

**ASH FILTRATE FROM PLANT RESIDUES (KADO-ATWONA) ENHANCED
MINERAL CONTENTS OF TRADITIONALLY PREPARED VEGETABLES**

BY

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DECLARATION

I, Abdikarim Maclow Mohamud, affirm that the dissertation presented is entirely my own work and has not been previously submitted to any academic institution for any form of recognition or award.

Signature 

Date 4th/12/2023

APPROVAL

We, as supervisors from Gulu University, hereby approve the submission of this dissertation.

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DEDICATION

This work is dedicated to my beloved parents, Haji Maclow Mohamud and Dahabo Hassan, as well as my siblings and friends for their invaluable support throughout my academic journey.

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ACRONYMS

AOAC	Association of Official Analytical Chemists
UDHS	Uganda Demographic Health Service.
UBOS	Uganda Bureau of Statistics
MND	Micronutrient deficiency
FAAS	Flame Atomic Absorption spectrophotometer
RDA	Recommended Daily Allowance

ABSTRACT

Micronutrient deficiencies remain a significant public health concern for children under the age of five and women of reproductive age in Northern Uganda, as well as other regions across the globe. The present study aimed to examine the impact of different quantities of sesame residue ash filtrate on the mineral composition and sensory acceptability of *Vigna unguiculata* (cowpea) and *Cucurbita pepo* (pumpkin) leaves, prepared using traditional methods. The ash filtrate was derived from residual sesame plant material. The concentrations of minerals in both the ash filtrate and cooked vegetables were analyzed utilizing an atomic absorption spectrophotometer. Thirty grams each of cowpea and pumpkin leaves were subjected to cooking with varying amounts of sesame ash filtrate. The experiment was conducted with four different treatments, including 0 mL (control), 15 mL, 30 mL, and 45 mL of sesame ash filtrate. Standard procedures were employed to investigate sensory assessments among 97 participants and mineral analyses of traditionally prepared vegetables with varying ash filtrate application. The findings reveal that the application of ash filtrate at a rate of 15 mL resulted in the highest overall acceptability scores of 4.69 and 4.18 for cooked cowpea and pumpkin leaves, respectively. The addition of 15 mL of sesame ash filtrate resulted in significant improvements in the concentrations of zinc (18.25-59.50 mg/Kg, p value= 0.01, α = 0.05), iron (24.6-128.95 mg/Kg, p value= 0.01, α = 0.05), magnesium (129.75-305.15 mg/Kg, p value= 0.01, α = 0.05), calcium (299.5-353.85 mg/Kg, p value= 0.03, α = 0.05), potassium (172.75-303.25 mg/Kg, p value= 0.005, α = 0.05), and sodium (190.0 -301.0 mg/Kg, p value= 0.002, α = 0.05) in cooked cowpea and pumpkin leaves. In order to optimize the utilization of ash filtrate, it is recommended that households add approximately 15 mL of the filtrate to 30 g of vegetables (equivalent to one market bundle).

Keywords: *Plant residues Ash filtrate; micronutrient deficiency traditionally prepared vegetables.*

CHAPTER ONE: INTRODUCTION

1. 1 Background

Micronutrient deficiencies (MNDs) are an omnipresent public health challenge (Galani et al., 2020). Globally, over one billion people suffer from one or more chronic micronutrient deficiency-related illnesses (Ahmed et al., 2013). Reports indicate that about 90% of those at-risk live in Africa and Asia (Galani et al., 2020). The most affected groups are women of reproductive age and children under 5 years (Galani et al., 2020). A multitude of micronutrient deficiencies have been identified, including but not limited to calcium, iron, zinc, iodine, selenium, and various vitamin deficiencies (Theodore, 2010). The dire consequences of these deficiencies have been well documented. As stated by Udho and Nankumbi (2019), zinc deficiency can lead to impaired immunological functioning, growth retardation, and loss of appetite. Cognitive impairment has been linked to vitamin B-12 deficiencies (Omona, 2021) and iron deficiency (Balikowa, 2011) but its effect on children is not clear (Kikafunda et al., 2009). Diseases such as night blindness, ricket and anemia have been widely studied and associated with Vitamin A (Bhandari & Banjara, 2015), vitamin D (Janner et al., 2010) and iron (Pavord e t al., 2012) deficiencies, respectively.

In the region of sub-Saharan Africa, specifically in Nigeria, Ethiopia, Kenya, Somalia, and Uganda, there is a high incidence of deficiencies in iron, iodine, zinc, and vitamin A among children under the age of 5. The prevalence rates for these deficiencies are 70%, 42%, 25%, and 48%, respectively, as reported by Ecker and Weinberger in 2010 and Harika et al. in 2017. The prevalence of Musculoskeletal and Neurological Disorders (MNDs) among the population of Uganda is reported to be 69%, according to Fungo's study in 2009. Children younger than 15 years (46%) and women of reproductive age (23%) are the most affected (Balikowa, 2011).

MNDs results from low dietary intake of Vitamins and minerals (Bhandari & Banjara, 2015). Like vitamins, adequate intake of minerals is compromised by perennial consumption of largely plant-based foods such as starchy foods, legumes and vegetables. This is because such plant-based foods are regarded as poor-quality sources of micronutrients as compared to animal sources (Mekuria et al., 2021). Furthermore, consistent intake of animal-derived micronutrients has been linked to improved economic status, as per Shivakumar et al. (2019). However, this may not be a viable option for impoverished nations and households. Hence, it is imperative for developing nations such as Uganda, which are severely impacted by micronutrient deficiencies as per Ukeyima et al. (2019), to undertake persistent measures to combat such deficiencies. This will help prevent the adverse implications on public health and overall development.

Numerous strategies including fortification and micronutrient supplementation have been used to boost micronutrient intake (Lutter et al., 2021). The strategy that is most employed is the supplementation of micronutrients, as indicated by Adoko et al. (2021). However, it is only curative but not preventative, and hence it is only used to avert severe cases of malnutrition (Barffour et al., 2019; Brown et al., 2007). Furthermore, the efficacy of supplementation use among the general population is impeded by restricted access application rate from exorbitant costs, insufficient supply, and challenges in storage and transportation, as noted by Barffour et al. (2019), Horton, Begin, and Greig (2008), and Nair et al. (2016). Therefore, it is imperative to establish and implement preventive measures aimed at alleviating micronutrient deficiency at the household level.

Therefore, the current study intends to contribute to the challenges of micronutrient deficiencies from the perspective of ash filtrate. Ash filtrate is obtained from burnt crop residues. According to Bergeson et al. (2016), the plant residues commonly utilized for filtrate production include beans (*Phaseolus vulgaris L.*), banana peels, sunflower, and Sesame stem.

The process of obtaining ash filtrate in the Acholi sub-region involves adding water to ash obtained from burnt crop residues. The filtrate that has been collected is utilized for culinary purposes (Tara, 2014). According to Ngoualem et al. (2020), the addition of filtrate to vegetables and hard-to-cook foods, such as dried legumes, is known to reduce cooking time and enhance flavor. According to Mallemo et al. (2010), a prior investigation revealed that ash filtrate comprises a range of macronutrients and micronutrients, such as iron, iodine, magnesium, calcium, potassium, phosphorus, and zinc. The degree to which ash filtrate, a commonly utilized substance in food preparation, augments its micronutrient composition is not adequately understood. The present study aims to conduct an empirical investigation into the impact of ash filtrate utilization on the micronutrient composition and sensory acceptability of conventionally prepared vegetables.

1.2 Statement of the Problem

Micronutrient deficiencies (MNDs) continue to be prevalent in low-income countries, such as Uganda. The aforementioned deficiencies are prevalent among children under the age of five and women of reproductive age, as reported by Bégin et al. (2001), Gupta et al. (2020), and Ohanenye et al. (2021). According to the 2016 Uganda Demographic and Health Survey report (UBOS 2017), in the Acholi sub-region, 71% of children under the age of 5 and 47% of women between the ages of 15-49 were found to be anaemic. The primary cause of micronutrient deficiencies (MNDs) is the limited consumption of foods that are rich in these nutrients, as noted by Gupta et al. (2020). This is often due to poor dietary quality, as highlighted by Nair et al. (2016). In Uganda, commonly consumed foods such as cereals, roots, and legumes (Gitau et al., 2019) may not provide sufficient micronutrients as needed by the body. Regrettably, fortified foods are financially burdensome for most households within the communities.

The utilization of ash filtrate in culinary applications is not a novel concept, however, its impact on the micronutrient composition of the prepared food remains inadequately comprehended.

The production and application of filtrate in cooking vegetables has predominantly relied on experiential knowledge rather than empirical research. Three insights have been generated from the data, the first being that the source of the filtrate differs among households. The quantity of water added exhibits significant variation, thereby impacting the mineral concentrations of the filtrate. Finally, the quantity of filtrate added may vary depending on the type and quantity of vegetables being prepared. In addition to the aforementioned insights, prior research conducted by Mallemo et al. (2010) revealed that ash filtrate comprises a range of macronutrients and micronutrients such as iron, iodine, magnesium, calcium, potassium, phosphorus, and zinc. The efficacy of incorporating ash filtrate in food preparation to enhance its nutrient content remains uncertain. The degree of improvement and the impact of varying levels of application on sensory perception remain unclear. The objective of this study is to examine the impact of ash filtrate on the micronutrient composition and sensory acceptability of traditionally prepared vegetables, with a focus on the source of the filtrate.

1.3 The Purpose of the Study

The purpose of this study was to evaluate the use of ash filtrate as traditionally practiced in Acholi sub-region and assess its contribution to dietary mineral concentration of traditionally prepared vegetables. This study is intended to contribute towards efforts in addressing micronutrient deficiency in the Acholi sub-region.

1.4 Objectives of the Study

1.4.1 General objective of the study

To investigate the effect of ash filtrate as an alternative source of micronutrients in commonly consumed traditionally prepared vegetables.

1.4.2 Specific objectives of the study

- i. To determine micronutrient contents and pH of selected sources of ash filtrate used in Acholi sub-region.
- ii. To assess the effect of using ash filtrate on micronutrient contents of selected traditionally prepared vegetables.
- iii. To evaluate the sensory acceptability of selected traditionally prepared vegetables.

1.5 Hypothesis

Ho:1. There is no significant difference in micronutrient contents of selected sources of ash filtrate used in Acholi sub-region.

Ho: 2. Ash filtrate has no significant effect on consumers sensory acceptability of selected traditionally prepared vegetables.

Ho: 3. There is no significant difference in the extent of change in micronutrient contents of selected vegetable prepared traditionally using ash filtrate.

1.6 The Significance of the Study

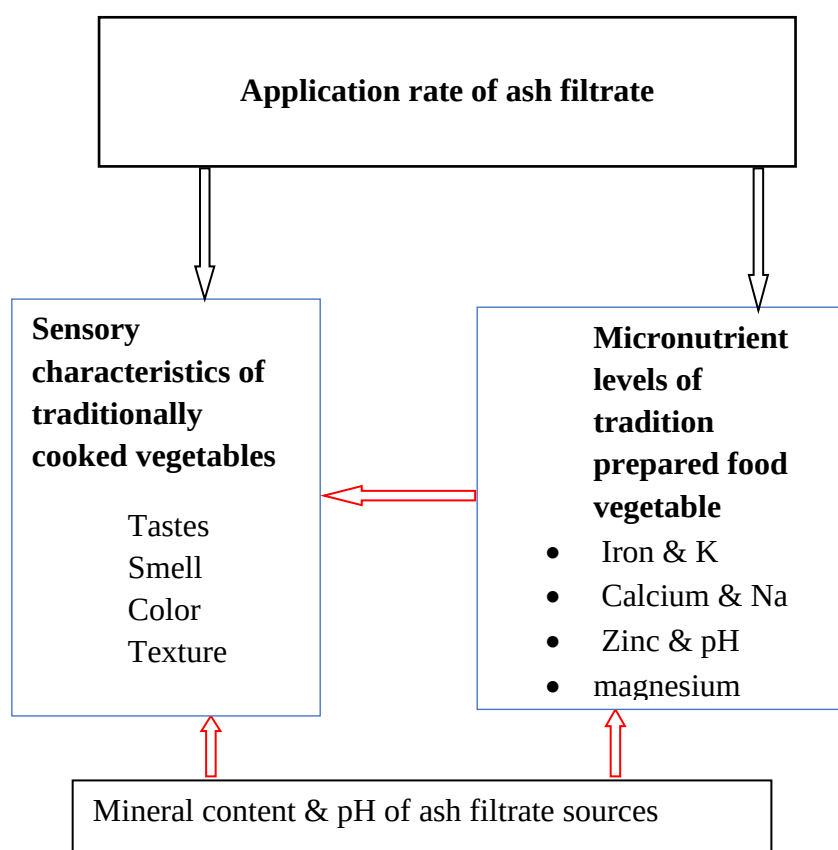
Micronutrient deficiency represents a prevalent form of malnutrition within the Acholi sub-region. According to Gupta et al. (2020), the demographic groups most significantly impacted are children under the age of five and women of reproductive age. To address the issue of micronutrient deficiencies, there has been an increased focus on utilizing fortified food supplements. Fortified food supplements are often unaffordable for many households within the local communities. Utilizing local remedies, such as compounding foods with nutritious local food sources, can provide a cost-effective and easily accessible alternative for households within the community. The present study utilized ash filtrate derived from crop residues produced locally to examine its impact on mineral contents and sensory acceptability of certain

traditionally prepared vegetables. The data produced by this study proved valuable in addressing micronutrient deficiency within the sub-region.

This study will generate empirical scientific data on the utilization of ash filtrate in food preparation and establish the impact of ash filtrate on micronutrient intake. This study is significant as it provides valuable information on the micronutrient composition of conventionally prepared vegetables using ash filtrate. This data can be instrumental in addressing micronutrient deficiencies and associated health concerns in various communities. In addition, the study will furnish empirical data that can be utilized by governmental and non-governmental organizations (NGOs) in the process of policy formulation. Furthermore, this study will prove to be valuable in conducting literature reviews and will establish a fundamental basis for forthcoming research in associated fields.

1.7 Conceptual Framework

The conceptual framework guiding this study is portrayed in Figure 1. The framework shows that the micronutrient level of ash filtrate and ash filtrate application rate may affect the micronutrient levels of traditionally prepared foods and sensory attributes of the traditionally prepared foods.



Key

 Dependent variables.	 Interaction of interest
 Independent variables.	 Interaction not interested in

Figure 1.1: Conceptual framework for mineral level and sensory attributes of traditionally cooked vegetables

1.8 Scope of the Study

The present study was conducted to investigate the impact of ash filtrate (*kado-atwona*) application rate on the micronutrient composition and sensory attributes of traditionally prepared vegetables in the Acholi sub-region. The study was conducted in the sub-region, specifically in Gulu city and Omoro districts, due to the high prevalence of micronutrient deficiencies in recent years, as reported by UBOS in 2018. Laboratory analysis was performed at the Gulu University laboratories. The research was carried out between June and October of 2022.

CHAPTER TWO: LITERATURE

2.1 The Relationship between Ash Contents and Mineral Content

According to Chaney (2012), ash is defined as the inorganic residue that remains after the removal of water and organic matter through heating and is used as a measure of the total mineral content in a food. According to Grzyb et al. (2020), the composition of cereal crop residue ash is primarily comprised of SiO_2 (51%) and K_2O (17%), with moderate levels of CaO and Cl_2O (6% each), and trace amounts of other elements ($< 3\%$). According to Tara et al. (2016), the composition of sugarcane residue ash in 12 distinct reports indicates a comparable SiO_2 content (54%) to that of ashes from cereal crop residues. According to Zhai et al. (2021), the ashes of sugarcane residues displayed elevated levels of Al_2O_3 (11%) and O_3 (8%), while lower levels of K_2O (8%) and CaO were noted. The analysis of soybean residue ash composition revealed a lower percentage of SiO_2 (21%) compared to cereals and sugarcane, which are classified as grasses. However, the ash composition contained higher levels of K_2O (21%), CaO (17%), MgO (6%), and P_2O_5 (5%), with trace amounts ($<3\%$) of other elements (Hedayati, 2022; Pyar & Peh, 2018). According to recent research, an analysis of the ashes indicates that the primary components of rice husk and rice straw ash are silicon (64.5%–74.8%), tungsten (8.70%), potassium (6.98%–13%), phosphorus (4.95%), and calcium (4.33%) (Hakeem et al., 2022). The constituents found in coffee husk and cocoa pod husk are primarily potassium (72.1%–77.5%), calcium (6.82%–9.76%), and magnesium (3.02%–5.5%) as reported by Azizah et al. (2022) and Wanjekeche et al. (2003). It can be inferred that the mineral content varies depending on the source residue. Therefore, the initial phase of the present investigation involved comprehending the mineral constitution of the ash filtrate derived from prevalent plant remnants.

2.2 Methods of Measuring Ash Content in Foods

There are three primary analytical procedures employed to determine the ash contents of foods, namely dry ashing, wet ashing, and low-temperature plasma dry ashing. The selection of a specific analytical method is contingent upon the purpose of the analysis, the nature of the food sample, and the equipment at hand. According to Tara et al. (2016), the ash content in fresh food is typically below 5%. However, certain processed foods, such as dried beef, may contain ash levels as high as 12%.

2.2.1 Dry ashing procedure

Dry ashing procedures uses a high temperature muffle furnace capable of maintaining temperatures of greater than 500 °C (El-Hosry et al., 2023). Typically, a specimen is subjected to a temperature of 500-600°C for a duration of 24 hours. Volatile substances, including water, undergo vaporization. Organic substances are burned in the presence of oxygen to CO₂, H₂O and NO₂. According to Galani et al. (2020), most minerals undergo conversion into oxides, carbonates, sulfates, phosphates, chlorides, or silicates. Although most minerals have low volatility at these high temperatures, some are volatile and may be partially lost, e.g., iron, lead and mercury (Karpukhina et al., 2021). If an analysis is being carried out to determine the concentration of one of these substances, then it is advisable to use an alternative ashing method that uses lower temperatures (Matusiewicz, 2017).

One of the benefits of utilizing this method is its safety, minimal reagent requirement, and ability to analyze multiple samples concurrently. Nevertheless, the process of utilizing muffle furnaces is time-intensive, typically taking between 12-24 hours. Additionally, the operation of muffle furnaces can be quite expensive due to high electrical costs. Furthermore, there is a risk of losing volatile minerals such as Cu, Fe, Pb, Hg, Ni, and Zn at high temperatures, as noted in studies by El-Hosry et al. (2023) and Matusiewicz (2017).

In recent times, there has been a development of analytical instruments that utilize microwave heating to dry ash samples, as reported by Harris and Marshall in 2017. These devices have the capability to be programmed to extract a significant amount of moisture initially, utilizing a low heat, and subsequently transform the sample to ash, utilizing a high heat. Microwave instruments significantly decrease the duration needed to conduct an ash analysis, typically completing the analysis in under an hour. A significant drawback is the inability to conduct a simultaneous analysis of multiple samples, unlike a muffle furnace (Muse Mitchell, 1995).

2.2.2 Wet ashing

The technique of wet ashing is predominantly employed in the process of sample preparation for the subsequent analysis of minerals. According to Ebert et al. (2021) and Faridah & Holinesti (2021), the process involves the breakdown and removal of the organic matrix surrounding the minerals, resulting in their presence in an aqueous solution. Typically, a dehydrated food specimen is quantified and placed into a flask that contains potent acids and oxidizing agents such as nitric, perchloric, and/or sulfuric acids. Subsequently, the mixture is subjected to heat treatment (Faridah & Holinesti, 2021). The process of heating is sustained until the entirety of the organic matter has undergone digestion, resulting in the sole presence of mineral oxides in the solution, as per the findings of Mammi et al. (2022). The selection of the appropriate temperature and duration of the reaction is contingent upon the specific nature of the acids and oxidizing agents employed. As per the findings of Mindarti et al. (2020), the process of digestion usually lasts for a duration ranging from 10 minutes to a few hours, while being carried out at temperatures of approximately 350°C. The solution obtained can subsequently undergo mineral-specific analysis, as stated by Dutta and Sharma (2020). A minimal amount of volatile minerals is lost due to the utilization of lower temperatures, which is comparatively faster than dry ashing. When working with perchloric acid, a labor-intensive process, it is necessary to utilize a specialized fume cupboard due to the hazardous nature of

the substance. Additionally, it is important to note that this process has a low sample throughput, as stated by Hedayati (2022). The ashes were obtained using the dry ashing method in the present study. The primary objective of the study was to determine the mineral content of the ashes derived from various plant residues, rather than establishing their ash content. Upon critical examination of the literature, it is evident that most ash preparations for mineral analysis are conducted within a laboratory setting, where conditions can be regulated. The ash was prepared within the community, replicating the typical household practice where environmental conditions are unregulated, as per the present investigation.

2.3. Measurement of Mineral Concentration

In the food industry, it is often essential to possess knowledge regarding the concentration and type of specific minerals present in food products. According to Harris and Marshall (2017), minerals can be identified based on their low volatility, capacity to react with specific chemical reagents resulting in measurable changes, and distinctive electromagnetic spectra. According to Mekuria et al. (2021), atomic absorption or emission spectroscopy is a highly effective technique for determining the identity and concentration of minerals present in food. Instruments utilizing this principle can quantify the complete range of minerals present in food items, with the ability to detect concentrations as low as a few parts per million (Majesty et al., 2019).

2.3.1 Atomic Absorption Spectroscopy (AAS)

Atomic Absorption Spectroscopy (AAS) is considered as one of the pioneering techniques for elemental analysis that has been commercially developed (Tyler, 2001). The initial discovery of the phenomenon occurred in 1802, as documented by William Hyde Wollaston, an esteemed English scientist, who made observations and provided a description of the dark lines present in the sun's spectrum (Aletan & Kwazo, 2020). Atomic Absorption Spectroscopy (AAS) is a

technique utilized for the determination of mineral concentrations in various types of samples. The process entails the absorption of a specific wavelength of light by free atoms of an element, as stated by Hedayati (2022). This methodology is highly sensitive and allows for the detection of trace amounts of an element down to 1 ppm utilizing a flame-based procedure. The graphite furnace procedure has the capability to achieve detection limits as low as 0.001ppm. The method operates on the principle of absorbance, wherein a stable state of freely dissociated ground-state atoms is generated using a heat source (flame). This is achieved by passing light of a specific wavelength through the flame. The wavelength is indicative of the energy needed to stimulate an electron from its ground state to the first excited state, usually for a particular element. Subsequently, the quantity of light absorbed by the atoms during their transition to the excited state, also known as atomic absorption, was measured (Harris & Marshall, 2017). The concentration of an element in a solution can be calculated using the measured absorbance, with reference to a calibration graph.

One of the benefits of utilizing AAS instrumentation is its cost-effectiveness per analysis, user-friendly operation, exceptional sensitivity, and accuracy. One limitation of this method is its inability to analyze multiple samples simultaneously. Additionally, it exhibits lower sensitivity in comparison to graphite furnace techniques and necessitates relatively larger sample volumes ranging from 1-3 mL.

2.3.2 Inductively Coupled Plasma Atomic Emission Spectrometry (ICP AES)

The elemental species in Inductively Coupled Plasma Atomic Emission Spectrometry (ICP AES) systems undergo atomization and ionization within a high-temperature plasma, as described by Tyler (2001). Inductively coupled plasma (ICP) demonstrates favorable detection limits and an extensive linear range for most elements. ICP typically analyzes a variety of sample types, such as trace elements in polymers, wear metals in oils, and unique catalysts. The ICPs possess two distinct modes of operation, namely capacitive (E) mode characterized

by low plasma density and inductive (H) mode characterized by high plasma density. The transition from E to H heating mode is initiated by external inputs, as reported by de Andrade et al. (2020). The ICP AES instruments are restricted to analyzing solely liquid samples. Prior to analysis, it is necessary to implement a dissolution procedure for solid samples. According to this study, anabolic-androgenic steroids (AAS) may be utilized in low-income countries due to their accessibility and cost-effectiveness.

2.4 Application of Ash Filtrate in Cooking

Edible salt is a naturally occurring evaporite that can be obtained from various sources such as the sea, underground ore, or natural brine. It typically comprises a minimum of 97% sodium chloride (NaCl). According to Tara et al. (2016), it is a common practice in culinary arts to use it exclusively for the purpose of augmenting the taste of various dishes. Furthermore, there exist other distinct salts that have been recorded for application in food preparations, such as Lakes' deposits (Ngoualem et al., 2020), plant-based ashes (Tara et al., 2016), and evaporites obtained from these filtrates (Ngoualem et al., 2020). Based on the results of the chemical composition analysis, it has been determined that these substances are composed of a mixture of salts, which include both cations and anions.

According to Mindarti et al. (2020), the predominant cations observed are usually sodium or potassium, whereas the primary anions consist of carbonates, bicarbonates, sulfates, and chlorides. The prevalent utilization of these articles has been recorded in diverse African nations, including Nigeria, Niger, Chad, Cameroon, Ghana, Kenya, Burkina Faso, Uganda, Tanzania, Sudan, Central and East African countries, as reported by Mubaiwa et al. in 2019. Furthermore, according to Mubaiwa et al. (2019), these incidents have also been documented in various Asian nations, including Indonesia, India, and Sri Lanka, as well as in Papua New Guinea in Oceania and South American countries such as Bolivia, Paraguay, Colombia, and Peru. The salts employed in culinary applications, with a historical origin dating back to 4000

BCE, were originally formulated in areas where conventional sodium chloride salt was not easily obtainable. Hence, they can be categorized as conventional salts, as per the research conducted by Onwuka and Okala in 2003. In Africa, these substances have been documented to have various applications such as reducing the cooking time of legumes, vegetables, and cereals (Onwuka & Okala, 2003), enhancing the green color of vegetables, increasing the viscosity of sticky ones, serving as an emulsifier, and improving flavor (Lin et al., 2022). The cooking of legumes involves several processes to render them palatable, digestible, and accessible to nutrient availability (Cai et al., 2021). One of the primary constituents of plant cell wall composition comprises pectic substances. These substances must undergo degradation to facilitate the softening of internal cell tissue, including the bean (Wanjekeche et al., 2003). According to Zhang et al. (2022), the use of commercial table salt can expedite the cooking process of legumes by promoting the breakdown of pectin. This is achieved through a process of ion exchange and chelation, whereby sodium ions replace or extract ions from the intercellular cement.

According to Ngoualem et al. (2020), in certain regions of the world, an autochthonous ground salt is utilized to expedite the cooking process of legumes. The primary constituent of ground salt is trona, which is a hydrated sesquicarbonate of sodium. This renders it highly alkaline, as per research conducted by Ngoualem et al. (2020) and Pyar & Peh (2018). Research conducted by Gondek et al. (2020) has demonstrated that alkalinity exerts a significant impact on the softening of legumes, likely attributable to its effect on the process of starch gelatinization, resulting in a reduction in required cooking time. In certain regions of the world, such as rural Africa, plant ash and/or plant ash filtrate is utilized as a customary culinary supplement in lieu of ground salt (Pyar & Peh, 2018). Plant ash and ground salt are both highly alkaline and have been shown to have elevated mineral content; both factors which probably contribute to the observed reduced cooking time (Mubaiwa et al., 2019). According to previous research

conducted by Mubaiwa et al. (2019) and Wanjekeche et al. (2003), the addition of either plant ash or ground salt did not result in a significant difference in the cooking time of beans.

In Northern Uganda, there is a prevalent indigenous practice of leaching water through ash material generated from crop plant residue to obtain a concentrated ash filtrate (Onwuka & Okala, 2003). The ash filtrate is incorporated into the cooking water of particular food items, such as dried legumes that are challenging to cook (Bwembya et al., 2018). Women residing in the locality have reported two primary anecdotal justifications for this custom. According to El-Haddad and O'Leary (1994), there are two potential benefits associated with the use of plant ash filtrate in cooking. Firstly, it is believed to reduce the cooking time of various staple foods. Secondly, it is thought to enhance the palatability of certain foods. Legumes such as beans are considered as essential food items in developing nations (Araro et al., 2020), including Uganda. However, they are known to be challenging to prepare, particularly after undergoing a hardening stage, which is a physiological effect of inadequate storage conditions.

According to Tara et al. (2016), it has been reported that residents of Northern Uganda have observed a reduction in the cooking time of dried legumes by using a filtrate made from residual crop ash. The agricultural remnants commonly utilized for ash production include leguminous crop residues and sesame (*Sesamum indicum*). Although there is a substantial amount of information available regarding the utilization of rock salt to expedite the cooking process of legumes, the investigation into the use of crop ash and filtrate as an additive is restricted.

2.5 Determination of Physico-chemical Composition of Ash Filtrate

The primary components of Traditional Alkaline Salt (TAS) were identified as sodium, potassium, chlorides, phosphates, carbonates, and bicarbonates, regardless of their color or geographical origin. As per the findings of Onwuka & Okala's report (2003), plant-based ash salts did not exhibit the presence of iron and copper, whereas lake deposits were found to be

devoid of iron. According to Ebert et al. (2021), it has been found that plant-based ash salts contain a greater amount of potassium, whereas lake deposits have a higher concentration of sodium. The author emphasizes that regular consumption of salt obtained from plant-based ash has the potential to improve the functioning of the kidneys, bones, and cardiovascular system. On the other hand, the ingestion of rock salt-derived sodium has been associated with non-communicable diseases. Babich et al. (2019) found that the presence of bivalent cations in salts significantly affects the viscosity of charged hydrocolloids in adhesive vegetables and the preservation of green color during cooking. According to a recent study, there exists a significant correlation between the color of rock salts and their ionic composition, particularly with respect to major ions such as sodium, potassium, carbonates, and bicarbonates. According to a study conducted by Kégah Ngoualem et al. (2020), it was found that samples classified as "white" (plant-based ash and rock salt) exhibit a higher concentration of major components in comparison to those classified as "black". As per the findings of Onwuka and Okala (2003), the hue of ash and rock salts derived from plants in Cameroon does not vary based on agro-ecological zones. A similar observation was noted by Cai et al. (2021); however, the results obtained in Cameroon exhibit notable differences. According to the author's observations, the lake deposits sampled in Cameroon displayed a higher concentration of sodium (twice as much for "black" color), carbonates (three times higher for both colors), and bicarbonates (five times higher for both colors) in comparison to the samples collected in Abuja, Nigeria. It is important to note that as per the literature, the chemical composition of salt derived from plant-based ash and rock seems to differ based on the physical composition of the salts but remains uniform across agroecological zones. Therefore, it can be inferred that the physicochemical composition of ash filtrate derived from different plant residues cannot be acquired from current literature.

2.6 Effect of Ash Filtrate Application on Physiochemical Properties of Traditionally Prepared Vegetables

The nutritional composition of foods is subject to alteration upon the incorporation of ingredients. This variation is specific and contingent upon the nature of the nutrient, as indicated by Bwembya et al. (2018). According to Olaniran et al. (2020), a study has observed that the nutritional composition of the composite derived from a blend of cassava, orange flesh sweet potato, and cowpea flour at varying proportions is notably distinct, except for moisture. The ratios of ingredients used in blending determine changes in macronutrient and micronutrient contents. The incorporation of mushrooms into soy biscuits resulted in a significant improvement in the nutritional profile of the composite, particularly in terms of energy, iron, and fat content, as reported by Purbowati et al. (2021). A recent study has reported that a combination of various food ingredients can significantly increase the proximate composition of complementary food, which includes maize, soybean, peanut, and powder of *moringa oleifera*, except for crude fat and carbohydrates (Olusanya et al., 2020).

According to Mekuria et al. (2021), the proximate composition of staple grain (maize) was enhanced through the addition of honey larvae (*Apis mellifera*), resulting in a significant improvement in lipids (14.3 g/100 g), protein (12.56 g/100 g), and energy (427.18 kcal/100 g) content of the composite, as observed from a statistical perspective. Enhancement of proximate composition has been shown to improve the micronutrient content of public health significance. According to Adoko et al. (2021), it was observed that enhancing the nutritional value of flatbread by incorporating 30% orange-fleshed sweet potato resulted in a significant increase in vitamin A content, meeting 83.3% of the recommended daily allowance for pre-school children. According to Tumwine et al. (2019), the incorporation of skimmed milk powder and vegetables into millet-based composite flour resulted in a significant increase in the zinc and Vitamin A content. Specifically, the zinc content increased from 2.1mg/100 g to 4.1mg/100 g,

while the Vitamin A content increased from 15.5 µgRAE/100 g to 161µgRAE/100 g. The incorporation of different components can potentially impact the nutritional value of food items, either positively or negatively. The incorporation of oyster mushroom flour into wheat flour has been found to have a significant positive impact on the nutritional composition of bread, particularly in terms of fiber, protein, zinc, and iron (Okafor et al., 2012). On the contrary, it was observed that the orange flesh sweet potato-enriched pieces of bread exhibited a decrease in fat, protein, energy, and protein content, as reported by Kidane et al. in 2013. Based on the impact of incorporating diverse ingredients, it is evident that the influence of ingredient variation on nutritional composition is not consistent, but rather contingent upon the specific blending ratios and types of ingredients utilized. Consequently, the impact of incorporating ash filtrate into food items cannot be inferred from existing literature and thus constituted the focus of this investigation.

2.7 Effect of Ash Filtrate Application on Sensory Characteristics of Traditionally Prepared Vegetables

The fundamental sensory characteristics that impact the overall acceptability of a product to consumers include color, aroma, flavor, mouthfeel, and texture. The impact is heavily influenced by the food components and the techniques employed in food processing, as stated by Sommer (2013). The acceptability of food products among consumers can be influenced positively or negatively by variations in food ingredients. According to Farzana and Mohajan's study in 2015, the inclusion of mushrooms in wheat flour biscuit blended with soy flour resulted in enhanced consumer preference for sensory characteristics. According to Adoko et al. (2021), the flavor of pancakes produced from various ratios of OFSP and Iron-rich beans was found to be significantly distinct.

According to Irakiza et al. (2021), there were no significant differences observed in the crust color and crumb appearance between the soy wheat bread samples and the whole wheat bread

samples in another study. However, the texture, flavor, and overall acceptability of the same study exhibited significant differences. Based on the preceding discussion, it is important to note that the impact of adding ingredients on consumer preference cannot be broadly generalized, but rather is contingent upon the specific sensory attributes involved. In contrast, a study conducted in 2014 observed that sensory evaluations for taste, texture, and color were significantly higher for yoghurt blended with baobab flavor compared to the control group (yoghurt without the added flavor), while appearance did not show a significant difference (Chipurura et al., 2014). It is implied that when studying consumer sensory preference, greater emphasis should be placed on individual sensory attributes rather than overall acceptability. The impact of adding ingredients is likely to vary based on the nature of the product. According to a particular study conducted by Woreda in 2015, flat-breads containing Orange-Fleshed Sweet Potato (OFSP) were found to be well-received and favored by caregivers of preschool children in terms of all organoleptic characteristics.

On the other hand, a separate study conducted by Kebebu et al. (2013) indicated that the incorporation of wheat flour and broad bean flour in a ratio of 70:30 for pasta production did not result in any significant impact on the sensory preference of consumers with regards to all organoleptic characteristics. It is pertinent to acknowledge, based on literature, that the perceived impact of ingredient incorporation on the sensory characteristics of food items is contingent upon the specific ingredients utilized and the intended final product. Thus, it is evident that the impact of ash filtrate addition on consumer sensory preference for food cannot be ascertained from existing literature. The present study evaluated the impact of varying application rates of ash filtrate on the sensory acceptability of traditionally prepared vegetables.

CHAPTER THREE: MATERIALS AND METHOD

3.1 Study Design

The study employed cross-sectional and experimental designs, incorporating both qualitative and quantitative methodologies. A qualitative methodology was employed to gather data regarding the prevalent sources of ash filtrate and the vegetables that are commonly prepared using ash filtrate. In contrast, the Completely Randomized Design (CRD) was employed to gather quantitative data in laboratory experiments. Furthermore, sensory characteristics were included as a component of the quantitative design.

3.2 Study Area

The research was conducted in Gulu and Omoro districts of the Acholi sub-region in Northern Uganda, as shown in Figure 2. The Gulu district is situated near Lamwo District in the northern direction, while Pader District and Omoro District are located towards the east. Towards the south lies the Oyam District, while the Nwoya District is situated in the southwest and Amuru District in the west. The district of Gulu is situated at coordinates 32°17'57.0"E and 2°46'54.0"N and is approximately 333 kilometers (Km) away from the capital city of Kampala by road. The district of Omoro is geographically delineated by Gulu District to the north, Pader District to the east, Oyam District to the south, and Nwoya District to the west. The headquarters of the district is situated in the town of Opit, which is approximately 30 kilometers east of Gulu, the principal city in the Acholi subregion. The district of Omoro is located approximately 311 kilometers to the north of the capital city of Kampala via road.

A laboratory analysis was conducted at Gulu University's multifunctional laboratory.

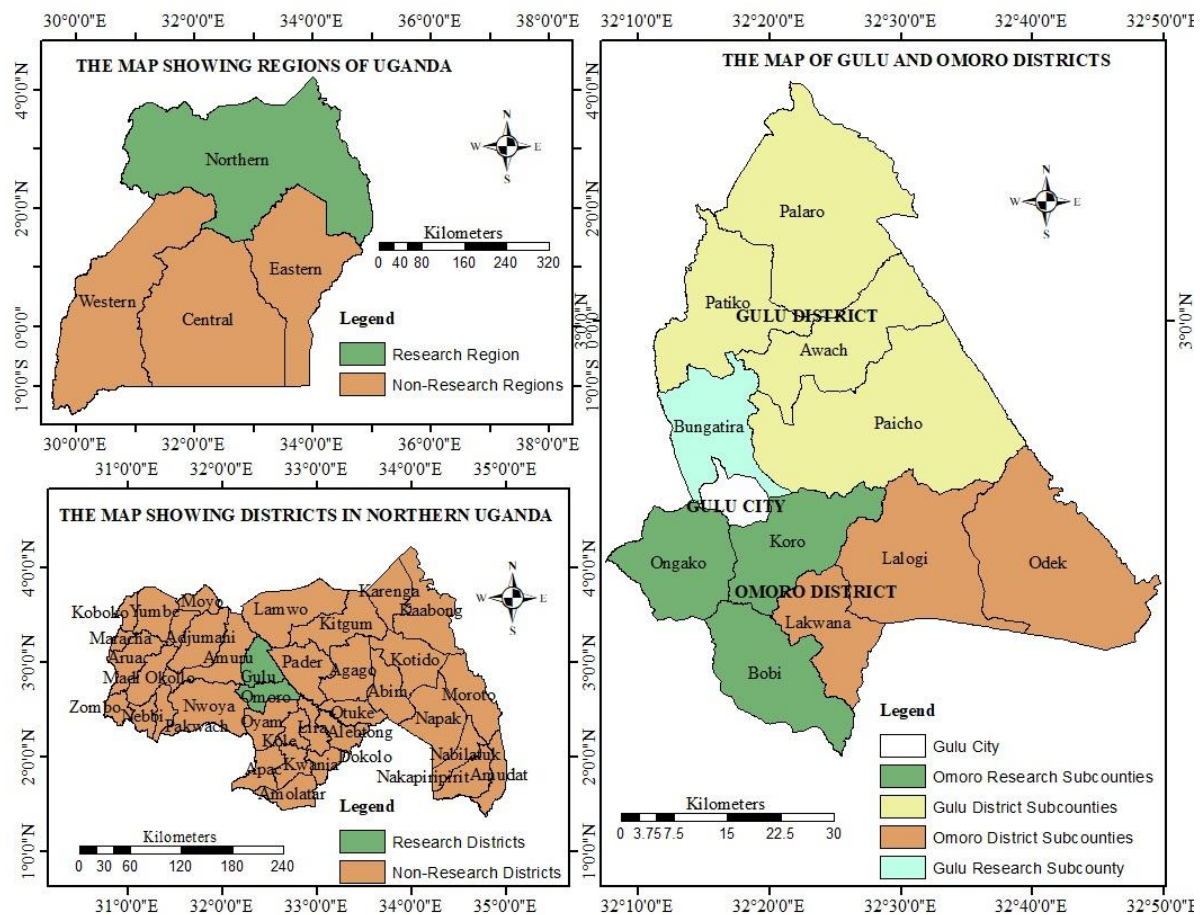


Figure 2.1: Map indicating the location of study districts and sub counties of Gulu and Omoro district in Northern Uganda

3.3 Determination of Micronutrient Contents of Selected Sources of Ash Filtrate used in Acholi Sub-Region

3.3.1 Sample collection and filtrate preparation

Focus Group discussions (FGDs) were conducted in Gulu and Omoro districts as described by (Access, 2013), to identify the common sources of ash filtrate and preparation methods. Briefly, Eight FGDs were conducted among 10 participants per session, each session lasting for 60 minutes. The women who participated in this were purposively selected due to their skill in making ash filtrate. The responses were captured by both audio recording with permission from the group and hand-written notes. From the FGDs, the common sources of ash filtrate used at the household level were banana peel, sesame, sunflower, and bean residues, others such as were also used sources of filtrate. Out of the four plant residues outlined, most of the participants involved in FGDs pointed out sesame residues as the most preferred and used plant source for ash filtrate in Acholi sub-region due to their availability and accessibility. From the FGDs, the preparation of plant residues ash was as follows (i) gathering dried plant residues in one place (ii) burning of gathered plant residues in the evening and allowing them to cool overnight. (iii) in the morning, the plant residue ash is collected in a polythene and transported home for storage in a pot. For the preparation of ash filtrate from plant residues ash (*Buru*), the following procedures were obtained from FGDs (i) using the right hand, three handful of the ash are transferred to the small container (700 mL) having holes of uniform diameter at the bottom (ii) the ash in the small container of is pressed using a right hand feast to compact (iii) thereafter sprinkled with water in plastic cup of 500 ml which then using the thumb the wet ash near the interior edge of the container is pressed to full compact it (iv) one cup (500 mL) full of water is poured on top of the wet ash in the small container, and then allowed to fully drained into a container about 400 ML.

3.3.1.1 Filtrate preparation in the laboratory

Based on the information obtained from FGDs, four plant residues were collected from the study areas and transported to Gulu university Faculty of Agriculture and environment for ash filtrate preparation and analysis. Following the burning of the plant residues into ash, the processing of the filtrate was done by two approaches in order to obtain optimal plant mineral concentrations. First, ash filtrate preparation was optimized by varying the amount of water added to a fixed mass of each plant ash. In brief, 200 mL of deionized (DI) water was added to 100 g of each plant residues ash placed in small container (700 mL capacity) with small holes of uniform diameter to allow water to drain for 1h at room temperature. The volume of ash filtrate collected was recorded. The procedure was repeated for 300, 400, and 500 mL of DI water, and the respective volume of ash filtrate collected recorded.

Second, to determine the optimal amount of ash required, 350 mL of deionized (DI) water was added to varying amount of plant residue ash. To 100 g of each plant residues ash placed in a small container (700 mL) with small holes of uniform diameter as before, 350 mL OF DI water was added and allowed to stand for 1h at room temperature. The volume of ash filtrate collected was recorded. The procedure was repeated for 200, 300, and 400 g of ash each obtained from the remaining plant residues, and the respective volumes of ash filtrate collected were recorded.

3.3.2 Analysis of mineral content and pH in ash filtrate

The mineral contents of the ash filtrate were analyzed using the methods outlined in the publications of Paterne et al. (2019) and AOAC (2005). 10 mL of 3% HNO₃ was added to 20 mL of ash filtrate for each sample. The sample was diluted with deionized water to a final volume of 100 mL and subsequently filtered through Whatman filter paper No. 41. The standard solutions for the respective mineral elements were prepared with a concentration range of 0.2 to 1.0 mg/L for magnesium, 0.1 to 1.0 mg/L for zinc, 0.5 to 4.0 mg/L for iron, 0.3

to 3.0 mg/L for calcium, and 10.0 to 20.0 mg/L for sodium and potassium. The concentrations of zinc, iron, magnesium, potassium, sodium, and calcium were determined through the utilization of an atomic absorption spectrophotometer (BUCK SCIENTIFICA, model 210 VGP, USA). Deionized water was utilized as a blank. The absorbance values of calcium (Ca), magnesium (Mg), iron (Fe), potassium (K), sodium (Na), and zinc (Zn) were measured at their respective wavelengths. A standard curve was generated by plotting the absorbance of individual mineral element ions against their respective concentrations in parts per million (ppm). The mineral element ion content of each ash sample was determined by extrapolating the absorbance of each sample using the standard curve. The mineral concentrations were quantified in milligrams per liter (mg/L) for each sample. The measurements were conducted in four replications. To each standard solution of Zn and Fe, 5 mL of Lanthanum nitrate solution (10% w/v) and 0.2% HNO₃ were added. For the Ca and Mg solutions, 5 mL of 0.2% HNO₃ (3 mol/L) were added to lower the pH. The sample, which was specifically for Fe and Zn, was subjected to a lamp current of 12 and 10mA, respectively. A band pass of 6.2 and 0.5nm was utilized to minimize interference.

The pH values of each ash filtrate were measured using a pH meter with the model number INE-PHSJ-4J. The measurements were conducted in four replicates. The result obtained from the optimization was used for selection of the plant residue with the highest mineral concentration.

3.4 Micronutrients Content Change in Selected Vegetables Prepared Traditionally using Ash Filtrate

3.4.1 Preparation of selected vegetables with ash filtrate

Sesame ash was selected because it produced ash filtrate with higher plant mineral content compared to other plant sources. It was noted that varying water quantity produced optimal plant mineral compared to variation of ash weight. As such, ash filtrate from 400 mL of DI

water added to ash was selected, and then used for preparation of traditionally cooked cowpea and pumpkin leaves at different application rates. From the FGD, cowpea (*Vigna unguiculata*) and pumpkin (*Cucurbita pepo*) leaves were among the common vegetables prepared using ash filtrate as one of the ingredients.

Vigna unguiculata (Cow peas) and *Cucurbita pepo* (pumpkin) leaves were prepared by a local woman cooking with ash filtrate is traditional practice in Acholi sub-ethnic group. The woman who participated in cooking was selected due to her skill in making vegetables cooked with ash filtrate. Briefly, each bundle of vegetables (~30 g) was bought from the local market and transported to the sensory evaluation site, and vegetable leaves were picked from the leaf stalk, but for pumpkin leaves the midrib were removed to reduce the roughness. Thereafter, each vegetables leaves were spread under the sunlight in a cleaned polythene bag for 10 minutes to repel worms and drive off dew on the leaves. After 10 minutes, each vegetable was collected, and cut into very small pieces using hand wooden knife. Then each cut vegetables leaf was added to boiling water followed by addition of ash filtrate at the rate of 0 mL, 1table spoon (15 mL), 2 tablespoons (30mL), and 3 tablespoons (45 mL) and the vegetables cooked until they were ready based on the experience of the women. Each of the cooked vegetables (30 mL) were packed 100 mL plastic container for further laboratory analysis.

3.4.2 Analysis of mineral content

During sample preparation, each of the cooked cowpea and pumpkin leaves were oven-dried for 24 hours (AOAC, 2005; Method 930.15), and thereafter, the dried cooked vegetables were dry ashed using Vulcan Furnace (AOAC 930.15, 2000) (Thermo SCIENTIFICA T16A, USA) for 3hours. The ash of each sample was added 10 mL of 3% HNO₃. Thereafter, the extract diluted with distilled water up to 100 mL, and the mixture was filtered through Whatman filter paper No. 41. The standard solutions of the respective mineral elements were prepared as

described earlier in section 3.3.3 and the mineral contents determined using atomic absorption spectrophotometer as described before in section (3.3.3).

3.5 The Effect of Application Rate of Ash Filtrate on Sensory Acceptability of selected Traditionally Prepared Vegetables

3.5.1 The study participants and selection criteria

The main participants of the study were women because they can effectively evaluate the sensory attribute as they are the one mostly involved in food preparation in Acholi Sub-region (Nankumbi, 2019). The number of participants (n) was calculated using a standard formula according to Kasiulevičius, Šapoka, & Filipavičiūtė, (2006) . The formula is presented mathematically in equation.

$$(n) = \frac{Z^2 P(1-P)}{e^2} \dots\dots\dots \text{Equation 1}$$

Where: n is the required sample size; Z is confidence level at 95% (standard value = 1.96); p is prevalence of anaemia among women (32%) and children (53%) under the age 5 in Acholi sub-region of Uganda (UBOS, 2016), and e is margin of error at 5% (standard value = 0.05).

For p = 53%, $n_1 = (1.97 * 0.53 * (0.47)) / 0.05^2 = 196$

For p = 32%, $n_2 = (1.97 * 0.32 * 0.68) / 0.05^2 = 171$

$n = (n_1 + n_2) / 2 = (196 + 171) / 2 = 184$, and the number of participants for Gulu (92 participants) and Omoro Districts (92 participants) was a half of the total number of samples.

From equation 1, the required participant sample size is 88. To cater for attrition, the number of participants was adjusted upwards by 15 % resulting into a final sample size of 97.

Multistage was employed to select women of reproductive age that was participate in the study. Gulu and Omoro districts, two sub-counties were selected randomly and thereafter two parishes were simply randomly selected. From each parish selected, two villages were randomly

selected. follow by purposive selection of caregivers particularly women with children below 5 years.

3.5.3 Sensory evaluation

The sensory evaluation was conducted utilizing a modified 5-point hedonic scale, as adapted from Adoko et al. (2021). The scale ranged from 1 (dislike extremely) to 5 (like extremely) and was employed to assess sensory perceptions of smell, color, taste, after-taste, texture, and overall acceptability. Before the exercise, the participants were provided with an orientation on the sensory evaluation protocol. Subsequently, a cooked vegetable specimen measuring 15, 30, and 45 mL was individually dispensed onto disposable plates for presentation. Before and following the evaluation of each cooked vegetable sample, the participant was provided with clean water to rinse their mouth. This was done to prevent any potential over or under-scaling of the sensory characteristics. The participants were situated at a considerable distance from each other to prevent any external interference.

3. 6. Data Analysis

Statistical Package for the Social Sciences was used to examine the data (SPSS version 25). Data were analyzed using One-way Analysis of Variance (ANOVA) and descriptive statistics (mean, standardization, and bar graph) were used to compare (i) the ash filtrate mineral composition and pH of the different plant ash source; (ii) plant mineral of the traditionally cooked cowpea and pumpkin leave with different application rate of sesame ash filtrate; and (iii) the rating level of each sensory characteristic of the traditionally cooked cowpea and pumpkin leave with different application rate of sesame ash filtrate. Furthermore, mean separation was done using studentized Post Hoc Tukey test because the separation was only done among application rates. A 95% confidence interval was used for the comparative analysis ($p \leq 0.05$). The results were shown as means $\pm$ standard deviation (SD).

3.7. Ethical Consideration

The study obtained ethical clearance from the Gulu University Research Ethics Committee (GUREC- 2022-268), as documented in Appendix VI. The Chief Administrative Officer of Gulu district granted permission for the research to be conducted within the community. Prior to participation, the participants were requested to provide their consent and were provided with a consent form to sign. The Minister of Health has reported that there was a rigorous adherence to the standard operating procedures for COVID-19. The confidentiality of the information obtained from the participants was maintained at the highest level. Ash is a commonly consumed substance in the Acholi sub-region. It is noteworthy that this substance is free from allergens that may trigger any allergic reactions during the study. In the event of any participant response, medical management was provided by a physician, as the study was conducted within a hospital setting. Finally, individuals with any prior history of allergies were excluded from participation in the study.

3.8. Limitation of the Study

The study did not take in to consideration the mineral bioavailability in the vegetables despite a number of reports that antinutritional factors such as phytate and oxalate (Gitau et al., 2019) exist in vegetables. In these limitations there could have been over or underestimate of the mineral levels in the vegetables. In addition, the difficulty in leaching all the minerals into the filtrate by filtration method. There are high chances of some minerals being retained in the ash residue. Also, the level of minerals in the ash depends of factors such as the soil condition, and climatic condition which vary from place to place, and hence the result may not be applicable over a long geographical area (Mallikarjuna et al., 2012).

CHAPTER FOUR: RESULTS

4.1. Micronutrient contents of selected sources of ash filtrate used in Acholi sub-region.

4.1.1. Effect of varying water volume on different plant ash filtrates' pH and mineral contents

Table 4.1: Filtrate recovery, mean pH and mineral concentration of 100 g of ash segregated by source.

Source	DI-A (mL)	FR (mL)	pH	Mineral Concentration (mg L ⁻¹)					
				Fe	Zn	Mg	Ca	K	Na
Sesame residues	200	70	11.23±0.1*	3109±15	703.0±0.7	794.7±0.7	1592.8±2.3*	100±45*	200±22
	300	160	11.24±0.2*	3104±80	614±9	788.7±0.6	1634±41.3*	180±76*	207±78
	400	270	11.28±0.5*	3282.4±3	894.6±41	790.7±0.1	1781.7±41.3*	200±83*	202±97
	500	330	11.30±0.1*	3009.2±1	787.2±108	773.1±0.1	1033.4±119.6*	250±65*	209±93
Banana peels	200	45	13.37±0.7*	2734±70	17.0±5.4	114.8±	165.4±29.7	800±0.6	900±31
	300	100	13.48±0.2*	1806±90	15.2±0.6	198.9±0.1	175.8±0.3	880±0.4	907±90
	400	250	13.16±0.2*	680.4±22	25±1.8	122.1±0.1	Bdl	900±0.7	902±28
	500	320	13.0±0.3*	1806±51	23.4±2.1	206.1±0.1	Bdl	950±0.9	909±19
Bean residues	200	60	11.46±0.4*	3202.8±7	38±2.1	786.8±0.1	74.0±28.9	150±15	500±10
	300	150	11.45±0.5*	2120.4±5	18.0±6.2	785.6±0.1	87.2±21.5	200±16	507±11
	400	245	11.49±0.1*	1994.4±5	12.6±0.3	771.7±0.1	114.6±32.0	210±23*	502±14
	500	335	11.48±0.2*	3308±18	14±2.3	775.7±0.1	1235.4±46.1	260±12*	509±25
Sunflower residues	200	80	12.0±0.8*	1773.2±1	15.8±2.6	768.45±0.1	1144.1 ± 84.6	300±2.5	430±5
	300	165	11.99±0.01*	1496± 37	13.6±0.6	770.1±0.02	1049.8±86.3	308±3.6	437±6
	400	270	11.86±0.9*	1787.2±9	13.6±0.7	781.6±0.2	906.8±106.4	313±53	442±7
	500	370	11.95±0.1*	3041.6±8	24.2±1.4	770.4±0.1	868.8±72.41	3180±60	449±8

Bdl= below detectable limit, Mean Standard Deviation with * are significantly different at $p \leq 5\%$, values shown are mean of $n = 4$ replicates, errors are shown as standard deviation. Zn= Zinc, Fe= iron, Mg=Magnesium, K= potassium, Na= Sodium, Ca= calcium, mgL⁻¹ = milligram per liter, Weight of ash was fixed at 100 g. FR = filter recovered, and DI-A = di-ionized water added.

From Table 4.1, except for sesame ash filtrate, the pH of ash filtrates from different plant sources increased with increasing water volume (from 200 -500 mL). The rise in pH with increasing water volume was significant ($p \leq 0.05$) for all sources of filtrate. The greatest and

the smallest increment in ash filtrate pH were ~1.4% and 1.0% respectively. The highest and the lowest pH rise were observed in banana (13.48) and sesame (11.30) residues, respectively. Filtrate from sesame recorded the highest mineral contents compared to other plant residues. Both iron (0.16-3.2%) and calcium (35.5%) contents from sesame ash filtrate increased with increasing water volume added. To the contrary, iron and calcium contents from beans, banana and sunflower residues ash filtrates declined with increasing water volume added. Sodium and potassium followed a similar trend to calcium. However, with magnesium there was decrease between 0.76-2.7% with increasing water volume in sesame ash filtrate only. Except for calcium content in sesame ash filtrate, variation in the amount of water did not significantly (p-value = 0.056) impact the mineral contents of ash filtrates from other plant residues. However, for banana peel ash, calcium contents were below detection limits for water volume above 300 mL.

4.1.2. Effect of varying ash weight on different plant ash filtrate's pH and mineral content

Table 4.2. Filtrate recovery means pH and mineral concentration at varying ash weight segregated by source.

Source	AA (g)	FR (mL)	pH	Concentration (mgL ⁻¹)					
				Fe	Zn	Mg	Ca	K	Na
Sesame residue ash	100	230	11.26±0.1*	2606.4±56	28.8±9.05	787.15±0.1*	979.0±16.1*	90±1.5*	100±7
	200	215	11.24±0.8*	1350.8±86	31.04±7.50	785.5±0.71*	1094.4±2.8*	105±1*	107±6
	300	155	11.17±0.5*	2232.8±73	17.0±7.64	787.5±0.71	969.0±198	120±5*	102±7
	400	90	11.37±0.5*	1432.8±77	781.4±109	794.35±0.01	491.0±42.71	170±6*	109±8
Banana peel ash	100	200	12.96±0.1*	1846.4±47	26.2±2.6	184.75±0.07	150.8±2.3	600±2.5	800±5
	200	100	13.14±0.2*	1628.4±90	28.2±2.35	186.10±0.14	74.0±28.8	650±3.6	807±6
	300	80	12.99±0.1*	3254.4±45	14.2±1.4	219.15±0.07	18.0±0.57	700±53	802±7
	400	45	13.03±0.1*	1901.6±89	34.2±2.23	257.15±0.07	150.8±2.2	750±60	809±8
Bean residue ash	100	180	11.50±0.3*	978±35	15.8±1.98	784.85±0.07	1684.4±59	150±0.5*	300±5
	200	165	11.65±0.2*	879.2±67	19.0±3.68	785.7±0.14	Bdl	200±0.6	307±6
	300	145	11.89±0.8*	1225.2±55	26.8±1.2	777.5±0.71	Bdl	210±3.4	302±7
	400	70	12.30±0.4*	2219.6±80	21.0±0.85	774.45±0.07	Bdl	260±0.6*	309±8
Sunflower residue ash	100	235	11.87±0.5*	2091.2±35	26.4±6.79	774.50±0.17	979.8±169.4	300±25	130±33
	200	170	12.21±0.7*	1921.6±19	16.8±3.96	751.25±0.49	1189.6±16	308±60	137±75
	300	145	12.73±0.3*	1693.6±12	15.6±1.13	669.65±0.64	1153.8±141.7	313±50	142±80
	400	70	13.16±0.9*	2165.2±10	19.3±0.14	445.65±0.07	568.4±23.19	3180±10	149±90

Means ± Standard deviation in the same row with * superscript is significantly different at 5%. Bdl = below detectable limit. Zn= Zinc, Fe= iron, Mg=Magnesium, K= potassium, Na= Sodium, Ca= calcium, mgL-1 = milligram per liter Volume of DI water was fixed at 350 mL. FR = filter recovered, and AA = Ash added

The result of varying ash weight on pH and mineral content of different ash filtrate are summarized in Table 4.2. Except for sesame ash filtrate, varying the ash weight from 100-400 g, significantly ($p \leq 0.05$) increased ash filtrate's pH from 12.96-13.03 for banana, 11.5-12.30 for beans, and 11.87-13.16 for sunflower residues. Irrespective of weight, sesame ash filtrate recorded the highest mineral contents compared to the other ash filtrates. Except for calcium and magnesium, varying ash weight did not significantly ($p \leq 0.05$) impact potassium, iron, sodium, and zinc contents. However, for banana peel ash, increasing weight above 100 g led to content of calcium being below detectable level at standard concentration range (0.5 ppm - 5 ppm) and dilution factor of 10. Sesame ash filtrate had a higher iron and zinc composition and lower pH composition compared to other plant sources, and hence sesame was chosen on this basis.

4.1.3 Mineral levels of ash filtrate from sesame extracted at fixed ash weight and water volume.

The result of the first and second optimization are summarized in Figure 4.1. First optimization (Figure 4.1a) which involved varying water volume from (200-500 mL) had a higher level of mineral contents than the second optimization (Figure 4.1b) which involve varying the mass of different plant residue ash weight from 100 g to 400 g. For instance, increasing water volume added (from 200 mL to 500 mL), increases ash filtrates calcium and zinc contents whereas its magnesium and iron contents were lowered. Irrespective of water volume added, iron was the highest mineral recorded followed by calcium. Ash filtrate had the lowest sodium content followed by potassium (Figure 4.1a). Adding 400 mL of water to 100 g of ash resulted in ash filtrate with the highest iron and zinc contents. Therefore, addition of 400 mL of water to 100 g of ash could be adopted for ash filtrate preparation at household levels (Figure 4.1b).

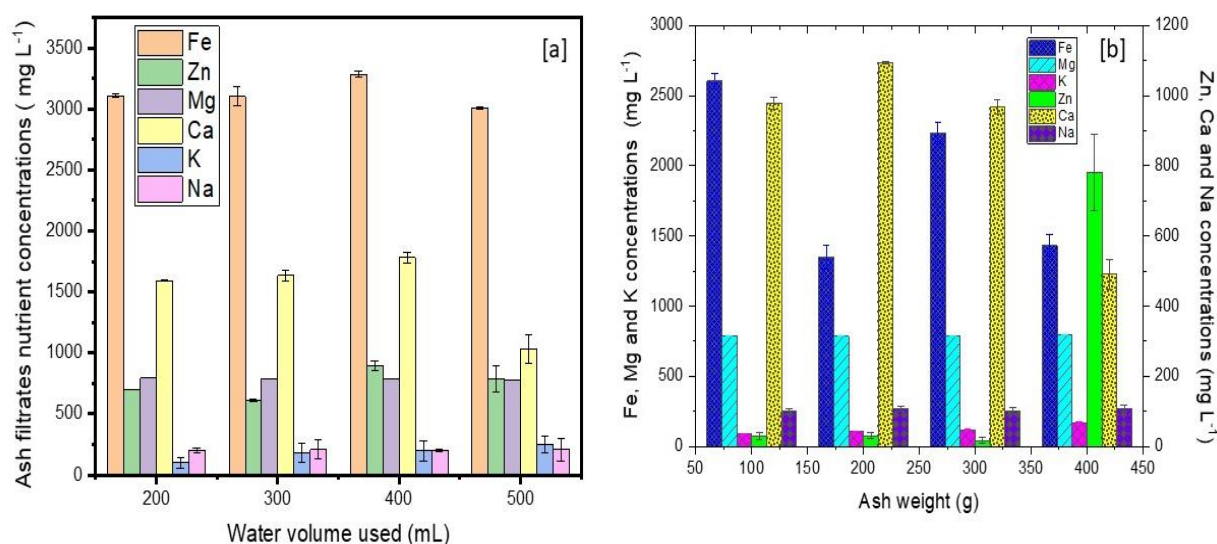


Figure 4.1. Mineral concentration of ash filtrate from sesame extracted at fixed ash weight (b) and fixed water volume (a).

Figure 4.1a: Mineral concentration at fixed ash weight fixed (100 g) but varying volume (200, 300, 400, and 500 mL) of water; Figure 4.1b: Mineral concentration at fixed water volume fixed (350 mL) but varying ash weight (100, 200, 300, and 400 g); Minerals: Ca = Calcium, Mg = Magnesium, Zn = Zinc, Fe = Iron K= potassium, Na= Sodium

4.2. Effect of Ash Filtrate Application Rate on Mineral Concentration of Traditionally Prepared Vegetables

The sesame ash filtrate used in the cooking was obtained after adding 400 mL of DI (deionized) water to 100 g of sesame ash residues placed in a plastic container (700 mL) containing small holes to allow the filtrate passage and using measuring cylinder. Application rates of 0 (nothing added), 15 (equivalent to three (03) teaspoons), 30 (equivalent to six (06) teaspoon), and 45 mL (equivalent to nine (09) teaspoons) were used in the cooking process. Mineral concentrations for each traditionally prepared cowpea and pumpkin leaves at different ash filtrate application rates in comparison with the control (prepared without ash filtrate) are presented in Table 4.3 and Table 4.4, respectively.

Table 4.3: The mean mineral concentrations in traditionally prepared vegetables segregated by application rate of ash filtrate and vegetable type.

Vegetable type	Mineral (mgKg ⁻¹)	Application rate of ash filtrate (ml)			
		0	15	30	45
Cowpea Leaves	Zn	13.9±2.3 ^{ab}	18.25±0.07 ^{bc}	25.35±6.6 ^{bc}	29.35±2.90 ^c
	Fe	9.1±0.14 ^a	24.6±0.42 ^b	42.1±0.42 ^c	56.0 ±0.070 ^d
	Mg	51.65±0.07 ^a	129.75±0.07 ^b	154.25±6.3 ^c	161.85±0.64 ^c
	Ca	18.5±0.7 ^a	299.5±67.18 ^b	280.5±2.12 ^b	298.95±3.180 ^b
	K	95.75±0.7 ^{ab}	172.75±0.07 ^{bc}	187.45±0.64 ^{bc}	250.05±65.97 ^c
	Na	333.35±6.3 ^a	301.0±8.49 ^b	257.35±0.92 ^c	190.01±3.18 ^d
Pumpkin Leaves	Zn	35.75±0.21 ^a	46.9 ±0.28 ^b	54.55±0.07 ^c	59.50±0.710 ^d
	Fe	42.60±5.90 ^a	60.15±0.21 ^b	89.10±0.98 ^c	128.95±0.07 ^d
	Mg	164.7±0.14 ^a	198.3±0.56 ^b	281.8±1.40 ^c	305.15±0.21 ^d
	Ca	385.00±7.0 ^a	353.85±5.4 ^a	302.85±2.01 ^b	271.3±20.60 ^b
	K	251.00±18.2 ^a	303.25±7.5 ^a	253.15±6.8 ^a	212.65±6.20 ^a
	Na	285.5±17.7 ^{ac}	240.0±0.10 ^{bc}	257.0±0.70 ^c	260.80±1.80 ^a

Mean ± Standard deviation (n=4) in the same raw with different superscript are significantly different at $p \leq 0.05$. Zn= Zinc, Fe= iron, Mg=Magnesium, K= potassium, Na= Sodium, Ca= calcium, mgKg⁻¹ = milligram per kilogram.

Compared to the control, zinc contents in traditionally prepared cowpea leaves significantly increased ($p \leq 0.05$) with rising quantity of ash filtrate (15-45 mL) added. However, ash filtrate application rates of 15 and 30 mL did not significantly affect the zinc content of traditionally prepared cowpea leaves (Table 4.3). Concentrations of Fe, Mg, and K followed similar trend as for zinc. Furthermore, Fe recorded the lowest percentage increase (4.69%) with rising ash filtrate application rates. Increasing ash filtrate application rates resulted in the highest percentage increase (28.1%) in Ca concentrations (Table 4.3). However, ash filtrate application rate 15, 30, and 45 ml resulted in a significantly ($p \leq 0.05$) lower sodium content compared to the control. The reduction in sodium concentrations corresponding to ash filtrate applications rates of 15, 30 and 45 mL were 9.7, 22.8, and 43%, respectively (Table 3).

Ash filtrate application rate of (15-45 mL) resulted in a significant ($p \leq 0.05$) reduction in Ca content (8.09-29.5%) compared to the control (Table 3). The observed content of K and Na followed a similar trend as that for Ca. Application of 45 mL of ash filtrate resulted in the lowest (8.65%) and the highest (15.28%) percentage decreases in Na and K concentrations, respectively, (Table 3). Also, Zn (31.19-66.43%), Fe (17.55%-86.35%), and Mg (20.4-85.28%) concentrations in cooked pumpkin leaves significantly ($p \leq 0.05$) rose with increasing ash filtrate application rates (15, 30, and 45 mL) compared to the control (pumpkin leaves cooked without ash filtrate).

4.3. Effect Of Application Rate of Ash Filtrate on the Sensory Quality of Traditionally Prepared Cowpeas and Pumpkin Leaves

4.3.1 Socio-demographic statistics of caregivers from Omoro District who participated in the study.

The participant's sociodemographic data is summarized in figure 4.2

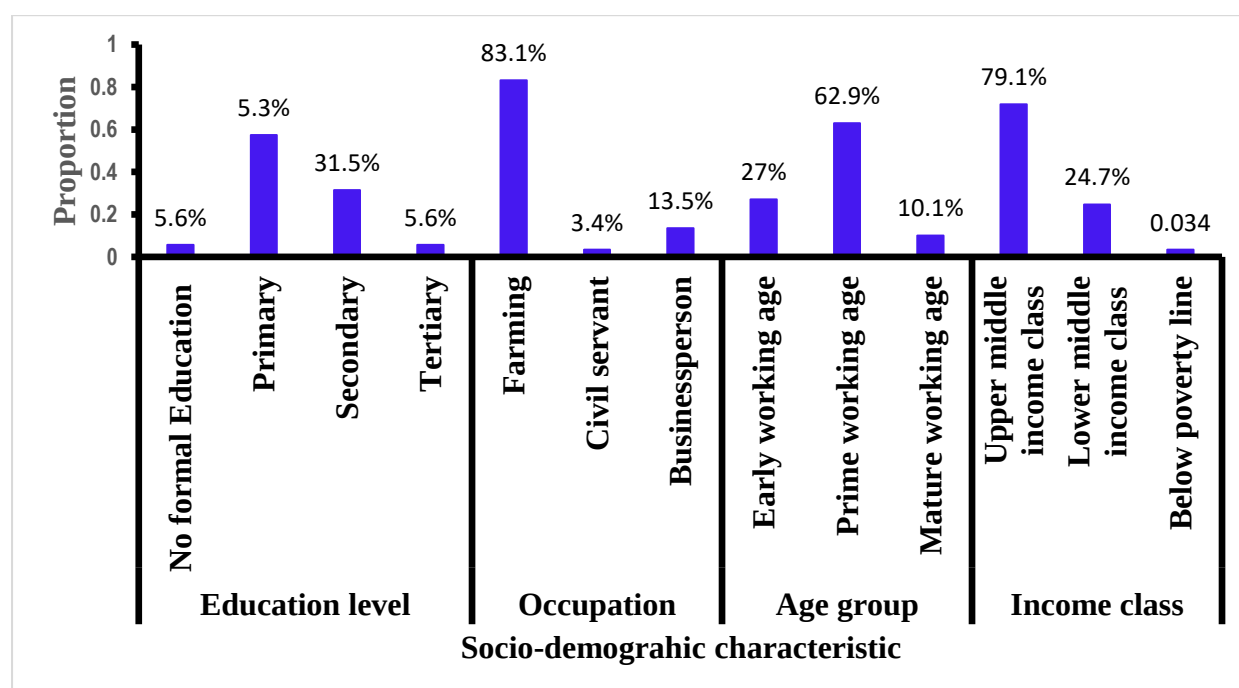


Figure 4.2. Socio-demographic Characteristics of participants of Omoro district who participated in the study.

Income groups were categorized according to Economic policy research center (EPRC) data on per capita daily consumption expenditure in purchasing power parity, Upper middle-class income (UG sh. 36,500-73,000), Lower middle income (UG Sh. 14,600-36,500), Below poverty line (< UG sh.7,300) (n = 89); Age group categorized based on Uganda Age Structure by Index mundi, Early Working age (15-24years), prime working age (25-54years), mature working age (> 54years).

The study involved 89 untrained female panelists from Omoro District. Prime working age of participants predominated (62.9%) in the study, followed by early- and mature-working age caregivers (Figure 4.2). More than quarter of the caregivers had no formal education (Figure 4.5) whereas over 50% completed their elementary education (particularly, primary, and

secondary). Many participants (83.0%) were farmers. Only 3.4% and 13.5% of caregivers work as civil servants and businesspersons, respectively. About three quarters of caregivers (71.9%%) fall in the upper middle-income class, 24.7% of them belong to the lower middle-income class. Only 3.4% of them belonged below the poverty line.

4.3.2 Influence of ash filtrate application rate on mean sensory score rating of traditionally prepared cowpea leaves.

Table 4.4. Mean sensory perception participants on traditionally prepared cowpea and pumpkin leaves at different application levels of ash filtrate.

Vegetable type	Sensory attribute	Application level of ash filtrate (ml) and mean scores			
		0	15	30	45
Cowpea leaves	Smell	2.42±1.16 ^a	4.77±0.52 ^b	3.53±1.16 ^c	3.72±1.04 ^c
	Color	2.08±0.93 ^a	4.41±0.76 ^b	3.58±1.16 ^c	3.29±1.00 ^c
	Taste	2.31±1.06 ^a	4.36±0.92 ^b	3.28±1.08 ^c	3.38±1.05 ^c
	Texture	2.10±1.02 ^a	4.39±0.90 ^b	3.07±1.04 ^c	3.17±1.08 ^c
	After-taste	2.26±1.16 ^a	4.43±1.04 ^b	3.28±1.10 ^c	3.20±1.10 ^c
	Overall acceptability	2.28±1.14 ^a	4.69±0.62 ^b	3.38±1.09 ^c	3.47±0.93 ^c
Pumpkin leaves	Smell	3.69±1.09 ^a	4.10±1.06 ^b	4.17±1.05 ^b	4.09±1.0 ^{ab}
	Color	3.48±1.11 ^a	4.16±1.01 ^b	4.19±0.99 ^b	4.09±1.06 ^b
	Taste	3.30±1.20 ^a	3.85±1.19 ^b	3.77±1.25 ^b	3.90±0.98 ^b
	Texture	3.36±1.04 ^a	3.76±1.22 ^{ab}	3.83±1.19 ^b	3.61±1.01 ^{ab}
	After-taste	3.46±1.08 ^a	3.92±1.24 ^b	3.97±1.70 ^b	3.83±1.05 ^{ab}
	Overall acceptability	3.61±1.17 ^a	4.15±1.02 ^b	4.18±1.09 ^b	4.20±0.93 ^b

± Standard deviation (n=89) in the same row with different superscript are significantly different at $p \leq 0.05$, on 5points hedonic scale. **The Scale:** 1=Dislike strongly, 2. Dislike, 3. Neither like nor dislike, 4. Like, 5. Like strongly

The mean sensory score of consumer rating of traditionally prepared cowpea and pumpkin leave with & without ash filtrate are summarized in Table 4.4. For application rates of 15, 30, and 45 mL, the sensory score for cowpea leaves were higher than the sensory score observed in cowpea leave traditionally prepared without (0 mL) ash filtrate (Table 4.4). For instance, scores for application rates of 15, 30, and 45 mL resulted in a significant ($p \leq 0.05$) higher sensory score for smell than the control. The sensory scores ranged from 1.3-2.35 points. Color,

taste, texture, and overall acceptability followed a similar trend. The optimum sensory score (for all the sensory attributes) corresponded to cowpea leaves traditionally prepared with 15 mL of ash filtrate.

On the contrary, ash filtrate application rate of 15 mL had no effect on the mean score of texture (Table 4.4). Scores for ash filtrate application rate of 15, 30, and 45 mL resulted in a significantly higher sensory score for smell than the control (Table 4.4). The difference in sensory scores ranged between 10.34-13.01%. Color, taste, texture, after-taste, and overall acceptability sensory scores followed a similar trend. Overall, traditionally prepared pumpkin with 30 mL of ash filtrate had the optimal sensory score.

CHAPTER FIVE: DISCUSSION

5.1 Ash Filtrate Mineral Composition and pH of Different Plant Source

The results of pH in the current study indicated that ash filtrates from plant residues were basic (pH >10) regardless of their sources (Table 4.1 and 4.2). These basic pH values are consistent with those from prior studies on the creation of alkaline crude extracts from burned plant components (Cai et al., 2021; Lin et al., 2022; Ulloa et al., 2017), predominantly existing as carbonates and hydroxides of calcium, potassium, magnesium, and sodium (Bwembya et al., 2018). The present study observed the highest and the lowest pH values in banana and sesame residues ash filtrates, respectively (Table 4.1 or 4.2), and which could be due to differences in the mineral compositions of the used sesame, banana peel, sunflower, and bean residues as indicated in Table 4.1 and 4.2.

The high pH values (basic) associated with plant ash residues (Table 4.2) could be ascribed to the presence of strongly basic potassium and sodium in each ash filtrate. Previous studies indicated that high ash filtrate pH values may lead to rise in food's pH (Tara, 2014; Piskin et al., 2022). This could interfere with the bioavailability of plant minerals as result of formation of stable hydroxide compounds, making it difficult to absorb in the ileum. So, to minimize food pH rise, households can use cooking oils like palm oil, which is high in free fatty acids(Matthäus, 2007). The fatty acids help in lowering the pH via partial neutralization reaction with hydroxyl ions(Li et al., 2020). This can increase the bioavailability of the plant minerals that are necessary to address micronutrient deficiencies. Also, the alkaline ash filtrate provides its consumers with protection against high levels of free fatty acids in cooking due to autoxidation.

The result of minerals of each ash filtrate found in the current study for calcium, magnesium, potassium, iron, sodium, and zinc (Table 4.1 and 4.2) could be attributed to the high mineral

content in the ash of the respective plant residues used. Previous studies indicated that the percentage of ash is 14.6% in banana (Pyar & Peh, 2018), 40% of biomass weight in sunflower (Yelatontsev & Mukhachev, 2021), and 4.82% in bean residues (Brigide et al., 2014). Furthermore, the high minerals of the ash filtrate could be ascribed to the fertile soil in which each plant crop was grown (Oumarou, 2016). Also, dirt which is accidentally left on plant parts during harvest and when ash is removed from the ground after the plant parts are burned, could explain the high composition of mineral as observed in this study since they may have added additional elements to the ash (Mubaiwa et al., 2019). Thus, the good ash-to-ash filtrate transfer exhibited by each ash in the present study may have resulted in leaching of the plant minerals from ash-to-ash filtrate, and hence enhanced quantity of these elements in the ash filtrate. However, the variation in the amount of mineral in each ash filtrate in the present study could be attributed to interspecies different in the mineral's absorption of capacity of different plant sources. The results of this investigation concur with prior findings in crop ash (Tara, 2014; Piskin et al., 2022; Pyar & Peh, 2018; Yelatontsev & Mukhachev, 2021).

According to earlier research (Idowu & Aduayi, 2007; Nyombi, 2014), high sodium and low potassium concentrations in plant ash, could be attributed to an antagonistic effect of the specialized transport channel in the plant root system of the plants. As such, the antagonistic effect of the specialized transport channel may have caused the variation of mineral composition observed in the present study. Moreover, the traditional ash filtrate's coarse quality could have been ascribed to variation in concentration of plant minerals. Furthermore, the significant differences in the mean values (Table 4.1 and 4.2) might be a result of the fact that each ash was produced at a place with dynamic conditions, and hence may have resulted in variation in the composition of mineral as seen in this study. The higher amounts of plant minerals in sesame ash filtrate compared to sunflower, bean, and banana peel ash filtrates (Table 4.1 and 4.2) of in this study, could be attributed to ease transfer of plant minerals from

ash-to-ash filtrate as result of non-sticky nature of sesame ash (KégaNgoualem et al., 2020). More so, the difference in the concentration of sodium and potassium may be attribute to the fine nature of sesame ash, which can compact easily and thus resulted in long contact time between the ash and water (Tara et al., 2016). This implies that the high mineral composition of ash filtrate could be packaged in the adequate amount and used at house level as substitute for rock salt to tailor intake of the respective mineral which is vital in improving the health and nutrition status, which is essential in Acholi subregion that has high prevalent of micronutrient deficiency.

Therefore, ash filtrate obtained from sesame residue could be used to prepare food to improve the plant minerals' composition of the food normally consumed per person per day, and hence can be utilized to mitigate micronutrient deficiencies among children aged below five years and women in reproductive age. However, the extent to which addition of ash filtrate with high concentration such as in sesame residue increases mineral level in local dishes is not well known. Hence the following section 5.2 provides an understanding of change in mineral levels because of inclusion of ash filtrate in the local dishes using cowpea and pumpkin leaves commonly eaten in Acholi subregion.

5.2 Effect of Ash Filtrate Application Rate on the Mineral Composition of Traditionally Prepared Vegetables

Traditional prepared vegetables (cow pea and pumpkin leaves) with sesame ash filtrate at different application rates (15, 30, and 45 mL) had significantly ($p \text{ value} \leq 0.05$) high Ca, Mg, Zn, and Fe contents than the controls (Table 4.3). The high concentration of Mg (Table 4.3) in the ash filtrate can be attributed to minimal loss of magnesium ion during cooking (Hlongwane et al., 2022). In contrast, the lower concentration of Zn in the traditionally cooked vegetables may probably due to high loss of zinc ion during cooking time as a result of impact of ash filtrate on the cell wall of the vegetables exposing zinc ions for complexation. Bwembya et al.,

(2018) in their study noted zinc loss caused by soda ash addition to food during cooking ranged from 12.5% to 100% in *Hibiscus esculentus* (upright) and *Bidens pilosa*, respectively. Preparing both pumpkin and cowpea leaves with sesame ash filtrate increased their calcium contents (Table 4.3). The Calcium contents in cooked cowpeas leave rose from (18.5 mg/kg) in control to 298.95 mg/kg for 45 mL of ash filtrate added respectively. On the other hand, the calcium contents in cooked pumpkin leaves decreased from (385.0 mg/kg) in control to 271.3 mg/kg for 45 mL of ash filtrate added (Table 4.3).

The decrease in the concentration of the calcium in cooked pumpkin leaves could be attributed to significant losses of calcium during cooking as result of increase chelation with phytic acid and oxalate (Wang & Guo, 2021). While for cooked cowpea leaves, the results found could be ascribed to negligible loss of calcium during cooking due to reduce complex formation (Korant et al., 2023). The difference in the chelation could be attributed to varying concentration of chelating agents especially phytic acid and oxalate in pumpkin and cowpea leaves.

The composition of phytic acid (4.59mg/100g) (Korant et al., 2023) in cowpea leaves is lower than the composition of phytic acid (28.38mg/100g) (Njoku et al., 2014) in pumpkin leaves. It's interesting to note that the sesame ash filtrate's alkaline properties dissolve hemicelluloses and lignin, hydrolyze uronic and acetic esters, expand cellulose, and reduce its crystallinity, all of which disturb plant cell walls (Mubaiwa et al., 2019), and hence nutrients leached out leading to complexation of crucial minerals such as zinc, calcium. This implies the sesame ash filtrate affects cell wall of plant differently during cooking, and hence leading to variation in the amount of mineral leach and complexed.

Both Zinc and iron contents of cooked vegetables increased compared to the control. Zinc is a crucial mineral for enhancing the immune system, while iron, a vital component of hemoglobin which helps in metabolic and enzymatic functions. The increase in both iron and zinc concentrations of the cooked vegetables might probably be attributed to negligible mineral

losses during cooking because of reduced complex formation these minerals. Results of the current study agrees with earlier research on the use of sesame ash filtrate (Cai et al., 2021; Tara et al., 2016). However, the percentage increase in zinc (3.13-11.15%) and iron (17.02-51.54%) contents in the cooked cowpea of the present study is higher than the percentage increase (15% for zinc) recorded by Tara et al., (2016) in black bean cooked with sesame ash filtrate, which could be attributed to variation in leaching of the minerals in during cooking. This implies that ash filtrate with high micronutrient content could enrich rich foods with micronutrients in traditional dishes, which can contribute to mitigating micronutrient deficiency.

Also, the concentration of K and Na in cowpea and pumpkin leaves cooked with sesame ash filtrate were much higher than the level obtained in the controls. The results of the current study agree with those of a previous study on the impact of rock salt on traditionally prepared vegetables (Imaga et al., 2010; Kégah Ngoualem et al., 2020; Madodé et al., 2011; Tara et al., 2016). However, the increment in the levels of Na and K in the present study were lower than those found when rock salt was used due to the higher K and Na concentrations of rock salt. The concentration of K and Na in rock salt, according to Kégah Ngoualem et al., (2020) was reported to be 200 mg/100 g and 350 mg/100 g, respectively. This is higher than the percentage of K and Na in sesame observed in the current study (Table 4.3).

The result of Mg in the present could be ascribed to sesame ash filtrate's dampening effect on cooking's detrimental impact on the mineral composition of cooked foods (Bergeson, 2014). The outcome of the current investigation is in contrast to the outcome of rock salt-cooked beans as recorded by Kégah Ngoualem et al., (2020), and which could be attributed to the variation in dampening effect of ash filtrate and rock salt. Ca, K and Mg in foods have beneficial effect regarding high blood pressure (Niyi et al., 2019) while Na escalates it (Mallikarjuna et al., 2012). This implies that plant residues with high levels of these minerals are important nutrition

dimension in management cardio-vascular diseases, while caution should be taken by cooking vegetables with low levels of common salt (NaCl) while using ash filtrate though there is a traditional belief that it increases sensory quality of foods. The impact of incorporating high-concentration ash filtrate, such as that found in sesame residue, on the sensory attributes of indigenous cuisine remains unclear. Therefore, Section 5.3 offers insight into the alteration of sensory attributes caused by the addition of ash filtrate to traditional Acholi subregion dishes that incorporate cowpea and pumpkin leaves.

5.3 Effect of Ash Filtrate Application Rate on the Sensory Quality of Traditionally Prepared Cowpeas and Pumpkin leaves

The success of food-based nutritional innovations in society has been associated with the crucial variable of consumer acceptability (Guiné et al., 2020). The acceptability of a particular food product is significantly influenced by the extent of consumer preference for its sensory attributes. The sensory attributes of a product are greatly influenced by the composition of its ingredients, the proportions in which they are blended, and the processing methods employed (Otolowo et al., 2018). Even while the scores were always higher than those noted in the controls of the two vegetables, apart from cow pea leaves cooked with 15 mL sesame ash filtrate, traditionally cooked cowpea and pumpkin leaves with sesame ash filtrate had a negative mean sensory score (Table 4.4). Due to the influence of alkalinity on the breakdown of cowpea leaves' cell wall characteristics (Kégah Ngoualem et al., 2020), the texture of cowpea leaves cooked with sesame ash filtrate may have improved (Onwuka & Okala, 2003). Onwuka & Okala, 2003 further reported that the addition of ash filtrate and ground salt improve the texture of bean by softening the taste, which is consistent with the findings of other studies on bean.

In the present study, the study population's familiarity with eating pumpkin leaves prepared with ash filtrate may explain why the sensory score of pumpkin leaves cooked with 15 mL is

not statistically different from the control. The fact that the sensory score reported in the current study is higher than that found by Tara et al., (2016) when ground salt is used to cook beans could be related to the increased alkalinity of sesame ash filtrate in enhancing the textural quality of the dish. According to the results of the current study, the higher alkaline condition of the sesame ash filtrate may have increased the pH of the food, causing the cell wall of pumpkin and cowpea leaves to soften. This is because the pH of sesame ash filtrate (above 11.0) is higher than the pH of ground salt (10.9) (Kégah Ngoualem et al., 2020). The cowpea and pumpkin leaves cooked with the 45ml of ash filtrate scored the lowest for taste and after-taste due to the bitterness taste and after-taste, as a result of the excess ash filtrate added, which exceeded the daily volume used by the women involved in the study as observed by the participant's complain of ash filtrate ("*kado atwona*") being too much.

This was most likely due to the high alkalinity of the ash filtrate treatment. The outcome is consistent with that discovered by Kégah Ngoualem et al., (2020) and Onwuka & Okala, (2003), who observed that addition of too much ground salt (0.7g) to beans resulted in a poor sensory score rating. The preference for the ground salt treatment, on the other hand, was unexpected because prior research findings suggested that it contributed to an unpleasant color (Wanjekeche et al., 2003), which is in contrast to the outcome of the present study, which found that the addition of 15ml sesame ash filtrate improved the color (light brown) of the cooked vegetables, making it more appealing. It's noteworthy to note that, in contrast to the findings of the current study, adding ground salt to beans causes them to turn a darker, less appetizing hue and lowers their sensory score rating (Antonic et al., 2020; Starowicz & Zieliński, 2019).

However, the sensory scores decreased when more than 15ml of sesame ash filtrate was added because the sauce's black color made it less appetizing. According to Antonic et al., (2020) customers prefer brown-colored foods over dark items. Perhaps because black beans were

utilized and the color variability was less obvious than with the lighter colored beans previously used, Tara et al., (2016) study, using black beans did not produce the same results.

The capacity of sesame ash filtrate to enhance flavor, which is pleasing to customers, may be the cause of the traditionally cooked veggies' more pleasant-smelling aroma. Cow pea leaves cooked with 30 and 45ml of sesame ash filtrate, on the other hand, may be the cause of the piercing smell of the excess ash filtrate, which may not have reacted during the cooking time. The results, however, contradict the finding that foods treated with ground salt and table salt were preferred (Antonic et al., 2020; Bergeson, 2014; Kégah Ngoualem et al., 2020; Onwuka & Okala, 2003; Tara et al., 2016). Compared to the other treatments, both treatments had larger sodium contents, which may play a significant role in sensory acceptability.

The conclusion of this is that no more than 15ml of sesame ash filtrate should be given to cow pea leaves that have been cooked with it to increase consumption. According to the research findings by Tara et al., (2016), the presence of crop ash filtrate in cooked pigeon peas led to poorer ratings for the food's overall acceptability. Except for pumpkin leaves, which scored significantly lower overall acceptability for cowpea leaves cooked with 30 and 45ml of the ash filtrate, this is consistent with the findings of the current investigation. This provides more evidence that ash filtrate contributes to the cooked cowpea leaf's less sensory appeal than cooked pumpkin leaf.

In contrast to the findings of Bergeson, (2014)., this investigation found that the presence of 15% ash filtrate did affect the cooked cow pea leaf's general acceptability. The current study also found that when compared to cooked cowpea leaves with > 15% mushroom inclusion, the addition of 15% ash filtrate had the best sensory rating. Cooking cowpea leaves with the least quantity of sesame ash filtrate (15%) could therefore result in a vegetable sauce that has better sensory qualities for young children under five and women who are of childbearing age. However, the discovery that the application of ash filtrate had a negative effect on consumer

sensory appeal was not specific to this study. For instance, Bergeson, (2014). similarly reported that the sensory appeal among panelists was severely reduced by frying pigeon with ash filtrate application rate. Unfortunately, there hasn't been much attention paid to improving the sensory quality of traditionally prepared vegetables. Given that acceptance of food is largely determined by sensory appeal as opposed to nutritional quality, the observed negative sensory effect is a potential factor that should be carefully taken into account in future attempts to improve the efficacy of the ash filtration for enhancing nutrient contents from plant-based foods (Imtiyaz et al., 2021).

CHAPTER SIX: CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusion

The study investigated the effect of ash filtrate as alternative source of micronutrients in commonly consumed traditionally prepared vegetables and assessed its contribution to dietary mineral concentration of traditionally prepared vegetable in Acholi sub-region.

The chemical composition of ash filtrate from plant-based residue has been studied but there is no clear information about the effect of ash filtrate application on plant mineral content of traditionally cooked vegetables. This research was therefore designed to investigate the effect of ash filtrate application rate on mineral contents and sensorial quality of traditionally cooked vegetables.

The study has shown that ash filtrate from sesame plant residues is basic with pH values > 10. The ash filtrate further had high concentrations of iron and calcium and other essential nutrients.

This study further indicated that ash application rate improves mineral concentrations of traditionally prepared vegetables (cowpea and pumpkin leaves).

The study suggest that households should add 15 mL of sesame ash filtrate in 30 g of pumpkin/cow pea leaves for optimum nutrient contents and best sensory acceptability.

6.2 Recommendations

The study further recommends that the community should be sensitize on the usage of ash filtrate for vegetable cooking and its potential benefit in mitigating micronutrient deficiencies.

Even though ash filtrate has a high amount of essential minerals, future studies should focus on determining the concentration of heavy metals which could make its consumption harmful.

The high mineral composition of ash filtrate could offer microbial stability; however, this was not examined in the present study. Therefore, the future could focus on this area.

Given that acceptance of food is largely determined by sensory appeal as opposed to nutritional quality, the observed negative sensory effect is a potential factor that should be carefully considered in future attempts to improve the efficacy of the ash filtration for enhancing nutrient contents from plant-based foods.

The effect of ash filtrate inclusion on the proximate composition of traditionally cooked vegetables was not assessed yet it is very vital in determining the nutrient adequacy of foods. Therefore, further studies should be done in that area. The high mineral composition of ash filtrate could enhance the bioavailability of minerals; however, this was not examined in the present study. Therefore, the future could focus on this area. The high mineral composition of traditionally prepared vegetables could be affected by antinutritional factors; however, this was not examined in the present study. Therefore, the future could focus on this area.

REFERENCES

- Access, O. (2013). *Malnutrition in Sub – Saharan Africa : burden , causes and prospects*. 8688, 1–9. <https://doi.org/10.11604/pamj.2013.15.120.2535>
- Adoko, M. C., Olum, S., Elolu, S., & Ongeng, D. (2021). Addition of Orange-Fleshed Sweet Potato and Iron-Rich Beans Improves Sensory, Nutritional and Physical Properties But Reduces Microbial Shelf Life of Cassava-Based Pancake (Kabalagala) Designed for Children 2-5 Years Old. *Journal of Culinary Science and Technology*, 00(00), 1–25. <https://doi.org/10.1080/15428052.2021.1911899>
- Ahmed, T., Hossain, M., Istiaque, K., & Asia, S. (2013). *An estimated one third of under-5 children (178 million) are stunted , whereas 112 million are underweight , making malnutrition the most common ‘ disease ’ of children Global Burden of Maternal and Child Undernutrition and Micronutrient Deficiencies Gl. 61(suppl 1), 8–17*. <https://doi.org/10.1159/000345165>
- Aletan, U. I., & Kwazo, H. A. (2020). Analysis of the Proximate Composition, Anti-Nutrients and Mineral Content of *Maerua Crassifolia* Leaves. *Nigerian Journal of Basic and Applied Sciences*, 27(1), 89–96. <https://doi.org/10.4314/njbas.v27i1.12>
- Antonic, B., Jancikova, S., Dordevic, D., & Tremlova, B. (2020). Apple pomace as food fortification ingredient: A systematic review and meta-analysis. *Journal of Food Science*, 85(10), 2977–2985. <https://doi.org/https://doi.org/10.1111/1750-3841.15449>
- Araro, T., Gemechu, F., Wotango, A., & Esho, T. (2020). Chemical Formulation and Characterization of Complementary Foods from Blend of Orange-Fleshed Sweet Potato, Brown Teff, and Dark Red Kidney Beans. *International Journal of Food Science*, 2020. <https://doi.org/10.1155/2020/4803839>

- Azizah, S. N., Febrianto, N. A., & Sukardi, . (2022). Antioxidant Properties of Cocoa Pod Husk Powder as Affected by Slicing and Oven-Drying. *Pelita Perkebunan (a Coffee and Cocoa Research Journal)*, 38(3), 190–199.
<https://doi.org/10.22302/iccricri.jur.pelitaperkebunan.v38i3.535>
- Babich, O., Dyshlyuk, L., Noskova, S., Sukhikh, S., Prosekov, A., Ivanova, S., & Pavsky, V. (2019). In vivo study of the potential of the carbohydrate-mineral complex from pine nut shells as an ingredient of functional food products. *Bioactive Carbohydrates and Dietary Fibre*, 18, 100185. <https://doi.org/https://doi.org/10.1016/j.bcdf.2019.100185>
- Balikowa, D. O. (2011). Social determinants of health: Food fortification to reduce micronutrient deficiency in Uganda: Strengthening the National Food Fortification Programme. *World Conference on Social Determinants of Health, 19-21 October 2011*.
- Barffour, M. A., Hinnouho, G. M., Kounnavong, S., Wessells, K. R., Ratsavong, K., Bounheuang, B., Chanhthavong, B., Sitthideth, D., Sengnam, K., Arnold, C. D., Brown, K. H., & Hess, S. Y. (2019). Effects of Daily Zinc, Daily Multiple Micronutrient Powder, or Therapeutic Zinc Supplementation for Diarrhea Prevention on Physical Growth, Anemia, and Micronutrient Status in Rural Laotian Children: A Randomized Controlled Trial. *Journal of Pediatrics*, 207, 80-89.e2. <https://doi.org/10.1016/j.jpeds.2018.11.022>
- Bégin, F., Cervinkas, J., & Mannar, V. (2001). Food fortification with vitamin A: The potential for contributing to the elimination of vitamin A deficiency in Africa. *Food and Nutrition Bulletin*, 22(4), 408–415. <https://doi.org/10.1177/156482650102200411>
- Bergeson, T. L. (2014). Use of filtrate from crop residue ash for cooking in rural households in Northern Uganda. *Master's Thesis, University of Northern British Columbia, April*.
- Bergeson, T. L., Opio, C., & Arocena, J. M. (2016). Elemental composition and potential health impacts of *Phaseolus vulgaris* L. ash and its filtrate used for cooking in Northern Uganda.

- African Journal of Food, Agriculture, Nutrition and Development*, 16(4), 11351–11366.
<https://doi.org/10.18697/ajfand.76.16170>
- Bhandari, S., & Banjara, M. R. (2015). Micronutrients Deficiency, a Hidden Hunger in Nepal: Prevalence, Causes, Consequences, and Solutions. *International Scholarly Research Notices*, 2015, 1–9. <https://doi.org/10.1155/2015/276469>
- Brigide, P., Canniatt-Brazaca, S. G., & Silva, M. O. (2014). Nutritional characteristics of biofortified common beans. *Food Science and Technology (Campinas)*, 34(3), 493–500.
<https://doi.org/10.1590/1678-457x.6245>
- Brown, K. H., De Romaña, D. L., Arsenault, J. E., Peerson, J. M., & Penny, M. E. (2007). Comparison of the effects of zinc delivered in a fortified food or a liquid supplement on the growth, morbidity, and plasma zinc concentrations of young Peruvian children. *American Journal of Clinical Nutrition*, 85(2), 538–547.
<https://doi.org/10.1093/ajcn/85.2.538>
- Bwembya, G., Thwala, J. M., Otieno, D. A., & Sibiya, T. E. (2018). Assessment of nutritional quality of cooked Swazi leafy vegetables. *African Journal of Food, Agriculture, Nutrition and Development*, 18(1), 13052–13073. <https://doi.org/10.18697/ajfand.81.16830>
- Cai, Y., Huang, L., Chen, B., Zhao, X., Zhao, M., Zhao, Q., & Van der Meeren, P. (2021). Effect of alkaline pH on the physicochemical properties of insoluble soybean fiber (ISF), formation and stability of ISF-emulsions. *Food Hydrocolloids*, 111, 106188.
<https://doi.org/https://doi.org/10.1016/j.foodhyd.2020.106188>
- Chaney, R. L. (2012). Food safety issues for mineral and organic fertilizers. In *Advances in Agronomy* (Vol. 117). <https://doi.org/10.1016/B978-0-12-394278-4.00002-7>
- Chipurura, B., Pswarayi, F., & Muchuweti, M. (2014). Sensory properties and consumer

- acceptance of a stirred-type yoghurt produced from baobab (. *African Journal of Food , Agriculture, Nutrition and Development*, 14(2), 8695–8708.
- de Andrade, M. F., da Silva, I. J. S., Pimentel, M. F., Paim, A. P. S., Cervera, M. L., & de la Guardia, M. (2020). Ultrasonic nebulization inductively coupled plasma optical emission spectrometry method for wine analysis. *Spectrochimica Acta Part B: Atomic Spectroscopy*, 170, 105924. <https://doi.org/https://doi.org/10.1016/j.sab.2020.105924>
- Dutta, M., & Sharma, M. (2020). Complementary foods: A review on types, techniques and nutritional content. ~ 90 ~ *International Journal of Home Science*, 6(1), 90–96.
- Ebert, S., Baune, M.-C., Broucke, K., Royen, G. Van, Terjung, N., Gibis, M., & Weiss, J. (2021). Buffering capacity of wet texturized plant proteins in comparison to pork meat. *Food Research International*, 150, 110803. <https://doi.org/https://doi.org/10.1016/j.foodres.2021.110803>
- Ecker, O., & Weinberger, K. (2010). *Patterns and determinants of dietary micronutrient deficiencies in rural areas of East Africa OLIVIER ECKER* □. 4(June), 175–194.
- El-Haddad, E.-S. H. M., & O’Leary, J. W. (1994). Effect of salinity and K/Na ratio of irrigation water on growth and solute content of *Atriplex amnicola* and *Sorghum bicolor*. *Irrigation Science*, 14(3), 127–133. <https://doi.org/10.1007/BF00193134>
- El Hosry, L., Sok, N., Richa, R., Al Mashtoub, L., Cayot, P., & Bou-Maroun, E. (2023). Sample Preparation and Analytical Techniques in the Determination of Trace Elements in Food: A Review. *Foods*, 12(4). <https://doi.org/10.3390/foods12040895>
- Faridah, A., & Holinesti, R. (2021). Evaluation of Nutritional Content of Beef Rendang Using Wet and Dry Seasonings. *IOP Conference Series: Earth and Environmental Science*, 810(1). <https://doi.org/10.1088/1755-1315/810/1/012055>

- Farzana, T., & Mohajan, S. (2015). Effect of incorporation of soy flour to wheat flour on nutritional and sensory quality of biscuits fortified with mushroom. *Food Science and Nutrition*, 3(5), 363–369. <https://doi.org/10.1002/fsn3.228>
- Fungo, R. (2009). Potential of bananas in alleviating micronutrient deficiencies in the great lakes region of East Africa. *African Crop Science Conference Proceedings*, 9(December), 317–324.
- 267802717_Potential_of_bananas_in_alleviating_micronutrient_deficiencies_in_the_great_lakes_region_of_East_Africa
- Galani, Y. J. H., Orfila, C., & Gong, Y. Y. (2020). A Review of Micronutrient Deficiencies and Analysis of Maize Contribution to Nutrient Requirements of Women and Children in Eastern and Southern A review of micronutrient deficiencies and analysis of maize contribution to nutrient requirements of women an. *Critical Reviews in Food Science and Nutrition*, 0(0), 1–24. <https://doi.org/10.1080/10408398.2020.1844636>
- Gitau, P. W., Kunyanga, C. N., Abong, G. O., Ojiem, J. O., & Muthomi, J. W. (2019). Assessing Sensory Characteristics and Consumer Preference of Legume-Cereal-Root Based Porridges in Nandi County. *Journal of Food Quality*, 2019. <https://doi.org/10.1155/2019/3035418>
- Gondek, M., Weindorf, D. C., Thiel, C., & Kleinheinz, G. (2020). Soluble Salts in Compost and Their Effects on Soil and Plants: A Review. *Compost Science & Utilization*, 28(2), 59–75. <https://doi.org/10.1080/1065657X.2020.1772906>
- Grzyb, A., Wolna-Maruwka, A., & Niewiadomska, A. (2020). Environmental factors affecting the mineralization of crop residues. *Agronomy*, 10(12). <https://doi.org/10.3390/agronomy10121951>
- Guiné, R. P. F., Florença, S. G., Barroca, M. J., & Anjos, O. (2020). The Link between the

- Consumer and the Innovations in Food Product Development. *Foods (Basel, Switzerland)*, 9(9). <https://doi.org/10.3390/foods9091317>
- Gupta, S., Brazier, A. K. M., & Lowe, N. M. (2020). Zinc deficiency in low- and middle-income countries: prevalence and approaches for mitigation. *Journal of Human Nutrition and Dietetics*, 33(5), 624–643. <https://doi.org/10.1111/jhn.12791>
- Hakeem, I., Agwa, I., Tayeh, B., & Hamdy, M. (2022). Effect of Using a Combination of Rice Husk and Olive Waste Ashes on High-strength Concrete Properties. *Case Studies in Construction Materials*, 17, e01486. <https://doi.org/10.1016/j.cscm.2022.e01486>
- Harika, R., Faber, M., Samuel, F., Mulugeta, A., Kimiywe, J., & Eilander, A. (2017). Are Low Intakes and Deficiencies in Iron, Vitamin A, Zinc, and Iodine of Public Health Concern in Ethiopian, Kenyan, Nigerian, and South African Children and Adolescents? *Food and Nutrition Bulletin*, 38(3), 405–427. <https://doi.org/10.1177/0379572117715818>
- Harris, G. K., & Marshall, M. R. (2017). Ash Analysis. In S. S. Nielsen (Ed.), *Food Analysis* (pp. 287–297). Springer International Publishing. https://doi.org/10.1007/978-3-319-45776-5_16
- Hedayati, A. (2022). *Ash transformation in thermochemical conversion of different biomass resources with special focus on phosphorus*.
- Hlongwane, Z. T., Siwela, M., Slotow, R., & Munyai, T. C. (2022). Effect of geographical location, insect type and cooking method on the nutritional composition of insects consumed in South Africa. *Journal of Insects as Food and Feed*, 8(5), 537–556. <https://doi.org/10.3920/JIFF2021.0067>
- Horton S., Begin F., Greig A., and L. A. (2008). *Micronutrient Supplements for Child Survival:(vitamin A and Zinc)*.

- Idowu, M. K., & Aduayi, E. A. (2007). Sodium-potassium interaction on growth, yield and quality of tomato in ultisol. *Journal of Plant Interactions*, 2(4), 263–271. <https://doi.org/10.1080/17429140701713803>
- Imaga, N. A., Gbenle, G. O., Okochi, V. I., Adenekan, S., Duro-emmanuel, T., Oyeniyi, B., Dokai, P. N., Oyenuga, M., Otumara, A., & Ekeh, F. C. (2010). *Phytochemical and antioxidant nutrient constituents of Carica papaya and Parquetina nigrescens extracts*. 5(16), 2201–2205.
- Intiyaz, H., Soni, P., & Yukongdi, V. (2021). Role of Sensory Appeal, Nutritional Quality, Safety, and Health Determinants on Convenience Food Choice in an Academic Environment. *MDPI*, 17.
- Irakiza, P. N., Chuma, G. B., Lyoba, T. Z., Mweze, M. A., Mondo, J. M., Zihahirwa, P. K., Mapatano, S., Balezi, A. Z., & Mushagalusa, G. N. (2021). Fortification with mushroom flour (*Pleurotus ostreatus* (Jacq.) P. Kumm) and substitution of wheat flour by cassava flour in bread-making: Nutritional and technical implications in eastern DR Congo. *Agriculture and Food Security*, 10(1), 1–12. <https://doi.org/10.1186/s40066-021-00301-0>
- Janner, M., Ballinari, P., Mullis, P. E., & Fluč, C. E. (2010). High prevalence of vitamin D deficiency in children and adolescents with type 1 diabetes. *Swiss Medical Weekly*, 140(SEPTEMBER), 3–8. <https://doi.org/10.4414/smw.2010.13091>
- Karpukhina, E., Vlasova, E., Volkov, D., & Proskurnin, M. (2021). Comparative Study of Sample-Preparation Techniques for Quantitative Analysis of the Mineral Composition of Humic Substances by Inductively Coupled Plasma Atomic Emission Spectroscopy. *Agronomy*, 11, 2453. <https://doi.org/10.3390/agronomy11122453>
- Kasiulevičius, V., Šapoka, V., & Filipavičiūtė, R. (2006). Sample size calculation in epidemiological studies. *Gerontologija*, 7(4), 225–231. <https://doi.org/013165/AIM.0010>

- Kebebu, G. A., Dahi, W., Whiting, S. J., & Ali, K. A. (2013). Formulation and acceptability testing of a complementary food with added broad bean (*Vicia faba*) in southern Ethiopia. *African Journal of Food, Agriculture, Nutrition and Developments*, 13(September 2020), 15.
- Kégah Ngoualem, F., Nguimbou, R. M., Muhammad Khan, A., & Ndjouenkeu, R. (2020). Chemistry and functionalities of lake deposits and plant-based salts used in food preparations: A review. *Food Chemistry*, 321, 126674. <https://doi.org/10.1016/j.foodchem.2020.126674>
- Kidane, G., Abegaz, K., Mulugeta, A., & Singh, P. (2013). Nutritional analysis of vitamin A enriched bread from orange flesh sweet potato and locally available wheat flours at samre worda, northern ethiopia. *Current Research in Nutrition and Food Science*, 1(1), 49–57. <https://doi.org/10.12944/CRNFSJ.1.1.05>
- Kikafunda, J. K., Lukwago, F. B., & Turyashemererwa, F. (2009). Anaemia and associated factors among under-fives and their mothers in Bushenyi district, Western Uganda. *Public Health Nutrition*, 12(12), 2302–2308. <https://doi.org/10.1017/S1368980009005333>
- Korant, N. P., Ramani, H. R., Patel, P. S., Bk, R., & Sankat, K. B. (2023). Review on nutritional and anti-nutritional factor of raw , cooked and sprouted cowpea. 12(4), 585–589.
- Li, C., Li, C., Yu, H., Cheng, Y., Xie, Y., Yao, W., Guo, Y., & Qian, H. (2020). Chemical food contaminants during food processing: sources and control. *Critical Reviews in Food Science and Nutrition*, 0(0), 1–11. <https://doi.org/10.1080/10408398.2020.1762069>
- Lin, Z., Wei, H., Zhang, Y., Liu, P., Liu, Y., Huang, Z., Lv, X., Zhang, Y., & Zhang, C. (2022). Improving emulsification properties of alkaline protein extract from green tea residue by enzymatic methods. *Current Research in Food Science*, 5, 1235–1242. <https://doi.org/10.1016/j.crfs.2022.07.016>

- Lutter, C. K., Grummer-Strawn, L., & Rogers, L. (2021). Complementary feeding of infants and young children 6 to 23 months of age. *Nutrition Reviews*, 79(8), 825–846. <https://doi.org/10.1093/nutrit/nuaa143>
- Madodé, Y. E., Houssou, P. A., Linnemann, A. R., Hounhouigan, D. J., Nout, M. J. R., & van Boekel, M. A. J. S. (2011). Preparation, consumption, and nutritional composition of West African cowpea dishes. *Ecology of Food and Nutrition*, 50(2), 115–136. <https://doi.org/10.1080/03670244.2011.552371>
- Majesty, D. K. C., Winner, K., Univeristy, R., Prince, O., & Ijeoma, E. (2019). *Nutritional, Anti-nutritional and Biochemical Studies on the Oyster Mushroom, Pleurotus ostreatus*. May.
- Mallema, R., Ogwok, P., Makokha, V., Mugampoza, E., & Ugen, A. (2010). Effects of banana peel-ash-extract on cooking time and acceptability of hard-to-cook beans (*Phaseolus vulgaris* l.). *International Journal of Tropical Agriculture and Food Systems*, 3(1). <https://doi.org/10.4314/ijotafs.v3i1.50014>
- Mallikarjuna, S. E., Ranjini, A., Haware, D. J., Vijayalakshmi, M. R., Shashirekha, M. N., & Rajarathnam, S. (2012). Mallikarjuna2013-Mineral Composition of Four Edible Mushrooms. *Hindawi*, 2013, 5.
- Mammi, L. M. E., Buonaiuto, G., Ghiaccio, F., Cavallini, D., Palmonari, A., Fusaro, I., Massa, V., Giorgino, A., & Formigoni, A. (2022). Combined Inclusion of Former Foodstuff and Distiller Grains in Dairy Cows Ration: Effect on Milk Production, Rumen Environment, and Fiber Digestibility. *Animals*, 12(24), 1–11. <https://doi.org/10.3390/ani12243519>
- Matthäus, B. (2007). Use of palm oil for frying in comparison with other high-stability oils. *European Journal of Lipid Science and Technology*, 109(4), 400–409. <https://doi.org/10.1002/ejlt.200600294>

- Matusiewicz, H. (2017). Sample preparation for inorganic trace element analysis. *Physical Sciences Reviews*, 2(5), 20178001. <https://doi.org/10.1515/psr-2017-8001>
- Mekuria, S. A., Kinyuru, J. N., Mokua, B. K., & Tenagashaw, M. W. (2021). Nutritional Quality and Safety of Complementary Foods Developed from Blends of Staple Grains and Honey Bee Larvae (*Apis mellifera*). *International Journal of Food Science*, 2021. <https://doi.org/10.1155/2021/5581585>
- Mindarti, S., Zalizar, L., Damat, Saati, E. A., & Fajriani, S. (2020). Characterization of fiber fraction, physical and chemical properties of coffee flour (*Coffea* sp.) as functional foodstuff for diabetes mellitus patient. *IOP Conference Series: Earth and Environmental Science*, 462(1). <https://doi.org/10.1088/1755-1315/462/1/012017>
- Mubaiwa, J., Fogliano, V., Chidewe, C., & Linnemann, A. R. (2019). Influence of alkaline salt cooking on solubilisation of phenolic compounds of bambara groundnut (*Vigna subterranea* (L.) Verdc.) in relation to cooking time reduction. *LWT*, 107, 49–55. <https://doi.org/https://doi.org/10.1016/j.lwt.2019.02.067>
- Nair, M. K., Augustine, L. F., & Konapur, A. (2016). Food-Based Interventions to Modify Diet Quality and Diversity to Address Multiple Micronutrient Deficiency. *Frontiers in Public Health*, 3(January), 1–14. <https://doi.org/10.3389/fpubh.2015.00277>
- Niyi, O. H., Jonathan, A. A., & Ibukun, A. O. (2019). Comparative Assessment of the Proximate, Mineral Composition and Mineral Safety Index of Peel, Pulp and Seeds of Cucumber (<i>Cucumis sativus</i>). *Open Journal of Applied Sciences*, 09(09), 691–701. <https://doi.org/10.4236/ojapps.2019.99056>
- Njoku, P. C., Nzediegwu, E., Ayuk, A. A., Nzediegwu, C., Efenudu, I. U., & Erhayimwen, M. A. (2014). Anti-nutrient composition of pumpkin leaf (*Telfiaria occidentalis*) at three temperature regimes. In *Pakistan Journal of Nutrition* (Vol. 13, Issue 12, pp. 678–682).

<https://doi.org/10.3923/pjn.2014.678.682>

- Nyombi, K. (2014). Effect of native soil fertility and mineral fertilizer on growth of pine seedlings in Uganda. *Annals of Forest Research*, 56, 283–296.
- Ohanenye, I. C., Emenike, C. U., Mensi, A., Medina-Godoy, S., Jin, J., Ahmed, T., Sun, X., & Udenigwe, C. C. (2021). Food fortification technologies: Influence on iron, zinc and vitamin A bioavailability and potential implications on micronutrient deficiency in sub-Saharan Africa. *Scientific African*, 11, e00667. <https://doi.org/https://doi.org/10.1016/j.sciaf.2020.e00667>
- Okafor, J. N. C., Okafor, G. I., Ozumba, A. U., & Elemo, G. N. (2012). Quality characteristics of bread made from wheat and nigerian oyster mushroom (*Pleurotus plumonarius*) powder. *Pakistan Journal of Nutrition*, 11(1), 5–10. <https://doi.org/10.3923/pjn.2012.5.10>
- Olaniran, A. F., Okonkwo, C. E., Osemwegie, O. O., Iranloye, Y. M., Afolabi, Y. T., Alejolowo, O. O., Nwonuma, C. O., & Badejo, T. E. (2020). Production of a complementary food: Influence of cowpea soaking time on the nutritional, antinutritional, and antioxidant properties of the cassava-cowpea-orange-fleshed potato blends. *International Journal of Food Science*, 2020. <https://doi.org/10.1155/2020/8873341>
- Olusanya, R. N., Kolanisi, U., van Onselen, A., Ngobese, N. Z., & Siwela, M. (2020). Nutritional composition and consumer acceptability of *Moringa oleifera* leaf powder (MOLP)-supplemented mahewu. *South African Journal of Botany*, 129, 175–180. <https://doi.org/10.1016/j.sajb.2019.04.022>
- Omona, J. (2021). Poverty eradication and wealth creation: The role and challenges of savings and credit cooperatives (SACCOs) in Uganda. *African Journal of Business Management*, 15(8), 198–210. <https://doi.org/10.5897/AJBM2021.9234>

- Onwuka, U. N., & Okala, O. (2003). Effects of selected salts on the cooking time, protein content and sensory properties of African yam beans and cowpeas. *Food Service Technology*, 3(1), 3–7. <https://doi.org/10.1046/j.1471-5740.2003.00060.x>
- Otolowo, D. T., Olapade, A. A., & Makanjuola, S. A. (2018). Predicting the Nutritional and Rancidity Properties of Dehydrated Catfish (*Clarias gariepinus*) Using Response Surface Methodology. *Preventive Nutrition and Food Science*, 23(4), 347–355. <https://doi.org/10.3746/pnf.2018.23.4.347>
- Oumarou, M. B. D. (2016). Soil fertility under four tree species in the semi-arid climate of Niger. *United Nations University Land Restoration Training Programme [Final Project]*, 36.
- Pavord, S., Myers, B., Robinson, S., Allard, S., Strong, J., & Oppenheimer, C. (2012). UK guidelines on the management of iron deficiency in pregnancy. *British Journal of Haematology*, 156(5), 588–600. <https://doi.org/10.1111/j.1365-2141.2011.09012.x>
- Piskin, E., Ciancesi, D., Gulec, S., Tomas, M., & Capanoglu, E. (2022). Iron Absorption: Factors, Limitations, and Improvement Methods. *ACS Omega*, 7(24), 20441–20456. <https://doi.org/10.1021/acsomega.2c01833>
- Purbowati, Kartika Wening, D., Afiatna, P., Maryanto, S., & Nasifah, I. (2021). Instant Porridge with Red Beans (*Phaseolus vulgaris* L.) and Oyster Mushrooms (*Pleurotus ostreatus*) as A Complementary Feeding. *E3S Web of Conferences*, 317, 04028. <https://doi.org/10.1051/e3sconf/202131704028>
- Pyar, H., & Peh, K. K. (2018). Chemical compositions of banana peels (*Musa sapientum*) fruits cultivated in Malaysia using proximate analysis. *Research Journal of Chemistry and Environment*, 22(Special issue II), 108–113.

- Shivakumar, N., Kashyap, S., Kishore, S., Thomas, T., Varkey, A., Devi, S., Preston, T., Jahoor, F., Sheshshayee, M. S., & Kurpad, A. V. (2019). Protein-quality evaluation of complementary foods in Indian children. *American Journal of Clinical Nutrition*, 109(5), 1319–1327. <https://doi.org/10.1093/ajcn/nqy265>
- Sommer, J. (2013). Consumer Perception and Evaluation of Packaging: The effect of consumption goal and perishability on consumer perception of packaging functions for bakery products. *Wageningen University & Research*, 1–71.
- Starowicz, M., & Zieliński, H. (2019). How Maillard Reaction Influences Sensorial Properties (Color, Flavor and Texture) of Food Products? *Food Reviews International*, 35(8), 707–725. <https://doi.org/10.1080/87559129.2019.1600538>
- Tara, L. B., Christopher, O., & Peter, D. M. (2016). Crop ash filtrate influence on cooking time and sensory preferences for dried black beans (*Phaseolus vulgaris* L.). *African Journal of Food Science*, 10(8), 132–142. <https://doi.org/10.5897/ajfs2016.1456>
- Tulchinsky H Theodore. (2010). Micronutrient Deficiency Conditions: Global Health Issues. *Public Health Reviews*, 32(1), 243–255. https://publichealthreviews.biomedcentral.com/track/pdf/10.1007/BF03391600%0Ahttps://search.proquest.com/docview/848717211?accountid=13828%5Cnhttp://find.shef.ac.uk/openurl/44SFD/44SFD_services_page?url_ver=Z39.88-2004&rft_val_fmt=info:ofi/fmt:kev:mtx:jou
- Tumwine, G., Atukwase, A., Tumuhimbise, G. A., Tucungwirwe, F., & Linnemann, A. (2019). Production of nutrient-enhanced millet-based composite flour using skimmed milk powder and vegetables. *Food Science & Nutrition*, 7(1), 22–34. <https://doi.org/https://doi.org/10.1002/fsn3.777>
- Tyler, G. (2001). ICP-OES , ICP-MS and AAS Techniques Compared. *Technical Note 05: ICP*

Optical Spectroscopy, 3, 1–11.

UBOS. (2016). Uganda Demographic and Health Survey 2016. *Udhs*, 625.
www.DHSprogram.com

Udho, S., & Nankumbi, J. (2019). *Iron deficiency among pregnant women attending an antenatal clinic in Northern Uganda : a cross- sectional study*. 1–15.

Ukeyima, M. T., Acham, I. O., & Amaechi, B. A. (2019). Quality Evaluation of Maize Based Complimentary Food Supplemented with Garden Peas. *Asian Food Science Journal*, September, 1–10. <https://doi.org/10.9734/afsj/2019/v12i130074>

Ulloa, J., Barbosa, M., Vázquez, J., Ulloa, P., Ramírez, J., Carrillo, Y., & Torres, L. (2017). Production, physico-chemical and functional characterization of a protein isolate from jackfruit (*Artocarpus heterophyllus*) seeds. *CyTA - Journal of Food*, 15, 1–11.
<https://doi.org/10.1080/19476337.2017.1301554>

USE OF FILTRATE FROM CROP RESIDUE ASH FOR COOKING IN RURAL HOUSEHOLDS IN. (2014). April.

Wang, R., & Guo, S. (2021). Phytic acid and its interactions: Contributions to protein functionality, food processing, and safety. *Comprehensive Reviews in Food Science and Food Safety*, 20(2), 2081–2105. <https://doi.org/https://doi.org/10.1111/1541-4337.12714>

Wanjekeche, E., Wakasa, V., & Mureithi, J. G. (2003). *Effect of Germination, Alkaline and Acid Soaking and Boiling on the Nutritional Value of Mature and Immature Mucuna (Mucuna pruriens) BEANS*.

Woreda, Z. (2015). *Development of Maize Based Orange – Fleshed Sweet Potato Flat Bread for Lactating Mothers at Hawassa*. 5(5), 183–190.
<https://doi.org/10.5923/j.food.20150505.01>

- Yelatontsev, D., & Mukhachev, A. (2021). Utilizing of sunflower ash in the wet conversion of phosphogypsum – a comparative study. *Environmental Challenges*, 5, 100241.
<https://doi.org/https://doi.org/10.1016/j.envc.2021.100241>
- Zhai, J., Burke, I. T., & Stewart, D. I. (2021). Beneficial management of biomass combustion ashes. *Renewable and Sustainable Energy Reviews*, 151.
<https://doi.org/10.1016/j.rser.2021.111555>
- Zhang, Y. Y., Stockmann, R., Ng, K., & Ajlouni, S. (2022). Revisiting phytate-element interactions: implications for iron, zinc and calcium bioavailability, with emphasis on legumes. *Critical Reviews in Food Science and Nutrition*, 62(6), 1696–1712.
<https://doi.org/10.1080/10408398.2020.1846014>

APPENDICES

Appendix I: Informed consent form

Title of the study: Ash Filtrate from Plant Residues (*Kado-Atwona*) Enhanced Mineral Contents of Traditionally Prepared Vegetables

Investigator(s): ABDIKARIM

Institution(s): Gulu University

Introduction

Good morning/afternoon! My name is (Interviewer mentions his/her name)

As a student of Gulu University, I am currently conducting research on the feasibility of applying ash filtrate (*kado-atwona*) to enhance the main content of selected plant minerals in traditionally prepared vegetables within Gulu district

The research has been granted approval by the Gulu University Research Ethics Committee (GUREC).

During the course of the study, participants were presented with 18 samples of traditionally cooked vegetables with ash filtrate and were asked to evaluate each sample based on their degree of liking using the provided scale and rank their preference accordingly. The present study comprises a cohort of 88 women within the reproductive age range.

1.1.1 Purpose:

The objective of the study is to enhance the micronutrient content of conventionally prepared vegetables, with the aim of increasing the consumption of these vegetables among women of reproductive age and children under the age of 5. The results of this study are anticipated to make a valuable contribution to the national initiatives aimed at addressing micronutrient deficiencies, specifically iron-deficiency, among women of reproductive age and children under the age of five in Uganda. Prior to tasting and in between each sample, you will be furnished with fresh water for rinsing your mouth. We kindly request that you express your level of preference for each sample.

Please do not hesitate to inquire about any aspect of the study that you may wish to comprehend at any point in time. Once the study has been presented and all inquiries have been addressed, you will be requested to provide your signature on a consent form. You will be provided with a copy of the consent form for your records.

1.1.2 Procedures

Your involvement in this study will require the preparation of the sauce for each sample. The sauce that has been prepared will be presented to you on a disposable plate. You will be kindly asked to taste the sauce and provide your assessment of the various attributes based on your personal preference.

You have been selected to participate in this study as a female of reproductive age who has a child under the age of five.

1.1.3 Risk/discomforts

Based on our assessment, we have determined that there are no anticipated hazards or adverse effects that may result from your involvement in this research. This is due to the fact that the ingredients in the composites have a lower probability of inducing an allergic reaction. Individuals with allergies will be ineligible to participate in the study. Furthermore, if any participant experiences discomfort while tasting the various composite formulas, they will be attended to by medical personnel as the evaluation will be conducted in a hospital setting. Furthermore, study participants are at liberty to withdraw their participation at any time and at their own discretion.

1.1.4 Benefits

We kindly request your consent to participate in the study. Active participation in all study phases will facilitate the acquisition of skills related to the preparation and combination of various ingredients to produce wholesome cuisine. Furthermore, this measure will aid in mitigating the potential hazards of malnutrition among children and women of reproductive age within your household and the wider community. There are no financial or personal benefits associated with your participation in the study.

1.1.5 Confidentiality

Participants' identities will remain confidential as we will utilize codes for identification purposes. The data collected will be exclusively available to the research team. The digital copies of the data will be safeguarded with a password, while physical copies will be securely stored under lock and key. Access to confidential information will be restricted to the principal investigator only.

1.1.6 Alternative

You do not have to participate in this study if you are not interested

1.1.7 Cost

If you choose to participate in the study, please note that there will be some supplementary expenses involved, including the time and equipment required for the preparation of the vegetable sauce.

1.1.8 Questions

Should you have any inquiries pertaining to the study or your rights as a research participant, please feel free to reach out to the principal investigator.

1.1.9 Statement of voluntariness

Participation in the research study is voluntary and individuals may choose to join at their own discretion. Participants are entitled to withdraw from the study at any point in time without incurring any penalty.

If you encounter any concerns regarding your rights and involvement in the study, kindly reach out to the Chairperson of the Gulu University Research Ethics Committee, Dr. Gerald Obai, through his telephone number 0772305621 or email addresses lekobai@yahoo.com/lekobai@gmail.com. Alternatively, you may contact the Uganda National Council for Science and Technology at Plot 6 Kimera Road, Ntinda, Kampala, through their telephone number 0414705500.

1.1.10 Statement consent

The researcher has provided me with a detailed explanation of the study procedures, potential hazards and advantages, as well as my privileges as a study participant. I comprehend that my choice to partake in this study will not have any impact on me personally. My identity will remain confidential while utilizing this information. I acknowledge that I have the option to withdraw my participation at any given time. I acknowledge that my signature on this form does not constitute a waiver of any of my legal rights. Rather, it serves as an indication that I have been duly informed about the research study and have voluntarily agreed to participate. A duplicate of this form will be furnished to me.

Name of participant.....

Signature/Thumbprint.....Date.....

Name of
witness.....signature.....Date.....

Name of interviewer.....

Signature.....Date.....

Appendix II: Data Collection tools

Laboratory data collection tool for parameters being analyzed

Two commonly used food sources, cow peas and pumpkin leaves, are traditionally prepared with and without ash filtrate application. These food sources are subjected to laboratory analysis, primarily for nutritional composition, specifically for micronutrient content analysis.

Parameter	Sample code (results indicate means $\pm$ SD of samples analyzed in triplicates)				
	V11	V22	V33	V44	V55
Mineral analysis					
calcium					
zinc					
magnesium					
iron					

Sensory Evaluation Form

My name is ABDIKARIM, and I am a student at Gulu University. I am currently conducting research on the Ash Filtrate from Plant Residues (*Kado-Atwona*) Enhanced Mineral Contents of Traditionally Prepared Vegetables.

During the course of the study, you will be presented with 18 samples of traditionally prepared cow peas and pumpkin leaves that have been treated with varying levels of ash filtrate. You will be asked to taste each sample and rate your degree of liking using the provided scale. Please rank the samples according to your degree of preference.

Prior to tasting and in between each sample, you will be provided with clean water to rinse your mouth. It is requested that you

ADMINISTRATIVE DETAILS

Date	Household number
Questionnaire identity Number	Team leader
Team number	Questionnaire check by:
Village and sub-county name	

SCALE

1. Dislike strongly, 2. Dislike, 3. Neither like nor dislike, 4. Like, 5. Like strongly

Sample code	Smell	Color	Taste	Texture	After-taste	Overall acceptability
V11						
V22						
V33						
V44						
V55						

Thank you for your participation

Appendix III: Samples for Ash filtrate for different plant residues



The photos for the different ash filtrate.

Appendix IV: Informed Consent Form for Focus Group Discussion

I'm ABDIKARIM, a student of Gulu University conducting research on the topic: **Ash Filtrate from Plant Residues (*Kado-Atwona*) Enhanced Mineral Contents of Traditionally Prepared Vegetables**

During the focus group discussion, you will be asked questions on ash filtrate application level, production of ash filtrate, vegetables cooked using ash filtrate and method of preparation. You kindly asked to provide answers to those questions. Focus group discussion will only have women as the participant and will last for one hour. There will be eight focus groups with each having eight women as the participants.

1. What is this form?

This document outlines the objectives of the focus group and the study, as well as the study protocols, potential hazards, and drawbacks. Upon electing to take part in the study (with a focus on female participants), you will be requested to provide your signature on this document. The selected sample is being compared with the control to determine the impact of ash filtrate application rate on consumer sensory preference and overall acceptability of traditionally cooked vegetables with ash filtrate.

2. The purpose of this focus group

This focus group is being conducted as a component of academic research led by ABDIKARIM MACLOW (Tel. 0789491397, email: ducaalle2000@gmail.com). The objective of the study is to investigate the utilization of ash filtrate for the purpose of augmenting the mineral content of conventionally prepared vegetables in the Acholi sub-region. The results obtained from this study will be utilized to furnish essential information required for the alleviation of micronutrient inadequacy in underdeveloped nations.

3. What will I be asked to do in this focus group?

Upon your agreement to participate, you will be requested to engage in a discussion regarding a set of inquiries pertaining to prevalent sources and techniques of ash filtration production, customary vegetables prepared with ash filtrate, and the process of vegetable preparation utilizing ash filtrate. During the discussion, the following questions will be asked:

What is the most common source of ash filtrate? Please indicate the three most preferred sources in order of degree of preference, from the sources that have been outlined. Could you please provide more context or information about the ash filtrate source you are referring to? This will help me provide a more accurate and professional response to your question. Could you please provide more context or information about the type of ash you are referring to and the purpose of collecting and storing it? This will help me provide a more accurate and professional response. Could you please provide more context or information about the type of ash and the purpose of preparing the ash filtrate? This will help me provide a more accurate and detailed response. What are the essential precautions to consider when preparing ash filtrate?

4. Benefits

We kindly request your consent to participate in the study. Your participation in the focus group discussion would be valuable in documenting the preparation of ash filtrate and the traditional cooking of vegetables using ash filtrate. Moreover, this will aid in mitigating the hazards of malnourishment among children and women of childbearing age in your domicile and the surrounding locality. There are no financial or personal benefits associated with your participation in the study. However, participants will receive a bar of soap.

5. Risks

There is no risk associated with participating in this study, as the discussion will solely revolve around ash filtrate-related questions. Please feel free to contact the individual who is leading the discussion. The facilitator and lead investigator will endeavor to safeguard confidentiality

and anonymity during the discussion. However, we cannot provide an absolute assurance that there will be no privacy breach or that other participants will not disclose any information, whether intentionally or unintentionally. However, it should be noted that the discussion will require a duration of one hour. As a gesture of compensation for the time lost, a bar of soap will be provided.

6. Voluntary participation

Participation in this focus group is entirely voluntary, and you are not obligated to take part if you choose not to. If you encounter any inquiries that cause discomfort, you are not obligated to respond to them. You are free to discontinue the discussion at any point without incurring any adverse consequences and without being obligated to provide a rationale for your choice. In this instance, all data pertaining to your involvement will be permanently deleted. As participation is voluntary, participants will not relinquish their rights by taking part in the study. For any concerns related to your rights and involvement in the study, kindly reach out to the Chairperson of the Gulu University Research Ethics Committee, Dr. Gerald Obai, through his telephone number 0772305621 or email addresses lekobai@yahoo.com/lekobai@gmail.com. Alternatively, you may contact the Uganda National Council for Science and Technology at Plot 6 Kimera Road, Ntinda, Kampala, through their telephone number 04147055007, Ensuring privacy and confidentiality. The investigator will take every effort to protect your privacy. Everything you say in this focus group will be kept confidential. The notes from the discussion will not contain your name or any other information that would allow you to be linked to specific statements. Only the moderator and the investigator conducting the study will have access to the notes. Investigator will present the general findings from the entire study to each political party that participated. The names of the participants will not appear in any report. By participating, you also accept to keep this conversation confidential and to not discuss the identity or comments of the other participants outside of this room.

8. Statement of voluntary consent

By affixing my signature to this document, I hereby express my voluntary consent to participate in the focus group. I have reviewed the consent form and it was presented to me in a language that is both comprehensible and familiar. I have had the privilege of posing inquiries and receiving adequate responses. I comprehend that I have the option to withdraw from the discourse at any given moment.

Name of the participant.....

Signature/Thumbprint.....Date.....

Name of witness.....signature.....Date.....

Appendix V: GUREC Approval Letter

GULU UNIVERSITY

P.O. Box 166, Gulu (U)
Website: www.gu.ac.ug
Email: gurec@gu.ac.ug



Tel: +256 471 432 096
Fax: +256 471 432 913
Mob: +256 772 305 621
+256 776 812 147

RESEARCH ETHICS COMMITTEE

02/12/2022

To: Abdikarim Mohamud

Gulu university
078991397

Type: Initial Review

Re: GUREC-2022-268: APPLICATION OF ASH FILTRATE (KADO-ATWONA) TO ENHANCE PLANT MINERAL CONTENTS OF SELECTED TRADITIONALLY PREPARED VEGETABLES IN GULU CITY, 3.0, 2022–26

I am pleased to inform you that the Gulu University REC, through expedited review held on **19/06/2022** approved the above referenced study.

Approval of the research is for the period of **02/12/2022** to **02/12/2023**.

As Principal Investigator of the research, you are responsible for fulfilling the following requirements of approval:

1. All co-investigators must be kept informed of the status of the research.
2. Changes, amendments, and addenda to the protocol or the consent form must be submitted to the REC for re-review and approval **prior** to the activation of the changes.
3. Reports of unanticipated problems involving risks to participants or any new information which could change the risk benefit: ratio must be submitted to the REC.
4. Only approved consent forms are to be used in the enrollment of participants. All consent forms signed by participants and/or witnesses should be retained on file. The REC may conduct audits of all study records, and consent documentation may be part of such audits.
5. Continuing review application must be submitted to the REC **eight weeks** prior to the expiration date of **02/12/2023** in order to continue the study beyond the approved period. Failure to submit a continuing review application in a timely fashion may result in suspension or termination of the study.
6. The REC application number assigned to the research should be cited in any correspondence with the REC of record.
7. You are required to register the research protocol with the Uganda National Council for Science and Technology (UNCST) for final clearance to undertake the study in Uganda.

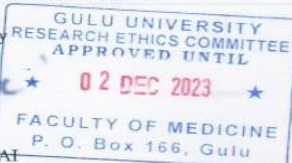
The following is the list of all documents approved in this application by Gulu University REC:

GULU UNIVERSITY
RESEARCH ETHICS COMMITTEE
APPROVED UNTIL
★ 02 DEC 2023 ★
FACULTY OF MEDICINE

No.	Document Title	Language	Version Number	Version Date
1	Informed Consent forms	english	3.0	2022-11-26
2	Informed Consent forms	english	3.0	2022--26
3	Informed Consent forms		3.0	2022--26
4	Informed Consent forms	acholi	3.0	2022-11-26
5	Protocol		3.0	2022--26
6	covid -19 Management	english	2.0	2022-07-13
7	revised data collection tool	english	2.0	2022-07-13

Yours Sincerely

[Handwritten Signature]



Dr. Gerald OBAI
For: Gulu University REC

Appendix VI: Originality Report

GULU

P. O. Box 166
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UNIVERSITY

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PLAGIARISM CHECK

Declaration for Originality Form

This form must be completed and signed for all scholarly work produced.

Name: MR. ABDIKARIM MACLOW MOHAMUD

Personal File No.(staff) Reg. (student). 20/X/2016/MFN/PS

Faculty/Institute: AGRICULTURE AND ENVIRONMENT

Department: FOOD SCIENCE AND POST-HARVEST TECHNOLOGY

Title and bibliographic description of the work
ASH FILTRATE FROM PLANT RESIDUES (KADO-ATWONA) ENHANCED MINERAL CONTENTS OF TRADITIONALLY PREPARED VEGETABLES

Declaration.

1. I understand what plagiarism is and I am aware of the University policy on this regard,
2. I declare that this ...**Master Thesis**... (thesis, dissertation, essay, assignment, paper, report etc.) is my original work and has not been submitted elsewhere for examination, award of a degree or publication. Where other people's work or my work has been used, this has been properly acknowledged and referenced in accordance with Gulu University requirements,
3. I have not sought or used the services of any professional agency to produce this work,
4. I have not allowed, and shall not allow anyone to copy my work with the intention of passing it off as his/her own,
5. I understand that any false claim of this work shall result in disciplinary action in accordance with University Policy on Plagiarism.

Signature 

Date 5/6/2023

Originality Report

The article/thesis/document titled above have been subjected to plagiarism check and the level was found to be.....**22%** (percent) this is classified as:

- ☐ Minor
☒ **Moderate**
☐ Serious

Yours sincerely,



Dr. Ongaya Kizito (PhD)
AG. UNIVERSITY LIBRARIAN