 555558.

				C (16) HIS113 [3.56] – (*NE2*)
				C (15) HIS113 [3.28] – (*NE2*)
				C (13) HIS113 [3.75] – (*NE2*)
				O (9) TYR116 [3.86] – (*CB*)
				O () ILE185 [3.76] – (*CD1*)
				H3 () ILE185 [3.63] – (*CD1*)

Table 13: Kaempferol interaction.

Polar	pi-pi	cation-pi	Other
O(3) TRP94 – [3.82] (NE1)	C(7) TRP94 – [3.60] (CD2, CE2, CE3)	H (1) TRP94 - [3.29](CD1,CD2, E2,CZ2)	O(3) TRP94 – [3.76] (*CE2*)
H(1) TRP94 – [3.28] (*NE1*)	(10) TRP94 – [3.54] (CD2, CE3)	H(3) TYR255 – [3.44] (*CZ*)	O(4) TRP94 – [3.82] (*CZ2*)
O(5) ASP97 – [2.93] (*OD1*)	C(1) TRP94 - [3.42] (CE2,CE3,CH2,CZ2,CZ3)		O(1) TRP94 – [3.57] (CH2,CZ3)
H(2) ASP97 – [2.01] (*OD1*)	C(2) TRP94 - [3.25] (CE3,CH2,CZ3)		H(2) ASP97 – [3.19] (*CB,CG*)
O(4) HIS113 – [3.74] (ND1,NE2)	C(8) TRP94 – [3.34] (CE3,CZ3)		C(9) ASP97 – [3.32] (*OD1*)
O(2) HIS113 – [3.78] (*NE2*)	C(9) TRP94 – [3.46] (*CE3,CZ3*)		C(10) ASP97 – [3.20] (*OD1*)
O(6) TYR255 – [3.03] (*OH*)	C(4) TRP94 – [3.50] (CH2,CZ2)		O(3) VAL112 – [3.80] (*CG2*)
H(3) TYR255 – [2.10] (*OH*)	C(5) TRP94 – [3.70] (CH2,CZ2)		H(1) VAL112 – [3.42] (*CG2*)
	C(3) TRP94 – [3.64] (*CH2*)		O(2) HIS113 – [3.40] (*CD2*)
	C(14) TYR116 – [3.60] (*CE2*)		O(4) HIS113 – [3.63] (*CE1*)
	C(12) TYR116 – [3.38] (*CE2*)		O(2) TYR116 – [3.25] (CB,CD2,CE2)

How to cite this article: Vikrant C S, Lalit R S, Sandip S P, Abhay S C. *In Silico* Approach to Combat HIV Using Phytoconstituents of *Moringa oleifera Lam*. J O J Immuno Virology. 2015;1(2): 555558.

Polar	pi-pi	cation-pi	Other
			CG)
			C(12) – [3.80] ARG188 (NH1,NH2)
			C(14) – [*3.57*] ARG188 (*NH2*)
			C(13) – [*3.86*] TYR255 (*OH*)
			C(15) – [*3.77*] TYR255 (*OH*)
			C(11) – [2.94] GLU288 (CD,OE1,OE2)
			C(6) – [*3.74*] GLU288 (*OE1*)
			C(13) – [*3.23*] GLU288 (*OE1*)

Table 14: Niaziminin interaction.

Hydrogen bonds	Polar	Hydrophobic	Other
N(1) – [*3.44*] GLN200 (*OE1*)	O(3) – [*3.02*] ASP97 (*OD1*)	C(11) – [*3.74*] TRP102 (*CZ3*)	O(6) – [*3.47*] TRP94 (CD2,CE3,CG)
	H(1) – [*2.13*] ASP97 (*OD1*)	C(11) – [*3.82*] CYS186 (*SG*)	H(1) – [*3.29*] ASP97 (CB,CG)
	O(2) – [*3.40*] ASP97 (*OD1*)	C(19) – [*3.50*] PHE199 (*CB*)	C(8) – [*3.13*] ASP97 (CG,OD1)
	O(6) – [*3.50*] ASP97 (*OD1*)		C(11) – [*3.32*] ASP97 (CG,OD1)
	O(4) – [*3.89*] SER285 (*OG*)		C(2) – [*3.73*] ASP97 (*OD1*)
	O(5) – [*3.77*] SER285 (*OG*)		C(18) – [*3.55*] ARG188 (*NH2*)
	H(2) – [*2.95*] SER285 (*OG*)		S(1) – [*3.34*] GLN200 (CD,NE2,OE1)
	O(4) – [*3.02*] GLU288 (*OE2*)		C(16) – [*3.48*] GLN200 (*OE1*)
			C(17) – [*3.38*] GLN200 (*OE1*)
			C(9) – [*2.90*] GLU288 (CD,OE1,OE2)
			C(7) – [*3.35*] GLU288 (*OE2*)

How to cite this article: Vikrant C S, Lalit R S, Sandip S P, Abhay S C. *In Silico* Approach to Combat HIV Using Phytoconstituents of *Moringa oleifera Lam*. J O J Immuno Virology. 2015;1(2): 555558.

Table 15: Ferulic acid interaction.

Polar	Hydrophobic	pi-pi	Cation-pi	Other
O4 (*4*) TRP94 – [*3.75*] (*NE1*)	C10 (*14*) TRP94 – [*3.58*] (*CD1, CG*)	C1 (*5*) TRP94 – [*3.68*] (*CH2, CZ2*)	H1 (*15*) HIS113 – [*3.62*] (*CD2*)	O4 (*4*) PHE93 – [*3.23*] (*CB*)
O3 (*3*) ASP97 – [*3.37*] (*OD1*)	C8 (12) TRP94 – [3.59] (*CD1,CE2*)	C4 (*8*) TRP94 – [*3.51*] (*CZ2*)	H1 (15) TYR116 – [3.72] (*CD2,CE2*)	O4 (*4*) TRP94 – [*3.29*] (*CD1, CG*)
O1 (*1*) HIS113 – [*3.74*] (*NE2*)	C7 (11) TRP94 – [3.74] (*CE2,CZ2*)	C5 (9) HIS113 – [3.05] (*CD2,CG*)		C8 (*12*) TRP94 – [*3.50*] (*NE1*)
O2 (2) ARG188 – [3.59] (*CZ, NH1,NH2*)	C10 (*14*) TRP102 – [*3.57*] (*CZ3*)	C6 (10) HIS113 – [3.27] (*CD2,CG*)		C10 (*14*) TRP94 – [*3.83*] (*NE1*)
H1 (15) ARG188 – [2.99] (*CZ, NH1,NH2*)	C8 (*12*) VAL112 – [*3.31*] (*CG2*)	C2 (*6*) HIS113 – [*3.51*] (*CD2*)		O3 (*3*) ASP97 – [*3.53*] (*CB, CG*)
O1 (*1*) ARG188 – [*3.18*] (*NH1*)	C10 (*14*) VAL112 – [*3.77*] (*CG2*)	C4 (*8*) HIS113 – [*3.88*] (*CD2*) C1 (*5*) HIS113 – [*3.89*] (*CE1*) C6 (10) TYR116 – [3.32] (*CB, CD2,CG*)		O3 (*3*) TRP102 – [*3.62*] (*CZ3*) O4 (4) TRP102 – [3.34] (*CH2,CZ3*) O4 (*4*) VAL112 – [*3.52*] (*CB, CG2*)
		C5 (*9*) TYR116 – [*3.60*] (*CD2*)		O2 (*2*) HIS113 – [*3.26*] (*CD2*) C1 (*5*) HIS113 – [*3.86*] (*NE2*) C2 (*6*) HIS113 – [*3.27*] (*NE2*) C3 (*7*) HIS113 – [*3.51*] (*NE2*) C5 (*9*) HIS113 – [*3.36*] (*NE2*) C6 (*10*) HIS113 – [*3.71*] (*NE2*) C9 (*13*) HIS113 – [*3.81*] (*NE2*)
				O2 (2) TYR116 – [3.12] (CD2,CE2, CG)
				C9 (13) ASP187 – [3.79] (OD1)
				C9 (13) ARG188 – [3.23] (NH1)

How to cite this article: Vikrant C S, Lalit R S, Sandip S P, Abhay S C. *In Silico* Approach to Combat HIV Using Phytoconstituents of *Moringa oleifera Lam*. J O J Immuno Virology. 2015;1(2): 555558.

Table 16: Vanillin interaction.

Polar	Hydrophobic	pi-pi	Other
O1 (*1*) – ASP97 [*3.43*] – (*OD1*)	C8 (*11*) – TRP94 [*3.45*] – (CE3, CZ3)	C4 (*7*) – TRP94 [*3.69*] – (CD2, CE2, CG)	O2 (*2*) – TRP94 [*3.81*] – (*CG*)
O2 (*2*) – ASP97 [*3.12*] – (*OD1*)	C7 (*10*) – TRP94 [*3.83*] – (*CZ2*)	C6 (*9*) – TRP94 [*3.46*] – (CD1, *CD2, CE2,CG)*	C5 (*8*) – TRP94 [*3.32*] – (*NE1*)
H1 (*12*) – ASP97 [*2.30*] – (*OD1*)	C5 (*8*) – VAL112 [*3.06*] – (*CB, CG2*)	C2 (*5*) – TRP94 [*3.47*] – (CE2, CZ2)	C6 (*9*) – TRP94 [*3.27*] – (*NE1*)
O3 (*3*) – HIS113 [*3.71*] – (*NE2*)	C6 (*9*) – VAL112 [*3.37*] – (*CG2*)	C5 (*8*) – TRP94 [*3.43*] – (CE2, CZ2)	O2 (*2*) – ASP97 [*3.51*] – (*CB, CG*)
	C7 (*10*) – HIS113 [*3.51*] – (CD2, CE1, CG)	C3 (*6*) – TRP94 [*3.80*] – (CH2, CZ2)	H1 (*12*) – ASP97 [*2.95*] – (*CB, CG*)
	C7 (*10*) – TYR116 [*3.72*] – (*CB*)		C8 (*11*) – ASP97 [*3.75*] – (*OD1*)
			O3 (*3*) – HIS113 [*3.41*] – (*CD2, CG*)
			C7 (*10*) – HIS113 [*3.72*] – (ND1, NE2)
			O3 (*3*) – TYR116 [*3.50*] – (CB, CD2, CG)

Table 17: 1,2,3-Cyclopentanetriol interaction.

Polar	Hydrophobic	Other
O () – ASP97 [3.00] – (OD1)	C () – TRP94 [3.46] – (CD1,CD2, CE2,CE3, CG)	O () – TRP94 [3.75] – (CE3, CG)
H () – ASP97 [2.03] – (OD1,OD2)	C () – VAL112 [3.39] – (CG2)	H () – ASP97 [2.76] – (CB, CG)
	C () – HIS113 [3.55] – (CE1)	O () – ASP97 [3.30] – (CB, CG)
	C () – CYS186 [3.55] – (SG)	C () – ASP97 [3.63] – (OD1)

How to cite this article: Vikrant C S, Lalit R S, Sandip S P, Abhay S C. *In Silico* Approach to Combat HIV Using Phytoconstituents of *Moringa oleifera Lam*. J O J Immuno Virology. 2015;1(2): 555558.

Table 18: Astragalin interaction.

Polar	Hydrophobic	pi-pi	cation-pi	Other
O4 (4) – TRP94 [3.75] (NE1)	C10 (*14*) – TRP94 [3.58] (CD1,CG)	C1 (*5*) – TRP94 [3.68] (CH2,CZ2)	H1 (*15*) – HIS113 [3.62] (CD2)	O4 (*4*) – PHE93 [3.23] (CB)
O3 (3) – ASP97 [3.37] (OD1)	TRP94 – C8 (*12*) [3.59] (CD1,CE2)	C4 (8) – TRP94 [3.51] (CZ2)	H1 (*15*) – TYR116 [3.72] (CD2,CE2)	O4 (4) – TRP94 [3.29] (CD1, CG)
O1 (1) – HIS113 [3.74] (NE2)	C7 (*11*) – TRP94 [3.74] (CE2,CZ2)	C5 (9) – HIS113 [3.05] (CD2, CG)		C8 (12) – TRP94 [3.50] (NE1)
O2 (*2*) – ARG188 [3.59] (CZ, NH1,NH2)	C10 (*14*) – TRP102 [3.57] (CZ3)	C6 (10) – HIS113 [3.27] (CD2, CG)		C10 (14) – TRP94 [3.83] (NE1)
H1(*15*) – ARG18 [2.99] (CZ, NH1,NH2)	C8 (12) – VAL112 [3.31] (CG2)	C2 (6) – HIS113 [3.51] (CD2)		O3 (3) – ASP97 [3.53] (CB, CG)
O1 (*1*) – ARG188 [3.18] (NH1)	C10 (*14*) – VAL112 [3.77] (CG2)	C4 (*8*) – HIS113 [3.88] (CD2)		O3 (*3*) – TRP102 [3.62] (CZ3)
		C1 (*5*) – HIS113 [3.89] (CE1)		O4 (4) – TRP102 [3.34] (CH2,CZ3)
		C6 (*10*) – TYR116 [3.32] (CB, CD2,CG)		O4 (4) – VAL112 [3.52] (CB, CG2)
		C5 (*9*) – TYR116 [3.60] (CD2)		O2 (*2*) – HIS113 [3.26] (CD2)
				C1 (*5*) – HIS113 [3.86] (NE2)
				C2 (*6*) – HIS113 [3.27] (NE2)
				C3 (*7*) – HIS113 [3.51] (NE2)
				C5 (*9*) – HIS113 [3.36] (NE2)

How to cite this article: Vikrant C S, Lalit R S, Sandip S P, Abhay S C. *In Silico* Approach to Combat HIV Using Phytoconstituents of *Moringa oleifera Lam*. J O J Immuno Virology. 2015;1(2): 555558.

				C6 (*10*) – HIS113 (NE2) [3.71]
				C9 (*13*) – HIS113 (NE2) [3.81]
				O2 (*2*) – TYR116 (CD2,CE2, CG) [3.12]
				(*OD1*) – ASP187 C9 (13) [3.79]
				(NH1) – ARG188 C9 (13) [3.23]

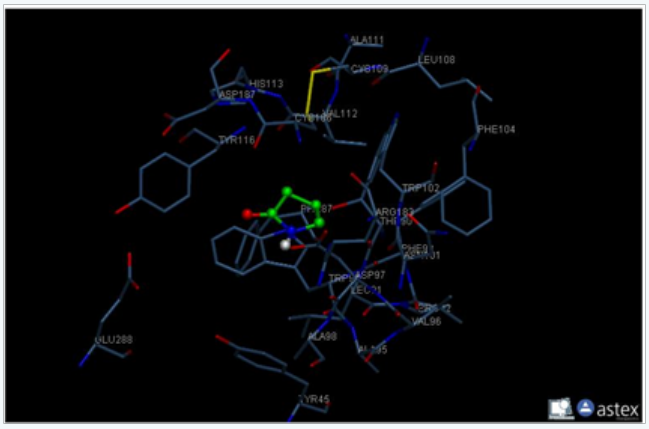


Figure 1: 2-Pyrrolidinone ball and stick model.

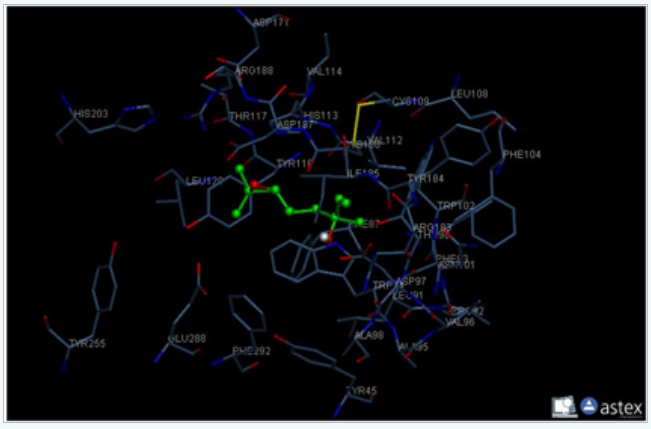
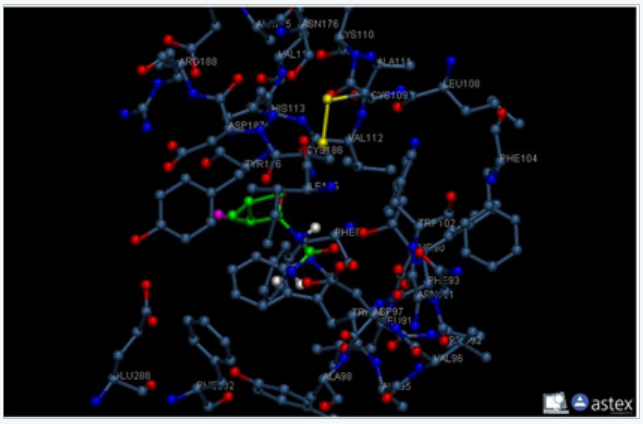


Figure 2: Linalool oxide ball and stick model.



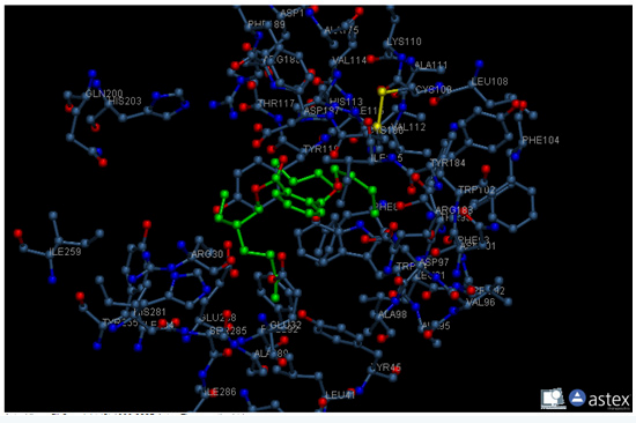


Figure 3: Upiol ball and stick model.

How to cite this article: Vikrant C S, Lalit R S, Sandip S P, Abhay S C. *In Silico* Approach to Combat HIV Using Phytoconstituents of *Moringa oleifera Lam*. J O J Immuno Virology. 2015;1(2): 555558.

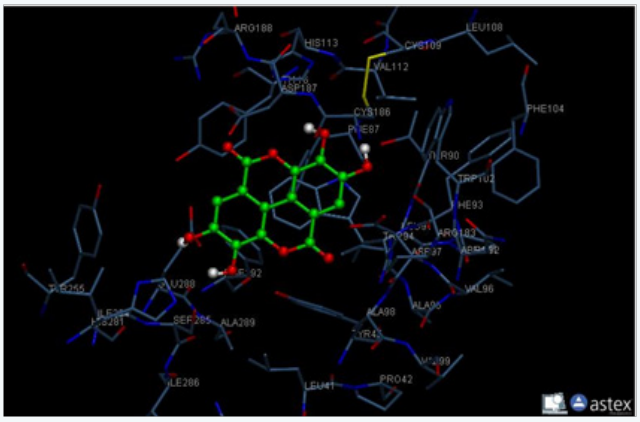


Figure 5: Ellagic acid ball and stick model.

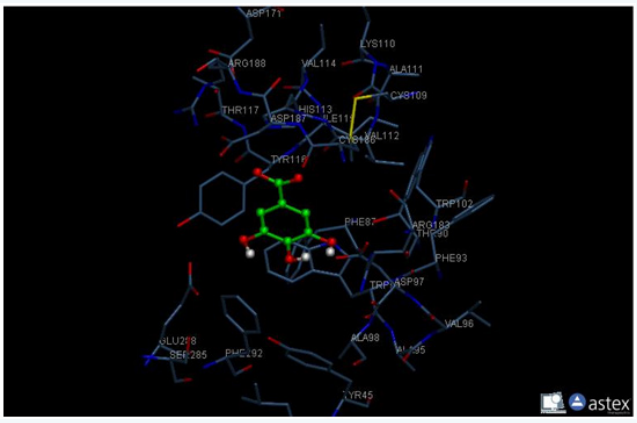


Figure 6: Gallic acid ball and stick model.

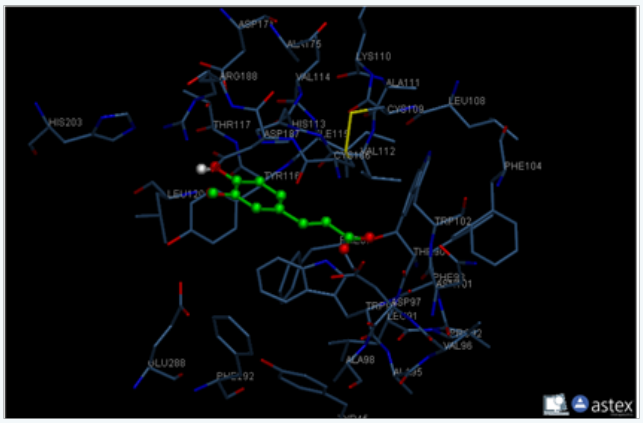


Figure 7: Ferulic acid ball and stick model.

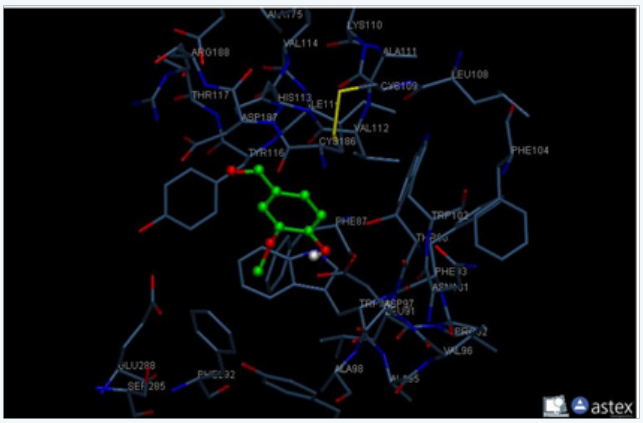


Figure 8: Vanillin ball and stick model.

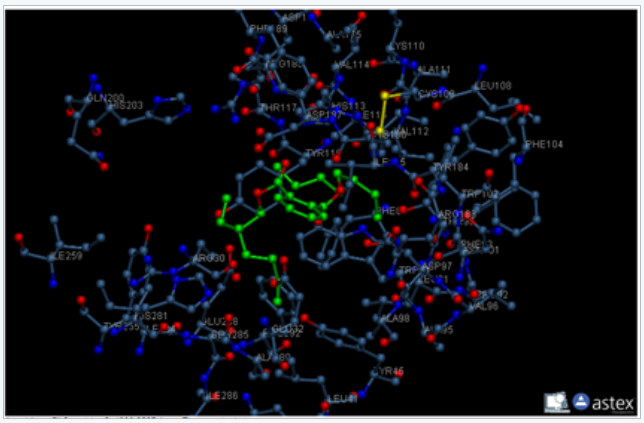


Figure 9: 1,2,3-Cyclopentanetriol ball and stick model.

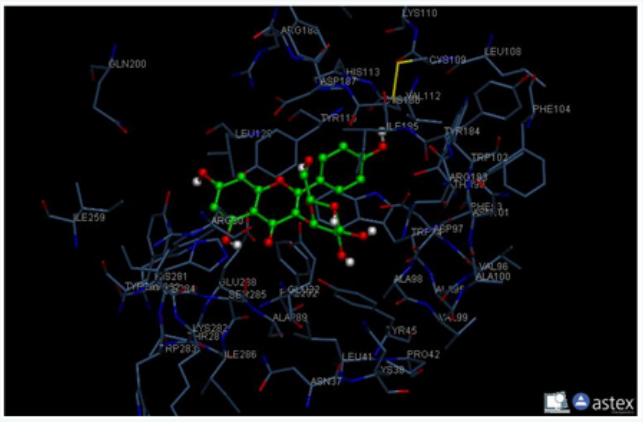


Figure 10: Astragalin ball and stick model.

How to cite this article: Vikrant C S, Lalit R S, Sandip S P, Abhay S C. *In Silico* Approach to Combat HIV Using Phytoconstituents of *Moringa oleifera Lam*. J O J Immuno Virology. 2015;1(2): 555558.

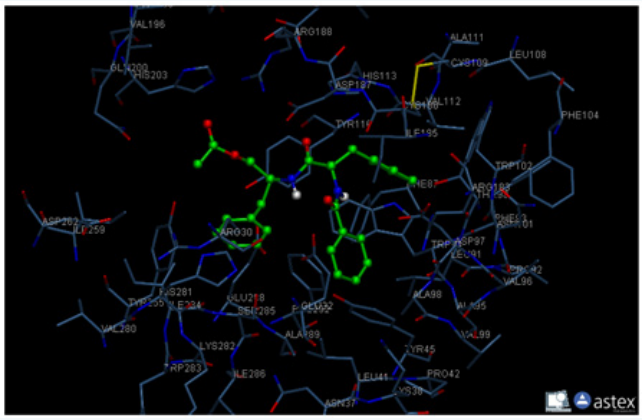


Figure 11: Aurantiamide acetate ball and stick model.

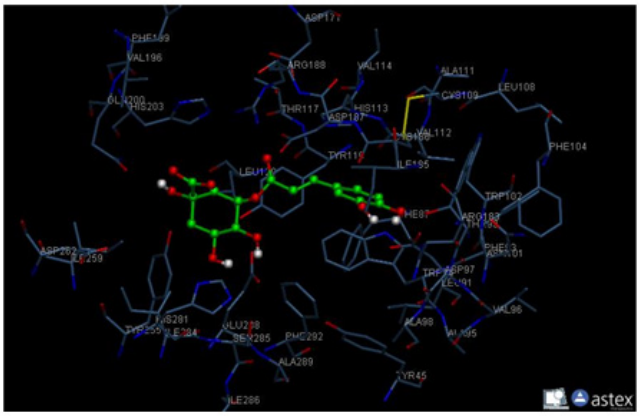


Figure 12: Chlorogenic acid ball and stick model.

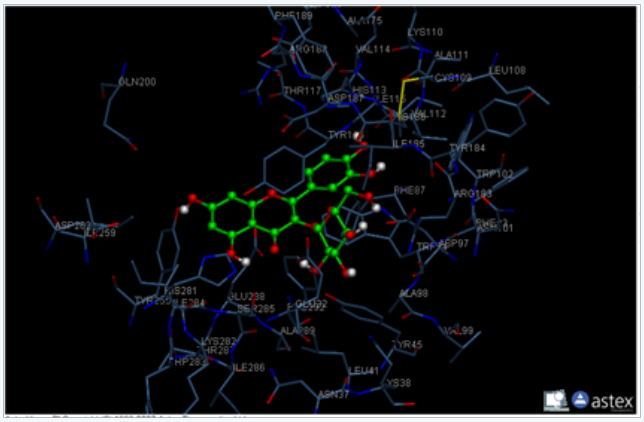


Figure 13: Isoquercetin ball and stick model.

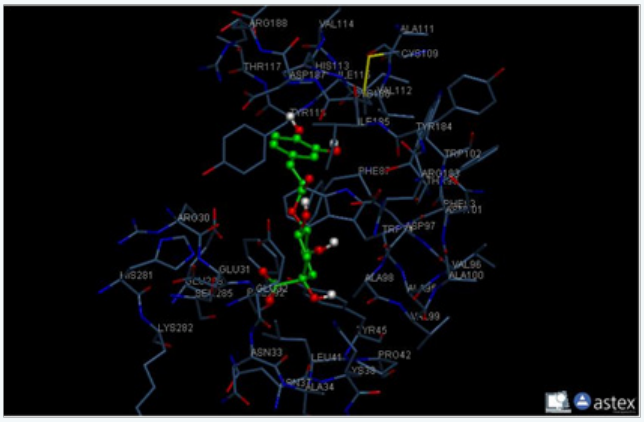


Figure 14: Crypto-chlorogenic acid ball and stick model.

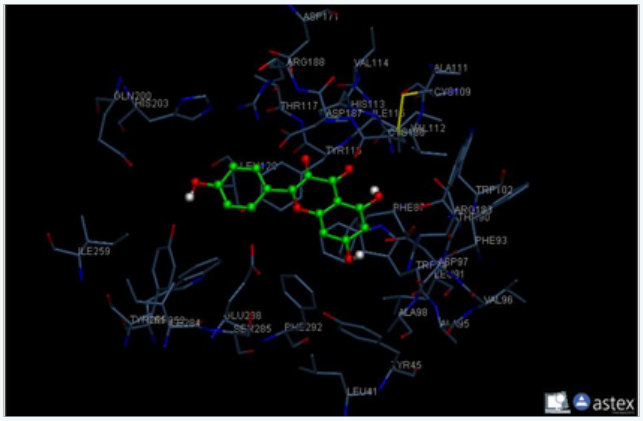


Figure 15: Kaempferol ball and stick model.

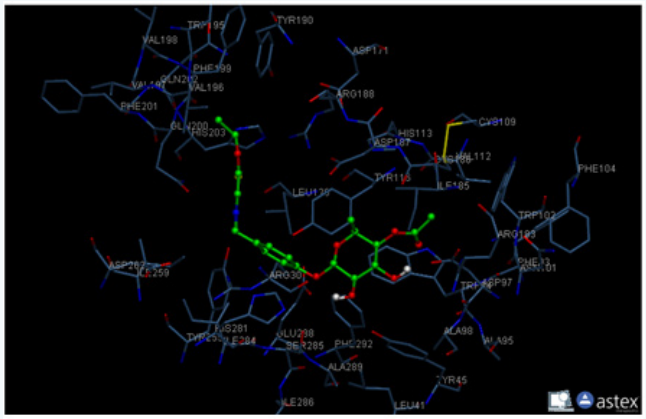


Figure 16: Niaziminin ball and stick model.

How to cite this article: Vikrant C S, Lalit R S, Sandip S P, Abhay S C. *In Silico* Approach to Combat HIV Using Phytoconstituents of *Moringa oleifera Lam*. J O J Immuno Virology. 2015;1(2): 555558.

Discussion

Moringa oleifera known for its high nutritional and therapeutic potential, only since last two decades serious efforts has been made to explore this plant scientifically. Phytochemical analyses have shown that *M. oleifra* is rich in phenolic acids, flavonoids, alkaloids, phytosterols and glycosides. These phytochemical classes contributing to its diversified pharmacological activities viz. analgesic, anti- inlammatory, antihypertensive, antioxidant, antitumor, antiarthritic, antispasmodic, antiurolithic and hepato protective, etc. In the present investigation 16 phytochemicals of *M. oleifera* were docked against CXCR4 receptor. After molecular docking study of selected phytoconstituents and considering their docking score, two compounds viz. ellagic acid and aurantiamide acetate are found to be promising candidate against the CXCR4 receptor. Literature survey has shown that ellagic acid and aurantiamide acetate contribute to diverse pharmacological properties. Ellagic acid (EA) is known to possess multiple biological activities, such as inhibition of proliferation, angiogenesis, oxidation, HIV protease and other processes involved in inflammation and carcinogenesis [20-23]. Whereas, Aurantiamide acetate showed significant anti-inflammatory / antiarthritic and analgesic activity mediated via inhibition of TNF-alpha, IL-2 and other cytokines [24]. *In vitro* and *in vivo* studies demonstrate that aurantiamide acetate may suppress the growth of human malignant gliomas via inhibiting intracellular autophagic flux [25]. From the above references and our research findings, we suggest the possibility of ellagic acid and aurantiamide acetate to develop as a CXCR4 antagonist. However, further *in vitro* and *in vivo* studies needed to validate their biological potential.

Conclusion

Based on the above discussion, we have observed that ellagic acid and aurantiamide acetate is promising candidate against the CXCR4 receptor. The results of present investigation may possibly provide the rationale behind the use of *M. oleifera* in HIV infected patients. In future, there is a great need to work on the active principles from *M. oleifera* to formulate the best alternative formulations alone or in combinations with ART drugs to increase the quality of life of patients.

Acknowledgement

Authors are grateful to the Haffkine Institute for Training, Research & Testing for providing the opportunity to conduct present investigation.

Supplementary Material

Graphical abstract.

References

1. Sharp PM, Hahn BH (2011) Origins of HIV and the AIDS Pandemic. Cold Spring Harb Perspect Med 1(1): 1-22.
2. Bombaywala MA, Hajare RA, Bakde BV, et al. NANOTECHNOLOGY-IN HIV/AIDS THERAPY. International Journal of Pharma Research and Development 2003; 2(1): 1-4.
3. http://www.who.int/gho/hiv/en/ [Last accessed on 2nd Jun 2015].
4. http://naco.gov.in/upload/2014%20mslns/NACO_English%202013-14.pdf [Last accessed on 2nd June 2015].
5. Kesarkar R, Sangar VC, Oza G, et al. (2014) Synthesis, Characterization and Hepatoprotective Activity of Neem Gold Nanoparticles for Improved Efficacy and Sustained Drug Release Profile of Azidothymidine. Int J Pharm Sci Rev Res 26(2): 117-122.
6. Ryan R, Dayaram YK, Schaible D, Coate B, Anderson D (2013) Outcomes in Older Versus Younger Patients Over 96 Weeks in HIV-1–Infected Patients Treated with Rilpivirine or Efavirenz in ECHO and THRIVE. Curr HIV Res 11(7): 570-575.
7. Tan Q, Zhu Y, Li J, Chen Z, Han GW, et al. (2013) Structure of the CCR5 chemokine receptor-HIV entry inhibitor maraviroc complex. Science 341(6152): 1387-1390.
8. Berson JF, Long D, Doranz BJ, Rucker J, Jirik FR, et al. (1996) A seven-transmembrane domain receptor involved in fusion and entry of T-cell-tropic human immunodeficiency virus type 1 strains. J Virol 70(9): 6288-6295.
9. Clercq D (2009) The AMD3100 story: the path to the discovery of a stem cell mobilizer (Mozobil). Biochem Pharmacol 77(11): 1655-1664.
10. Olson ME (2002) Combining data from DNA sequences and morphology for a phylogeny of Moringaceae (Brassicales). Syst Bot 27(1): 55-73.
11. Ramachandran C, Peter KV, Gopalakrishnan PK (1980) Drumstick (*Moringa oleifera*): a multi-purpose Indian vegetable. Econ Bot 34(3): 276-283.
12. Aslam M, Anwar F, Nadeem R, Rashid U, Kazi TG, et al. (2005) Mineral composition of *Moringa oleifera* leaves and pods from different regions of Punjab, Pakistan. Asian J Plant Sci 4: 417-421.
13. Bennett RN, Mellon FA, Foidl N, Pratt JH, Dupont MS, et al. (2003) Profiling glucosinolates and phenolics in vegetative and reproductive tissues of the multi-purpose trees *Moringa oleifera* L. (horseradish tree) and *Moringa stenopetala* L. J Agric Food Chem 51: 3546-3553.
14. Amaglo NK, Bennett RN, LoCurto RB, Rosa AS, LoTurco V, et al. (2010) Profiling selected phytochemicals and nutrients in different tissues of multipurpose tree *Moringa oleifera* L., grown in Ghana. Food Chem 2010 122(4): 1047-1054.
15. Gowrishankar R, Kumar M, Menon V, Divi SM, Saravanan M, et al. (2010) Trace element studies on *Tinospora cordifolia* (Menispermaceae), *Oci-mumsanctum* (Lamiaceae), *Moringa oleifera* (Moringaceae) and *Phyllanthus niruri* (Euphorbiaceae) using PIXE. Biol Trace Elem Res 133(3): 357-363.
16. Mbikay M (2012) Therapeutic potential of *Moringa oleifera* leaves in chronic hyperglycemia and dyslipidemia: a review. Front Pharmacol 3(24): 1-12.
17. Bikhadi Z, Hazai E (2009) Application of PM6 semi-emperical method to modelling Protein enhances docking accuracy of Autodock. J Cheminform 1: 1-15.
18. Solis FJ, Wets RJB (1981) Minimization by random search techniques. Math Oper Res 6: 19-30.
19. Upgade A, Bhaskar A, Kumarsamy P (2014) Evaluation of Natural compounds as potential drug against DENV non- structural proteins: *in silico Study.* Asian J of Biochem 9(3): 131-141.

How to cite this article: Vikrant C S, Lalit R S, Sandip S P, Abhay S C. *In Silico* Approach to Combat HIV Using Phytoconstituents of *Moringa oleifera Lam*. J O J Immuno Virology. 2015;1(2): 555558.

20. Hseu YC, Chou CW, Senthil Kumar KJ, Fu KT, Wang HM, et al. (2012) Ellagic acid protects human keratinocyte (HaCaT) cells against UVA induced oxidative stress and apoptosis through the upregulation of the HO-1 and Nrf-2 antioxidant genes. Food Chem Toxicol 50(5): 1245-1255.

21. Bae JY, Choi JS, Kang SW, Lee YJ, Park Y, et al. (2010) Dietary compound ellagic acid alleviates skin wrinkle and inflammation induced by UVB irradiation. Exp Dermatol 19(8): e182-e190.

22. Jimenez F, Mitts TF, Liu K, Wang Y, Hinek A (2006) Ellagic newly synthesized elastic fibers from premature enzymatic degradation in dermal fibroblast cultures. J Invest Dermatol 126(6): 1272-1280.

23. Nutan, Modi M, Goel T, Das T, Malik S, et al. (2013) Ellagic acid and gallic acid from *Lagerstroemia speciosa* L. inhibit HIV-1 infection through inhibition of HIV-1 protease and reverse transcriptase activity. Indian J Med Res 137: 540-548.

24. Sashidhara KV, Rosaiah JN, Tyagi E, Shukla R, Raghubir R, et al. (2009) Rare dipeptide and urea derivatives from roots of *Moringa Oleifera* as potential anti inlammatory and antinociceptive agents. Eur J Med Chem 44: 432-436.

25. Yang Y, Zhang L, Yang BX, Tian J, Zhang L (2015) Aurantiamide acetate suppresses the growth of malignant gliomas *in vitro* and *in vivo* by inhibiting autophagic flux. J Cell Mol Med 19(5): 1055-1064.

How to cite this article: Vikrant C S, Lalit R S, Sandip S P, Abhay S C. *In Silico* Approach to Combat HIV Using Phytoconstituents of *Moringa oleifera Lam*. J O J Immuno Virology. 2015;1(2): 555558.