THE CONCEPT OF VALUE CHAINS IN AGRICULTURE, CLIMATE ACTION AND ENVIRONMENTAL RESOURCES

GLOBAL ISSUES & LOCAL PERSPECTIVES

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SAEREM BOOK CHAPTERS First Published 2025 ISBN 978-978-60709-7-1

Published By:

Society for Agriculture, Environmental Resources & Management (SAEREM)

First published 2024

SAEREM World

Nigeria

Typeset in Times New Roman

SAEREM BOOK CHAPTERS First Published 2025 ISBN 978-978-60709-7-1

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SAEREM BOOK CHAPTERS First Published 2025 ISBN 978-978-60709-7-1

Printed at: SAEREM World

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Preface

This book adopts an exegetical approach as well as a pedagogic model, making it attractive agriculture and environmental economics teachers, professional practitioners and scholars. It is eschews pedantry and lays bars the issues in such clarity that conduces to learning. The book elaborates on contemporaneous ***The Concept of Value Chains in Agriculture, Climate Action and Environmental Resources*** issues of global significance and at the same time, is mindful of local or national perspectives making it appealing both to international and national interests. The book explores the ways in which climate change, food security, national security and environmental resources issues are and should be presented to increase the public's stock of knowledge, increase awareness about burning issues and empower the scholars and public to engage in the participatory dialogue climate change, food security, national security and environmental resources necessary in policy making process that will stimulate increase in food production and environmental sustainability.

The Concept of Value Chains in Agriculture, Climate Action and Environmental Resources: Global issues and Local Perspectives is organized in three parts. Part One deals with The Concept of Value Chains in Agriculture, Part Two is concerned with The Concept of Climate Actions and Part Three deals with the Concept of Value Chains and Environmental Resources.

Eteyen Nyong/ Ignatius Onimawo

April 2025

SAEREM BOOK CHAPTERS First Published 2025 ISBN 978-978-60709-7-1

Chapter Twenty Four

"A Study on the Anticariogenic Efficacy of Some Ethnobotanical Plants on Oral Bacteria: A Review"

Simpson Victor Bamidele[1], Akemien Nerioya Neri[2], Akhideno Lawson Oseigbokan[3], Alli Sheriffdeen Abiola[4], Adeleye Opeyemi Adebola[5].

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1. Introduction

Dental cavities represent the leading oral health issue globally. While other conditions like mouth and throat cancers and oral lesions pose serious health concerns internationally, dental caries affect approximately 2.43 billion people, representing 36% of the world's population (Peres, M. A., McPherson, L. M. D., Weyant, R. J., & Daly, B., 2019). This makes it one of the world's most prevalent chronic infectious diseases. Dental cavities develop as an ongoing oral condition where vulnerable tooth surfaces break down. This occurs when bacteria in the mouth break down sugars from food, creating acids that damage the hard structures of teeth (Chang, C.H. & Glick, M., 2020).

Various bacteria naturally inhabit the human mouth. These bacteria can accumulate and form a sticky coating on teeth called plaque, which also contains a mixture of saliva, food particles, and other natural materials (Nascimento, J. R., Peres, M. A., & Li, Q., 2022). Plaque tends to accumulate in specific areas: the fissures and depressions of back teeth, spaces around dental work, and along the gum margins. Once harmful bacteria settle on tooth surfaces, they convert sugar into sticky substances that help them attach to smooth tooth surfaces. This process plays a crucial role in tooth decay, particularly on smooth surfaces, as these bacteria then turn sugar into lactic acid (Holde, G. E., Oscarson, N., & Baker, S. R., 2019). Caries can result in various symptoms, including pain and difficulty with basic functions like eating and chewing. It can also affect a person's confidence when smiling and speaking due to teeth that are missing, stained, or damaged. The bacteria responsible for causing cavities are varied, consisting of different types that can survive with or without oxygen, as well as those that can only live without oxygen (Okoronkwo, C. U., & Ede, T., 2020).

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Gums are called “gingiva,” and their inflammatory diseases are collectively referred to as gingivitis. Gum disease is an infection of the gum tissue that surrounds and supports the teeth. It is a major cause of tooth loss in adults as well as in the elderly (Chang, C. H., Smith, J. K., & Lee, M., 2021). In early stages, it is called gingivitis, and when gingivitis is not treated properly, it may advance to periodontitis because of nonspecific signs and symptoms that patients may fail to notice (Li, X., Zhang, Y., & Wang, L., 2023). Gingivitis is a common and mild form of gum disease (periodontal disease) that causes irritation, redness, and swelling (inflammation) of the gingiva, the part of your gum around the base of your teeth. It is important to take gingivitis seriously and treat it promptly. Gingivitis can lead to much more serious gum disease called periodontitis, and ultimately tooth loss (Martinez-Garcia, M., Silva, M. F., & Chang, C. H., 2020).

The most common cause of gingivitis is poor oral hygiene that encourages plaque to form on teeth, causing inflammation of the surrounding gum tissues. Plaque is an invisible, sticky film composed mainly of bacteria that forms on teeth when starches and sugars in food interact with bacteria normally found in the mouth. Plaque requires daily removal because it re-forms quickly (Ramalingam, L., Hapsari, A., & Li, X. F., 2018). Plaque that stays on teeth can harden under the gum line into tartar, which collects bacteria. Tartar makes plaque more difficult to remove, creates a protective shield for bacteria, and causes irritation along the gum line. Professional dental cleaning is required to remove tartar. The longer plaque and tartar remain on the teeth, the more they irritate the gingiva, causing them to become swollen and bleed easily. Tooth decay (dental caries) may also result - if not treated, gingivitis can advance to periodontitis and eventual tooth loss (Sasaki, K. & Inagaki, T., 2021).

Risk factors of gingivitis include poor oral care habits, smoking or chewing tobacco, older age, dry mouth, poor nutrition (including vitamin C deficiency), dental restorations that do not fit properly or crooked teeth that are difficult to clean, and conditions that decrease immunity such as

leukemia, HIV/AIDS, or cancer treatment. Chronic gingiva inflammation has been associated with some systemic diseases such as respiratory disease, diabetes, coronary artery disease, stroke, and rheumatoid arthritis. Some research suggests that the bacteria responsible for periodontitis can enter the bloodstream through gum tissue, possibly affecting the heart, lungs, and other body parts, though more studies are needed to confirm such a link (Gadeyne S. L., Holde, G. E., & Kassebaum, N. J., 2017). Trench mouth, also known as necrotizing ulcerative gingivitis (NUG), is a severe form of gingivitis that causes painful, infected, bleeding gums and ulcerations. Trench mouth is rare today in developed nations but remains more common in developing countries with poor nutrition and poor living conditions (Peres *et al.*, 2019).

The lower incidence of dental caries among users of chewing sticks (compared to non-users) has been attributed to their superior mechanical cleansing action on the teeth (Nascimento *et al*., 2022). Hence, there is a need to study and demonstrate the bactericidal efficiency of selected chewing sticks against dental caries and gingivitis. Chewing sticks from plants were used historically by early Arab, Babylonian, Greek, and African societies for cleaning teeth. Some African chewing sticks reportedly contain fluoride ions, silicon, tannic acid, sodium bicarbonate, and other natural plaque-inhibiting substances that can reduce bacterial colonization and plaque formation (Muhammad, A. I., & Adeyemi, R. F., 2022).

Ethnobotanical plants, utilized in various African societies, often carry historical and cultural significance. *Garcinia kola* (commonly called bitter kola) is frequently chewed to freshen breath and possibly reduce oral microbial loads (Enwonwu, C.O., 2018). *Piper guineense* (West African pepper), used as a culinary spice, may also possess antimicrobial properties relevant to dental plaque management (Adebayo, A.M., & Dzoyem, J.P., 2020). Together, these plants have generated interest for their purported roles in controlling cariogenic bacteria, in part because of

their phytochemicals—such as polyphenols, alkaloids, and terpenoids—that can inhibit bacterial growth or biofilm formation (Ogunti, E.O., 2019).

Furthermore, a significant number of these plant species have reported medicinal properties that may be antibacterial. *Piper guineese* and *Garcinia kola* are rich in flavonoid compounds such as oxyayain A, oxyayain B, ayanin, and distemonanthin. These components have been implicated in anti-tumorantitumor activity and antioxidative activity, as well as the treatment of bacterial, fungal, and viral infections (Li *et al.,* 2023). A recent report suggests these active principles are tannin-like substances belonging to a large group of non-dialyzable polyphenols of varying molecular weights (Chang *et al.,* 2021). The effects of chewing sticks and modern toothbrushes with toothpaste on oral and dental hygiene have been comparatively reviewed (Holde *et al.*, 2019). It has been reported that Africans who use chewing sticks exhibit fewer carious lesions than those relying on toothbrushes (Okoronkwo & Ede, 2020). The roots and stems of are commonly employed as chewing sticks (Nascimento *et al*., 2022).

This paper reviews existing literature on the anticariogenic efficacy of *Garcinia kola* and *Piper guineense* with respect to their potential to inhibit or kill oral pathogens (*Streptococcus mutans*, *Lactobacillus acidophilus*, *Streptococcus sanguis*, etc.). It provides a background on dental caries, highlights relevant phytochemical constituents, examines antimicrobial trials, and outlines challenges in standardizing these ethnobotanical agents for preventive oral health strategies.

2. Background on Dental Caries and Oral Pathogens

2.1 Pathophysiology of Dental Caries

Dental caries is typically defined by the localized breakdown of tooth enamel and dentin, primarily resulting from acidogenic and aciduric plaque biofilms that demineralize the tooth surface. This

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disease process is closely associated with cariogenic bacteria—most notably Streptococcus mutans—which produce organic acids through carbohydrate fermentation, thereby creating an environment that depletes the mineral content of teeth and leads to cavity formation (Chang & Glick, 2020). *Streptococcus mutans* is often regarded as a principal etiological agent due to its ability to synthesize extracellular polysaccharides from sucrose—enabling robust adherence—and produce lactic acid via fermentation (Periasamy & Kolenbrander, 2019). *Lactobacillus* species contribute to lesion progression in deeper dentinal layers, while *Streptococcus sanguis* and other oral commensals can shape overall biofilm ecology (Holde *et al.*, 2019).

2.2 Limitations of Conventional Approaches

Although **fluoride** (found in toothpaste, mouth rinses) strengthens enamel and **chlorhexidine** mouthwashes exhibit broad antimicrobial activity, drawbacks include cost, potential adverse effects (e.g., staining, taste alteration), and antibiotic resistance concerns (Chang & Glick, 2020). In low-resource settings, reliance on local plants (chewing sticks, traditional mouth rinses) is more culturally integrated and accessible (Okoronkwo & Ede, 2020). This environment has encouraged scientific inquiry into the antibacterial efficiency of such **ethnobotanical** solutions.

2.3 Ethnobotanical Plants in Caries Management

Ethnobotanical practices commonly involve chewing sticks, herbal mouth rinses, and plant-based formulations derived from species with reported antimicrobial, anti-inflammatory, or antioxidant properties (Nascimento *et al.*, 2022). For instance, Salvadora persica (miswak) has long been recognized for its mechanical and antimicrobial effects on plaque biofilms, attributed to naturally occurring fluorides, alkaloids, and tannins (Alam, M.R., & Rahman, K., 2023). Similarly, West African plants such as Garcinia kola (bitter kola) and Piper guineense (West African pepper)

contain phytochemicals—especially flavonoids, tannins, saponins, and essential oils—that may inhibit bacterial adherence and acidogenesis (Adebayo & Dzoyem, 2020; Ajayi F. A., Babalola, A. O., & Adewusi, B., 2023). These constituents can disrupt the formation of cariogenic biofilms by weakening bacterial cell walls or impeding glucosyltransferase enzymes essential for S. mutans adhesion (Chang *et al.*, 2020).

Various African communities use chewing sticks or extracts from Garcinia kola and Piper guineense for daily oral cleansing (Okeke, C. E., & Anozie, O. N., 2021). These practices align with World Health Organization recommendations that, in areas where modern dental supplies are limited, chewing sticks or other traditional methods can maintain oral health (World Health Organization, 2021). The recognized antimicrobial, anti-inflammatory, or antioxidant actions of these plants suggest that they may inhibit cariogenic bacteria or reduce gingival inflammation (Nascimento *et al*., 2022).

3. *Garcinia kola* (Bitter Kola)

3.1 Taxonomy, Distribution, and Traditional Usage

Garcinia kola is a tropical tree predominantly found in the humid forests of West and Central Africa. Commonly referred to as “bitter kola,” its seeds are consumed raw or utilized in various herbal formulations to address coughs, throat infections, and even serve as an aphrodisiac (Nwachukwu, C. E., Adeoti, T. B., & Fadeyi, O., 2021). The seeds are also traditionally chewed for oral hygiene purposes—specifically to freshen breath or mitigate mouth odour (Adedokun, B.A., & Salisu, K.D., 2023).

3.2. Phytochemical Composition

Research from the past few years indicates that *Garcinia kola* contains a range of bioactive

compounds, including flavonoids, tannins, and xanthones. Among these, kola-viron has been identified as a notable polyphenolic complex (Okafor, M.E., & Omotayo, B.J., 2022). Flavonoids and tannins can disrupt bacterial cell walls, inhibit extracellular polysaccharide synthesis, and neutralize free radicals, thereby potentially slowing the progression of dental caries (Chang & Glick, 2020). Tannins, in particular, exert an astringent effect on oral tissues, potentially reducing plaque adhesion (Mbhele, L., & Ogunlade, S., 2021).

3.3. Antimicrobial Evidence

In vitro experiments have frequently demonstrated zones of inhibition for *Garcinia kola* extracts against common oral pathogens such as *Streptococcus mutans*, *Streptococcus sanguis*, and *Lactobacillus acidophilus* (Ayodele, A.O., & Afolabi, M.A., 2023). These findings reinforce the potential role of bitter kola in combating cariogenic bacteria and highlight the need for further standardized research protocols to determine optimal dosages and formulation strategies. Observed MIC (minimum inhibitory concentration) levels range widely—somewhere between 6–25 mg/mL, depending on extraction technique and solvent. This variance highlights the need for standardized extraction protocols (Nascimento *et al.*, 2022). Moreover, partial synergy with mechanical plaque disruption is suggested, as chewing the seeds can physically dislodge debris while the phytochemicals exert chemical inhibition (Oduro *et al.*, 2019).

3.4 Mechanisms of Action for Caries Control

Reduction of Bacterial Adherence

Interfering with the activity of glucosyltransferase enzymes in *Streptococcus mutans* can disrupt the formation of the sticky glucans necessary for bacterial adhesion. Extracts from bitter kola (*Garcinia kola*) have been suggested to inhibit this enzyme, thereby reducing plaque accumulation on tooth surfaces (Chang & Glick, 2020).

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Modulation of Salivary pH

Polyphenols found in plant extracts may help neutralize acid or lower acid production in the oral cavity. Although preliminary research indicates the potential for salivary pH modulation, additional in vivo studies are required to fully understand the effects on oral acid–base balance (Nascimento *et al*., 2022).

Anti-Inflammatory Effects: Tannins and flavonoids present in numerous plant extracts exhibit anti-inflammatory properties that can help mitigate gingival inflammation. By reducing inflammation in the gingiva, these compounds indirectly contribute to caries control through a healthier oral environment and decreased plaque retention (Chang & Glick, 2020; Okafor & Adebayo, 2022).

3.5 Safety and Limitations

While *Garcinia kola* is widely ingested with minimal adverse effects reported, caution remains about high-dose usage or potential allergenic responses (WHO, 2009). Clinical trials with well-defined dosing remain limited, restricting formal endorsement by dental associations (Enwonwu C.O., 2018).

4. *Piper guineense* (West African Pepper)

4.1 Overview and Traditional Application

Also known as “Guinea pepper” or “Uziza,” *Piper guineense* is a climbing vine cultivated primarily in West Africa. The dried fruits and seeds serve as spices in local cuisine, imparting a pungent flavor (Adebayo & Dzoyem, 2020). Ethnobotanical usage extends to respiratory,

gastrointestinal, and oral health, with some cultures employing *P. guineense* decoctions for mouth rinses to soothe gum inflammation or freshen breath (Maiyo *et al.*, 2024).

4.2 Phytochemicals

Phytochemical analyses shows **alkaloids** (piperine), **essential oils**, **phenolic compounds**, and **terpenes** (Essien, A. E., Bello, O. O., & Sambo, A., 2022). Piperine, responsible for pungency, has demonstrated antibacterial and anti-inflammatory properties, particularly against Gram-positive bacteria (Chang & Glick, 2020). Meanwhile, some phenols can disrupt bacterial membranes or inhibit acid production by *Streptococcus mutans* (Nascimento *et al.*, 2022).

4.3 Anticariogenic Investigations

Only a handful of studies address *Piper guineense* specifically for **cariogenic bacteria**. Some in vitro assays show moderate zones of inhibition (7–12 mm) against *S. mutans* and *Lactobacillus acidophilus* at certain extract concentrations (Ogunti E.O., 2019). Additionally, synergy with other herbal components—like sodium bicarbonate or essential oils—may enhance bacterial inhibition and reduce plaque formation (Adebayo & Dzoyem, 2020).

4.4 Mechanistic Insights

1. **Cell Membrane Disruption**: Piperine can integrate into lipid membranes, increasing permeability and leading to bacterial cell death (Ramalingam *et al.*, 2018).
2. **Inhibition of Acid Production**: Studies suggest that pepper extracts can reduce the acidifying potential of *S. mutans*, though more data is needed on the actual metabolic pathways (Nascimento *et al.*, 2022).

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3. **Biofilm Reduction**: The presence of aromatic oils can hamper quorum sensing or hamper exopolysaccharide matrix formation, diminishing plaque adherence (Periasamy & Kolenbrander, 2019).

4.5 Challenges

- **Taste and Acceptability**: *Piper guineense* is quite pungent. This could be beneficial (fresh breath, antibacterial) but might limit compliance.
- **Standardized Extraction**: Variation in harvest times, plant parts (leaves vs. seeds), or solvent usage significantly affects antimicrobial potency.
- **Clinical Testing**: Human trials remain scant, thus the true efficacy and safety for daily oral usage is not fully confirmed (Adebayo & Dzoyem, 2020).

5. Synergistic or Combined Usage

Some reports hypothesize that combining Garcinia kola and Piper guineense—or formulating them alongside fluoride or xylitol—could offer stronger anticariogenic effects (Ololade, O.B., & Odetola, A., 2021). For instance, the pungent components in pepper might expedite plaque disruption, while the polyphenols in bitter kola inhibit acid production. However, synergy remains largely speculative without comprehensive studies (Okoronkwo & Ede, 2020).

6. Methodologies in Anticariogenic Research

6.1 In Vitro Approaches

Common laboratory protocols involve:

- **Agar well diffusion**: measuring inhibition zones against *S. mutans* or *Lactobacillus*.

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- **Broth microdilution**: determining MIC (minimum inhibitory concentration) or MBC (minimum bactericidal concentration).
- **Biofilm assays**: quantifying plaque-like accumulation on hydroxyapatite discs or polystyrene wells.

  In these setups, standardization of plant extracts (mass of dried plant, solvent ratio, evaporation technique) is crucial (Nascimento *et al.*, 2022).

6.2 In Vivo and Clinical Trials

Fewer studies proceed to **clinical** or **semi-clinical** stages:

a. **Chewing gum** or **mouth rinse** prototypes containing the extracts.
b. Assessing plaque index, salivary pH, or *S. mutans* colony count over a few weeks. Results from pilot studies are promising but typically remain limited by small sample sizes and short durations (Chang & Glick, 2020).

7. Observed Mechanisms and Key Phytochemicals

7.1 Flavonoids and Tannins

Garcinia kola seeds are rich in **kolaviron** (a flavonoid complex) and tannins that disrupt bacterial adhesion to tooth surfaces (Karim A., Umar, S., & Bello, M., 2021).

7.2 Alkaloids and Essential Oils

Piper guineense contains **piperine** and other volatile oils known to degrade bacterial cell membranes or hamper enzymatic processes essential for acidogenesis (Adebayo & Dzoyem, 2020).

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7.3 Anti-Inflammatory

Chronic gingivitis is often co-present with caries, so the anti-inflammatory effect of these plants can indirectly slow disease progression by maintaining healthier gingiva (Chang & Glick, 2020).

8. Conclusion

Both *Garcinia kola* (bitter kola) and *Piper guineense* (West African black pepper) display promising anticariogenic potential, grounded in their ability to suppress pathogenic oral bacteria, limit biofilm development, and possibly reduce acid production. Nonetheless, translating preliminary in vitro observations and anecdotal data into standardized therapeutic strategies necessitates further research on extraction consistency, clinical trial designs, and the creation of palatable oral-care products. Integrating these ethnobotanical agents with standard oral hygiene practices may enhance dental caries prevention, especially in settings with limited resources. Ongoing investigations that bridge age-old traditional knowledge and modern scientific rigor could yield safe, effective, and culturally acceptable oral health solutions.

Dental caries continues to be one of the most prevalent oral health challenges worldwide, often linked to *Streptococcus mutans* and *Lactobacillus spp*. As interest grows in ethnobotanical interventions for oral health, this review highlights how *Garcinia kola and Piper guineense* could complement existing dental care practices. These plants harbor bioactive compounds—such as flavonoids, tannins, saponins, and essential oils—with proven or potential antimicrobial properties against cariogenic bacteria. While early in vitro findings are encouraging, additional studies are essential to identify optimum extraction techniques, guarantee safety, and refine delivery systems for clinical use. Ultimately, the promising attributes of these ethnobotanical plants warrant more rigorous validation through controlled clinical trials and uniform extraction protocols, potentially broadening their incorporation into mainstream oral hygiene regimens.

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9. Recommendations

Leveraging the local availability and affordability of *Garcinia kola and Piper guineense* can offer cost-effective oral health solutions in African communities. Due to their accessibility and longstanding use, these botanicals are well positioned to enhance dental care interventions (Okoronkwo & Ede, 2020). Their incorporation into existing community-based healthcare strategies aligns with traditional medical practices and can bolster patient compliance and acceptance among diverse populations (WHO, 2021).

Standardized cultivation and extraction protocols are essential to ensure consistent phytochemical profiles and mitigate variability in bioactive compound content (Nascimento *et al*., 2022). Moreover, formulating these extracts with flavour-masking agents may reduce the pungency of *Piper guineense* and the bitterness of *Garcinia kola*, thus improving palatability and promoting regular usage.

Large-scale, rigorously designed clinical studies involving heterogeneous demographic groups are likewise necessary to confirm the definitive efficacy of these botanicals, identify optimal dosing, and assess long-term safety (Chang & Glick, 2020; Adebayo & Dzoyem, 2020). Investigating innovative delivery methods—ranging from herbal dentifrices and antimicrobial mouth rinses to chew-based systems—could also prove beneficial. Combining these plant extracts with established anticariogenic agents (e.g., fluoride or xylitol) may yield synergistic effects (Periasamy & Kolenbrander, 2019).

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