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The Role of Herbal Medicines in Central American Indigenous Communities; Improving Accessibility to Type 2 Diabetes Mellitus Treatment

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The Role of Herbal Medicines in Central American Indigenous Communities; Improving Accessibility to Type 2 Diabetes Mellitus Treatment

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by

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ABSTRACT

Indigenous communities in Central America have used various plant medications to treat illnesses and diseases for centuries. Clinicians must consider improving traditional healthcare methods that are intrinsic to indigenous communities in order to increase access to effective treatments, particularly for diseases that these communities are more at risk for. This work aims to propose a method to identify whether traditional preparations of five plants (*Anacardium occidentale* L., *Hamelia patens* Jacq., *Momordica charantia* L, *Neurolaena lobota* L. R. Br. Ex Cass., and *Tecoma stans* L. juss. ex Kunth) can reduce blood glucose levels in rats with type two diabetes. Additionally, I propose an additive, non-toxic effect in decreasing blood glucose levels when metformin is used in conjunction with high concentrations of plant infusions. My goal is to provide indigenous communities with appropriate dosage information and uplift the knowledge they have held within their cultures.

INTRODUCTION

1.1 – The Importance of Access to Alternative Medicine

Research on the efficacy of traditional medicinal plants is crucial in the support of underserved, rural communities of Central America. Given the high prominence of chronic illnesses in indigenous communities, there is a strong need for accessible and affordable treatments. For example, indigenous populations in Central America are "particularly at risk from diabetes, resulting from marginalisation and lack of access to care and prevention, in addition to dramatic lifestyle changes, including nutrition transition to a diet high in refined carbohydrates" (Giovannini et al., 2016). Despite these risk factors, diabetes medications in Central America are often high in price and only found in highly populated areas, leaving rural communities with little options for treatment. Mayan communities have been identified as being at a higher risk for respiratory infections, as their homes are often situated in areas with stark seasonal climate changes, higher elevations, and smoke from fireplaces (Kufer et al., 2010). Since herbal medicines are often intrinsically a part of indigenous culture, it is important for researchers to outline the symptoms of illnesses and diseases, if any, significantly affected by a particular plant. Confirming the efficacy of a plant can also have a positive impact on the perception of indigenous traditional medicine techniques. For example, a study on Q'eqchi' Mayan plants demonstrated that there is a "pharmacological basis for the selection of these plants, indicating that the healers are likely to choose plant species that have high biological activity" (Awad et al., 2009). Careful attention should be given to the work done within indigenous communities to improve their own health, and these methods should be uplifted if they are deemed to be safe for broad treatment.

1.2 –Traditional Approaches to Medical Care

Traditional medicinal methods have been in place for centuries in cultures across the globe. Traditional medicine is defined by the World Health Organization as "the sum total of the knowledge, skills, and practices based on the theories, beliefs, and experiences indigenous to different cultures, whether explicable or not, used in the maintenance of health as well as in the prevention, diagnosis, improvement or treatment of physical and mental illness" (Jansen et al., 2021). When considering traditional medicine, it is important not to refer to it as less than non-traditional, "scientific" medicine, but rather one that is based on centuries of knowledge and experience. At the same time, it is also important to have a system in place to regulate methods that may harm patients. Given the various chemicals that can be found within an herbal product, it is necessary to be aware of any interactions a treatment can have with prescribed medications or additional herbal preparations. A concerning consequence of misuse of herbal medicines is hepatotoxicity and nephrotoxicity, or liver and kidney disease, respectively (Britza et al., 2022). Therefore, there is a significant need for rural and indigenous communities in Central America to have adequate informational resources on herbal medicines that are safe for use, as well as appropriate dosage and preparation information.

1.3 – Traditional Techniques in Asia

Various traditional medicinal techniques have stemmed from Asia. For example, Traditional Chinese medicine (TCM) has become a big market for alternative therapy across the globe. In 2016, China exported $526 million USD worth of traditional Chinese medicine to the United States (Britza et al., 2022). TCM includes methods such as herbal medication, acupuncture, and other forms of physical therapy. It works to "trace symptoms to patterns of the underlying disharmony, by measuring the physiological indicators" (Jansen et al., 2021). Most

notably, the compound artemisinin has become the most effective treatment against malaria after having popularity within TCM techniques. The plant in which it was discovered, *Artemisia annua* L.*,* was first used to relieve fevers, a symptom associated with malaria, and had its earliest documentation during the East Jin Dynasty in 266-420 A.D. (Wang et al., 2018). Had these methods not been recorded and respected in the scientific community, it may have been more difficult to consider herbal medicines as potential treatment. Diabetic symptoms were initially documented in China as "Xiaoke", meaning increased thirst. A common herb used to treat Xiaoke was *Coptis chinensis*, which was later found to have an active ingredient, berberine, with hypoglycemic and hypolipidemic properties. After several years of clinical studies, berberine has been found to "target glucose metabolism through both insulin-dependent and independent pathways, increasing insulin sensitivity (partly through increased insulin receptor expression), insulin secretion, glucose uptake, and stimulating activation of the AMP-activated protein kinase (AMPK) pathway" (**Figure 1**; Wang et al., 2018). By outlining pathways and establishing clear physiological effects, clinicians are better able to understand the role traditional medicine can have in treating illnesses and diseases in need of accessible treatments.

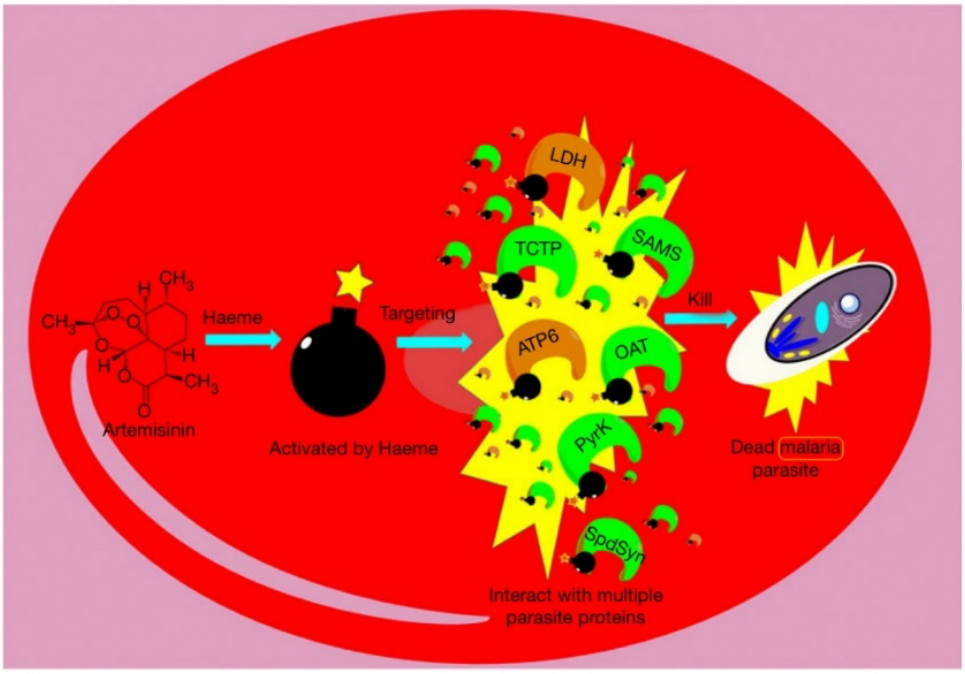

Figure 1. The proposed pathway of artemisinin as an anti-malarial compound (Wang et al., 2018).

Kampo, also known as traditional Japanese medicine, has continued into modern-day medicine, as it is taught in all Japanese medical schools (Jansen et al., 2021). Kampo focuses on treating the whole body, as opposed to local areas of the body. Various Kampo formulations exist that combine different components of plants to address symptoms. For example, Shakuyakukanzoto, composed of *Paeoniae radix* and *Glycyrrhizae radix*, works to relieve muscle pain and spasms through skeletal muscle relaxation and antispasmodic action on gastrointestinal smooth muscle (Satoh, 2013). Additionally, *Uncariae rhynchophylla* has been shown to be effective against behavioral and psychological symptoms of dementia in patients with Alzheimer's disease (Satoh, 2013). Extensive studies have been conducted to outline the pathways affected by these treatments, as well as to identify the chemical components involved.

1.4 – Traditional Techniques Used in Africa

Despite European influence on African healthcare post-colonization, Traditional African medicine continues to support a vast majority of the African community. In 1997, the ratio of traditional medicine practitioners to patients in Ghana was 1:400, in contrast to the doctor to patient ratio of 1:12,000 (Busia, 2005). These stark differences demonstrate the important role traditional medicine has played in accessibility to healthcare for Ghanaian communities. The Kwame Nkrumah University of Science and Technology in Ghana even implemented an Herbal Medicine Bachelors of Science program, acknowledging its importance in the scientific community (Busia, 2005). Plant medicines also hold an important role in traditional healing methods. A study conducted by Amuri et al. identified nine plant species popular among traditional healers in Ghana as having antihyperglycemic properties in animal models (**Figure 2**) (Amuri et al., 2017). Lower glucose blood levels were suggested via glucose transporters, particularly through a decrease in SGLT-1 or GLUT-2 expression. Given the prominent role of herbal medicines in African healthcare, it is important to continue identifying the physiological effects traditional plant medicines can have on health conditions.

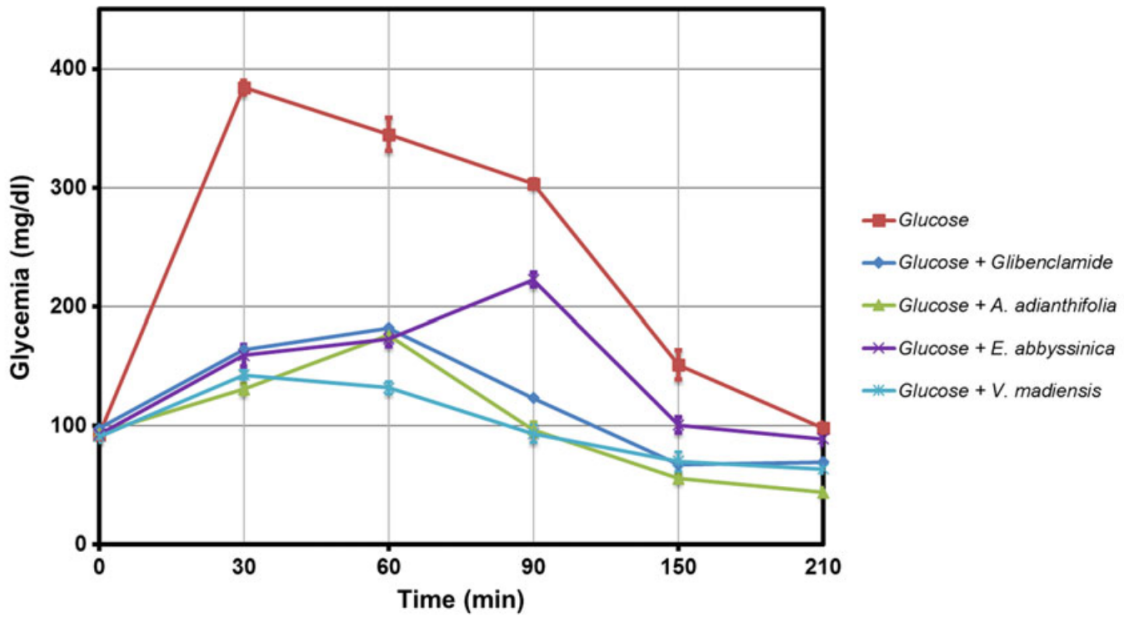

Figure 2. Blood glucose concentration over time in guinea pigs treated with various plant aqueous extracts (Amuri et al., 2017).

1.5 – Traditional Techniques Used in Mexico and Central America

Mexico and Central America are comprised of various indigenous groups that have centuries of historical medicinal techniques, which continue to play a large role in modern-day healthcare. There are various examples of Mayan medicinal methods that have continued in popularity. For example, swelling or inflammation caused by a cold is often treated with the use of a steam bath, also called a "temascal" in some areas of Guatemala (**Figure 3**) (Kufer et al., 2010). These cave-like structures are often found in the homes of indigenous families and used on a regular basis. Despite the temascal's popularity, research has been done to bring awareness to the harmful effects of carboxyhemoglobin concentrations as a result of carbon monoxide exposure (Lam et al., 2011).

Figure 3. Image of a temascal being prepared for use (Lam et al., 2011).

When discussing Mayan medicine, it is important to consider the implications of their spiritual beliefs on treatment and techniques. *Aire*, which translates to air, is often explained by Mayans to cause pain by coming close to the surface of the body. In Eastern Guatemala, Ch'orti' Mayans use a method similar to cupping, called *ventosas*, to treat this pain (Kufer et al., 2010). Spiritual healers also play an important role in indigenous medicine. Ch'orti' Mayans involve the expertise of *chucureros,* spiritual healers, to cure espanto, "the loss or imprisonment of a part of the soul or spirit, caused by a sudden fright" (Kufer et al., 2010). In addition to herbal medicines and plants, these healers are said to be able to release the spirit from the victim through rituals. The role and influence of spiritual healers in traditional medicinal techniques should be respected if clinicians want to improve access to health care in indigenous populations.

The Peninsula of Yucatan, Mexico is inhabited by Yucatec Mayans that continue to use centuries of ancient Mayan medicinal knowledge. According to interviews conducted in the rural community of Tope, Yucatán, knowledge of plant treatments are often passed down within the family or from a well-respected member of the community (Frank & Durden, 2017). Species of

the genus *Croton* are often used against fever, respiratory illnesses, and dermatological problems. Additionally, the leaves of *Piscidia piscipula* L. are used to treat gastrointestinal disorders such as diarrhea and cramps. The same plant species has been shown to have antimycotic effects, serving as an effective treatment against fungal infections. It also has activity against *Helicobacter pylori*, a type of bacteria associated with gastrointestinal issues (Ankli et al., 2002). Despite these studies, physicians in the community of Tope, Yucatán, refute the efficacy of plant-based medicines, arguing that "it's a practice left from the old traditions… [and the physicians] don't think it really makes a difference either way" (Frank & Durden, 2017). Given that many of these physicians are not local to the regions they care for, they may not understand the cultural importance of using traditional medicines. Given this, it is important to experimentally determine the relevancy of medicinal knowledge held within indigenous communities to ensure they are not falsely criticized or met with disbelief.

The state of Oaxaca has the largest population and highest concentration of indigenous people in Mexico (Espinoza Giacinto et al., 2016). Given this, *curanderismo,* or traditional healing, has a large role in the treatment of illnesses within the Oaxacan community. In a study conducted on Oaxacan residents, a third of the sample reported using traditional healers to help cure illnesses such as *susto* (strong fright) and *nervios* (nerves) (Espinoza Giacinto et al., 2016). A study conducted on the Mazatecs of northern Oaxaca compared the different treatments used for various illnesses. For fevers, also known as *chijin-ndae*, treatment involves "baths in cold water using crushed, foam-forming leaves of *Cestrum nocturnum*, *Tagetes erecta* or *Valeriana scandens* rubbed on the skin" (Giovannini & Heinrich, 2009). It is also common for Mazatecs, as well as other indigenous groups, to combine plant medicines and spiritual techniques. The study also outlined the methods by which Mazatecs attain their medicine, demonstrating disparities in

accessing pharmaceuticals as they must travel to the municipality. Meanwhile, medicinal plants are often traded within the local area of Sierra Madre Oriental. Understanding the disparities underlying health care access is important to implement realistic and effective treatment for common diseases in rural, indigenous areas.

1.6 – Common Herbal Medicines Used to Treat Diabetes in Central America

Several studies have been conducted to identify the role of herbal medicines in treating chronic illnesses such as diabetes, kidney diseases, and cardiovascular diseases. A review conducted by Giovanni et al. identified relevant knowledge on plants used to manage diabetes in Central America. Given that type two diabetes (T2D) incidence is three times higher in indigenous populations than in the general population, it is important to identify appropriate and accessible treatment in these communities (Ferrier, 2014). Giovanni et al. compiled information on the part of the plant used as well as the mode of use. Similarly, a field study was conducted to identify plants used to treat T2D in the region of Chimaltenango, Guatemala (Cruz & Andrade-Cetto, 2015). Through patient interviews, researchers were able to identify not only the part of the plant used, but also the method of preparation and quantities consumed. To determine the efficacy of traditional plant treatments, consideration must be made for the current techniques used by indigenous communities.

A study conducted by Harinantenaia et al. measured the effect of active compounds found in *Momordica charantia* L. on diabetes-induced mice. Compounds 4 and 5, shown below, demonstrated lower hypoglycemic activity than glibenclamide, a hypoglycemic drug (**Figure 4**). However, the compounds significantly decreased blood glucose levels when compared to the control group (Harinantenaina et al., 2006). It is important to note that ether and ethyl acetate fractions of the *Momordica charantia* L. extract were used, as opposed to a water-based infusion

that is more commonly used in traditional medicine techniques. Additionally, it is not noted what part of the plant was used for the extract. In Central American communities, the leaf and stem are used for medicinal infusions.

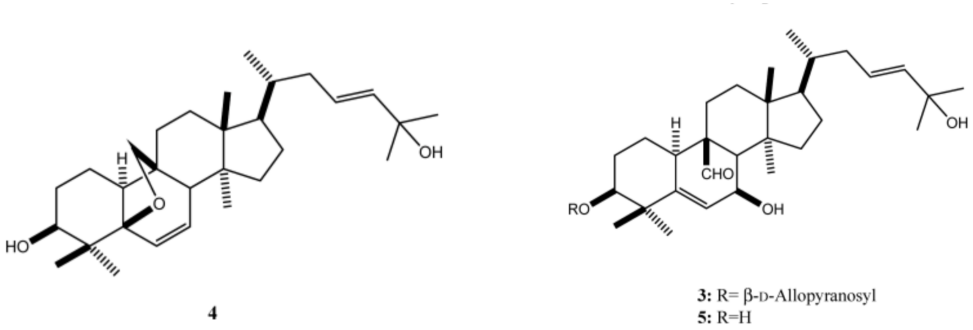

Figure 4. The structures of compound 4 and compound 5 in *Momordica charantia* (Harinantenaina et al., 2006).

The antidiabetic effect of *Anacardium occidentale* L. was studied in diabetic, fructose-fed rats (Olatunji et al., 2005). Focus was placed on the stem and bark of the plant, which were pulverized and filtered in methanol. Diabetic rats treated with a single daily dose of *Anacardium occidentale* L. (200.0 mg/kg body weight) were found to have significantly reduced blood plasma glucose. Pandurangan et al. studied the antihyperglycemic effect of *Hamelia patens* Jacq. in diabetes induced rats (Pandurangan et al., 2011). Focus was placed on the stems of the plant, which contrasts the documented use of the leaf in Central American communities. Petroleum ether extracts (PEHP) and ethanolic extracts (EEHP) at high (400 mg/kg. b.w.) and low (100 mg/kg, b.w.) concentrations were orally administered for 20 days. Both PEHP and EEHP extracts were found to have a significant effect in lowering blood glucose levels, but higher dosages were most effective.

In a study conducted by Aguilar-Santamaria et al., *Tecoma stans* L. leaves were extracted with water, aligning with cited use in Central American communities via water-infused leaves. Rats were induced with diabetes using a Streptozotocin (STZ) treatment. No difference in blood glucose levels was detected between treated and control diabetic rats, despite previous research having identified a hypoglycemic effect (Aguilar-Santamaría et al., 2009). No recent papers were found to be published on antidiabetic effects of *Neurolaena lobata* (L.) in an animal model. Further research should be conducted to confirm whether these plants can serve as treatment for T2D, with particular focus placed on replicating the traditional methods documented as being used by indigenous communities in Central America. Additionally, considerations should be made for the additive effects these plants can have when used in conjunction with prescribed T2D medication.

1.7 – Common Non-Traditional Medicines Used to Treat Diabetes

Metformin (1,1-dimethylbiguanide) is the most recommended drug for hyperglycemia in type 2 diabetes patients (**Figure 5**). The antihyperglycemic drug works by improving peripheral sensitivity to insulin and inhibiting the absorption and production of glucose (Davidson & Peters, 1997). Researchers have also proposed a mechanism by which metformin decreases hepatic glucose production by inhibiting gluconeogenesis (Viollet et al., 2012). Dosages usually begin at 500 mg twice daily or 850 mg once daily (Davidson & Peters, 1997). Despite potentially high costs for metformin, some T2D patients in Mexico and Central America are able to receive appropriate treatment. In a study conducted in Tope, Yucatan, patients admitted to using both herbal medicines and prescribed drugs: “I take natural medicines when I feel that the pills aren’t doing enough or are hurting my stomach. But I only take [natural medicines] sometimes. Every once in a while.” (Frank & Durden, 2017). Given the high chance of Central American

communities taking both types of treatments at the same time, it is important to identify any adverse or additive effects when used in conjunction with each other.

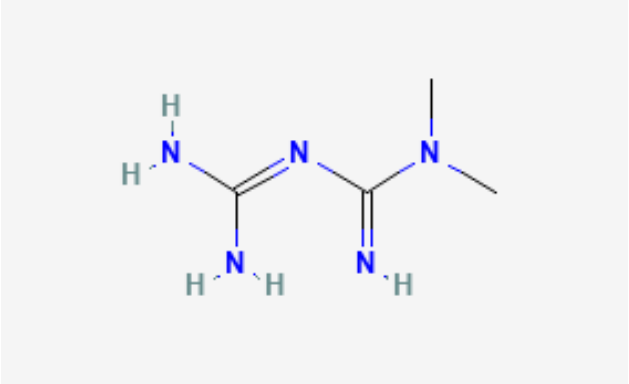

Figure 5. The structure of metformin.

1.8 – Summary of Goals

Given the prevalent use of herbal medicines in Central American indigenous communities to treat T2D, research should be conducted to confirm their antihyperglycemic effects, as well as non-toxic, safe dosages. I plan to study the effect of five plants (*Anacardium occidentale* L., *Hamelia patens* Jacq., *Momordica charantia* L, *Neurolaena lobota* L. R. Br. Ex Cass., and *Tecoma stans* L. juss. ex Kunth) in reducing blood glucose levels in T2D rat models. I hypothesize that herbal medicines prepared in a manner reflecting traditional methods can significantly decrease blood glucose levels at high concentrations in water-based and chloroform-based infusions. I also hypothesize that when used in conjunction with metformin, high concentrations of plant material have additive, antihyperglycemic effects with no hepatoxicity observed. The results of this study are important as we work to improve access to effective T2D treatment in Central America.

MATERIALS AND METHODS

2.1 – Plant Material and Extraction

Five plants cited for popular herbal medicine use in Central America (Belize, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, and Panama) will be selected for use. For this proposal, the plants selected are as follows: *Anacardium occidentale* L., *Hamelia patens* Jacq., *Momordica charantia* L, *Neurolaena lobota* L. R. Br. Ex Cass., and *Tecoma stans* L. juss. ex Kunth. These plants have been selected for their popularity as T2D treatment in indigenous communities. The plants will be grown in a greenhouse under standardized conditions. The part of each plant cited as being used most in herbal medicine techniques will be identified and extracted **(Table 1).** For plants listed as being infused, a plant infusion method will be used (Abubakar & Haque, 2020). Thus, the plant material will be ground into a fine powder and soaked in hot water. High and low solvent to sample ratios will be used to determine the effectiveness, if any, of varying plant dosages (4:1, and 12:1). Consideration must be given to the varying solubility of potential active compounds in the plant material. Therefore, chloroform will also be used as a nonpolar solvent. Chloroform provides advantages in extracting compounds such as terpenoids, flavonoids, fats, and oils. The nonpolar solvent is also able to be absorbed and metabolized in the body, despite having sedative and carcinogenic effects (Abubakar & Haque, 2020).

Table 1. Plant species cited as being used for diabetes treatment in Central America (GU = Guatemala, PA = Panama, SA = El Salvador, BE = Belize, NI = Nicaragua) (Cruz & Andrade-Cetto, 2015), (Giovannini et al., 2016).

Species	Country	Plant part	Preparation	Evidence for Antidiabetic Activity
Anacardium occidentale L.	GU, PA	Leaf, bark	Oral infusion, 3 cups/day for 15 days	Olatunji, L. A., Okwusidi, J. I., & Soladoye, A. O. (2005). Antidiabetic Effect of Anacardium occidentale. Stem-Bark in Fructose-Diabetic Rats. Pharmaceutical Biology, 43(7), 589–593. https://doi.org/10.1080/13880200500301712
Hamelia patens Jacq.	SA, GU, BE	Leaf	Oral infusion, 4 cups/day for 30 days	Pandurangan, D., Ahmad, A., Koul, S., Sharma, B., & Kumar, M. (2011). Blood glucose lowering potential of Hamelia patens stem in alloxan induced diabetic rat. 2, 23–27
Momordica charantia L. (Cucurbitaceae)	NI, GU, BE, PA	Leaf, stem	Oral infusion	Harinantenaina, L., Tanaka, M., Takaoka, S., Oda, M., Mogami, O., Uchida, M., & Asakawa, Y. (2006). Momordica charantia Constituents and Antidiabetic Screening of the Isolated Major Compounds. Chemical and Pharmaceutical Bulletin, 54(7), 1017–1021. https://doi.org/10.1248/cpb.54.1017
Neurolaena lobota L. R. Br. Ex Cass.	BE, GU, NI	Leaf	Oral infusion, 4 cups/day for 20 days	Giovannini, P., Howes, M.-J. R., & Edwards, S. E. (2016). Medicinal plants used in the traditional management of diabetes and its sequelae in Central America: A review. Journal of Ethnopharmacology, 184, 58–71. https://doi.org/10.1016/j.jep.2016.02.034
Tecoma stans L. juss. ex Kunth	GU, SA	Leaf, bark	Oral infusion, 4 cups/day for	Aguilar-Santamaría, L., Ramírez, G., Nicasio, P., Alegría-Reyes, C., & Herrera-Arellano, A. (2009). Antidiabetic activities of Tecoma stans (L.) Juss. Ex Kunth. Journal of Ethnopharmacology,

2.2 – Animal Model and Treatment

Goto-Kakizaki (GK) rats, which serve as a non-obese and genetic T2D experimental model, will be obtained at 28 days of age. The rats will be housed at standard room temperature (23 +/- 2℃) in polypropylene cages. Diet will consist of standard pellets, germinated grams, and water *ad libitum*. Rats will be randomly assigned to one of the following groups detailed below (**Figures 7, 8, 9, 10, 11**). All treatment groups except Group I and Group II will be repeated for each of the five plant materials being investigated with new rat samples. Plant extracts will be administered via oral gavage.

Figure 6. An outline of the treatment groups to be tested without plant material.

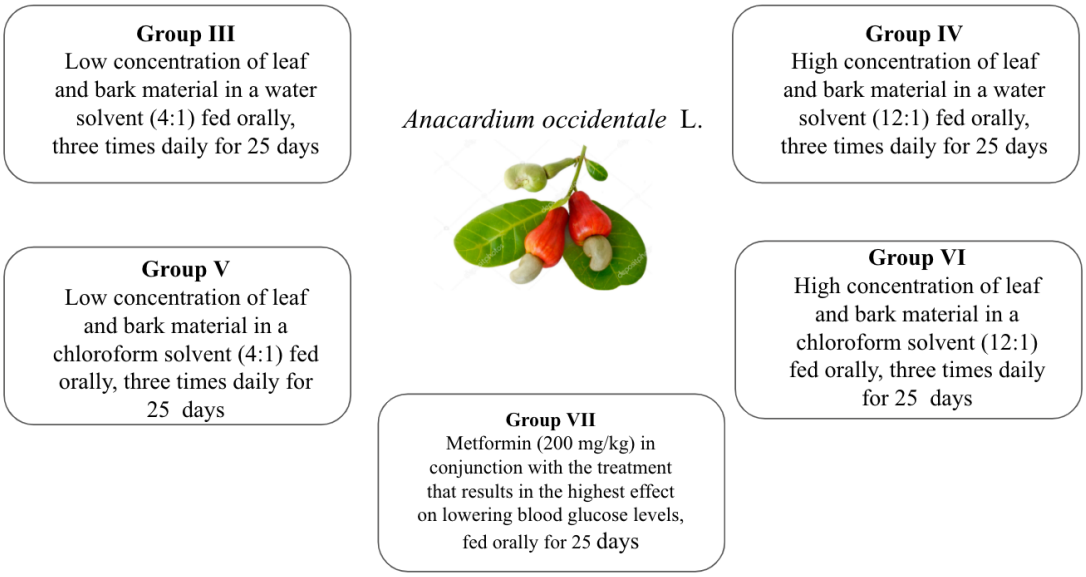

Figure 7. An outline of the varying treatments to be tested using *Anacardium occidentale* L. plant material, in accordance with traditional methods used in surveyed indigenous communities of Central America.

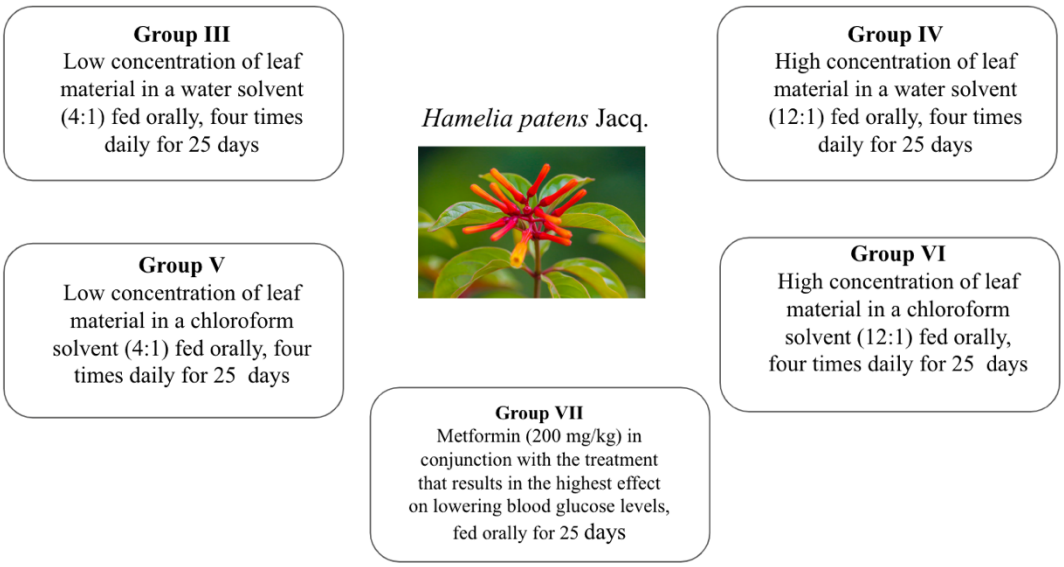

Figure 8. An outline of the varying treatments to be tested using *Hamelia patens* Jacq. plant material, in accordance with traditional methods used in surveyed indigenous communities of Central America.

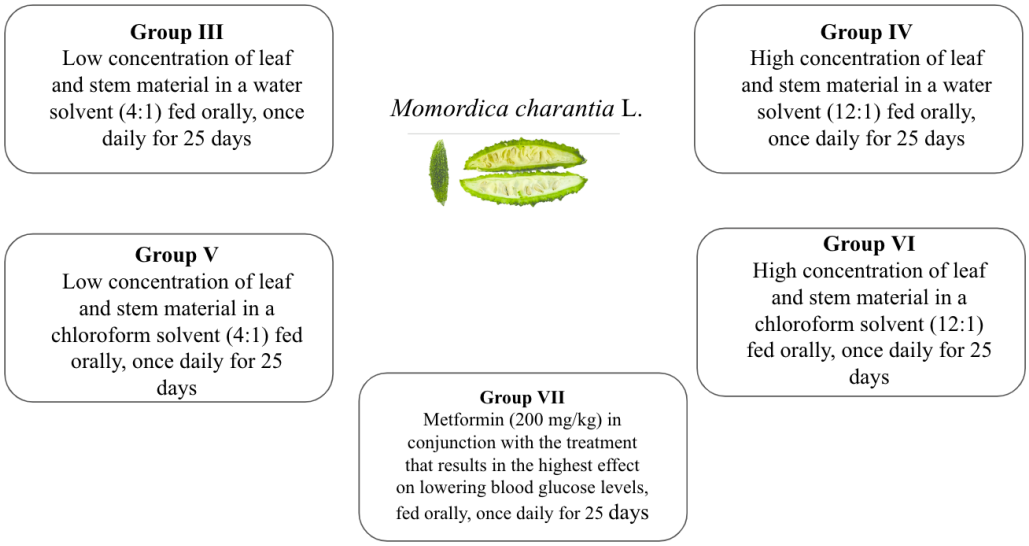

Figure 9. An outline of the varying treatments to be tested using *Momordica charantia L.* plant material, in accordance with traditional methods used in surveyed indigenous communities of Central America.

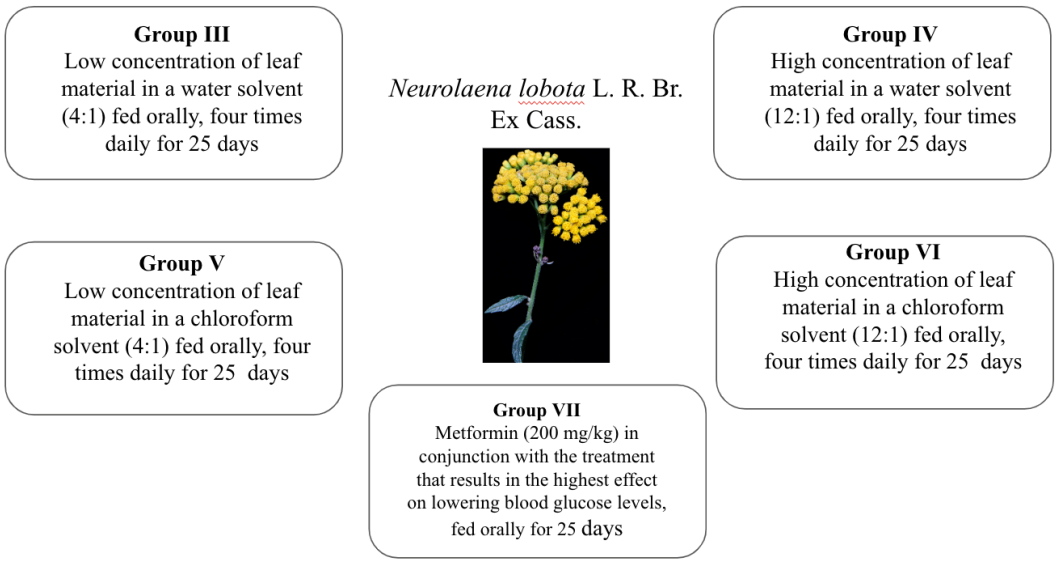

Figure 10. An outline of the varying treatments to be tested using *Neurolaena lobota L. R. Br. Ex. Cass*. plant material, in accordance with traditional methods used in surveyed indigenous communities of Central America.

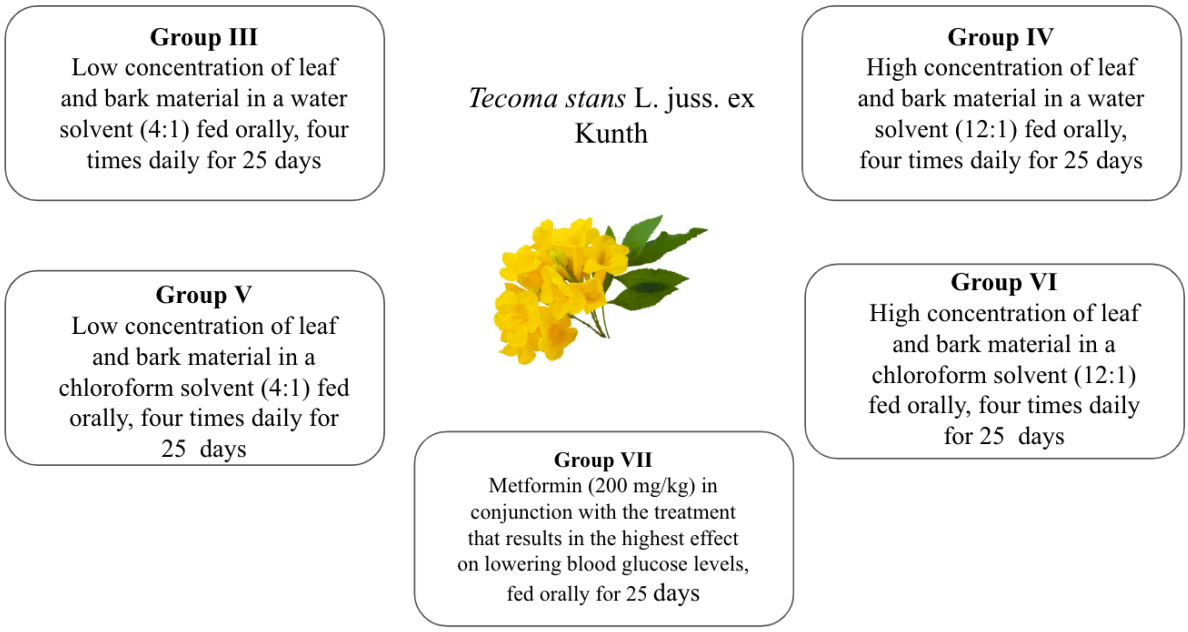

Figure 11. An outline of the varying treatments to be tested using *Tecoma stans L. Juss. ex Kunth*. plant material, in accordance with traditional methods used in surveyed indigenous communities of Central America.

2.3 – Glucose Administration

All treatment groups will receive a glucose solution (2.0 g/kg bw) via oral gavage at time zero, 12 hours after fasting, daily throughout the course of the experiment.

2.4 – Blood Sample Collection

The development of diabetes in the GK rats will be confirmed by measuring blood glucose levels. Blood samples will be collected via blood vessel catheterization in the right jugular vein using methods developed by Feng et al. Rats will be fasted for 12 hours prior to their first blood sample collection at time zero. Fasting blood glucose concentrations will be measured at time zero by an automatic blood glucose monitoring system. A blood glucose of 200 mg dL^{-1} or greater will be set as the threshold of hyperglycemia (Cintra et al., 2014). Additional blood samples will also be taken 30, 60, 90, 120, 180, and 240 minutes after treatment. Blood samples will be collected on day 1, day 5, day 10, day 15, and day 25.

2.5 – Liver Function Test

Blood samples of all treatment groups will be collected on day 1 and 25. Samples will be centrifuged to collect a serum sample. A biochemical test will be conducted to analyze the activities of aspartate transaminase (AST), alanine aminotransferase (ALT), and total bilirubin serum, which serve as markers of liver function (Muda & Atik, 2018).

2.5 – Statistical analysis

Results will be analyzed by one-way ANOVA for each plant species. Results will be considered statistically significant at $p < 0.05$.

PROJECTED RESULTS

Metformin treatment is expected to have a statistically significant effect on reducing blood glucose levels over time based on previous literature (Za'abi et al., 2021). All five plants are predicted to have a statistically significant effect on reducing blood glucose levels over time, but high plant concentrations are expected to have a greater effect than low plant concentrations (**Figure 12).** High plant concentrations in conjunction with metformin are expected to demonstrate an additive effect in blood glucose reduction. These trends are expected to persist over the course of 25 days **(Figure 13).** No statistical difference is expected to be observed between the control group and the treatment groups in the liver function tests after 25 days.

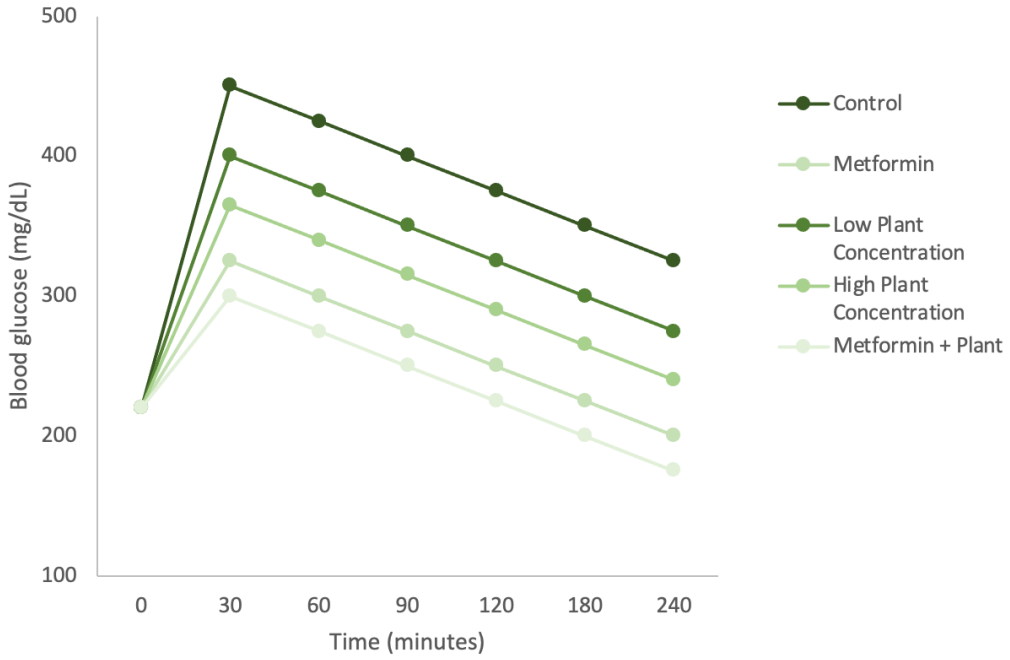

Figure 12. Projected blood glucose levels (mg/dL) over time after glucose treatment on day 25.

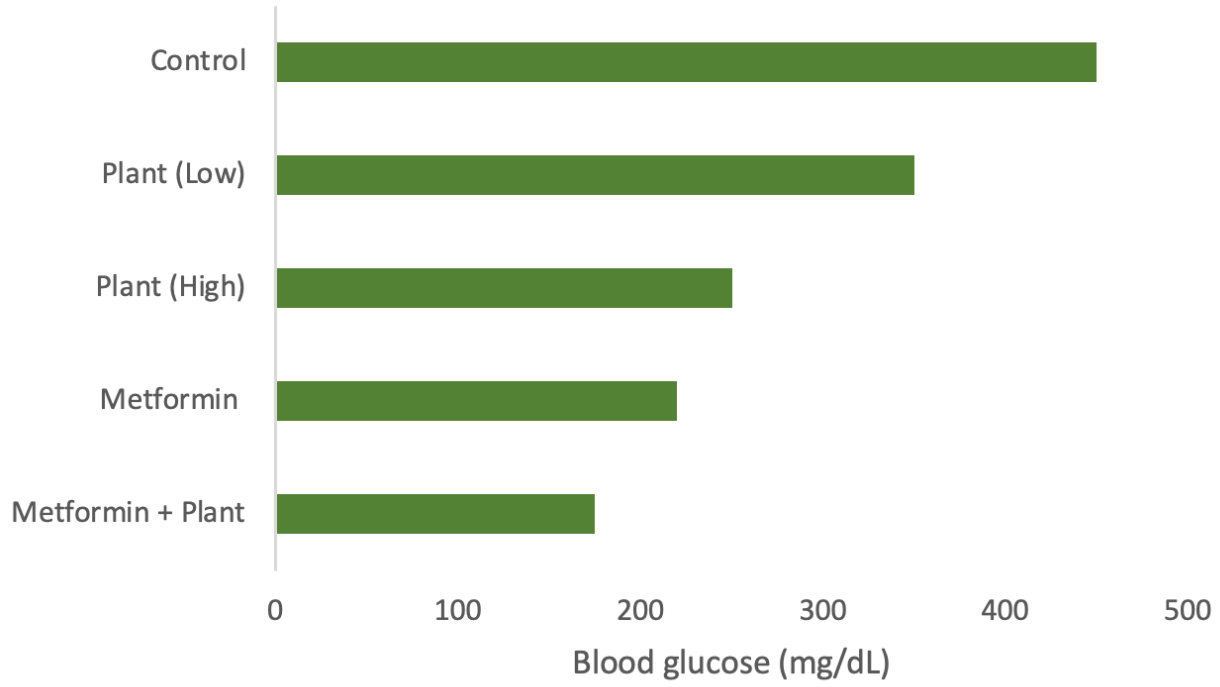

Figure 13. Projected average blood glucose levels (mg/dL) under various treatments over the course of 25 days.

DISCUSSION

Some limitations exist in this research proposal. For example, the use of the chloroform solvent may have a carcinogenic effect on the rats. However, its use would allow us to determine if a water solvent is less effective in achieving antihyperglycemic effects. Additionally, several blood samples a day may cause significant stress on the rats. The use of a blood vessel catheter should allow researchers to acquire several samples over the course of the 25 days without imposing additional stress on the rats from daily needle use. Finally, the liver toxicity tests may not detect a decrease in liver function within the 25-day period. Researchers may consider monitoring the rats for a longer period to ensure no hepatoxicity occurs.

To increase access to effective T2D treatments in Central American indigenous communities, clinicians should consider improving methods that are intrinsic to indigenous communities. My proposed results highlight the expected usefulness of herbal medicines in treating T2D patients. This study would be able to shed light on the appropriate preparation and dosage information of the five plants used, allowing indigenous communities to self-medicate safely. The research findings would also allow physicians in Central America to recommend treatments that may be more accessible for their patients. Future research should focus on clinical trials of T2D patients being treated with antihyperglycemic plants. Given that I predict no toxic effects when plant medications are taken in conjunction with plant treatments, clinicians should monitor the effect of taking both medications on hyperglycemia.

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