African Scientist Vol. 25, No. 3 September 30, 2024
Printed in Nigeria

1595-6881/2023 $80.00 + 0.00

https://africansciientistjournal.org

afs2024023/25302

Cytogenotoxicity Investigation on Three Commonly Sold Antimalarial Herbal Recipes in Southwest Nigeria Using Root Mitosis *Allium cepa* and Mouse Bone Marrow Micronucleus Assays

Akinboro Akeem[1]*, Olayioye Adesanya[2] Oyelami Fikayo Mary[1], Olaniran Abdulrazaq[1], Babalola Teniola Adefunke[1], Buhari Halimat Omoloa[1], Abidoye Ayobami Ademola[1], Oyekunle Damilola Deborah[1], Adeniran Mayowa Emmanuel[1], Olawale Anuoluwapo[1] and Adedapo Sofiyat Omolara[1]

[1]Department of Pure and Applied Biology, Ladoke Akintola University of Technology, Ogbomoso, P.M.B. 4,000, Oyo State.
[2]Department of Crop and Environmental Protection, Ladoke Akintola University of Technology, Ogbomoso, P.M.B. 4,000, Oyo State.

*Corresponding author Email: aakinboro@lautech.edu.ng, +234 813 472 7845

(Received March 31, 2024; Accepted in revised form July 31, 2024)

ABSTRACT: Malaria remains a major public health concern in Nigeria and some other African countries due to the high cost of its treatment with synthetic/orthodox medicines that are even resisted by Plasmodium species. Therefore, a significant number of people are using antimalarial herbal medicines that have not been toxicologically confirmed to be safe for the prevention and treatment of malaria. This study evaluated the toxicity of three commonly consumed antimalarial herbal recipes (AHR1, AHR2, and AHR3) formulated with different plant materials following the *Allium cepa* and bone marrow micronucleus assays. The AHR1, AHR2 and AHR3 inhibited root growth in *A. cepa* and cell division as well in the two test organisms in non-concentration-dependent manner. The antimalarial herbal recipes induced chromosomes aberrations and micronucleated cells that were not concentration-related. Phytochemicals belonging to twelve different classes were qualitatively detected in each of the three antimalarial herbal recipes. It can therefore be concluded that the investigated antimalarial herbal recipes (AHR1, AHR2 and AHR3) have weak cytotoxic, genotoxic and clastogenic effects on the cell division and chromosome morphology in *A. cepa* and Swiss albino mice, suggesting mild cyto-clastogenotoxicity. Nevertheless, these results call for caution when consuming any one of these investigated antimalarial herbal recipes.

Keywords: *Allium cepa*; Antimalarial herbal recipe; chromosomal aberrations; micronucleus; phytochemicals.

Introduction

Malaria remains a major disease burden of public health concern affecting people in the tropical and subtropical countries of the world. Its fatality is mostly recorded among children of less than five years and pregnant women (Akinboro *et al*., 2021a; Tajbakhsh *et al*., 2021). *Plasmodium falciparum* is known to cause highest number of fatal cases of malaria resulting in morbidity and mortality. Sub-Saharan African countries recorded the highest number of cases and deaths from malaria. It was reported that 228, 229 and 241 million cases of malaria were recorded in 2018, 2019 and 2020, respectively, out of which 405, 000, 409, 000 and 627, 000 deaths occurred in those years (Tajbakhsh *et al*., 2021; Ezeani *et al*., 2022; Chaniad *et al*., 2023). Malaria has been treated with some synthetic or orthodox chemotherapeutics such as chloroquine, primaquine, atovaquone and doxycycline. The resistance developed against the synthetic/orthodox antimalarial drugs by malaria causing parasite

especially *P. falciparum*, and the higher cost of the orthodox antimalarial drugs as compared with readily available antimalarial herbal medicines with or without any cost implication made many people to develop an interest in the use of antimalarial herbal medicines (Akinboro *et al*., 2021b). The recommendation of artemisinin combination therapy (ACT) comprising artemether & lumefantrine, artesunate & pyronaridine, artesunate & amodiaquine, artesunate & sulfadoxine-pyrimethamine, dihydroartemisinin & piperaquine and artesunate & mefloquine by WHO was due to increase in the number of cases of Plasmodium resistance to some first-line antimalarial single therapy (Phuwajaroanpong *et al*., 2022).

The age-long usage of medicinal plants to treat malaria without emergence of resistance to the known antimalarial herbal medicines either prepared with a single plant or a combination of plants is well established. In Nigeria, several antimalarial herbal medicines with significant potency have been documented (Ezeani *et al*., 2022; Okom *et al*., 2023). Antimalarial herbal medicines, like other herbal medicines for preventing and treating many other diseases, are being sold openly on Nigerian major streets as either ready-to-take (drink) or as herbal formulations (without adding a solvent to extract phytochemicals from it at the point of its sale). These outlets for the sales of herbal medicines are patronized by many people who do not consider safety of their health as an issue of paramount importance. It is necessary and important to ensure that antimalarial herbal medicines are efficacious and safe for human consumption. Although, herbal medicines are considered an alternative source of prevention, treatment and management of diseases globally today, however, contamination of these alternative herbal medicines through the plant materials or method of preparation makes many of them unsafe for human consumption (Babandi *et al*., 2024). This study therefore aimed at evaluating toxicity of three commonly sold antimalarial herbal formulations in Southwestern Nigeria to eukaryotic cells using two genetic assays.

Materials and methods

Procurement of antimalarial herbal recipes: Three commonly patronized formulated antimalarial herbal recipes were bought from herbal sellers in 'Oja Igbo' market in Ogbomoso North Local Government, 'Gambari' market in Gambari town, Surulere North Local Council Development Authority (LCDA), and 'Oko' market, in Oko town, Surulere Local Government, Oyo State, Southwest Nigeria. The first Antimalarial Herbal Recipe 1 (AHR 1) was formulated by the herbal seller with seven dried plant materials; *Cymbopogon citratus* (leaf), *Morinda lucida* (leaf), *Enantia chlorantha* (bark), *Alstonia boonei* (bark), *Sphenocentrum jollyanum* (seed), *Zingiber officinale* (corm) and *Khaya grandifoliola* (bark), the second Antimalarial Herbal Recipe 2 (AHR 2) was formulated with four dried plant materials; *Alstonia boonei* (bark), *Nauclea latifolia* (bark), *Tetrapleura tetrapetra* (fruit) and *Enantia chlorantha* (bark), and the third Antimalarial Herbal Recipe 3 (AHR 3) was formulated with six dried plants materials; *Tetrapleura tetraptera* (fruit), *Nauclea latifolia* (bark), *Enantia chlorantha* (bark), *Khaya grandifoliola* (bark), *Ancistrophyllum secundifolium* (bark) and *Croton lobatus* (seeds).

Preparation of antimalarial herbal recipes: The first antimalarial herbal recipe 1 (AHR 1) contained 20.0 g leaf of *Cymbopogon citratus*, 9.09 g leaf of *Morinda lucida*, 56.16 g bark of *Enantia chlorantha*, 49.41 g bark of *Astonia boonei*, 91.30 g seed of *Sphenocentrum jollyanum*, 30.07 g corm of *Zingiber officinale*, 34.0 g bark of *Khaya grandifoliola*. The second antimalarial herbal recipe 2 (AHR 2) had 7.32 g bark of *Astonia boonei*, 34.57 g bark of *Nauclea latifolia*, 7.57 g fruits of *Tetrapleura tetrapetra* and 8.12 g bark of *Enantia chlorantha* and the third antimalarial herbal recipe 3 (AHR 3) was prepared with 33.76 g fruit of *Tetrapleura tetraptera*, 33.75 g bark of *Nauclea latifolia*, 13 .91 g bark of *Enantia chlorantha*, 130.91 g bark of *Khaya grandifoliola*, 51.63 g bark of *Ancistrophyllum secundifolium* and 6.70 g seeds of *Croton lobatus*. The total weights of the plant materials in each of the antimalarial herbal recipes AHR 1, AHR 2 and AHR 3 were 290.03 g, 57.58 g and 270.66 g, respectively. Distilled water was added to each of the formulated antimalarial herbal recipes in ratio 1 to 5. The volume of distilled water added to AHR 1, AHR 2 and AHR 3 was 1,450.15 mL, 187.9 mL and 1,353.3 mL, respectively. Each herbal formulation in a glass jar was steam boiled for 2 hours and allowed to cool down before filtering each of them using a clean white muslin cloth in a Whatman filter paper (No 1). The herbal recipe was then kept at 4℃ inside a refrigerator for preservation until it was needed for further experiments.

Allium cepa assay: Onions were bought from Wazo market in Ogbomoso, Oyo, Nigeria and sun-dried for 1 week. Dried scales as well as primordial roots were carefully removed, leaving the primordial root-ring intact. The onions were rinsed with clean water and water droplets were wiped off with tissue paper. The prepared herbal recipe was considered to be absolute (100.0%) concentration which was double diluted with distilled water to obtain 50.0%, 25.0% and 12.5% lower concentrations. Fifteen onions of almost equal size were suspended on each concentration of antimalarial herbal recipe in 100 ml capacity glass beakers placed in a

cupboard for 24 hours root growth to occur. Further treatments of onions for root length measurement (macroscopic effect evaluation) and harvesting of root tips for microscopic evaluation of the effects of the three antimalarial herbal recipes on *Allium cepa* were carried out as previously reported (Akinboro *et al*; 2007; Madić *et al*., 2019; Ononamadu *et al*., 2020; Akinboro *et al*., 2021; Akinboro *et al*., 2023).

Micronucleus assay: Healthy female Swiss albino mice of 8 weeks old were raised in the animal house of the Department of Pure and Applied Biology, Ladoke Akintola University of Technology, Ogbomoso. A total of forty-two mice (n = 42) were divided into six groups (n = 7 mice per group). They were orally administered with the antimalarial herbal recipe at 100.0%, 50.0%, 25.0% and 12.5% (0.1 ml / 10g body weight) daily for 48 hours, while the mice assigned to the negative and positive control groups were orally administered with distilled water and sodium azide (0.05%), respectively. The dosed mice were then sacrificed by anesthetizing them with diethylether after 48 hours of the treatment with the antimalarial herbal recipe. The femurs of the treated mice were carefully removed and their bone marrow cells were flushed out into a test tube with freshly prepared Hank's Balanced Salt Solution (HBSS), thereafter, the mixture was spun in a centrifuge at 4000 rpm (Akinboro *et al*., 2014; Akinboro *et al*., 2021). Further treatments of pelleted cells to prepare slides for cytotoxicity and micronucleus evaluations followed Akinboro *et al*. (2023).

Qualitative phytochemical analysis: The antimalarial herbal recipes were qualitatively screened for phytochemicals such as alkaloids, flavonoids, saponins, tannins, phlobatannins, quinones, phytosterols, glycosides, cardiac glycosides, proteins and amino acids, phenolic compounds, anthraquinones and leucoanthocyanins following the standard procedures (Bati *et al*., 2024; Faruq *et al*., 2024).

Statistical analysis: The obtained data were analyzed using descriptive statistics and Duncan multiple range comparison under the analysis of variance (One – way ANOVA) in the SPSS software (version 21.0). Differences in the obtained mean values were considered significant at $p<0.05$ for the indices of cytogenotoxicity measured in this study.

Results

The mitotic activity of *Allium cepa* and Swiss albino mice bone marrow cells exposed to different concentrations of AHR 1, AHR 2 and AHR 3 is represented in Figure 1. AHR 1, AHR 2 and AHR 3 at different concentrations suppressed mitosis in the cells of *A. cepa* and albino mice. This was more inhibited in the *A. cepa* than in albino mice. AHR 3 at 100.0% induced the highest mitotic inhibition in *A. cepa*. At 12.5%, AHR 1 inhibited cell division most in *A. cepa*, while AHR 3 induced the least inhibition of mitosis in the bone marrow cells of Swiss albino mice. At 25.0%, there was highest mitotic inhibition in the *A. cepa* exposed to AHR 2, however, the least mitotic inhibition was caused by AHR 1 in *A. cepa*. The *A. cepa* treated with AHR 3 at 50.0% had the least percentage dividing cells, while AHR 2 recorded the highest percentage dividing cells in the bone marrow of mice.

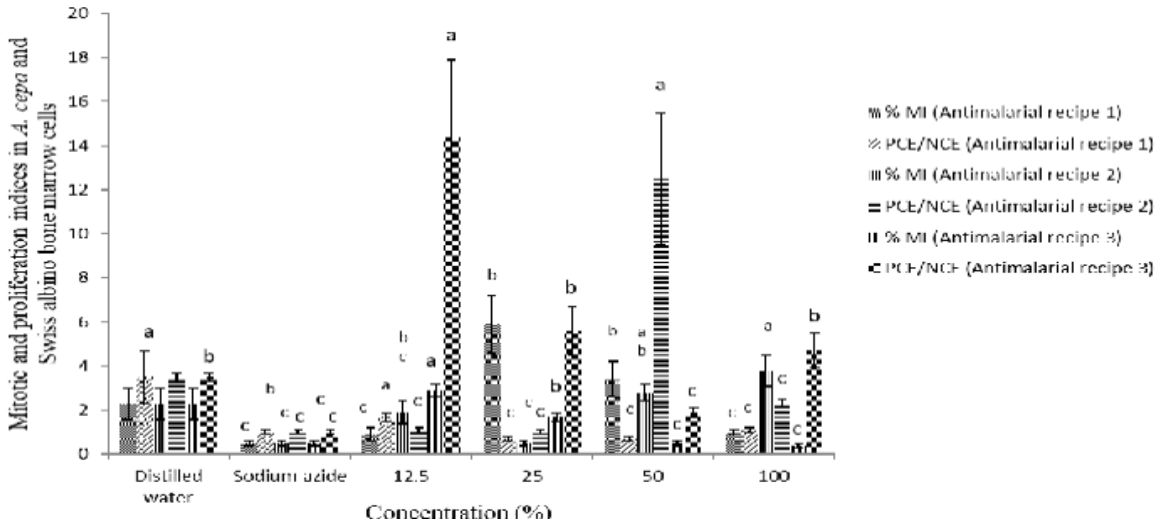

Figure 1: Effect of antimalarial herbal recipes on cell division in the root rips of *A. cepa* and bone marrow cells of Swiss albino mice

Chromosomal aberrations (CA) and micronuclei (MN) were induced in the cells of *A. cepa* and Swiss albino mice exposed to AHR 1, AHR 2 and AHR 3 (Figure 2). Distilled water induced no CA in *A. cepa* cells and 0.04% MN in the mice. Sodium azide induced 0.04 - 0.83% MN. At 12.5% concentration, AHR 1 and AHR 3 induced 3.17% CA in *A. cepa* and 2.5% MN in mice, while at 25.0% concentration it was 1.33% and 0.88% CA in *A. cepa* cells, respectively. At 50% concentration, AHR 1 induced 0.67% CA and 1.5% CA at 100.0% concentration in *A. cepa* cells.

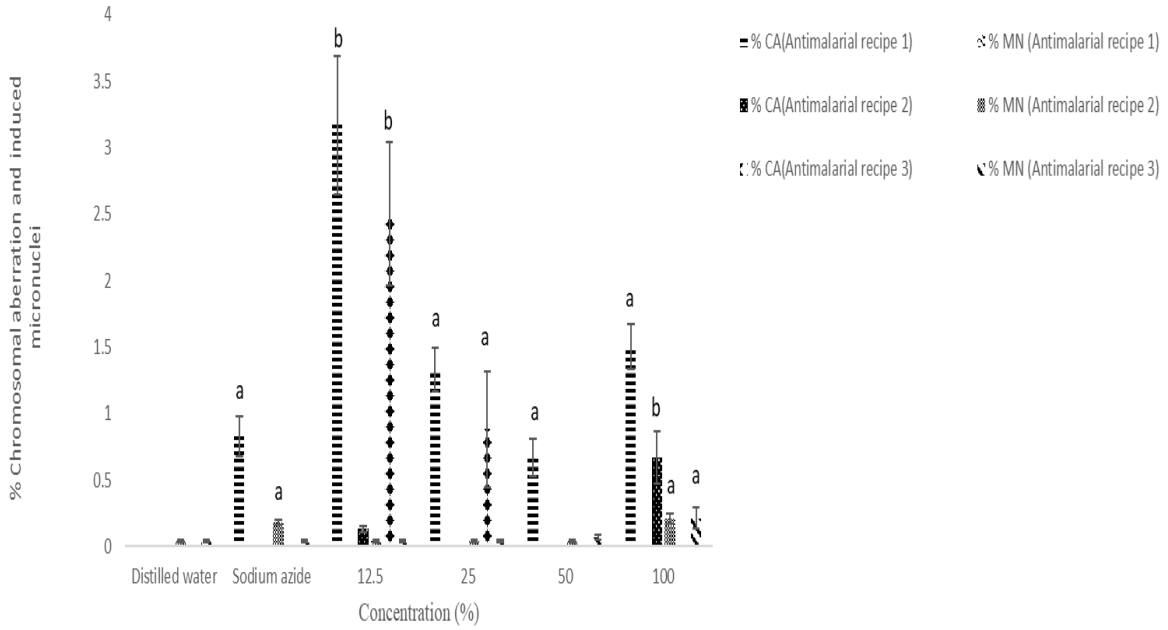

Figure 2: Induction of chromosomal aberrations in *A. cepa* and micronuclei in Swiss albino mice exposed to antimalarial herbal recipes

The root growth in *A. cepa* was inhibited by AHR 1, AHR 2 and AHR 3 (Figure 3). AHR 1 and AHR 2 inhibited *A. cepa* root growth most, while, AHR 3 caused the least root growth inhibition. The effective concentration (EC_{50}) capable of inhibiting 50% root growth of the negative control was 1.20%, 1.21% and 7.09% for AHR 1, AHR 2, and AHR 3, respectively. The order of toxicity of the antimalarial herbal recipes to the root growth of *A. cepa* is AHR 1 > AHR 2 > AHR 3.

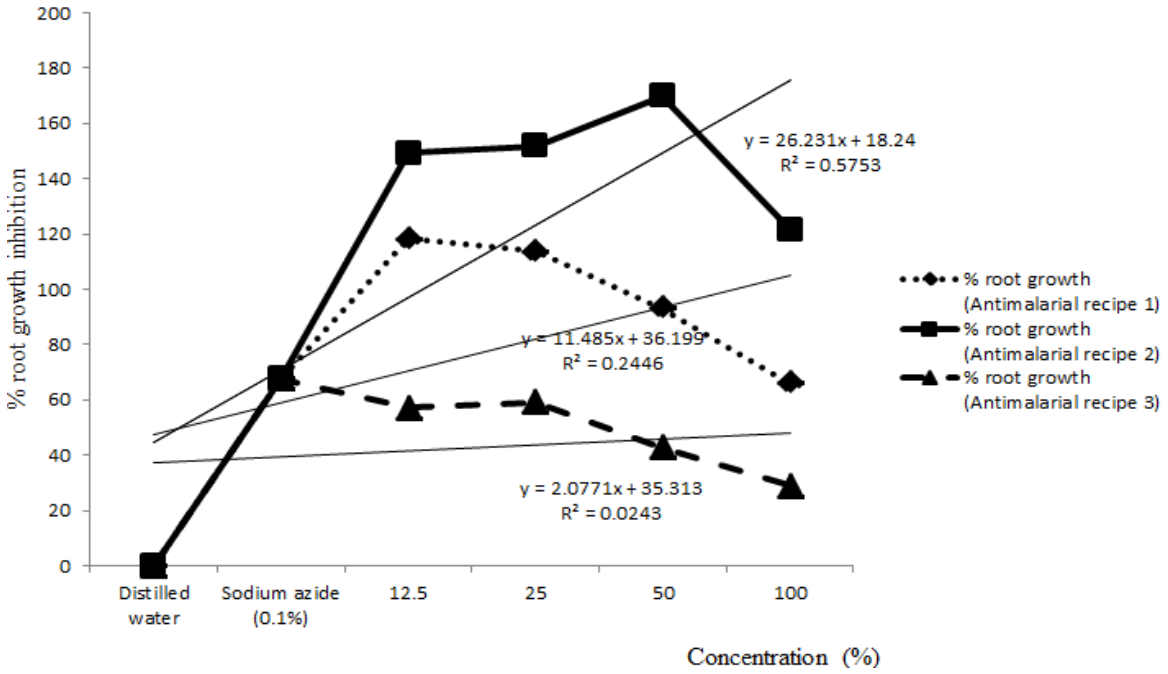

Figure 3: Activity of formulated antimalarial herbal recipes in the root growth of *A. cepa*

Table 1 shows the kind of phytochemicals qualitatively detected in the investigated antimalarial herbal recipes. AHR 1, AHR 2 and AHR 3 contained alkaloids, cardiac glycoside, proteins and amino acids, flavonoids, phenolic compounds, tannins, phlobatannins, phytosterols, quinones, anthraquinones, and saponins, while glycosides were found in AHR 2 and AHR 3 and leucoanthocyanins were detected in AHR 1 only.

Table 1: Phytochemicals qualitatively detected in the formulated antimalarial herbal recipes

Phytochemicals	**Antimalarial recipe 1 (AHR1)**	**Antimalarial recipe 2 (AHR2**	**Antimalarial recipe 3 (AHR3)**
Alkaloids	present	present	present
Glycosides	absent	present	present
Cardiac glycoside	present	present	present
Protein &amino acids	present	present	Present
Flavonoids	present	present	Present
Phenolic compounds	present	present	Present
Tannins	present	present	Present
Phlobatannins	present	present	Present
Phytosterols	present	present	Present
Quinones	present	present	Present
Anthraquinones	present	present	present
Leucoanthocyanins	present	absent	absent
Saponins	present	present	present

Discussion

The annual mortality rate from malaria has become a public health concern, considering the unsuccessful outcomes of the 'war' waged against the scourge of malarial attack in Nigeria and Africa in general. Apart from the unaffordable cost of orthodox antimalarial medications by many Nigerians due to poverty, a number of these medications are still not effective in treating malarial disease due to resistance developed to them by plasmodium species. Going by these challenges, alternative medicines of herbal origin are commonly used during malarial disease because of their better efficacy at all times without any record of resistance by plasmodium parasites, coupled with their availability with little efforts. The significant number of people using antimalarial herbal medicines that have not been certified to be safe toxicologically is a serious public health concern.

This study evaluated three commonly consumed antimalarial herbal recipes (AHR 1, AHR 2 & AHR 3) using *Allium cepa* root mitosis and bone marrow micronucleus assays to test for cytotoxicity and genotoxicity. The inhibition of mitosis in the *A. cepa* and mice bone marrow cells is an indication of mitodepressive effect of the investigated antimalarial herbal recipes. However, the mitodepressive effect of the investigated antimalarial herbal recipes was not concentration-dependent. This is a sign of weak antimitotic inhibitory activity of the herbal recipes. The ability of the three AHRs to induce more dividing cells in the test organisms than that obtained with distilled water (negative control) further confirms their mild mitotic inhibitory effect. Similar mitodepressive effect of leaves extracts of *Rubus fruticosus*, *Vaccinium myrtillus*, roots of *Potentilla erecta*, aerial part of *Geum urbanum*, and pods of *Phaseolus vulgaris* and their herbal mixture was reported (Timothy *et al*., 2014; Madić *et al*., 2019). A cytogenotoxic study using different organic extracts of *Jatropha mollisima* leaves on *A. cepa* cells and chromosomes was also reported (Dias *et al*. 2019). Mitotic index and proportion of polychromatic erythrocytes to normochromatic erythrocytes are good parameters to determine the level of cytotoxicity of chemical substances following the *A. cepa* and micronucleus assays, respectively (Akinboro *et al*., 2007; Zeyad *et al*., 2019; Akinboro *et al*., 2023). The results obtained from *A. cepa* are in good concordance with those obtained from other genetic toxicity assays, including animal models (Pesnya and Bolotov, 2022). The inhibition of root growth by the AHR 1, AHR 2 and AHR 3 in a non-concentration-dependent manner also corroborated weak cytotoxic effects of the herbal recipes. There is a direct correlation between mitotic activity and root growth. A high mitotic activity in plants is usually expected to cause an increase in root growth. The order of EC_{50} AHR1 > AHR2 > AHR3 suggests that AHR1 was most potent in term of inhibition of *A. cepa* root growth. However, AHR2 which had the least number (4) of plants in its formulation inhibited the root growth better than AHR3 which contained six constituent plants. These results further establish that the biological activity of herbal medicines depends on the kinds of phytochemicals present and interactions between them, but

not the number of plants they are formulated with. Antimitotic phytochemicals can act by antagonizing the process of mitosis at any stage in the cell cycle. The inhibition of mitosis may occur through delayed progression of cells entering the mitotic and DNA synthetic phases of the cell cycle, thereby promoting the accumulation of cells at interphase, disruption of spindle fibers leading to metaphase arrest (Raheel *et al*., 2017; Basu and Tripura, 2021). Scientific studies involving *A. cepa* assay have shown that some plant extracts that are being used as foods or, and traditional medicines contain cytotoxic, mutagenic, genotoxic and carcinogenic phytochemicals (Ihegboro *et al*., 2020). An antimalarial herbal mixture commonly sold in Kano state in Nigeria was investigated and found to contain carcinogenic constituents (Babandi *et al*., 2024).

The induction of chromosomal aberrations and micronucleated cells (in polychromatic & normochromatic erythrocytes) in *A. cepa* and Swiss albino mice bone marrow cells by the AHR1, AHR2 and AHR3 in non-concentration dependent manner suggests weak genotoxic effects. This is similar to our previous outcomes on the effect of an antimalarial herbal mixture containing leaves of *Azadirachta indica* and stem bark of *Alstonia boonei* (Akinboro *et al*., 2021). The three AHRs were formulated with plants that have been reported to possess phytochemicals with remarkable antioxidant properties. Achika *et al*. (2023) reported occurrence of flavonoids possessing antioxidant properties in some Nigerian plants used for treating malaria. These have various therapeutic effects such as anti-inflammatory, anti-diabetes, antiproliferative, cytotoxicity, antimutagenic, antigenotoxic, anti-microbial, anti-candidal, insecticidal and so on. The AHR 1, AHR 2 and AHR 3 contained flavonoids which could be free radicals (reactive oxygen species) scavengers thereby suppressing cytotoxicity, prevent oxidative stress that could lead to DNA damage, and at the same time improve DNA repair upon any eventual DNA damage (Owolarafe *et al*., 2020).

Conclusion

The investigated AHR1, AHR2 and AHR3 have weak cytotoxic and genotoxic effects on the *A. cepa* and Swiss albino mice bone marrow cells. Antioxidant phytochemicals detected in these antimalarial herbal recipes might be responsible for the observed effects in this study. However, caution should be observed in consuming these antimalarial herbal medicines either for prophylactic or curative measures. Interestingly, this study established that toxicity of medicinal herbal recipes is not a function of the number of plants they are formulated with but the kind of phytochemicals they contain.

References

Achika JI, Yusuf AJ, Ayo RG, Liman DU: Flavonoids from Nigerian indigenous medicinal plants and their bioactivities (A review). Phytomed Plus, 3: 100405. 2023.

Akinboro A, Bakare AA: Cytotoxic and genotoxic effects of aqueous extracts of five medicinal plants on *Allium cepa* Linn. J Ethnopharmacol, 112: 470–475. 2007.

Akinboro A, Mohamed KB, Asmawi MZ, Yekeen TA: Antimutagenic effects of aqueous fraction of *Myristica fragrans* (Houtt.) leaves on *Salmonella typhimurium* and *Mus musculus*. Acta Biochimi Pol, 61: (4):779-785. 2014.

Akinboro A, Rufai MA, Ogunbameru AD, Oladosu BE, Taiwo MO: Evaluation of an antimalarial herbal mixture and each extract for DNA and chromosomal mutations in Swiss albino mice and *Allium cepa* cells. Asian J Med Biol Res, 7 (3): 249-259. 2021a.

Akinboro A, Rufai MA, Adeagbo RA, Akanbi AO, Ogunkola AS, Okunola DO, Adeyeye TD, Akanbi YR: Evaluation of an antimalarial herbal recipe and its individual plant extracts for DNA fragmentation and clastogenicity potential in Swiss albino mice. Nig J Basic Appl Sci, 29(2):89-101. 2021b.

Akinboro A, Ibrahim A, Muhammed J, Oloyede H, Alimi R: Safety evaluation of an anti-haemorrhoid (pile) herbal recipe (locally called 'Agbo jedi-jedi') of Southwestern Nigeria using animal genetic assays. Toxicol Advances, 5(1):2. 2023.

Babandi A, Yussuff YM, Yakasai HM, Ya'u M, Shehu D, Ibrahim S, Abubakar N, Muhammad A, Babagana K, Abubakar SM, Abdullahi SS, Birniwa AH, Ibrahim A, Jagaba AH: Determination of heavy metals contamination, risk prediction and antioxidant properties of anti-malarial herbal mixture sold in Kano state, Nigeria. Case Stud. Chem Environ Eng, 9:100576. 2024.

Basu S, Tripura K: Differential sensitivity of *Allium cepa* L. and *Vicia faba* L. to aqueous extracts of Cascabela thevetia (L.) Lippold. S Afr J Bot, 139: 6778. 2021.

Bati K, Baeti PB, Kgakatsi NA, Majinda RRT, Gaobotse G, Kwape TE: Phytochemical screening, antioxidant, and cytotoxic activities of sequentially extracted *Euclea natalensis* leaf extracts. Sci Afr, 25: e02315. 2024.

Chaniad P, Techarang T, Phuwajaroanpong A, Plirat W, Viriyavejaku P, Septama AW, Punsawad C: Antimalarial efficacy and toxicological assessment of medicinal plant ingredients of Prabchompoothaweep remedy as a candidate for antimalarial drug development. BMC Complement Med Ther, 23:12. 2023.

Dias WLF, do Vale Junior EP, das Dores Alves de Oliveira M, Barbosa YLP, do Nascimento Silva J, da Costa Júnior JS, de Almeida, PM, Martins FA: Cytogenotoxic effect, phytochemical screening and antioxidant potential of *Jatropha mollissima* (Pohl) Baill leaves. S Afr J Bot, 123: 30–35. 2019.

Ezeani C, Ezenyi I, Erhunse N, Sahal D, Akunne T, Okoli C: Assessment of antimalarial medicinal plants used in Nigerian ethnomedicine reveals antimalarial potential of *Cucurbita pepo* leaf extract. Heliyon, 8: e09916. 2022.

Faruq MO, Rahim A, Arifuzzaman M, Ghosh GP: Phytochemicals screening, nutritional assessment and antioxidant activities of *A. viridis* L. and *A. spinosus* L. leaves: A comparative study. J Agric Food Res, 18: 101341. 2024.

Ihegboro GO, Alhassan AJ, Ononamadu Chimaobi J, Owolarafe T A, Sule MS: Evaluation of the biosafety potentials of methanol extracts/fractions of *Tapinanthus bangwensis* and *Moringa oleifera* leaves using *Allium cepa* model. Toxicol. Reports, 7: 671–679. 2020.

Madić V, Stojanović-Radić Z, Jušković M, Jugović D, Žabar Popović A, Vasiljević P: Genotoxic and antigenotoxic potential of herbal mixture and five medicinal plants used in ethnopharmacology. S Afr J Bot, 125: 290–297. 2019.

Owolarafe TA, Salawu K, Ihegboro GO, Ononamadu CJ, Alhassan AJ, Wudil AM: Investigation of cytotoxicity potential of different extracts of *Ziziphus mauritiana* (Lam) leaf *Allium cepa* model. Toxicol Reports, 7: 816–821. 2020.

Pesnya DS, Bolotov SE: Allium test genotoxicity data on water from river valley of Irtysh, West Siberia. Data Br, 41: 107861. 2022.

Phuwajaroanpong A, Chaniad P, Plirat W, Phoopha S, Septama AW, Chukaew A, Punsawad C: Antiplasmodial properties of aqueous and ethanolic extracts of ten herbal traditional recipes used in Thailand against *Plasmodium falciparum*. Trop Med Infect Dis, 7: 417, 7120417. 2022.

Raheel R, Saddiqe Z, Iram M, Afzal S: In vitro antimitotic, antiproliferative and antioxidant activity of stem bark extracts of Ficus benghalensis L. S Afr J Bot, 111: 248–257. 2017.

Sahu DK, Rai J, Rai M, Banjare MK, Nirmal M, Wani K, Sahu R, Pandey SG, Mundeja P: Detection of flonicamid insecticide in vegetable samples by UV–Visible spectrophotometer and FTIR. Results Chem, 2: 100059. 2020.

Tajbakhsh E, Kwenti TE, Kheyri P, Nezaratizade S, Lindsay DS, Khamesipour F: Antiplasmodial, antimalarial activities and toxicity of African medicinal plants: a systematic review of literature. Malar J, 20:349. 2021.

Timothy O, Idu M, Olorunfemi DI, Ovuakporie-Uvo O: Cytotoxic and genotoxic properties of leaf extract of *Icacina trichantha* Oliv. S Afr J Bot, 91:71–74. 2014.

Zeyad MT, Kumar M, Abdul M: Mutagenicity, genotoxicity and oxidative stress induced by pesticide industry wastewater using bacterial and plant bioassays. Biotech Reports, e00389. 2019.