GSC Advanced Engineering and Technology

Cross Ref DOI: 10.30574/gscaet

Journal homepage: https://gsconlinepress.com/journals/gscaet/

(RESEARCH ARTICLE)

Check for updates

Antibacterial activity of *Solanum macrocarpon* against clinically derived isolates of *Streptococcus mutans* from patients attending university of Maiduguri teaching hospital: Implantation of correlation analysis prior to mathematical and computational approaches

Adam Mustapha [1], Rabi'atu Shafiu Tijjani [1], Umar Muhammad Ghali [2,*], Shamsu Shuaibu Bala [3] and Afaf A Jibril [4]

[1] *Department of Microbiology, Faculty of Science, University of Maiduguri, PMB 1069, Maiduguri, Borno State, Nigeria.*
[2] *Department of Medical biochemistry, Near East University, Nicosia, Turkish Republic of Northern Cyprus.*
[3] *Rabiu Musa Kwankwaso College of advance and remedial studies, Tudunwada Kano, Nigeria.*
[4] *Faculty of Clinical Sciences, Bayero University, Kano 700006, Nigeria.*

GSC Advanced Engineering and Technology, 2022, 03(02), 010–017

Publication history: Received on 27February 2022; revised on 05 April 2022; accepted on 07 April 2022

Article DOI: https://doi.org/10.30574/gscaet.2022.3.2.0029

Abstract

Plants have been employed as herbal medicines in many parts of the world, and this tend to gain attention as complementary or alternative to modern medicines. This study is aimed to assess the antibacterial activity of*Solanum macrocarpon* against *Streptococcus mutans*.

Standard microbiological and biochemical techniques were used to isolates and identify *Streptococcus mutans.* The Distilled water, Ethanol, Methanol extraction were performed on different part of *Solanum macrocarpon* and tested for antibacterial activity using the Agar well diffusion method. All the extracts inhibit the growth of *Streptococcus mutans* except distilled water extract with no or little effect. The results also showed an increase in antibacterial activity with increase in concentration21 mm at 100% concentration to 4 mm of the crude extracts. This study therefore revealed that *Solanum macrocarpon*extract demonstrated greet inhibitory effect on the test organism. Thus, the result provides a basis for the traditional use of *Solanum macrocarpon* in cleaning teeth and toothache treatment.

Keywords: *Solanum macrocarpo; Streptococcus mutans;* Antibacterial; hospital; Computational approach

1 Introduction

The therapeutic value of medicinal plants have been recognized and appreciated from time [1].Traditional medicine has formed the basis upon which many modern drug isolation are derived and this is likely to continue to be so in the foreseeable future [1]. Medicinal plant is any plant, which in one or more of its organ contains substances that can be used for the therapeutic purposes or which, are precursors for the synthesis of useful drugs[2], [3]. This definition distinguishes those plants whose therapeutic properties and constituents have been established scientifically and plants that are regarded as medicinal but which have not yet been subjected to thorough investigation [1]. Plants and plant products with medicinal values have been used in many different forms and states to complement the conventional form of healthcare provision since antiquity in many parts of the world [4].

Solanum macrocarpon is a plant of the family *Solanaceae* like tomato, pepper and eggplant [5]. The botanical genus includes herbaceous plants or shrubs; leaves are usually alternate, sometimes opposite. The inflorescence is a cyme, usually single seed. The flowers are hermaphrodite, with star-shape corolla with five petals often returned back. The

*Corresponding author: U.M GHALI
Department of Medical biochemistry, Near East University, Nicosia, Turkish Republic of Northern Cyprus.

choice of *S. macrocarpon* by this study is justified by the fact that whereas it's nutritional properties as a vegetable are beneficial to the consumers [5]. In Nigeria, the fruits are eaten as laxatives and also chewed for cleaning the teeth. Their uses in indigenous medicine range from weight reduction to treatment of several ailments including asthma, allergic rhinitis, nasal catarrh, skin infections, rheumatic disease and swollen joint pains, gastro-esophageal reflux disease, constipation, dyspepsia[6]. It has the following co mmon names Gorongo in Kanuri, Gboma in Fon. Thus,the aim of this study is for the detection of antibacterial activity of *Solanum macrocarpon* on clinically derived *Streptococcus mutans*.

2 Material and methods

Solanum macrocarpon which is a plant used for cleaning of the teeth (Gorongo) was used on oral pathogen collected from patients attending Dental unit University of Maiduguri Teaching Hospital, Nigeria. The sample collected was tooth swab from one patient diagnosed with dental caries. The research was carried out in Department of Microbiology, University of Maiduguri in June 2021. The sample was collected using a sterile swab stick from the carious region of the teeth. The swab was then returned to its container, labeled and taken to the laboratory.

Solanum macrocarpon was purchased from a local market in Maiduguri, Borno State, Nigeria. Aqueous extraction was performed following the method of [7]where the dried extracts (Stem, Root, Leaves and stem) were blended into a fine powder using mortar and pestle. 20kg of each powdered plant materials were mixed with 100 ml of solvents (Distilled water, Ethanol, Methanol solution). The *Solanum macrocarpon* extract preparation were done as previously described by [8]. They were then allowed to soak for 24hrs at 60°C on a shaking water bath.

2.1 Culture Technique

Streak plate method for isolating pure culture of single specie was used. The swab was smeared on a small section at the edge of the agar plate. A sterile loop was used to drag through the swab-smeared area and streaking the area not inoculated for discrete colonies. blood Agar was used and observations were made by checking each plate for growth of bacterial colonies after 24hrs at 37°C of incubation period. Gram staining was done according to standard staining protocol [9].

3 Results of Biochemical Test

3.1 Catalase Test

A loopful of a bacterial culture was smeared onto a drop of hydrogen peroxide on a clean, grease-free slide. No gas bubble from the culture indicates a negative reaction. Other basic biochemical tests such as Capsule, oxidase and urase were done according to [9].

3.2 Phytochemical Screening of Plant Extract

Phytochemical screening of extract was based on methods described by [10]with some modifications. In this method, phytochemical screening was conducted to quantitatively determine the presence or absence of the following phytochemical in *Solanum macrocarpon* (Gorongo) (Root, Stem, Leaves and Seed) respectively. These are; Alkaloid, Tannin, Saponin, Flavonoid, Cardial glycoside, Volatile oil, Steroid. The quantitative screening was done in accordance with the standard procedure.

Table 1 Phytochemical analysis of *Solanum macrocarpon* root (Gorongo)

Root				
S/N	**Phyto Constituent**	**Methanol**	**Ethanol**	**Distilled Water**
1	Flavonoid	Negative (-)	Positive (+)	Negative (-)
2	Saponin	Negative (-)	Negative (-)	Negative (-)
3	Tannin	Negative (-)	Negative (-)	Negative (-)
4	Alkaloid	Positive (+)	Positive (+)	Positive (+)
5	Cardial glycoside	Negative (-)	Positive (+)	Positive (+)
6	Volatile oil	Negative (-)	Positive (+)	Negative (-)
7	Steroid	Negative (-)	Negative (-)	Positive (+)

3.3 Antibiotics Sensitivity Studies

The antibacterial activity testing was done by inoculating of isolates (agar well diffusion) were prepared by streaking the organisms on Mueller-Hilton agar plates as described [11] with slight modifications.

The result of phytochemical analysis of Stem of *Solanum macrocarpon* (Gorongo) is presented in Table 2.

Table 1 Phytochemical analysis of *Solanum macrocarpon* root (Gorongo)

Root				
S/N	**Phyto Constituent**	**Methanol**	**Ethanol**	**Distilled Water**
1	Flavonoid	Negative (-)	Positive (+)	Negative (-)
2	Saponin	Negative (-)	Negative (-)	Negative (-)
3	Tannin	Negative (-)	Negative (-)	Negative (-)
4	Alkaloid	Positive (+)	Positive (+)	Positive (+)
5	Cardial glycoside	Negative (-)	Positive (+)	Positive (+)
6	Volatile oil	Negative (-)	Positive (+)	Negative (-)
7	Steroid	Negative (-)	Negative (-)	Positive (+)

Table 2 Phytochemical analysis of *Solanum macrocarpon* stem (Gorongo)

Stem				
S/N	**Phyto Constituent**	**Methanol**	**Ethanol**	**Distilled Water**
1	Flavonoid	Negative (-)	Negative (-)	Negative (-)
2	Saponin	Negative (-)	Negative (-)	Negative (-)
3	Tannin	Positive (+)	Positive (+)	Negative (-)
4	Alkaloid	Positive (+)	Positive (+)	Positive (+)
5	Cardial glycoside	Positive (+)	Negative (-)	Negative (-)
6	Volatile oil	Negative (-)	Negative (-)	Negative (-)
7	Steroid	Positive (+)	Negative (-)	Positive (+)

The phytochemical analysis of leaves of *Solanum macrocarpon* shows the following results in Table 3.

Table 3 Phytochemical analysis of *Solanum macrocarpon* leaves (Gorongo)

Leaves				
S/N	**Phyto Constituent**	**Methanol**	**Ethanol**	**Distilled Water**
1	Flavonoid	Negative (-)	Negative (-)	Positive (+)
2	Saponin	Negative (-)	Negative (-)	Positive (+)
3	Tannin	Positive (+)	Positive (+)	Negative (-)
4	Alkaloid	Negative (-)	Positive (+)	Positive (+)
5	Cardial glycoside	Positive (+)	Positive (+)	Positive (+)
6	Volatile oil	Negative (-)	Negative (-)	Negative (-)
7	Steroid	Negative (-)	Negative (-)	Negative (-)

The plant phytochemical of the seeds with different solvents shows the following results in Table 4.

Table 4 Phytochemical analysis of *Solanum macrocarpon* seed (Gorongo)

Seed				
S/N	**Phyto Constituent**	**Methanol**	**Ethanol**	**Distilled Water**
1	Flavonoid	Positive (+)	Positive (+)	Positive (+)
2	Saponin	Negative (-)	Negative (-)	Positive (+)
3	Tannin	Positive (+)	Positive (+)	Positive (+)
4	Alkaloid	Positive (+)	Positive (+)	Positive (+)
5	Cardial glycoside	Positive (+)	Positive (+)	Positive (+)
6	Volatile oil	Negative (-)	Negative (-)	Negative (-)
7	Steroid	Positive (+)	Negative (-)	Negative (-)

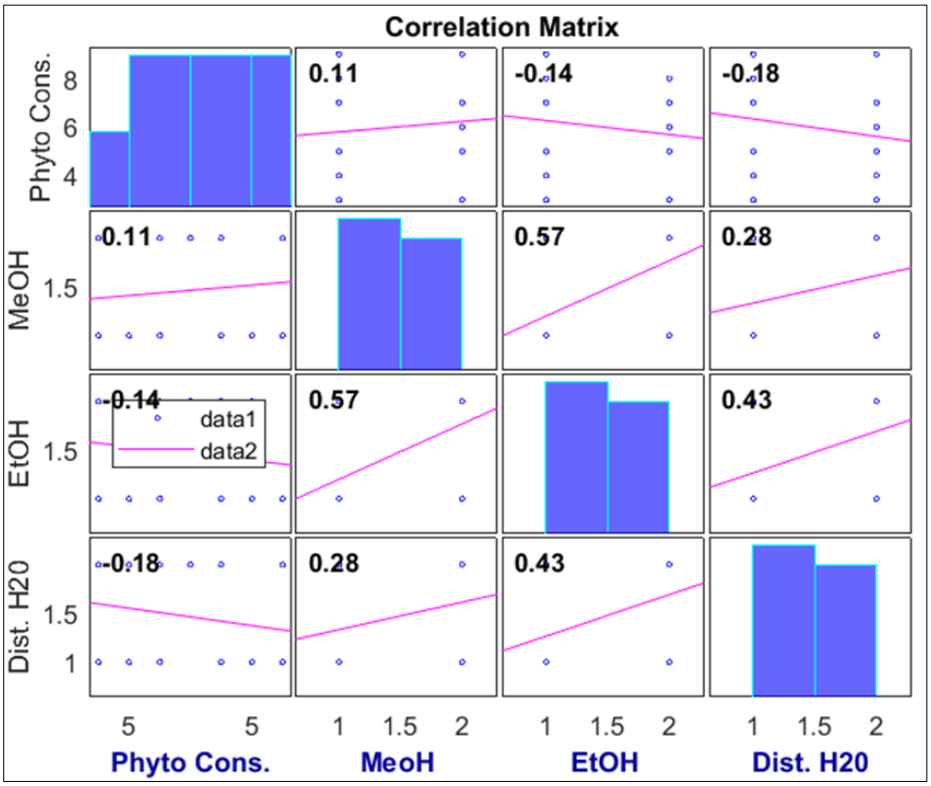

Figure 1 Correlation matrix of the phytochemical constituents with the respective solvents used during their extraction

Table 5 Sensitivity Patterns of Zone of Inhibition of *Solanum Macrocarpon* at Different Concentrations

Sensitivity Patterns of Zone of Inhibition of Methanol				
Concentration	**Leaves**	**Seed**	**Stem**	**Root**
100%	21 mm	0 mm	10 mm	5 mm
75%	15 mm	10 mm	15 mm	5 mm
50%	13 mm	15 mm	16 mm	7 mm
25%	10 mm	19 mm	16 mm	10 mm

Sensitivity Patterns of Zone of Inhibition of Ethanol				
Concentration	**Leaves**	**Seed**	**Stem**	**Root**
100%	10 mm	15 mm	20 mm	10 mm
75%	5 mm	10 mm	15 mm	10 mm
50%	5 mm	10 mm	15 mm	5 mm
25%	4 mm	8 mm	15 mm	4 mm
Sensitivity Patterns of Zone of Inhibition of Distilled water				
Concentration	**Leaves**	**Seed**	**Stem**	**Root**
100%	0.0 mm	0.0 mm	15 mm	15 mm
75%	0.0 mm	0.0 mm	13 mm	11 mm
50%	0.0 mm	0.0 mm	10 mm	10 mm
25%	0.0 mm	0.0 mm	5 mm	19 mm

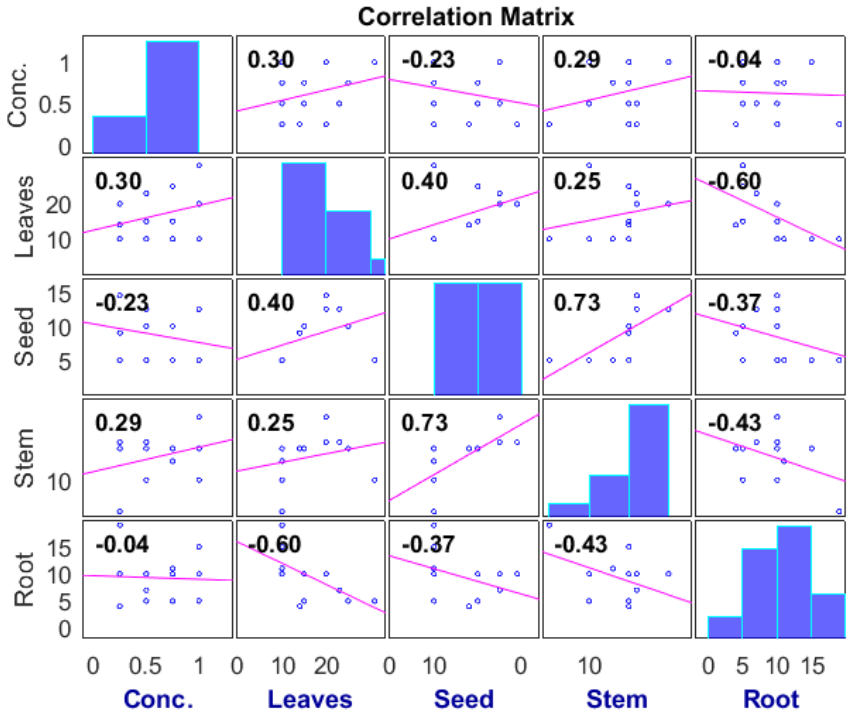

Figure 2 Correlation matrix based on the concentration against the sensitivity Patterns of Zone

4 Discussion

In this study, the phytochemical and antibacterial activity of *Solanum macrocarpon* on *Streptococcus mutans* was determined. Plants as natural sources of antimicrobials have long been in history due to the presence of excellent compounds that have no or less side effects [2]. In Nigeria, the plants serve many purposes including laxative, crushed to treat toothaches and chewed as teeth cleaning fruits.

The correlation matrix demonstrated in Figure 1 indicates the relationship between the solvents used in the extraction with the extracted phytochemical constituents. Based on that it can be observed that the extracted phytochemicals showed negative weak correlation with distilled water = -0.18 and Ethanol = -0.14. More also, the phytochemical constituents showed a weak positive relationship with methanol. Mathematically, this indicates that the extractions of

the phytochemicals have direct affinity with methanol than other solvents. This result is related to other finding in the literature in [12]–[23]. Furthermore, methanol and ethanol showed strong relationship with a correlation co-efficient value of 0.57. This can be attributed due to the fact that they are all under the same family.

The result obtained from this study showed that the ethanol extract of the *S*. *macrocarpon* showed clear zone of inhibition on Mueller Hinton agar plate but distilled water extract showed no zone of inhibition on the tested organism on Mueller Hinton agar plate.

More also, Figure 2 depicts the correlation co-efficient of the sensitivity patterns of zone of inhibition of the different parts of the plant; leaves, seed, stem and root with the concentration. Based on Figure 2, it can be observed that the sensitivity patterns of zone of inhibition of the root and seed showed weak negative relationship with the percentage concentration. While the stem and leaves parts of the plant showed weak positive relationship with the percentage concentration. This kind of analysis are done prior to any mathematical modelling process in order to understand the relationship between various variables. More studies that involves correlation analysis can be found in [22], [24]–[33].

Phytochemical screening of extracts was based on methods described by Trease& Evans (1983) with some modifications. In this method, phytochemical screening was conducted to quantitatively determine the presence or absence of the following phytochemical in Solanum macrocarpon (Root, Stem, Leaves and Seed) respectively. These are; Alkaloid, Tannin, Saponin, Flavonoid, Cardial glycoside, Volatile oil, Steroid. The quantitative screening was done in accordance with the standard procedure. The presence of the secondary metabolites is responsible for the antibacterial activity against the oral pathogen. This observation is similar to the work of [7] where *Salvadorapersica* against oral pathogens and use in oral health hygiene. The result show that when flavonoid is combine with Sodium hydroxide and extract and it shows yellow color the result is positive, for Saponin, distilled water and extract were combined no bubbling was observed it shows that the result is negative, for Tanin , ferric chloride and extract are combine it shows a dark green color which shows that the result is positive, for Alkaoid, wagner reagent and extract are combine it shows reddish brown color which shows that the result is positive, for cardial glycoside, extract, ferric chloride and H_2so_4 were combine and it shows reddish brown layer which shows that the result is positive.

Flavonoids is an integral phytochemical constituent of higher plant. They have anti-oxidant potentials hence could offer protection against cancer probably by enhancing the body defense against pathology- induced free radicals generation. The presence of steroids in *Solanum macrocarpon* extract observed in the present study also attests to the possible efficacy of therapeutic use of *Solanum macrocarpon.* Steroidal compound is of important and interest in pharmacy. Earlier it was noted that the potential of alkaloids as effective drugs and associated to the sedative properties and powerful effects on the nervous system hence the moderate to abundance of alkaloid support the efficacy of the use of *Solanum macrocarpon* in ethno-medicinal practice. Tannins (polyphenols with widely varying chemistry) are one of the major phytochemicals found in many higher plants. Tannins could have a beneficial effect on vascular health. They are useful as an anti-inflammatory agent. For human consumption, excess of tannins could be toxics. This is because tannins are metal ions chelators and tannins-chelated metals ions are not bioavailable hence could decrease the bioavailability of iron leading to anemia.

The activity of the compounds in this plant holds a potential of application in tooth pastes and treatment of oral pathogens as in shown in this study. High antibacterial activity is observed in ethanol and methanol extracts in all parts of the plants except distilled water extraction with mild activity from compound in stem and roots.

5 Conclusion

The findings suggest that *Solanum macrocarpon* may also have a selective inhibitory effect on the level of certain bacteria in saliva, especially several oral *Streptococcus* species. From this study, it can be concluded that *S. macrocarpon* extract has high antibacterial activity on oral pathogen, particularly *S. mutans* and also *S. macrocarpon* ethanol extract of the seed showed higher efficacy on oral bacteria than the water extract. The result obtained from the phytochemical analysis revealed the presence of alkaloid, cardiac glycoside, flavonoid, steroids and tannins in the ethanol extract of the dried seed of *Solanum macrocarpon*. The result of the sensitivity against the selected microorganism shows the zones of inhibition indicating activity against the test microorganism.Thus, its medical properties should be explored and assessed. This investigation has created the possibility of use of these plants in drug development for human consumption. However, the effects of these plants on more pathogenic organisms and toxicological investigations need to be carried out.

Compliance with ethical standards

Acknowledgments

Authors are grateful to University of Maiduguri Teaching Hospital and the relevant articles cited in this manuscript.

Disclosure of conflict of interest

Authors declare no known competing interest.

References

[1] A. Mustapha and N. Balaman, Anti-bacterial Activity of Salvadora Persica (chewing stick) On Streptococcus Mutans Isolate From Patients Attending University Of Maiduguri Teaching Hospital Dental unit ., pp. 715–717, 2017.

[2] M. Abiala, J. Olayiwola, O. Babatunde, O. Aiyelaagbe, and S. Akinyemi, Evaluation of therapeutic potentials of plant extracts against poultry bacteria threatening public health, *BMC Complement. Altern. Med.*, vol. 16, no. 1, pp. 1–8, 2016, doi: 10.1186/s12906-016-1399-z.

[3] E. Barbi *et al.*, Incidenza e storia naturale della PFAPA in Friuli-Venezia Giulia: Una ricerca collaborativa dei PdF, *Med. e Bambino*, vol. 20, no. 4, pp. 234–238, Apr. 2001.

[4] O. O. Oluwasina, I. V. Ezenwosu, C. O. Ogidi, and V. O. Oyetayo, Antimicrobial potential of toothpaste formulated from extracts of Syzygium aromaticum, Dennettia tripetala and Jatropha curcas latex against some oral pathogenic microorganisms, *AMB Express*, vol. 9, no. 1, 2019, doi: 10.1186/s13568-019-0744-2.

[5] G. Oboh, M. M. Ekperigin, and M. I. Kazeem, Nutritional and haemolytic properties of eggplants (Solanum macrocarpon) leaves, *J. Food Compos. Anal.*, vol. 18, no. 2–3, pp. 153–160, 2005, doi: 10.1016/j.jfca.2003.12.013.

[6] K. L. Brown *et al.*, Profile of blood cells and infla mmatory mediators in periodic fever, aphthous stomatitis, pharyngitis and adenitis (PFAPA) syndrome, *BMC Pediatr.*, vol. 10, Sep. 2010, doi: 10.1186/1471-2431-10-65.

[7] K. Almas, The effect of Salvadora Persica extract (miswak) and chlorahexidinegluconate on human dentin: A SEM study, *J. Contemp. Dent. Pract.*, vol. 3, no. 3, pp. 33–42, 2002, doi: 10.5005/jcdp-3-3-27.

[8] O. Aboaba and A. Ezeh, Antimicrobial activities of some Nigerian spices on some pathogens, *Agric. Biol. J. North Am.*, vol. 2, no. 8, pp. 1187–1193, 2011, doi: 10.5251/abjna.2011.2.8.1187.1193.

[9] A. L. Coykendall, Four types of Streptococcus mutans based on their genetic, antigenic and biochemical characteristics, *J. Gen. Microbiol.*, vol. 83, no. 2, pp. 327–338, 1974, doi: 10.1099/00221287-83-2-327.

[10] Oboh G ., Ekperigin , M . M ., and M . I . Kazeem , (2005). Nutritional and haemolytic properties of eggplants (Solanum macrocarpon) leaves , Journal of Food Composition and Analysis . 18 (2-, vol. 4, no. 2017, p. 221287, 2019, doi: 10.1099/00221287-83-2-327.Trease.

[11] B. Lemaitre, E. Nicolas, L. Michaut, J. M. Reichhart, and J. A. Hoffmann, The dorsoventral regulatory gene cassette spatzle/Toll/Cactus controls the potent antifungal response in Drosophila adults, *Cell*, vol. 86, no. 6, pp. 973–983, Sep. 1996, doi: 10.1016/S0092-8674(00)80172-5.

[12] A. G. USMAN, S. IŞIK, S. I. ABBA, and F. MERİÇLİ, Artificial intelligence–based models for the qualitative and quantitative prediction of a phytochemical compound using HPLC method, *Turkish J. Chem.*, vol. 44, no. 5, pp. 1339–1351, 2020, doi: 10.3906/kim-2003-6.

[13] A. G. U. Selin and I. S. I. Abba, A Novel Multi - model Data - Driven Ensemble Technique for the Prediction of Retention Factor in HPLC Method Development, *Chromatographia*, no. 0123456789, 2020, doi: 10.1007/s10337-020-03912-0.

[14] S. I. Abba, A. G. Usman, and S. Işik, Simulation for response surface in the HPLC optimization method development using artificial intelligence models: A data-driven approach, *Chemom. Intell. Lab. Syst.*, p. 104007, 2020, doi: 10.1016/j.chemolab.2020.104007.

[15] S. I. Abba *et al.*, Comparative implementation between neuro-emotional genetic algorithm and novel ensemble computing techniques for modelling dissolved oxygen concentration, *Hydrol. Sci. J.*, vol. 66, no. 10, pp. 1584–1596, 2021, doi: 10.1080/02626667.2021.1937179.

[16] S. I. Abba *et al.*, Emerging evolutionary algorithm integrated with kernel principal component analysis for modeling the performance of a water treatment plant, *J. Water Process Eng.*, vol. 33, no. October 2019, p. 101081, 2020, doi: 10.1016/j.jwpe.2019.101081.

[17] K. Mahmoud *et al.*, Prediction of the effects of environmental factors towards COVID-19 outbreak using AI-based models, *IAES Int. J. Artif. Intell.*, vol. 10, no. 1, pp. 35–42, 2021, doi: 10.11591/ijai.v10.i1.pp35-42.

[18] A. G. Usman, S. Işik, S. I. Abba, and F. Meriçli, Chemometrics-based models hyphenated with ensemble machine learning for retention time simulation of isoquercitrin in Coriander sativum L. using high-performance liquid chromatography, *J. Sep. Sci.*, no. December 2020, pp. 1–7, 2021, doi: 10.1002/jssc.202000890.

[19] W. Asnake Metekia, A. Garba Usman, B. Hatice Ulusoy, S. Isah Abba, and K. Chirkena Bali, Artificial intelligence-based approaches for modeling the effects of spirulina growth mediums on total phenolic compounds, *Saudi J. Biol. Sci.*, no. xxxx, 2021, doi: 10.1016/j.sjbs.2021.09.055.

[20] A. G. Usman, M. H. Ahmad, R. N. Danraka, and S. I. Abba, The effect of ethanolic leaves extract of Hymenodictyon floribundun on inflammatory biomarkers: a data-driven approach, *Bull. Natl. Res. Cent.*, vol. 45, no. 1, 2021, doi: 10.1186/s42269-021-00586-y.

[21] U. M. Ghali *et al.*, Advanced chromatographic technique for performance simulation of anti-Alzheimer agent: an ensemble machine learning approach, *SN Appl. Sci.*, vol. 2, no. 11, 2020, doi: 10.1007/s42452-020-03690-2.

[22] U. M. Ghali, M. Alhosen, A. Degm, A. N. Alsharksi, Q. Hoti, and A. G. Usman, Development Of Computational Intelligence Algorithms For Modelling The Performance Of Humanin And Its Derivatives In HPLC Optimization Method Development, vol. 9, no. 08, pp. 110–117, 2020.

[23] M. H. Ahmad, A. G. Usman, and S. I. Abba, Comparative performance of extreme learning machine and Hammerstein–Weiner models for modelling the intestinal hyper-motility and secretory inhibitory effects of methanolic leaf extract of Combretumhypopilinum Diels (Combretaceae), *Silico Pharmacol.*, vol. 9, no. 1, 2021, doi: 10.1007/s40203-021-00090-1.

[24] S. I. Haruna *et al.*, Compressive Strength of Self-Compacting Concrete Modified with Rice Husk Ash and Calcium Carbide Waste Modeling: A Feasibility of Emerging Emotional Intelligent Model (EANN) Versus Traditional FFNN, *Arab. J. Sci. Eng.*, vol. 46, no. 11, pp. 11207–11222, 2021, doi: 10.1007/s13369-021-05715-3.

[25] H. U. Abdullahi, A. G. Usman, S. I. Abba, and H. U. Abdullahi, Modelling the Absorbance of a Bioactive Compound in HPLC Method using Artificial Neural Network and Multilinear Regression Methods, *Dutse J. Pure Appl. Sci.*, vol. 6, no. 2, 2020.

[26] H. U. Abdullahi, A. G. Usman, and S. I. Abba, Modelling the Absorbance of a Bioactive Compound in HPLC Method using Artificial Neural Network and Multilinear Regression Methods, vol. 6, no. 2, pp. 362–371, 2020.

[27] M. Benaafi, M. A. Yassin, A. G. Usman, and S. I. Abba, Neurocomputing Modelling of Hydrochemical and Physical Properties of Groundwater Coupled with Spatial Clustering , GIS , and Statistical Techniques, 2022.

[28] G. M. Khalid and A. G. Usman, Application of data-intelligence algorithms for modeling the compaction performance of new pharmaceutical excipients, 2021.

[29] Q. B. Pham *et al.*, Potential of Hybrid Data-Intelligence Algorithms for Multi-Station Modelling of Rainfall, *Water Resour. Manag.*, 2019, doi: 10.1007/s11269-019-02408-3.

[30] U. M. Ghali *et al.*, Applications of Artificial Intelligence-Based Models and Multi- Linear Regression for the Prediction of Thyroid Stimulating Hormone Level in the Human Body, vol. 29, no. 4, pp. 3690–3699, 2020.

[31] A. Alamrouni, F. Aslanova, S. Mati, H. S. Maccido, and A. A. Jibril, Multi-Regional Modeling of Cumulative COVID-19 Cases Integrated with Environmental Forest Knowledge Estimation : A Deep Learning Ensemble Approach, no. December 2019, pp. 1–23, 2022.

[32] M. J. Ahseen, Modelling the Success of using Administrative Skills in Improving the Health Quality of People with Intellectual Disabilities using Adaptive Neuro-Fuzzy Inference System : A Case Study of Two Cities in Libya, no. December, 2021, doi: 10.5281/zenodo.5887010.

[33] S. I. Malami, F. H. Anwar, S. Abdulrahman, S. I. Haruna, S. I. A. Ali, and S. I. Abba, Implementation of hybrid neuro-fuzzy and self-turning predictive model for the prediction of concrete carbonation depth: A soft computing technique, *Results Eng.*, vol. 10, no. May, p. 100228, 2021, doi: 10.1016/j.rineng.2021.100228.