ANALYSIS OF THE MAASAI TRADITIONAL FOOD SYSTEM AND ETHNOMEDICINE FOR HEALTH BENEFITS AND BIOACTIVE POTENTIAL AGAINST GOUT AND METABOLIC DISORDERS

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ABSTRACT

Maasai's traditional food system (TFS) and Traditional Medicine (TM) are claimed to keep a low prevalence of diseases, including gout (hyperuricemia with uric-acid crystals in tissues) and predisposed/predisposing conditions thereof (GACs); however, anti-oxidants and anti-hyperuricemics (AHAs) are not well-established in the TFS and TM. This calls to establish the link between TFS qualities and health benefits; floral species against diseases: Gout, GACs, and risk factors thereof; and floral anti-oxidants and AHAs contents. Ethnobiological and ethnobotanical surveys with 21 Maasai TFS and TM practitioners (MTPs) in Monduli, Arusha, Tanzania revealed that TFS and TM had a diversity of 101 flora species distributed in 84 genera and 42 families. The TFS had 19 dishes and a diversity of 78 flora species with potential nutrition, therapeutic and protective roles against gout and GACs. Food processing technologies (FPT), nixtamalization, and meat roasting have potential protection against GACs. Cultural preferences and restrictions (CPR) ensure individual nutritional and health needs are met, and reinforce Maasai socio-structure and cohesion. About 79% of the flora species were used as medicine; some as food, and for food processing. The medicinal plants (MPs) managed 69 health conditions, including gout, "*Olgila*," and GACs. The root parts (54% species) were exploited the most; most flora (94%), sourced from the wild. Spectrophotometric analyses of 43 flora parts from 35 species commonly used in the TFS and TM showed total phenolic content (TPC) in mg GAE/g ranged between 0.02 ± 0.01 (*Zathoxylum chalybeum* fruit) and 231.39 ± 10.40 (*Rhus vulgaris* root). Total flavonoid content (TFC) in mg QE/g ranged between 1.24 ± 0.00 (*Lepidotrichilia volkensii* root) and 66.94 ± 0.03 (*Dalbergia melanoxylon* root-heartwood). Potassium content in mg K $100g^{-1}$ ranged between 97.68 (*Rhamnus prinoides* root) and 1392.01 (*Piper capense* root). *Croton megalocarpus*, *Piper capense*, *Tetradenia riparia*, and *Vachellia nilotica* had the highest content of calcium, iron, magnesium, manganese, and zinc, varying between 263.85 and 9117 µg/g dry weight (DW). The FPT and flora species with high TPC, TFC, and minerals content are potential antioxidants and AHAs against "*Olgila*" and GACs. Integrated conservation and promotion measures are needed to prevent the loss of TFS and TM.

DECLARATION

I, Richard Paul Clement, do hereby declare to the Senate of Nelson Mandela African Institution of Science and Technology that this work is original and has not been submitted elsewhere, nor is it concurrently under consideration for submission for a degree in any other institution.

31/07/2025

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Prof. Musa N Chacha Date

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Dr. Joseph Runyogote Date

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CERTIFICATION

The undersigned certify that, they have read and hereby recommend for the acceptance and approval by the Nelson Mandela African Institution of Science and Technology (NM-AIST), a dissertation entitled "*Analysis of the Maasai Traditional Food System and Ethnomedicine for Health Benefits and Bioactive Potential against Gout and Metabolic Disorders*" in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Life Sciences of the Nelson Mandela African Institution of Science and Technology.

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This work is dedicated to:

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For His wonderful grace and blessings throughout my study and life

My parents

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For their prayers and encouragement throughout my study: during the lifetime of my father (before passing away in October 2023) to the present moment of my mother's precious life.

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LIST OF ABBREVIATIONS AND SYMBOLS

Abbreviation or Symbol	Description
AAS	Atomic Absorption Spectrophotometer
ABTS	2,2′-azinobis(3-ethylbenzothiazoline-6-sulfonic acid
AGEs	Advanced Glycation End Products
AGP	Agro-pastoralist
AGZ	Agro-zerograzing
AHAs	Anti-hyperuricemia agents
AHS	Allopurinol hypersensitivity syndromes
AMP	Adenosine Monophosphate
AOR	Adjusted Odds Ratio
APR	Adjusted Prevalence Ratio
ARDS	Acute Respiratory Distress Syndrome
Asc	Ascorbic acid (Vitamin "C")
Asp	Aspirin
ATC	Arusha Technical College
ATP	Adenosine Triphosphate
BA	Bile Acid
BHT	Butylated hydroxytoluene
Bk	Bark
BMI	Body Mass Index
Ca	Calcium
CAT	Catalase
C-BAs	Conjugated Bile Acids
CCL-2	Chemokine C-C motif Ligand 2
C_E	Extract concentration
CI	Confidence Interval
CKD	Chronic Kidney Diseases
COPD	Chronic Obstructive Pulmonary Diseases
COVID-19	Coronavirus Disease
COX-1	Cyclooxygenase-1
COX-2	Cyclooxygenase-2
CPR	Cultural Preferences and Restrictions

CRISPR/Cas9	Clustered Interspaced Short Palindromic Repeats-Cas9
CRP	C-Reactive Protein
C_S	Standard sample concentration
CVD	Cardiovascular Diseases
DAMP	Damage-Associated Molecular Pattern
DDS	Dietary Diversity Scores
De	Dermal
DKA	Diabetic Ketoacidosis
DNA	Deoxyribonucleic Acid
DPPH	2,2´-diphenyl-1-picrylhydrazyl radical
DW	Dry Weight
EtOAc	Ethyl acetate
EtOH	Ethanol
Fe	Iron
FL	Fidelity Level
FPT	Food Processing Technologies
Ft	Fruit(s)
FTEA	Flora of Tropical East Africa
FXR	Farnesoid X Receptor
GA	Gallic acid
GACs	Gout Associated Conditions
GAE	Gallic Acid Equivalent
GFS	Globalized Food System
GMP	Guanosine Monophosphate
GPBAR-1/TGR-5	G-coupled Bile Acid Receptor 1
GPX/ GSH-Px /GP	Glutathione Peroxidase
GR	Glutathione Reductase
GSD-Ia	Glycogen Storage Disease Type Ia
H_2O_2	Hydrogen Peroxide
HAT	Hydrogen-Atom Transfer
HNE	4-hydroxynonenal
HPRT	Hypoxanthine Phosphoribosyl Transferase
IBD	Inflammatory Bowel Disease

IC_{50}	Concentration inhibiting 50% of a substance
ICF	Informant Consensus Factor
ICPC-3	International Classification of Primary Care-3
IFNγ	Interferon-gamma
IgA	Antibody A
IL-10	Interleukin-10
IL-1R1	Interleukin-1 receptor type 1
IL-1β	Interleukin-1beta
IL-6	Interleukin-6
IMP	Inosine Monophosphate
Ind	Indomethacin
IPs	Indigenous Peoples
ISE	Ethnobiology Code of Ethics
IUCN	International Union for Conservation and Nature
IUCN	International Union of Conservation of Nature
K	Potassium
KCs	Kupffer cells
LC	Least Concern
LDL	Low-density Lipoprotein
Lf	Leaves
LPS	Lipopolysaccharides
MDA	Malondialdehyde
MDs	Metabolic Diseases
MeOH	Methanol
Mg	Magnesium
Mn	Manganese
MPs	Medicinal Plants
MSU	Monosodium Urate
MTPs	Maasai TFS and TM practitioners
Na	Nasal
NADH	Reduced Nicotinamide Adenine Dinucleotide
NADPH	Reduced Nicotinamide Adenine Dinucleotide Phosphate
NAFLD	Non-alcoholic Fatty Liver Disease

NASH	Non-alcoholic Steatohepatitis
NF-kB	Nuclear Factor-kappa B
NLRP3	Nod-like receptor family pyrin domain containing 3
NO	Nitric Oxide
NOX4	NADPH oxidase 4
Nrf2	Nuclear Factor Erythroid 2-related Factor 2
NSAIDs	Nonsteroidal Anti-inflammatory Drugs
NT	Near-threatened
O_2	Oxygen
$O_2^{\bullet-}$	Superoxide
Oc	Ocular
Or	Oral
OS	Oxidative Stress
PC	p-cresol
PCS	p-cresyl sulfate
Pd	Pod(s)
PI (%I)	Percentage Inhibition
PRPS	Phosphoribosyl Pyrophosphate Synthetase
QE	Quercetin Equivalent
RDI	Recommended Daily Intake
RFC	Relative Frequency of Citation
RFC*s*	Specific Relative Frequency of Citation
RNOS	Reactive Nitrogen Oxide Species
RNS	Reactive Nitrogen Species
ROS	Reactive Oxygen Species
Rt	Root(s)
Rtb	Root-bark
Rz	Rhizome
SD	Standard Deviation
Sd	Seed(s)
SDG/SDGs	Sustainable Development Goal(s)
SDI	Socio-demographic Index
SET	Single-Electron Transfer

SFBs	Segmented Filamentous Bacteria
SOD	Superoxide Dismutase
St	Stem
Stb	Stem-bark
TALENs	Transcription Activator-like Effector Nucleases
Tb	Tuber
TC-BAs	Tauro-conjugated Bile Acids
TFC	Total Flavonoid Content
TFSs	Traditional Food System(s)
TH	Traditional Healers
TLR-2/TLR-4	Toll-like Receptor-2 or 4
TM	Traditional Medicine
TMA	Trimethylamine
TMAMQ	Tetramethoxy azobismethylene quinone
TMAO	Trimethylamine N-oxide
TMW	Traditional Midwives
TNF-α	Tumor Necrosis Factor Alpha
TPC	Total Phenolic Content
TPHPA	Tanzania Plant Health and Pesticides Authority
UA	Uric Acid
U-BAs	Unconjugated Bile Acids
UR	Use Reports
UV	Use Value Index
VU	Vulnerable
Wap	Whole aerial part(s)
Wd	Wood
WHR	Waist-hip Ratio
XDH	Xanthine Dehydrogenase
XMP	Xanthosine Monophosphate
XO	Xanthine Oxidase
XOIs	Xanthine Oxidase Inhibitors
XOR	Xanthine Oxidoreductase
ZFNs	Zinc Finger Nucleases

Zn	Zinc

CHAPTER ONE

INTRODUCTION

1.1 Background of the Problem

A food system is characterized by its qualities: The diversity of species culturally accepted as food, food processing technologies and cultural preferences or restrictions that shape food selection and dietary patterns (García-Montero *et al.*, 2021; Kuhnlein, 2015). Also, a food system has nutritional and health consequences for people consuming the foods derived from it (García-Montero *et al.*, 2021; Kuhnlein, 2015). For instance, the western or globalized food system (GFS) characterized by excess consumption of saturated fats, over-refined sugars, animal-based protein and low consumption of plant-based fiber is partly responsible for the increased prevalence of metabolic disease (MDs), including gout, obesity, type 2 diabetes, cardiovascular diseases and some types of cancer (García-Montero *et al.*, 2021). The MDs share the condition of an inflammatory disorder with impaired immune functions, frequently caused or accompanied by gut dysbiosis, oxidative stress (OS) and hyperuricemia (Chrysant, 2023; García-Montero *et al.*, 2021)

Hyperuricemia is an elevated serum uric acid (UA) level above the normal upper limit of 6.8 mg/dL (Strilchuk *et al.*, 2019). Hyperuricemia is caused either by reduced excretion, increased production of UA, or a combination of the two pathways (Yu *et al.*, 2018). The increased production of UA is caused by augmented activity of the Xanthine oxidoreductase (XOR) enzyme (Bortolotti *et al.*, 2021). The XOR is an enzyme with multiple physiological functions: It catalyzes the conversion of purines to produce uric acid (UA), while also producing reactive oxygen species (ROS): Superoxide ion and hydrogen peroxide, as well as reactive nitrogen species (RNS): Nitrogen oxide (Bortolotti *et al.*, 2021). The ROS and RNS play important roles in regulating commensal microbiomes and protection against infections, while UA is involved in maintaining blood pressure, antioxidant activity, fat accumulation and acting as a damage-associated molecular pattern (DAMP) (Bortolotti *et al.*, 2021). However, increased production of the ROS and RNS, as well as UA, due to elevated XOR activity, triggered mainly by diet, inflammation, hypoxic/ischemic conditions and sepsis (infection), among other factors, may respectively lead to OS and hyperuricemia, which are associated with the MDs (Bar-Or *et al.*, 2015; Bortolotti *et al.*, 2021).

Gout is the most common manifestation of hyperuricemia (Stack *et al.*, 2015). Gout is an inflammatory arthritis characterized by the sudden onset of redness, swelling, warmth and joint pain (Yu *et al.*, 2018). Gout's symptoms result from the deposition of monosodium urate (MSU) crystals, a uric acid salt, in joints, cartilage, synovial bursae, tendons or soft tissues (Yu *et al.*, 2018). Hyperuricemia or gout risk factors include genetic predisposition, age, sex, medical or health conditions, diet and lifestyle (Stack *et al.*, 2015; Strilchuk *et al.*, 2019). The GFS diets play a significant role in OS and hyperuricemia, leading to MDs (Allegrini *et al.*, 2022; Bortolotti *et al.*, 2021). For instance, a high intake of fructose increases fructose phosphorylation, leading to intracellular ATP and phosphate depletion, consequently, degradation of purine bases (Allegrini *et al.*, 2022). This led to augmented production of UA and ROS, subsequently causing hyperuricemia and OS, respectively (Allegrini *et al.*, 2022).

Hyperuricemia promotes the translocation of NADPH oxidase 4 from the cytosol to the mitochondria, increasing ROS generation with the inactivation of the aconitase enzyme, leading to fatty accumulation or obesity (Allegrini *et al.*, 2022). Furthermore, MSU, as a consequence of hyperuricemia, can activate macrophages and monocytes to produce the inflammatory cytokine interleukin-1beta The IL-1β through engaging and interacting with their Toll-like receptors (TLRs) 2 or 4 (TLR-2 or TLR-4) and plasma membrane (So & Martinon, 2017). The IL-1β further activates the responsive cells (endothelium and synoviocytes), leading to neutrophil influx and consequently inflammation (So & Martinon, 2017).

Activated inflammatory cells, such as macrophages or monocytes, produce reactive oxygen species (ROS) and inflammatory cytokines, causing damage to cells like endothelium and synoviocytes that leads to atherosclerosis, swelling and or pain in involved tissues (So & Martinon, 2017). The ROS can destroy damaged tissues or degrade dead cells, releasing purine bases, which are mainly catabolized in the liver to generate uric acid; thus, this may lead to hyperuricemia and, in turn, enhance inflammation and OS (Allegrini *et al.*, 2022; Bortolotti *et al.*, 2021). Furthermore, OS may cause lipid peroxidation, protein carbonylation and DNA base oxidation, leading to various pathophysiological conditions, including endothelial dysfunction, insulin resistance, and mutation (Andrés *et al.*, 2021).

Therefore, gout or hyperuricemia can lead to various inflammatory disaesess, like cardiovascular diseases (CVD), chronic kidney diseases (CKD) and cancer through the induction of the molecular risk factors: oxidative stress, inflammatory stress, insulin resistance and endothelial dysfunction, as well as clinical risk factors: Atherosclerosis, metabolic syndrome, diabetes mellitus, and hypertension (Chrysant, 2023). Thus, gout or hyperuricemia is often comorbid with such health conditions, CVD, CKD, diabetes mellitus, metabolic syndrome, psoriasis, thyroid dysfunction and urolithiasis (Yu *et al.*, 2018).

Some of the health conditions, predisposed by gout or hyperuricemia, like hypertension, diabetes, CKD, disorders of the liver and gastrointestinal disorders, can also predispose to gout or hyperuricemia by impairing uric acid excretion (Ragab *et al.*, 2017). Moreover, increased consumption of high-fat diets may trigger excessive use of cytochrome c oxidation electron flow, allowing mitochondrial β-oxidation of free fatty acids, resulting in OS, lipid oxidation and consequently atherosclerosis (Li *et al.*, 2021). Atherosclerosis may lead to hypertension and CKD, while OS may lead to insulin resistance or diabetes, consequently impairing uric acid excretion and resulting in hyperuricemia or gout (Ragab *et al.,* 2017). Moreover, increased consumption of high-purine diets may enhance their catabolism, leading to hyperuricemia or gout (Gherghina *et al.*, 2022; Li *et al.*, 2021). Still, some health conditions, like gut dysbiosis, sepsis, acute respiratory distress syndrome (ARDS), cancer, rarely pregnancy and hyperchlorhydria leading to hypoxia/ischemia, inflammation, or oxidative stress, may increase XOR activity and subsequently lead to hyperuricemia and or gout (Gherghina *et al.,* 2022; Horta-baas *et al.*, 2017; Stockton, 1897).

As a consequence of gout co-morbidities and the predisposing factors, gout mortality is projected to increase by 55% in 2060 (Mattiuzzi & Lippi, 2020a). Gout contributes to rheumatic diseases, which rank the fourth highest global impact on disability-adjusted life years and the second leading cause of disability, years lived with disability (Mody, 2017). In Tanzania, gout or hyperuricemia is known to increase the mortality rate associated with co-morbidities like cardiovascular diseases and chronic kidney disease (Kumar *et al.*, 2020).

Gout epidemiology shows that its prevalence worldwide ranges from less than 1% to 10%, while the incidence ranges from 0.58 to 2.89 per 1000 person-years. Men are more affected than pre-menopausal women, as estrogen hormone facilitates the excretion of uric acid (Dehlin *et al.*, 2020b). Developed countries have a higher prevalence and incidence of gout than developing countries (Dehlin *et al.*, 2020a; Mattiuzzi & Lippi, 2020b). Despite data scarcity, there is now a dramatic increase in gout cases in developing countries, such as those in sub-Saharan Africa: In more than 15 countries, gout cases have been reported (Kuo *et al.*, 2015; Mody, 2017). The dramatic increase of metabolic diseases (MDs) like gout and its comorbidities in African countries, including East Africa, is linked to the loss of traditional food systems (TFSs) and adaptation of a globalized food system (GFS) (Raschke & Cheema, 2008). The GFS is characterized by high saturated fats, sugars, refined foods and low-fiber foods, which are known to speed the development of MDs in communities adopting GFS (Raschke & Cheema, 2008).

Conventional therapies such as analgesics, anti-inflammatory, uricosuric agents and Xanthine oxidase inhibitors have been used in managing gout (Strilchuk *et al.*, 2019). These medications aim to maintain UA at normal levels of 6 mg/dL and relieve pain and inflammation associated with gout (Strilchuk *et al.*, 2019). Conversely, conventional drugs such as allopurinol, febuxostat, probenecid, pegloticase, lesinurad, colchicine and non-steroidal anti-inflammatory drugs are associated with side effects, some of which are life-threatening (Cronstein & Terkeltaub, 2006; Otani *et al.*, 2020; Strilchuk *et al.*, 2019). These side effects include the following: Kidney failure, hypersensitivity syndrome, gastrointestinal disorders, cardiovascular and respiratory disorders, thrombocytopenia, leukemia and encephalopathy (Cronstein & Terkeltaub, 2006; Otani *et al.*, 2020; Strilchuk *et al.*, 2019).

Besides, efforts have been made to develop gene therapy in an attempt to manage diseases involving genetic components (Baylis, 2018; Zhang *et al.*, 2020). Gout is a complex disease involving genetic disorders such as elevated phosphoribosyl pyrophosphate synthetase (PRPS) and deficiency in hypoxanthine phosphoribosyl transferase (HPRT) activities caused by mutation (Otani *et al.*, 2020). Current gene editing tools, such as the CRISPR/Cas9 system, TALENs, and ZFNs, are associated with potential risks, including off-target and on-target changes with unintended consequences (Baylis, 2018; Zhang *et al.*, 2020). So, the potential risks of gene therapies limit their application against diseases like gout.

Given the impact of gout and the challenges associated with its management, there is an urgent need to find safe, efficacious antioxidants and AHAs with preventive and or therapeutic effects against overproduction and or reduced excretion of UA. Despite various communities worldwide being confronted with progressive loss of TFSs, some indigenous peoples (IPs) have strongly upheld their cultural practices on their TFSs, and low prevalence of MDs, including gout and its comorbidities, have been reported in the IPs (Kuhnlein, 2015; Raschke & Cheema, 2008). As opposed to GFS, TFSs often provide complete diets with plenty of bioactive compounds, fiber, micronutrients, limited saturated fat, and refined carbohydrates, thereby lowering the risk of acquiring the MDs (Arjmandi & Mullins, 2021; Kuhnlein, 2015).

TFSs often integrate food components and processing technologies that ensure a high supply of nutrients and bioactive compounds important in managing MDs (Arjmandi & Mullins, 2021). For instance, dietary minerals and phenolic compounds are known to have preventive and or therapeutic roles against blood pressure, cardiovascular diseases, chronic kidney diseases, cancer, diabetes mellitus, metabolic syndrome and urolithiasis (Arjmandi & Mullins, 2021; McLean & Wang, 2021). Phenolic compounds as primary and secondary antioxidants, quench free radicals: The ROS, and chelate metals involved in the Fenton reaction, respectively, to prevent oxidative stress (OS) and inflammation (Amarowicz & Pegg, 2019). This lowers the risks of developing hyperuricemia or gout and GACs (Bortolotti *et al.*, 2021). For instance, a flavonoid, quercetin, acts as a primary antioxidant through scavenging a free radical like superoxide ($O_2^{\bullet -}$) and secondary antioxidant through chelating iron (II) cation, preventing the generation of more free radicals like hydroxyl radical from hydrogen peroxide (H_2O_2) produced by an enzyme like XOR (Amarowicz & Pegg, 2019; Bortolotti *et al.*, 2021). This lowers or prevents OS, which may lead to lipid oxidation, atherosclerosis, and inflammation: The risk factors for gout and GACs (Amarowicz & Pegg, 2019). Also, phenolic compounds like quercetin can inhibit the XOR enzyme, thereby preventing an increase in production of UA, hyperuricemia, OS and in turn, gout and GACs (So & Martinon, 2017). Likewise, a phenolic compound like hydroxytyrosol can inhibit TLR-4, decrease IL-1β, and promote commensal microbiota like Bifidobacteria; thus, it prevents inflammation in gout, CVD, and dysbiosis and lowers the risks of developing such conditions (García-Montero *et al.*, 2021; So & Martinon, 2017). The antioxidant capacity of a food, food component or any species correlates with the total phenol or flavonoid contents (Belew *et al.*, 2021). The higher the phenolic or flavonoid content, the higher the antioxidant capacity; consequently, the better the antioxidant or anti-hyperuricemia agents (AHAs) in managing conditions involving OS and or inflammations like gout or hyperuricemia and GACs (Belew *et al.*, 2021).

Still, minerals like Zinc (Zn), Manganese (Mn), Copper (Cu), Selenium (Se) and Iron (Fe) are important cofactors of antioxidant enzymes: superoxide dismutase (SOD), glutathione peroxidases (GSH-Px / GP) and catalase (CAT) enzymes (Di Fabrizio *et al.*, 2022). The antioxidant enzymes have important roles in preventing oxidative stress (OS) or mantining redox homeostasis through the following activities: A SOD, which constitutes Zn, Mn and Cu cofactors, converts superoxide ($O_2^{\bullet -}$) to less toxic hydrogen peroxide (H_2O_2) (Di Fabrizio *et al.*, 2022); the GSH-Px with Se cofactor and CAT with Fe and Mn cofactors, converts H_2O_2 to safe products, water (H_2O) and oxygen (O_2) (Rapa *et al.*, 2019). Also, GSH-Px reduce peroxide radicals to alcohols and oxygen (García-Montero *et al.*, 2021).

Furthermore, Mn can enhance the antioxidant and inhibitory activity of flavonoids like luteolin against XOR; thereby preventing OS and hyperuricemia or gout and GACs (Dong *et al.*, 2017). Moreover, magnesium (Mg) has anti-inflammatory and vasodilation activities through the reduction of C-reactive protein and increasing prostaglandin E_1, respectively, thereby lowering the risk of developing gout and GACs, including hypertension (Houston & Harper, 2008; Rapa *et al.*, 2019). Still, calcium (Ca) stimulates body antioxidants and mitigates OS associated with lead (Pb) and cadmium (Cd) exposure, as well as decreases lipid peroxidation products, thus again lowering the risks of developing gout and GACs (Szlacheta *et al.*, 2020). Moreover, potassium (K) can alkalize acidic urine to normal pH (6.5-6.8) and increase the release of NO, thereby reducing the risk of developing urolithiasis and hypertension respectively (Barbera *et al.*, 2016; McLean & Wang, 2021).

Also, K can slow down osteoporosis by preventing metabolic acidosis, thereby preventing kidney stones (urolithiasis) and consequently hyperuricemia or gout (McLean & Wang, 2021). A food system with good qualities: A diversity of species accepted as foods, food processing technologies and cultural preferences or restrictions that allow the adequate inclusion of such minerals and bioactive compounds, keeps a low prevalence of such MDs (Khamis *et al.*, 2020a, 2021). Thus, understanding the TFS qualities: The diversity of species culturally accepted as food, technologies developed to process foods and cultural preferences and restrictions (CPR) developed for food selection that ensure a high supply of the beneficial nutrients and bioactive compounds is the key to the discovery and development of anti-oxidants and AHAs against diseases including MDs such as gout and GACs.

Attention is drawn to the Maasai communities. Some IPs, such as the Maasai who live in remote areas of the Monduli district, Arusha, Tanzania, continue to practice their TFS. This community, like other Indigenous Peoples (IPs) maintaining their cultural practices, is reported to have a low prevalence of metabolic diseases (MDs), such as diabetes, gout and hypertension, despite consuming a high-meat diet (Khan *et al.*, 2013; Roulette *et al.*, 2018). A study by Mbalilaki *et al.* (2010) reported lower cardiovascular risks for Maasai, with high fat/low carbohydrate intake, in Monduli compared to the rural and urban Bantu, with low fat/high carbohydrate and high fat/high carbohydrate intake respectively: Mean body mass index, BMI

(Kg/m^2) was 20.7, 23.2 and 27.4 while mean systolic blood pressure (mm Hg) was 118.2, 133.8 and 133.5 for the Maasai, rural and urban Bantu, respectively (Mbalilaki *et al.*, 2010).

Also, the prevalence of obesity (BMI > 30) was 3%, 12 % and 34 %, while hypertensive (> 140 or > 90 mm Hg) was 4%, 16% and 21% for the Maasai, rural and urban Bantu, respectively (Mbalilaki *et al.*, 2010). Lower prevalences of the MDs and risk factors thereof among the Maasai are linked to the dietary diversity and integration of flora with preventive and therapeutic effects against the MDs and risk factors thereof in their TFS (Khamis *et al.*, 2021; Roulette *et al.*, 2018). For instance, from the same district, it was found that the prevalence of abdominal obesity by waist-hip ratio (WHR) decreased with higher dietary diversity scores (DDS) among Maasai male at adjusted prevalence ratio (APR) of 0.42; 95% CI, 0.22–0.77 and female at (APR = 0.63; 95% CI, 0.41–0.94) (Khamis *et al.*, 2021). Likewise, in the same district, it was reported that the odds for hypertension were significantly reduced among Maasai who consumed fruits, at an adjusted odds ratio (AOR) of 0.37; 95% CI, 0.18–0.77 (Khamis *et al.*, 2020a). Thus, the low prevalence of such MDs associated with gout or hyperuricemia suggests that the Maasai TFS plays a key role in preventing health conditions involving OS and inflammation, which lead to hyperuricemia or gout and predisposed/predisposing conditions thereof: gout-associated conditions (GACs).

However, the link between the qualities and health benefits of the Maasai TFS, as well as floral anti-oxidant, anti-hyperuricemia potentials such as minerals and phenolic compounds constituting the Maasai TFS, an integral part of the Maasai traditional medicine (TM), is not well-established. Therefore, this study aimed to establish an ethnobiological link between qualities and health benefits of the Maasai TFS and consequently, anti-oxidant and anti-hyperuricemia potentials of flora integrated in the TFS and TM, against diseases including gout and GACs, by Maasai living in the Monduli district of Arusha, Tanzania.

1.2 Statement of the Problem

Maasai communities still embrace cultural practices in their TFS and TM that keep a low prevalence of MDs, including gout, which is difficult to manage using conventional medicines (Roulette *et al.*, 2018; Strilchuk *et al.*, 2019). Frequent use of flora in the Maasai TFS and TM is reported to make MDs uncommon in the communities (Roulette *et al.*, 2018). For instance, the prevalence of GACs like obesity and hypertension was lower at 3% and 4% for the Maasai in Monduli as compared to urban Bantu with a prevalence of 34% and 21%, respectively (Mbalilaki *et al.*, 2010). Also, the odds for hypertension are significantly reduced among

Maasai who integrate fruits in their diets, at an adjusted odds ratio (AOR) of 0.37; 95% CI, 0.18–0.77 (Khamis *et al.*, 2020a).

However, the link between the qualities and health benefits of the Maasai TFS is not well established. Also, anti-oxidant and anti-hyperuricemia potentials like minerals and phenolic compounds in the Maasai TFS and TM are understudied. The absence of such information hinders scientists from developing safe and effective antioxidants and AHAs that can be used to prevent gout and GACs in communities that are currently prone to these devastating diseases in Tanzania and other places. This calls for establishing and using such information to prevent diseases, including gout and GACs and reduce the risk of developing MDs in the population.

1.3 Rationale of the Study

This study established the link between the qualities and health benefits of the Maasai TFS claimed to keep a low prevalence of MDs including gout and GACs, to expose the diversity of species, food (dishes) and food processing technologies with anti-hyperuricemia potentials against diseases, including gout and GACs or keeping low risks of developing the MDs. Also, it determined the content of phytochemicals, particularly polyphenols and minerals with biological activities against the MDs in commonly used flora in the Maasai TFS and TM to reveal the flora with significant contribution to antioxidants and anti-hyperuricemia potentials against diseases, including gout and GACs.

1.4 Research Objectives

1.4.1 General Objective

To establish the ethnobiological link between qualities and health benefits of Maasai TFS and consequently, antioxidants and anti-hyperuricemia potentials of the Maasai TFS and TM against diseases, including gout and GACs in Monduli, Arusha, Tanzania.

1.4.2 Specific Objectives

(i) To determine the ethnobiological link between the qualities (diversity of species accepted as foods; food processing technologies; cultural preferences and reflections for food selection) and health benefits of the Maasai TFS.

(ii) To determine flora used in Maasai TFS and TM against various diseases found in the Maasai Community living in Monduli, Arusha, Tanzania.

(iii) To determine the antioxidant capacity (total phenol and flavonoid content) of flora commonly used in Maasai TFS and TM against common diseases found in the Maasai community living in Monduli, Arusha, Tanzania.

(iv) To determine the nutrient element content of flora commonly used in Maasai TFS and TM against diseases commonly found in the Maasai community in Monduli, Arusha, Tanzania.

1.5 Research Questions

(i) What is the ethnobiological link between the qualities and health benefits of the Maasai TFS?

(ii) What flora in the Maasai TFS and TM are used against various diseases found in the Maasai Community living in Monduli, Arusha, Tanzania?

(iii) What antioxidant capacity (total phenol and flavonoid content) do flora commonly used in Maasai TFS and TM have against common diseases found in the Maasai community living in Monduli, Arusha, Tanzania?

(iv) What nutrient element content do flora commonly used in Maasai TFS and TM have against diseases commonly found in the Maasai community in Monduli, Arusha, Tanzania?

1.6 Significance of the Study

This study is expected to contribute to achieving Sustainable Development Goal number three (3), which addresses good health and well-being (Todd & Mamdani, 2017). The goal will be achieved by utilizing the good qualities and anti-hyperuricemia potentials of the Maasai TFS and TM in managing gout and GACs. This will reduce or eliminate the adverse side effects of conventional therapies used against the MDs. Consequently, the health and economic well-being, especially of the marginalized people, will be improved. Also, this study provides opportunities for conserving and promoting TFS and TM, and developing safe and efficacy therapies against diseases including the MDs: gout and GACs.

1.7 Delineation of the Study

This study was based on an ethnobiological survey of the Maasai traditional food system (TFS), ethnobotanical surveys of the Maasai TFS and traditional medicine (TM), and spectrophotometric analysis of flora used in the Maasai TFS and TM to establish potential antioxidants and AHAs against disease including gout, GACs and disease risk factors (Fig. 1).

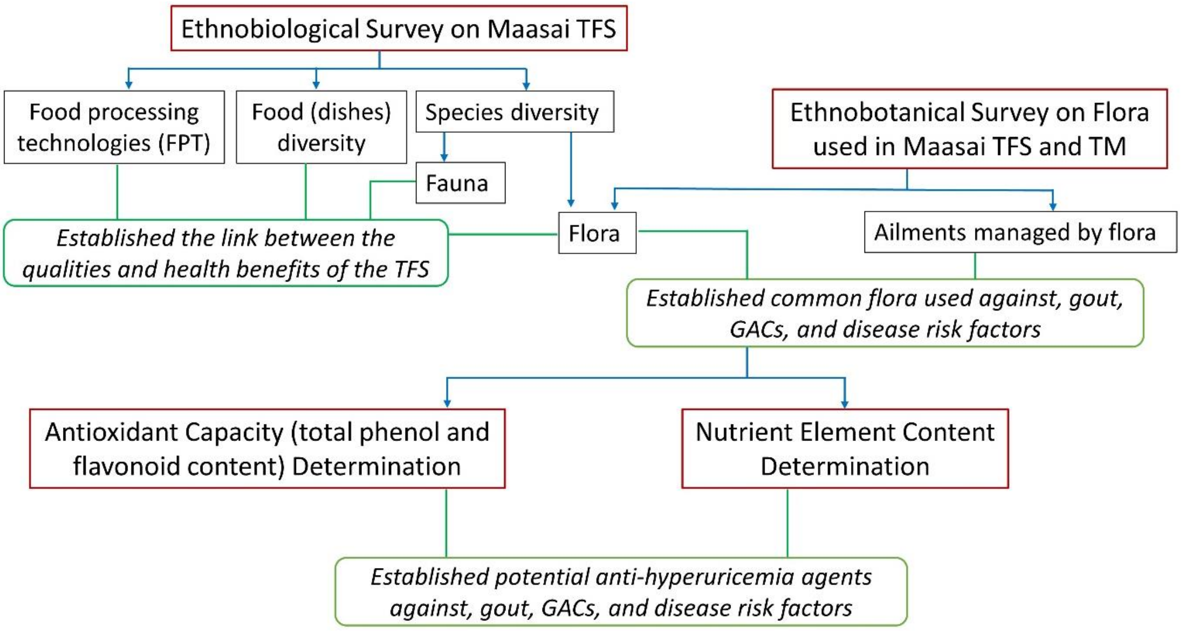


Figure 1: Graphical description of the delineation of the study

CHAPTER TWO

LITERATURE REVIEW

2.1 Gout Epidemiology and Impact

Gout is an inflammatory arthritis characterized by the sudden onset of redness, swelling, warmth and joint pain (Yu *et al.*, 2018). Gout incidence, prevalence and health loss have considerably increased and are still escalating, with all being higher in men than in women (Mattiuzzi & Lippi, 2020a). The burden of gout correlates with the socio-demographic index (SDI), with the incident risk of gout being greater (more than threefold) in high SDI regions than those with low SDI (Mattiuzzi & Lippi, 2020a). Gout mortality and morbidity increase with comorbid conditions like cardiovascular diseases, diabetes and kidney disorders (Otani *et al.*, 2020; Strilchuk *et al.*, 2019).

Besides, conventional therapies that are the cornerstone in managing gout are associated with side effects, some of which are life-threatening (Otani *et al.*, 2020; Strilchuk *et al.*, 2019). For instance, xanthine oxidase inhibitors (XOIs) like allopurinol and febuxostat are respectively associated with fetal allopurinol hypersensitivity syndromes (AHS) and a syndrome characterized by facial swelling, erythema and erythematous tongue (Strilchuk *et al.*, 2019). Also, uricosuric agents like probenecid and lesinurad are associated with increased risks of urolithiasis and nephrotoxicity, respectively (Strilchuk *et al.*, 2019). Moreover, uricases like pegloticase and rasburicase, the recombinant agents, are associated with immunogenic and hypersensitivity reactions (Strilchuk *et al.*, 2019).

Pegloticase can induce infusion-related reactions (dyspnea, erythema, flushing, headache, nausea or vomiting, musculoskeletal pain, changes in blood pressure and urticaria (Strilchuk *et al.*, 2019). Rasburicase can lead to serious hemolytic anemia, methemoglobinemia, and anaphylaxis (Otani *et al.*, 2020; Strilchuk *et al.*, 2019). Furthermore, anti-inflammatory agents including nonsteroidal anti-inflammatory drugs (NSAIDs), colchicine and prednisone used to manage inflammation and pain of gout are associated with side effects: Gastrointestinal toxicity, renal toxicity, or gastrointestinal bleeding, diarrhea, nausea or vomiting, wasting of skin and muscles, weight gain, diabetes, hypertension and osteoporosis (Cronstein & Terkeltaub, 2006).

Indeed, the epidemiological burden of gout remains high around the World; gout mortality is projected to increase by 55% in 2060 (Mattiuzzi & Lippi, 2020a).

2.2 Gout and Gout Associated Conditions (GACs) Risk Factors

Since colonialism to the present neocolonialism, the inequalities resulting from the political-economic forces have caused most indigenous Peoples (IPs), especially those living in sub-Saharan African countries, to progressively replace their traditional food system (TFS) with the globalized food system (GFS) (Raschke & Cheema, 2008).

The globalized or Western food system (GFS) is characterized by excess consumption of saturated fats, over-refined sugars, animal-based protein, and low consumption of plant-based fiber (Kuhnlein & Receveur, 1996; Li *et al.*, 2021). The regular consumption of GFS diets exposes consumers to higher levels of oxidative stress (OS) and a greater risk of ailments, including metabolic diseases (MDs) (Li *et al.*, 2021). This slows down the efforts toward achieving SDG 3. For instance, through increased consumption of the GFS diet, sub-Saharan African countries have experienced a rapid upsurge of the MDs, which include epidemics of obesity, diabetes, cardiovascular disease, gout and various cancers (Raschke & Cheema, 2008).

A high-fat diet produces free fatty acids, which can enter the mitochondria for β-oxidation or esterification to triglyceride Schiff bases (Li *et al.*, 2021). Excess fat accumulation stimulates mitochondrial β-oxidation of free fatty acids, thereby increasing the accumulation of reactive oxygen species (ROS) in cells through excessive use of cytochrome c oxidation electron flow (Li *et al.*, 2021). The ROS can oxidize unsaturated lipids deposited in fat, like low-density lipoprotein (LDL) and cause lipid peroxidation, which can result in atherosclerosis (Li *et al.*, 2021; Serra-Majem *et al.*, 2019). Atherosclerosis leads to cardiovascular and circulatory diseases due to plaques forming from macrophage foam cells and the aggregation of arterial endothelial cells (Li *et al.*, 2021). Indeed, a high-fat diet is among the risk factors for hypertension or preeclampsia in people or pregnant women, respectively, with high consumption of such a diet (Li *et al.*, 2021).

Besides, consumption of high-fat or high-carbohydrate diets may lead to obesity, a chronic disease characterized by increased accumulation of white adipose tissue (Li *et al.*, 2021). The adipose tissue may lead to the production of several proinflammatory cytokines, including tumor necrosis factor alpha (TNF-α) and interleukin-6 (IL-6). These adipokines, IL-6 and TNF-α, induce the production of ROS and OS (Kim *et al.*, 2019; Li *et al.*, 2021). Also, they are involved in insulin resistance and glucose intolerance, leading to diabetes (Li *et al.*, 2021; Purohit *et al.*, 2018). Moreover, TNF-α is involved in the inflammatory response (Purohit *et al.*, 2018). Also, diets containing high sugar, especially fructose, require a great deal of energy, ATP (adenosine triphosphate), and intracellular phosphate consumption for their metabolism (Gherghina *et al.*, 2022). This leads to increased purine degradation and UA synthesis, resulting in hyperuricemia and or gout (Gherghina *et al.*, 2022). Conversely, high serum UA level (hyperuricemia) can promote fat accumulation and increased blood sugar (Bortolotti *et al.*, 2021); thus, further increasing the risk of developing gout and GACs like diabetes, metabolic syndrome, chronic inflammation, and cancer (Allegrini *et al.*, 2022; Gherghina *et al.*, 2022).

Furthermore, excessive consumption of high-protein diets may produce excess amino acids, which can be transformed into fatty acids that later accumulate in the white adipose tissue (Kim *et al.*, 2019; Li *et al.*, 2021). When the cellular requirement of amino acids is met, the excess amino acids undergo deamination or transamination for conversion into acetyl-CoA, pyruvate, or any intermediate of the citric acid cycle to generate energy or fatty acids, which accumulate in adipose tissue. So, high consumption of high-protein diets can also lead to OS, inflammation and MDs associated with fatty acid and adipose tissue (Kim *et al.*, 2019; Li *et al.*, 2021). Moreover, high-protein diets, particularly those containing L-arginine protein, may produce excess nitric oxide (NO). Excess NO may have direct toxicity by binding with iron (Fe)-containing protein or indirectly by combining with superoxide. The resulting reactive nitrogen oxide species (RNOS), such as NO free radical and peroxynitrite, can lead to lipid peroxidation, DNA breaks, DNA modification, inhibition of enzymes, and the electron transport chain, which is responsible for energy synthesis. Consequently, the risk of developing MDs like diabetes, cancer and gout increases (Bortolotti *et al.*, 2021; Kim *et al.*, 2019; Li *et al.*, 2021).

Still, diet is known to modulate both the host immune system and gut microbiota by establishing a bidirectional dialogue with signaling pathways or metabolite productions that affect each other's functions (García-Montero *et al.*, 2021). This determines the diets or food systems' impact on individual health outcomes depending on the food system's qualities (García-Montero *et al.*, 2021). Consumption of GFS diets with their qualities as described earlier often has detrimental effects on the intestinal barrier, leading to leaky gut, gut dysbiosis, and altered metabolites (García-Montero *et al.*, 2021). This led to local inflammation and the presence of Lipopolysaccharides (LPS) in the bloodstream, thereby contributing to systemic endotoxemia and chronic inflammation (García-Montero *et al.*, 2021). Thus, various inflammatory conditions are known to be a result of the influence of GFS on gut microbiota (García-Montero *et al.*, 2021; Las-Heras *et al.*, 2022; Rapa *et al.*, 2019).

For instance, obesity can be associated with gut microbiota, which can convert bile acid (BA) from conjugated bile acids (C-BAs) to unconjugated bile acids (U-BAs), altering the chemical nature of the BA pool (Las-Heras *et al.*, 2022). The BAs in the altered pool can engage with systemic, liver, and adipose farnesoid X receptor (FXR) to induce obesity and weight gain (Las-Heras *et al.*, 2022). High-fat diet, particularly of animal sources, elevates the synthesis of tauro-conjugated BAs (TC-BAs), which promote the outgrowth of pathobionts such as *Bilophila wadsworthia* (Las-Heras *et al.*, 2022). Pathobionts like *Bilophila wadsworthia* may trigger local inflammation that damages the gut barrier; thus, leading to further systemic inflammation and augmented macrophage-mediated inflammation of adipose tissue that is both TLR-4 and CCL-2 dependent (Las-Heras *et al.*, 2022). This increases the risk of insulin resistance and type 2 diabetes (Las-Heras *et al.*, 2022). Though BAs engaged with the gut FXR or G-coupled bile acid receptor 1 (GPBAR-1/TGR-5) enhance local immunity and barrier functions or weight loss, respectively (García-Montero *et al.*, 2021; Las-Heras *et al.*, 2022).

Besides, red meat and predominantly processed meats contain high levels of L-carnitine, which, along with choline, betaine and lecithin, are the main precursors of a critical product, trimethylamine (TMA), by gut microbiota, especially from Firmicutes and Proteobacteria phyla (García-Montero *et al.*, 2021). The TMA is subsequently converted by the host liver enzyme to trimethylamine N-oxide (TMAO), which promotes inflammation, atherosclerosis and thrombosis, thereby increasing the risk of cardiovascular diseases (García-Montero *et al.*, 2021). Moreover, TMAO promotes arterial stiffness via increased production of advanced glycation end products (AGEs); thus, increasing the progression of cardiovascular and CKD (Aschner *et al.*, 2023). The AGEs can also be produced in processed meat (Zinöcker & Lindseth, 2018). It may induce gut dysbiosis and further AGE production (Aschner *et al.*, 2023). Also, AGEs can increase pro-inflammatory enzymes and cytokines via activation of NF-κB and decreased activity of nuclear factor erythroid 2-related factor 2 (Nrf2) (Rapa *et al.*, 2019). This increases the risk of developing such MDs associated with OS (Aschner *et al.*, 2023). So, red and processed meats from GFS promote gut dysbiosis and toxic product production, thereby increasing the risks of developing MDs, including gout and GACs (Gherghina *et al.*, 2022).

Likewise, red and processed meat may lead to the production of uremic toxins such as p-cresol (PC) and its derivatives, including p-cresyl sulfate (PCS), by some gut microbiota, which converts residual protein, tyrosine into the toxins in the host colon (Rapa *et al.*, 2019; Toft *et al.*, 2023). The uremic toxins are involved in the inflammatory state of chronic kidney diseases (CKD) by increasing the levels of the inflammatory cytokines, TNF-α and IL-6, and the resulting OS (Rapa *et al.*, 2019). So, high consumption of protein diets as characterized in the GFS increases the risk of CKD.

Equally, red and processed meat contain negative components such as heme iron, which has been correlated with the hyperproliferation of enterocytes and alteration of the intestinal barrier (García-Montero *et al.*, 2021). Also, the heme iron may associate with microbiota changes that may disrupt iron metabolism in the colon, leading to the production of free radicals and consequently diseases like inflammatory bowel disease (IBD) or colonic cancer (García-Montero *et al.*, 2021). Colon cancers are among the factors leading to hypergastrinemia, which is often associated with hyperchlorhydria, a high stomach acid (Shulkes & Baldwin, 2013). Other factors like Zollinger-Ellison syndrome, *Helicobacter pylori* infection and diminished renal or hepatic function may also lead to hyperchlorhydria (Shulkes & Baldwin, 2013). This condition is one of the marked conditions in gout patients (Stockton, 1897). So, the influence of GFS diets, particularly red and processed meats, on gut microbiota presents a risk factor for colorectal cancer and gout.

Also, red and processed meats are known to induce changes in the population of consensual microbiota, including *Bacteroides fragilis*, with an anti-inflammatory effect (García-Montero *et al.*, 2021). Capsular polysaccharides from such microbiota activate T regulatory lymphocytes (Treg), which produce anti-inflammatory cytokines like IL-10, which control inflammatory conditions like colorectal cancer (García-Montero *et al.*, 2021). So, high consumption of such a diet impairs the growth and activity of the microbiota, leading to inflammatory conditions (García-Montero *et al.*, 2021). A similar effect of GFS diets is evident with segmented filamentous bacteria (SFBs), which release vital antigens, leading to the production of IgA by B cells in the gut and even in the lung against fungal pathogens (García-Montero *et al.*, 2021). Thus, such influence of GFS diets on gut microbiota promotes various respiratory infections, including asthma, allergy and COVID-19 (Christ *et al.*, 2019; Las-Heras *et al.*, 2022).

Furthermore, high consumption of fats, particularly trans-fat acids, the major hallmarks of GFS, often causes gut dysbiosis, leading to impaired gut barrier integrity (Christ *et al.*, 2019; García-Montero *et al.*, 2021). This induces an enhanced flux of gut microbial-derived innate immune activators and modified dietary fats via the portal vein to the liver (Christ *et al.*, 2019). Consequently, the liver immune cells, including Kupffer cells (KCs), are activated, releasing pro-inflammatory factors that cause inflammation and in turn diseases like non-alcoholic fatty liver disease (NAFLD) and non-alcoholic steatohepatitis (NASH) (Christ *et al.*, 2019).

On the other hand, GFS is characterized by a lack or lower levels of fibers, vitamins, minerals and phytochemicals that have an important role in promoting the growth and activities of commensal microbiota, and the immune competence of the host (García-Montero *et al.*, 2021). Thus, its high consumption may lead to dysbiosis and immune deficiency, and consequently, the associated MDs (García-Montero *et al.*, 2021).

Now, it is evident that GFS diets are the risk factors of various ailments, including communicable and non-communicable diseases, as described in this section and summarized in Fig. 2. Some of the diseases are predisposing factors to each other, while some exacerbate other diseases (Dehlin *et al.*, 2020b; Gherghina *et al.*, 2022; Ragab *et al.*, 2017; Stack *et al.*, 2015). Also, all the disease conditions (Fig. 2) are associated with gout through predisposition or exacerbation (Dehlin *et al.*, 2020b; Horta-baas *et al.*, 2017; Peng *et al.*, 2022; Stockton, 1897). These gout-associated conditions (GACs) often occur as comorbidities with gout; thus, increasing the gout's morbidity and mortality (Gherghina *et al.*, 2022; Mattiuzzi & Lippi, 2020a).

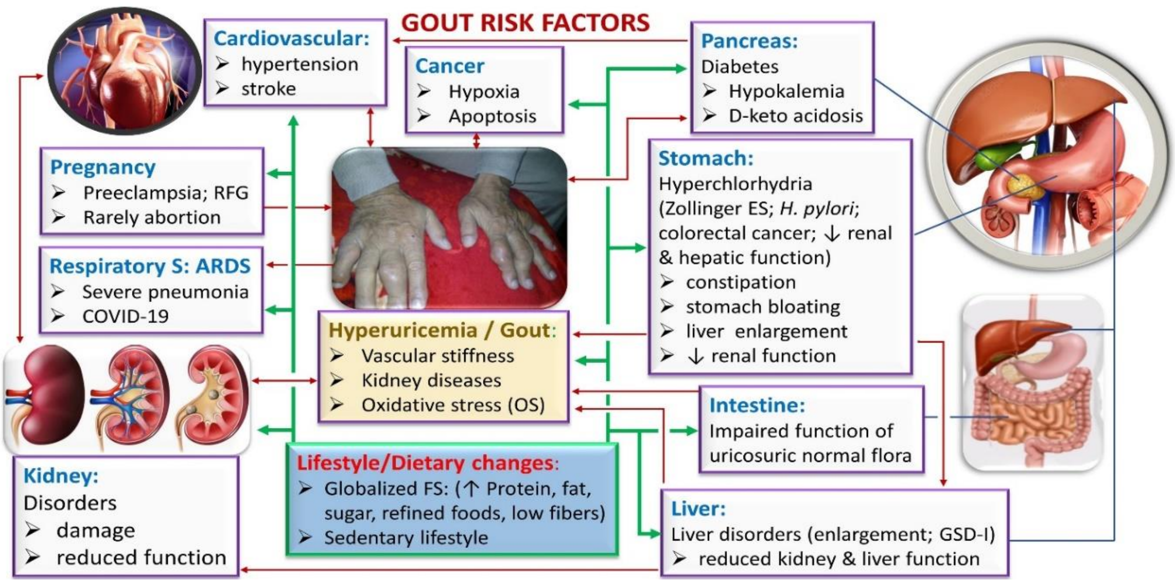


Figure 2: **Gout and GACs risk factors**

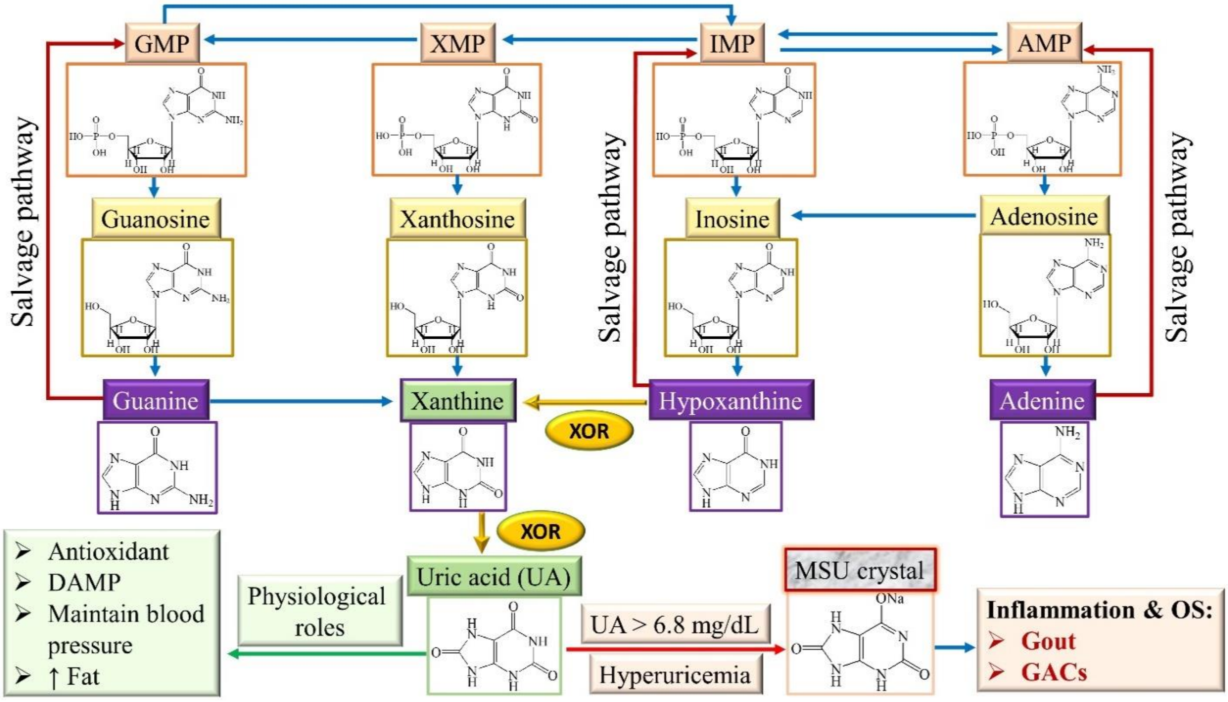


Figure 3: Catabolism and salvage pathway of purine nucleotides and physiologic and pathological roles of uric acid

Gout is caused by hyperuricemia as described earlier. Hyperuricemia is a consequence of increased production of UA or impaired urate excretion (Gherghina *et al.*, 2022). The UA production is catalyzed by the Xanthine Oxidoreductase (XOR) enzyme (Fig. 3), which is expressed in various tissues or organs: Adipose tissue, kidney, liver, lung, skeletal muscle, small intestine, vascular endothelium and brain (Allegrini *et al.*, 2022). The XOR has important physiological roles, including commensal microbiota regulation, infection prevention, blood pressure maintenance and anti-oxidant effect through its activities: Xanthine dehydrogenase (XDH), xanthine oxidase (XO), NADH oxidase, and nitrite reductase (Bortolotti *et al.*, 2021). The XOR activities involve the production of UA (Fig. 3), NO, hydrogen peroxide (H_2O_2), and superoxide ($O_2^{\bullet-}$), which are important in achieving the physiological roles (Bortolotti *et al.*, 2021).

However, increased XOR activities may lead to the overproduction of UA, ROS and RNOS, leading to hyperuricemia and OS. This condition increases the risk of developing gout and other MDs associated with OS (Gherghina *et al.*, 2022). Hypoxic/ischemic and inflammatory conditions increase human XOR gene (*hXOR*) expression and enzyme activity (Bortolotti *et al.*, 2021). Such increased gene expression and enzyme activity involve the conversion of XOR from XDH to its isoform XO, which is triggered by OS, which is associated with the conditions: Hypoxia/ischemia and inflammation (Bortolotti *et al.*, 2021; David *et al.*, 2015; Di Fabrizio *et al.*, 2022). This conversion usually is reversible, and it occurs when the XOR enzyme is released from the cells into the gastrointestinal lumen, urinary tract, and biological fluids like milk and serum (Bortolotti *et al.*, 2021). The conversion is irreversible under prolonged ischemic conditions, though (Bortolotti *et al.*, 2021). The XO catalyzes the conversion of purine products (xanthine or hypoxanthine) to UA (Fig. 3) along with the generation of H_2O_2 and $O_2^{\bullet-}$; thus, its increased activity leads to hyperuricemia and OS (Bortolotti *et al.*, 2021). This explains why some health conditions like acute respiratory distress syndrome (ARDS), cancer, pregnancy and hyperchlorhydria (Fig. 2) are the risk factors for gout: They may induce hypoxia/ischemia or be associated with inflammation (Gherghina *et al.*, 2022; Horta-baas *et al.*, 2017; Stockton, 1897). Also, hyperuricemia may be enhanced by the release of UA and degradation of purine products from apoptotic cells of cancerous or damaged tissues, thereby increasing the risk of developing gout (Bortolotti *et al.*, 2021).

Still, some genetic disorders like Lesch–Nyhan syndrome and over-expression of phosphoribosyl pyrophosphate synthetase (PRPP) promote increased production of UA (Gherghina *et al.*, 2022). Lesch–Nyhan syndrome is caused by hypoxanthine-guanine phosphoribosyl transferase (HPRT) deficiency. The HPRT is among the enzymes catalyzing the recycling of purine nucleotides through the salvage pathways (Fig. 3), thereby reducing purine degradation products, particularly hypoxanthine (Gherghina *et al.*, 2022). So its deficiency leads to hyperuricemia and or gout (Gherghina *et al.*, 2022). The PRPP catalyzes the de novo synthesis of purine starting from ribose-5-phosphate and ATP; thus, its overexpression leads to increased production of purines, which may be degraded into UA (Gherghina *et al.*, 2022). So, these genetic disorders or other factors like OS, which may lead to these disorders, are the risk factors of hyperuricemia and or gout (Gherghina *et al.*, 2022).

Alternatively, other health conditions like hypertension, diabetes, and some kidney, liver and gastrointestinal disorders (Fig. 2) may lead to hyperuricemia and or gout through impairing uric acid excretion (Ragab *et al.*, 2017). Hypertension reduces the glomerular filtration rate, leading to decreased glomerular blood flow and reduced excretion of UA; thus, the risk of developing hyperuricemia and or gout is increased (Ragab *et al.*, 2017). Diabetes may lead to hyperuricemia and or gout through diabetic ketoacidosis (DKA). The DKA often results in hypokalemia, a lower serum potassium level (< 3.5 mmol/L) as well as lower pH of serum (< 7.0) and urine (< 6.5) (Barbera *et al.*, 2016; Dhatariya *et al.*, 2020). Hypokalemia is among the factors promoting the stiffening of endothelial cells and the reduced release of NO, a powerful vasodilator; thus, it leads to hypertension, thereby increasing the risk of gout (Oberleithner *et al.*, 2009; Ragab *et al.*, 2017). Also, urinary acidic pH (5.0-5.5), which is associated with DKA among other factors, reduces the solubility of UA, leading to its precipitation as urate renal stones (Barbera *et al.*, 2016). Such stones impair renal UA excretion, leading to hyperuricemia and or gout (Barbera *et al.*, 2016).

Likewise, hyperchlorhydria may cause liver enlargement, which reduces the capacity of the kidney to excrete UA, leading to hyperuricemia and or gout (Stockton, 1897). Hyperchlorhydria is a marked condition in gout patients (Stockton, 1897). Glycogen storage disease type Ia (GSD-Ia) may also damage the liver and kidneys, leading to gout (Zhang & Zeng, 2016). Women who suffer from GSD-Ia frequently develop gout even before menopause (Zhang & Zeng, 2016). So, health conditions like hyperchlorhydria and GSD-Ia that impair the function of the liver and kidneys are the risk factors for developing hyperuricemia and or gout.

Also, impaired intestinal function can lower UA's excretion (Kasahara *et al.*, 2023; Sorensen, 1965). The intestine accounts for one-third of UA excretion, supported by the commensal microbiota like *Lactobacillus species*, which degrade UA by their enzyme activities: Uricase, allantoinase and allantoicase (Guo *et al.*, 2016; Sorensen, 1965). Consumption of GFS diets, particularly with high salts and additives, reduces the population of such species while favoring the pathobionts in the gut (García-Montero *et al.*, 2021; Guo *et al.*, 2016). This reduces the degradation of UA and its ultimate excretion by the intestine, thereby increasing the risk of hyperuricemia and or gout (Guo *et al.*, 2016).

On the other hand, gout or hyperuricemia can predispose to or exacerbate other diseases, including those predisposing to gout (Gherghina *et al.*, 2022). High UA level, hyperuricemia, is associated with the onset and increased progression of CKD, cardiovascular risk, hypertension, diabetes mellitus, metabolic syndrome and cognitive decline (Gherghina *et al.*, 2022). The UA pathogenesis is related to its pro-inflammatory and pro-oxidative roles (Allegrini *et al.*, 2022; Gherghina *et al.*, 2022). The UA promotes translocation of NADPH oxidase 4 (NOX4) from the cytosol to mitochondria, which increases the mitochondria ROS generation with the inactivation of aconitase; thus, promoting synthesis of fatty acid and triglyceride from citrate accumulated in the cytosol (Allegrini *et al.*, 2022). Also, high ROS generation leads to OS, which can reduce endothelial levels of antioxidant NO and activate peroxynitrite-mediated oxidation of lipids (Gherghina *et al.*, 2022). This explains why hyperuricemia may predispose to obesity and associated conditions like diabetes and hypertension (Gherghina *et al.*, 2022).

Moreover, extracellular UA crystals can prime monocytes and macrophages to produce pro-IL-1β and inflammasome components by engaging with Toll-like receptors (TLRs) 2 or 4 (TLR-2 or TLR-4), and activating the transcription factor nuclear factor kappa-light-chain-enhancer of activated B cells (NF-kB) (Allegrini *et al.*, 2022; So & Martinon, 2017). Also, UA crystals may interact with the plasma membrane, leading to the release of mitochondrial ROS into the cytosol and consequently activating the Nod-like receptor family pyrin domain containing 3 (NLRP3) inflammasome (Allegrini *et al.*, 2022; So & Martinon, 2017). The activated NLRP3 inflammasome produces bioactive cytokines, including IL-1β, that mediate inflammation (So & Martinon, 2017). IL-1β interacts with IL-1 receptor type 1 (IL-1R1) and its co-receptor of responsive cells like endothelium and synoviocytes, leading to increased inflammatory cascades and neutrophil influx through the production of more cytokines and chemokines (So & Martinon, 2017). So, hyperuricemia may lead to OS, responsible for pathophysiological responses like DNA damage, oxidation, inflammatory cytokine production, and cell apoptosis (Gherghina *et al.*, 2022). Thus, hyperuricemia or gout can predispose to various MDs, as pointed out earlier (Gherghina *et al.*, 2022) and shown in Fig. 2. Hyperuricemia or gout can also exacerbate other health conditions, including respiratory diseases like COVID-19 (Peng *et al.*, 2022).

Therefore, understanding the risk factors of gout and GACs is important in guiding research toward developing the best anti-hyperuricemia agent, which could be a system, substance or process that can manage the gout's risk factors, leading to increased production and or impaired excretion of UA. The anti-hyperuricemia agent will not only benefit the management of gout, but also the conditions predisposed by gout and vice versa.

2.3 Role of a Traditional Food System (TFS) in Promoting Health and Well-being

Traditional food systems (TFSs) profoundly contribute to the health of indigenous peoples (IPs) (Kuhnlein, 2015; Raschke & Cheema, 2008). Low prevalence of metabolic diseases (MDs) such as gout, diabetes, cardiovascular diseases and cancer have been documented among indigenous peoples (IPs) such as Maasai, Inuit and Tarahumara despite the wide variety of diets that exist between their TFSs (Kuhnlein, 2015; Raschke & Cheema, 2008). A traditional food system (TFS) is all foods from a particular culture available from local natural resources and culturally accepted (Kuhnlein, 2000). It has the following qualities: various species and species diversity accepted as food from the natural environment, technologies developed to harvest and process foods, sensory properties and dietary structure developed for food selection (Kuhnlein, 2000). These qualities are determined by indigenous peoples' reflections on the food system derived from their cultures and ecosystems (Kuhnlein, 2015); they determine food security and the resulting health and well-being of the IPs (Kuhnlein, 2015). So, the low prevalence of metabolic diseases (MDs) is linked to the qualities of the TFSs.

The diversity of species in a TFS always originates from the natural environment or is traditionally produced with inputs from the environment, and they are less processed (Kuhnlein *et al.*, 2006). Thus, they often provide complete diets with plenty of fiber, micronutrients, bioactive compounds and limited saturated fat and refined carbohydrates, thereby lowering the risks of acquiring MDs (Arjmandi & Mullins, 2021; Kuhnlein, 2015) Some traditional foods processing technologies (FPT) like nixtamalization (alkali treatment or cooking) and wet pounding (decortication of grains through soaking in water or alkaline solution and later pounding) are known to improve the quality of the foods or retain some compounds, which also reduce the risks of getting the MDs (Kirui, 2016; Muñoz-Cano *et al.*, 2013). For instance, the nixtamalization of corn using wood ash or soda "magadi" has the following activities: increases bioavailability of niacin, protective effect against the intake of sugar, and protective effect against aflatoxin contaminants (Kirui, 2016; MacDonald & Reitmeier, 2017; Muñoz-Cano *et al.*, 2013). Also, the wet pounding of grains like maize kernels has a protective effect against aflatoxin contaminants (Kirui, 2016).

Indeed, TFSs have enormous nutritional and health benefits, especially to the IPs (Lemke & Delormier, 2017). But approximately 400 million IPs in the world are among those at serious health risk because they face disparities and marginalization in social, economic and environmental conditions (Kuhnlein, 2015). These structural inequalities are rooted in discriminatory practices of colonialism and the post-colonial regimes (Hodgson, 2011). The demand for land and natural resources for various activities established by the regimens has caused many IPs to lose access to their land and natural resources that derive their TFS and support their livelihood (Hodgson, 2011; Lemke & Delormier, 2017). For instance, in East African countries, most of the IPs, including Maasai in Tanzania, have been confronted with land alienation, relocation or migration in favor of projects like land protection, tourism, industrialization and urbanization that are promoted by the regimens (Hodgson, 2011; Homewood *et al.*, 2009). Land alienation and relocation or migration into areas with resource constraints expose the IPs to the risks of losing the following: Diversity of species integrated in their TFS and the means to support their livelihood (Hodgson, 2011). Consequently, most of the IPs have adopted new ways of life and undergone unplanned dietary changes, which progressively replaced TFSs with the globalized food system, GFS (Raschke & Cheema, 2008).

The foods in GFS are mainly produced through industrial agriculture, which often utilizes unsustainable external inputs, mostly resulting in climate change and health problems (Gliessman, 2015). So, losing TFS practices and affordable means of supporting livelihood, as well as adopting GFS by the IPs, makes them more vulnerable to food insecurity and negative health consequences associated with the GFS (Kuhnlein, 2015; Lemke & Delormier, 2017; Pinstrup-Andersen & Watson-II, 2011). The GFS is characterized by high saturated fats, sugars, refined foods, and low fiber (Raschke & Cheema, 2008). Such sources of diets in GFS are known to speed the development of MDs, particularly in communities that adopted the system (Li *et al.*, 2021). Since colonialism to the post-colonial regimes, most of the IPs in East African countries have adopted the GFS, thereby are increasingly suffering from the epidemic of MDs (Raschke & Cheema, 2008). The MDs are estimated to cause 80% of the global disease burden and 70% of deaths in developing countries (Raschke & Cheema, 2008).

Certainly, structural inequalities have caused most of the IPs in East African countries, including Tanzania, to lose their TFS, thereby being exposed to the increasing burden of MDs. But, some IPs like Maasai are still practicing their TFS in their local areas, which constitute the accessible natural resources important for their culture and livelihood (Fontefrancesco & Lekanayia, 2018; Roulette *et al.*, 2018). Such IPs like the Maasai who live in remote areas of the Monduli district, Arusha, Tanzania, are claimed to have a low prevalence of MDs such as diabetes, gout and pressure (Khan *et al.*, 2013; Kumar *et al.*, 2012; Roulette *et al.*, 2018). A comparative study between the Maasai of Monduli and other communities, rural and urban Bantu, showed a lower prevalence of obesity and hypertension in the Maasai compared to other communities (Mbalilaki *et al.*, 2010): Prevalemce of obesity (BMI > 30) was 3%, 12 % and 34 %, while hypertensive (> 140 or > 90 mm Hg) was 4%, 16% and 21% for the Maasai, rural and urban Bantu, respectively (Mbalilaki *et al.*, 2010).

Furthermore, from the same district, it was found that the prevalence of abdominal obesity by waist-hip ratio (WHR) decreased with higher dietary diversity scores (DDS) among Maasai male at adjusted prevalence ratio (APR) of 0.42; 95% CI, 0.22–0.77 and female at (APR = 0.63; 95% CI, 0.41–0.94) (Khamis *et al.*, 2021). Still, in the same district, it was reported that the odds for hypertension were significantly reduced among Maasai who consumed fruits, at an adjusted odds ratio (AOR) of 0.37; 95% CI, 0.18–0.77 (Khamis *et al.*, 2020a). Accordingly, the low prevalence of such MDs associated with gout or hyperuricemia suggests that the Maasai TFS plays a vital role in preventing health conditions involving OS and inflammation, which lead to hyperuricemia or gout and predisposed/predisposing conditions thereof: gout-associated conditions (GACs).

However, the ethnobiological link between the health benefits and qualities of Maasai TFS: The diversity of species culturally accepted as food, technologies developed to process foods and cultural preferences and restrictions (CPR) developed for food selection, is not well established (Fontefrancesco & Lekanayia, 2018; Roulette *et al.*, 2018). Qualities of a TFS are important in developing a sustainable food system that ensures food security, health and well-being, particularly for IPs (Kuhnlein, 2015; Lambden *et al.*, 2007). Therefore, an ethnobiological survey was necessary to determine the link between the qualities of the Maasai TFS and the health benefits thereof provided to the Maasai peoples of Monduli, Arusha, Tanzania.

2.4 Health Benefits of Flora Used in TFS and TM

Indigenous peoples (IPs) use the flora in multiple contexts without distinction between food and medicine for their health and well-being (Roulette *et al.*, 2018). Thus, flora used in TFS with medicinal roles also supports TM of the IPs (Kimondo, 2020; Roulette *et al.*, 2018). About 80% of people in low-income countries rely on TM flora for their primary healthcare (Amjad *et al.*, 2020). In Tanzania, for instance, 80% of the population living in rural areas depend on TM flora to meet their primary health requirements (Hilonga *et al.*, 2018; Makule, 2018).

The flora especially used in TFS and TM are the main sources of phytochemicals, phytonutrients and minerals, increasing the use of the flora as nutraceuticals and therapeutic agents (Karau *et al.*, 2012a). Such nutraceuticals and therapeutic agents are important in managing various diseases, including gout and GACs (Fig. 2). Among the phytochemicals, phenolic compounds are ubiquitous in flora, including medicinal and edible plant foods used in TFS and TM (Kougan *et al.*, 2013). Phenolic compounds are classified into the following two major classes based on their basic structures: Non-flavonoids and flavonoids (Kougan *et al.*, 2013). They can also be classified into subclasses: phenolic acids, flavonoids, lignans, stilbenes and tannins (Amarowicz & Pegg, 2019). These compounds possess one or more aromatic rings with at least one aromatic ring substituted by one or more hydroxyl groups (Kougan *et al.*, 2013). The most commonly known natural phenolic compounds found in flora used in TFS and TM are nonflavonoids (Fig. 4) and flavonoids (Fig. 5). They have various biological activities, including antioxidant, anti-inflammatory and anti-hyperuricemia activities through mechanisms based on their structures (Kougan *et al.*, 2013). Some other secondary metabolites (Fig. 6) are also found in TFS and TM flora, though not ubiquitous like phenolic compounds. They also have important biological activities against ailments, including gout and GACs.

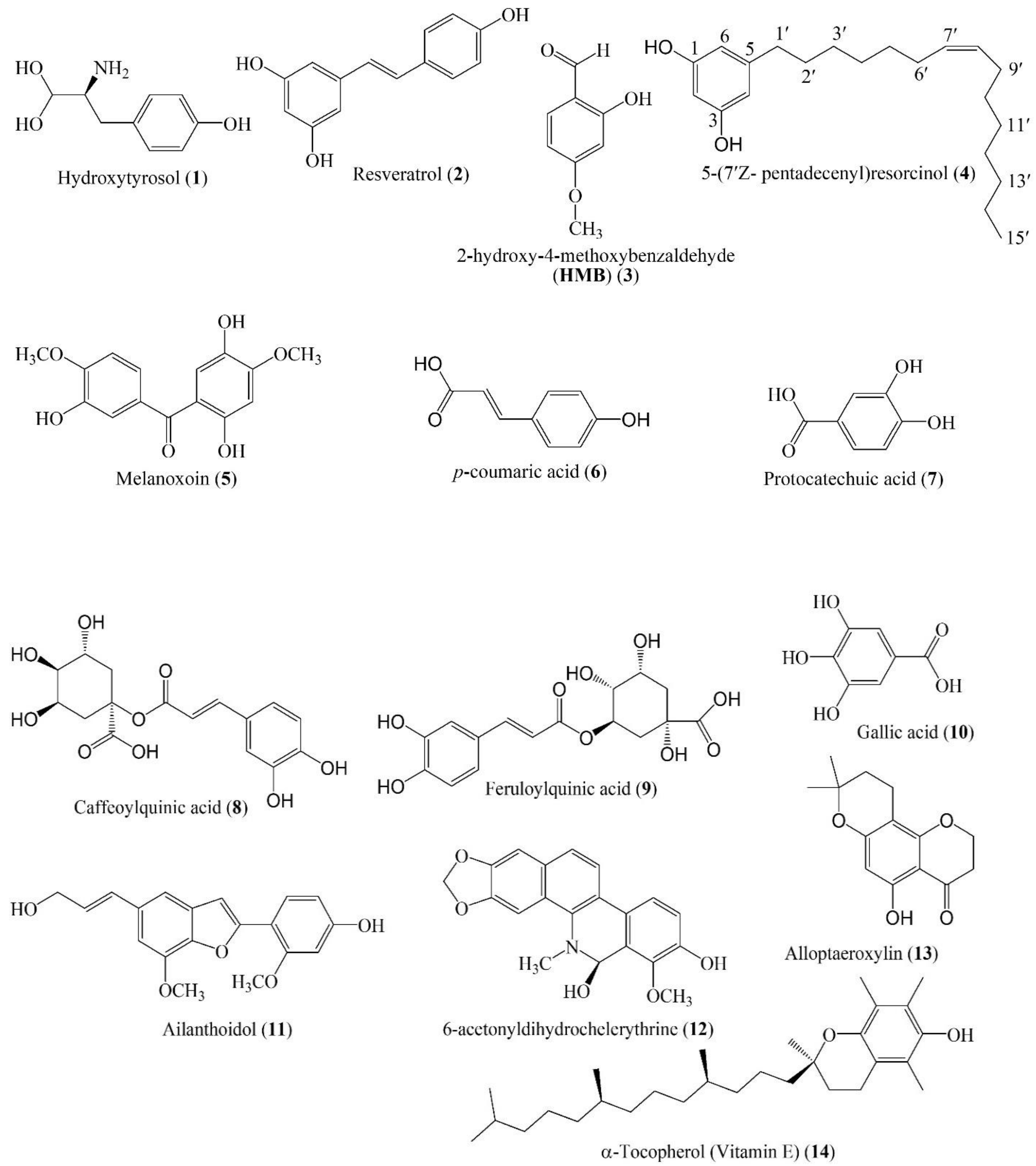
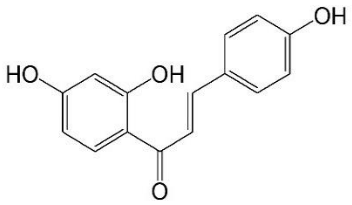
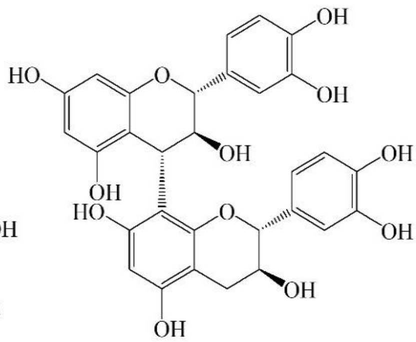


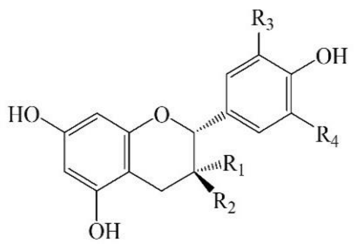
Figure 4: Non-flavonoid phenolic compounds commonly found in TFS and TM flora



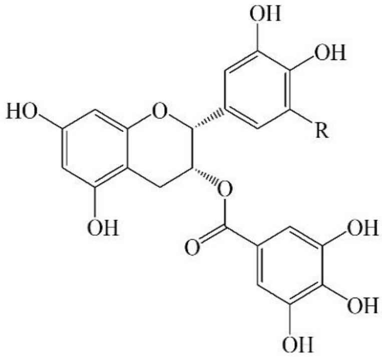
Isoliquilitigenin (**15**)



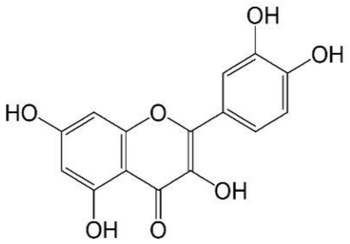
Procyanidin B3 (**21**)



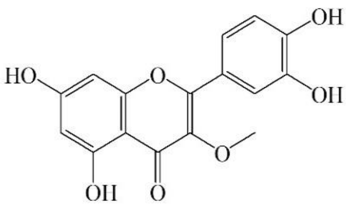
Catechin (**16**): R_1 = H, R_2 = OH, R_3 = H, R_4 = OH
Epicatechin (**17**): R_1 = OH, R_2 = H, R_3 = OH, R_4 = H
Epiafzelechin (**18**): R_1 = OH, R_2 = H, R_3 = H, R_4 = H



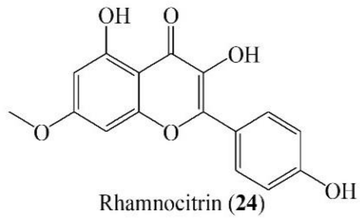
Epigallocatechingallate (**19**): R = OH
Epicatechingallate (**20**): R = H



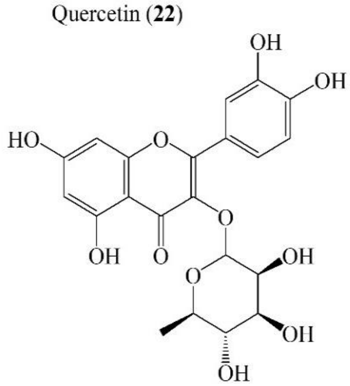
Quercetin (**22**)



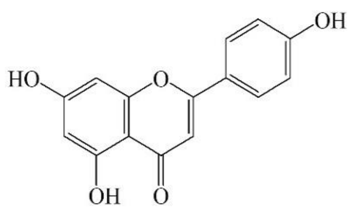
3-*O*-Methylquercetin (**23**)



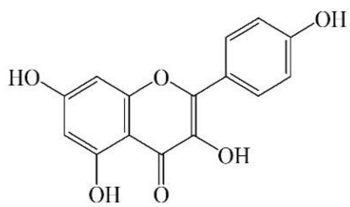
Rhamnocitrin (**24**)



quercetin-3-O-rhamnoside (**25**)



Apigenin (**26**)



Kaempferol (**27**)

Figure 5: Flavonoid phenolic compounds commonly found in TFS and TM flora

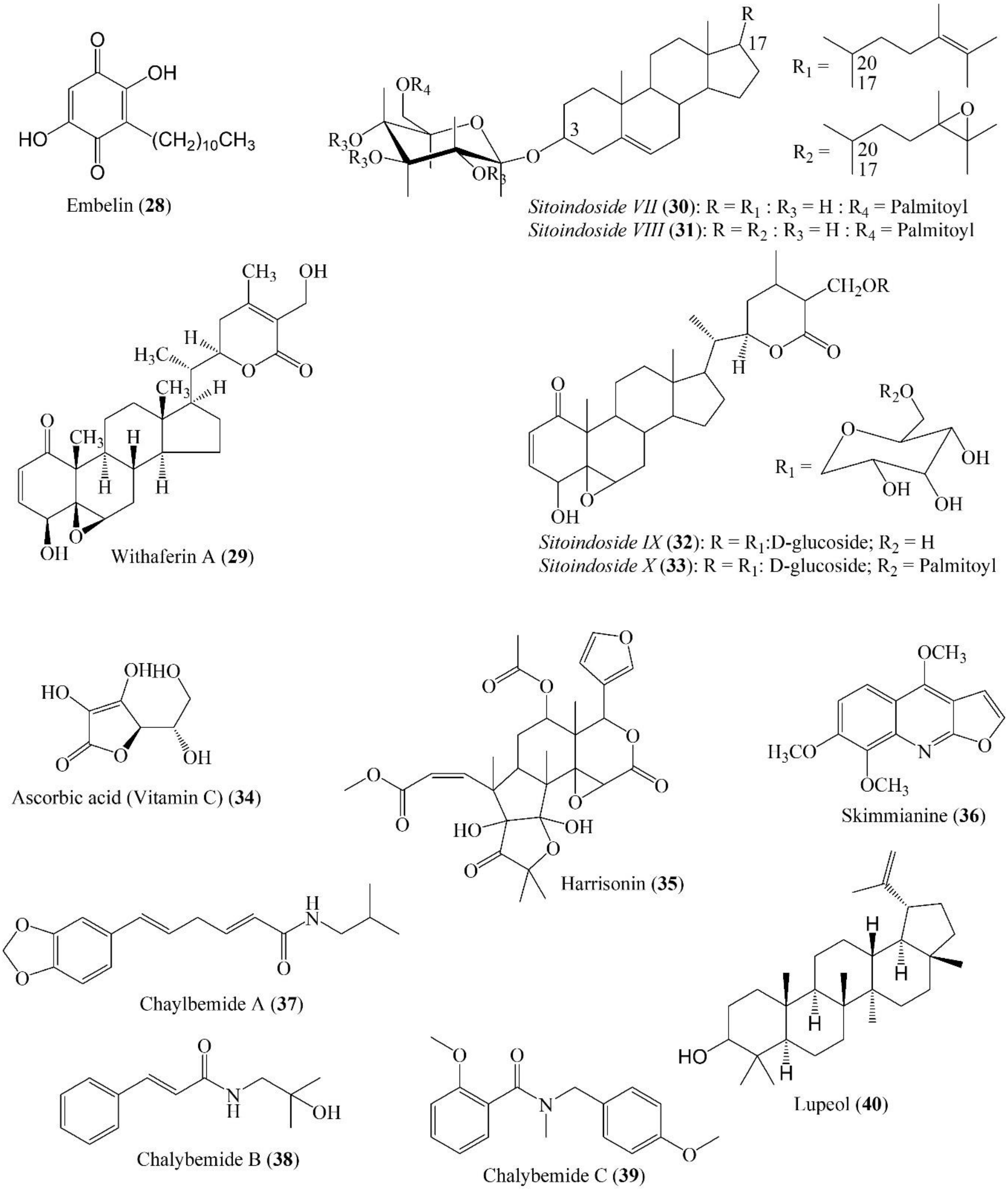


Figure 6: Non-phenolic compounds found in some TFS and TM flora

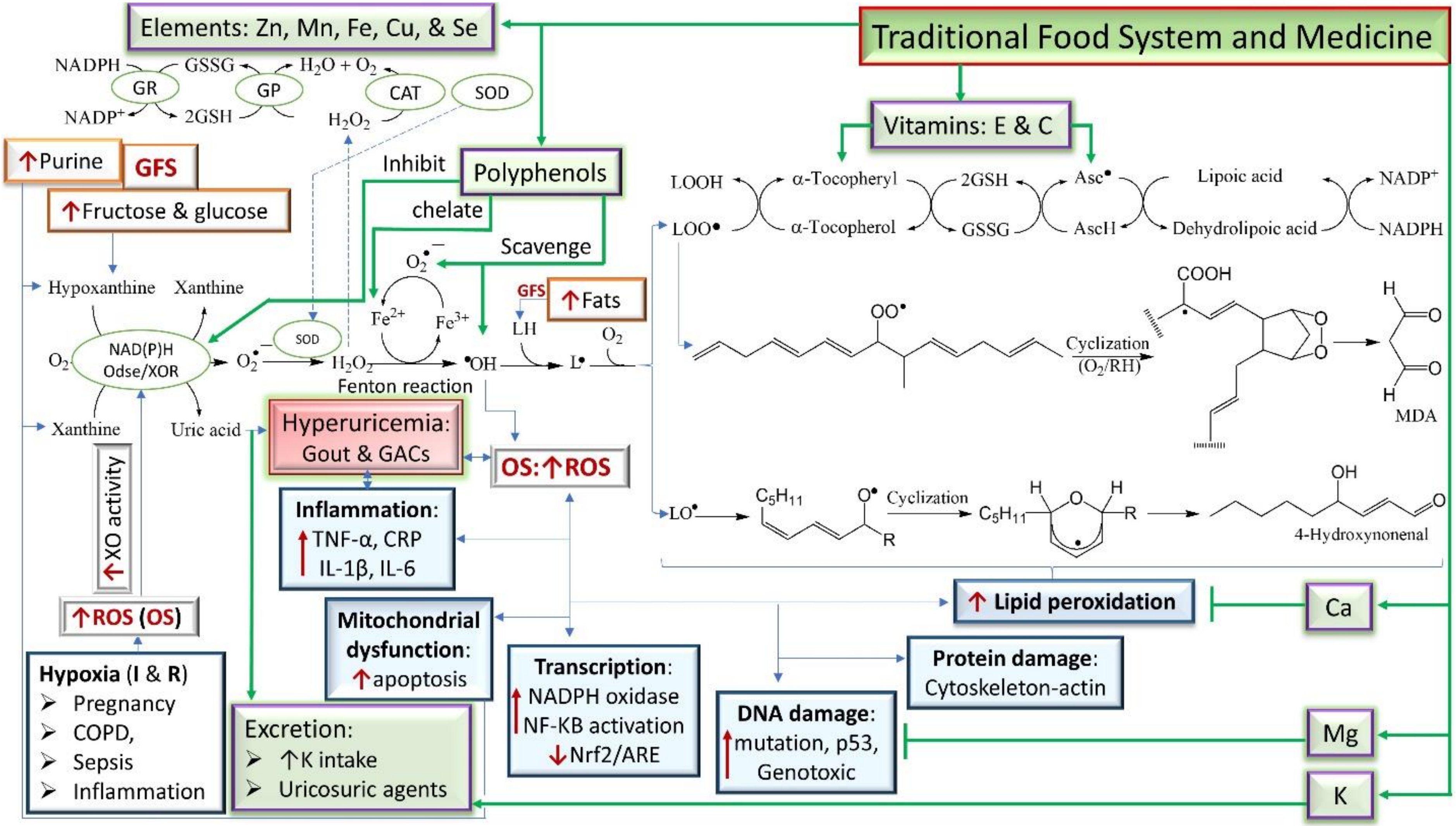


Figure 7: Oxidative stress (OS) and antioxidant system

Natural phenolic compounds are widely used as alternatives to synthetic antioxidants, which are reported to be dangerous to human health (Gupta & Sharma, 2006). Phenolic compounds as primary antioxidants can quench or scavenge free radicals like the ROS (superoxide and hydroxyl) (Fig. 7) through hydrogen-atom transfer (HAT) or single-electron transfer (SET) mechanisms, or the simultaneous occurrence of the two chemical processes: The HAT and SET (Amarowicz & Pegg, 2019). Also, phenolic compounds, particularly flavonoids, as secondary antioxidants, can inhibit oxidation without directly interacting with oxidative species through chelating metals involved in the Fenton reaction (Amarowicz & Pegg, 2019) as shown in Fig. 7. Moreover, some phenolic compounds have inhibitory activities against oxidative enzymes like XOR. Such antioxidant properties of phenolic compounds play a key role in preventing OS, which may lead to further OS, lipid peroxidation, DNA damage, generation of inflammatory transcriptional factors and cytokines, as well as cell death (Gherghina *et al.*, 2022) as illustrated in Fig. 7. Also, some phenolic compounds can prevent OS and inflammation through their modulatory effect on gut microbiota. Thus, phenolic compounds, especially from TFS and TM flora, are known to have health benefits against various diseases, including MDs. Though most communities, especially IPs, have lost or are at risk of losing such TFS and TM.

Mediterranean diets represent a TFS with components including phenolic compounds having enormous health benefits. For instance, hydroxytyrosol (**1**) (Fig. 4) is found in extra virgin olive oil and has antioxidant and anti-inflammatory effects (García-Montero *et al.*, 2021). The effects are achieved by hydroxytyrosol's roles: inhibits TLR-4 and NF-kB; decreases TNF-α, IL-1β and IL-6; lowers oxidation of lipids; promotes commensal microbiota like Bifidobacteria; and keeps the integrity of the gut epithelial barrier (García-Montero *et al.*, 2021). Moreover, hydroxytyrosol is known for cardiovascular disease (CVD) prevention in clinical trials (García-Montero *et al.*, 2021). Likewise, resveratrol (**2**) (Fig. 4) is a potent antioxidant and anti-inflammatory phenolic compound commonly found in red grapes (García-Montero *et al.*, 2021). It may block TLR-4, inhibit NF-kB, and silence proinflammatory genes (García-Montero *et al.*, 2021). Also, it decreases the Firmicutes to Bacteroidetes ratio, circumvents pathobionts' growth and proliferates beneficial gut microbiota like Lactobacillus and Bifidobacterium (García-Montero *et al.*, 2021). Thus, it also lowers the risk of developing MDs (García-Montero *et al.*, 2021).

Also, some flora used in TM contain phenolic compounds with various biological activities against diseases, including MDs. The 2-Hydroxy-4-methoxybenzaldehyde (HMB) (**3**) (Fig. 4) is the phenolic compound from TM flora; it has antioxidant and anticancer activities (Thangam *et al.*, 2019). Moreover, it has an apoptosis-inducing property on cancerous cells through cell cycle arrest and loss of mitochondrial membrane potential (Thangam *et al.*, 2019). Likewise, 5-(7'Z-pentadecenyl)resorcinol (**4**) (Fig. 4) has anticancer activity (Tane *et al.*, 2014).

Furthermore, melanoxoin (**5**) and isoliquiritigenin (**15**) (Fig. 4) have strong anticancer activity against tumor cell lines, including colorectal cancer (Chung, 2022). The anticancer activity of compounds **5** and **6** is linked by their carbonyl linkage (Chung, 2022). Besides, isoliquiritigenin (**15**) is among the compounds with NAD(P): The Quinone reductase (QR) induction property; it suppresses the formation of superoxide anion radical ($O_2^{\bullet-}$) through two-electron reduction of quinone to hydroquinone by the phase II enzyme (Cuendet *et al.*, 2006; Yin *et al.*, 2004). Also, the formed hydroquinone may kill tumor cells by generating oxygen radicals or inducing DNA crosslinking (Ross, 2004). Moreover, QR stabilizes the tumor suppressor gene (p53); thus, NAD(P): The QR induction effect of isoliquiritigenin (**15**) enhances its anticancer property (Chung, 2022; Ross, 2004).

Still, phenolic acids including compounds (**6**-**10**) (Fig. 4) have antioxidant properties through a radical-scavenging activity which depends on the number of hydroxy moieties attached to the aromatic ring (Amarowicz & Pegg, 2019). Also, the hydroxy groups of phenolic acids can interact with the membrane of bacteria to disrupt membrane structure (Amarowicz & Pegg, 2019); thus phenolic acids may have a modulatory effect on gut microbiota (García-Montero *et al.*, 2021). Phenolic acids are also reported to have anti-inflammatory, anticancer and antihyperglycemic effects thereby lowering the risk of developing MDs including gout and GACs (Allegrini *et al.*, 2022; Amarowicz & Pegg, 2019; Gherghina *et al.*, 2022).

Moreover, compounds **11**-**14** (Fig. 4) have antioxidant properties that are also linked to their hydroxy group attached to the aromatic ring(s) (Amarowicz & Pegg, 2019). In addition, 6-acetonyldihydrochelerythrine (**12**) has an antidiabetic property by inhibiting α-amylase and α-glycosidase (Ochieng *et al.*, 2020). Furthermore, α-tocopherol (vitamin E) (**14**) (Fig. 4) has a hydroxy group attached to the aromatic ring: it has an antioxidant property (Amarowicz & Pegg, 2019). Vitamin E has various health benefits: Lowers inflammatory cytokines including IFNγ, IL-6, and TNF-α; protects the epithelial barrier from ROS; prevents lipid peroxidation (Fig. 7); and it has anticancer activities (García-Montero *et al.*, 2021; Muruthi *et al.*, 2023b). Vitamin E is found in TM and TFS flora (García-Montero *et al.*, 2021; Muruthi *et al.*, 2023b).

Apart from non-flavonoid phenolic compounds (**1**-**14**), flavonoid compounds (**15**-**27**) (Fig. 5) also have various biological activities against gout and GACs. Flavonoid serves as both primary and secondary antioxidants through radical-scavenging and chelation of metals involved in the Fenton reaction, respectively (Amarowicz & Pegg, 2019; Gulcin, 2020) as shown in Fig. 7. Also, flavonoids can strongly bind to toxic metals, including lead (Pb), lowering the risks of developing kidney damage and the consequent hyperuricemia and gout (Gulcin, 2020). Moreover, proanthocyanidins (**16**-**21**) (Fig. 5) can reduce lipid peroxidation and inhibit the activity of cyclooxygenase-2 (COX-2), which may lead to inflammation through being activated by IL-1β (Amarowicz & Pegg, 2019; Chirisa & Mukanganyama, 2016; Qi *et al.*, 2023). Moreover, catechin (**16**), epicatechin (**17**), quercetin (**22**), and apigenin (**26**) (Fig. 5) have anticancer properties (Muruthi *et al.*, 2023b). Furthermore, apigenin, quercetin and kaempferol (**27**) have inhibitory activity against xanthine oxidase (XO); they lower the risk of developing hyperuricemia and GACs (Akram *et al.*, 2014; Ayyappan & Nampoothiri, 2020).

On the other hand, other secondary metabolites, the non-phenolic compounds (Fig. 6), have biological activities against MDs, including gout and GACs, but they are not ubiquitous in flora like phenolic compounds are (Gulcin, 2020). Embelin (**28**) is the main benzoquinone in the species of sub-family Myrsinodae (Midiwo *et al.*, 2001). It has an unusual scavenging capability on free radicals, particularly superoxide ($O_2^{\bullet-}$), than the synthetic antioxidants, which have side effects (Caruso *et al.*, 2020). Embelin can transform $O_2^{\bullet-}$ into molecular oxygen (O_2), decrease oxidative-stress biomarkers like malondialdehyde (MDA), and stimulate the body's antioxidant system: The SOD, CAT and GPX (Caruso *et al.*, 2020). Thus, Embelin can manage conditions associated with OS, like gout and GACs (Gherghina *et al.*, 2022; Midiwo *et al.*, 2001).

Besides, withaferin A (**29**) and sitoindosides *VII-X* (**30**-**33**) (Fig. 6) are found in some species of the Solanaceae family (Saleem *et al.*, 2020). Withaferin A has anti-lipid peroxidation, antioxidant, anti-angiogenic, anticancer and hepatoprotective activity (Gavande *et al.*, 2015; Saleem *et al.*, 2020). Withaferin A can inhibit NF-κβ activation; thus, reducing the risk of developing inflammatory conditions (Saleem *et al.*, 2020). Moreover, Withaferin A and sitoindosides *VII-X* have antioxidant activity linked to the hydroxylated long chain of the carbon-bearing acyl group in the compounds (Saleem *et al.*, 2020). Also, these compounds (**29**, **30**-**33**) (Fig. 6) have neural protective, memory enhancing and anti-stress properties via increasing levels of antioxidant enzymes and activation of synaptic and extrasynaptic Gamma Amino-butyric acid (GABA) receptors (Gavande *et al.*, 2015; Saleem *et al.*, 2020).

Furthermore, ascorbic acid (Vitamin C) (**34**) (Fig. 6) is commonly found in citrus fruits and vegetables (García-Montero *et al.*, 2021; Rapa *et al.*, 2019). Vitamin C has various health benefits including antioxidant activity, keeping gut barrier integrity, lowering inflammatory cytokine, IL-6 and preventing lipid peroxidation (Fig. 7) (García-Montero *et al.*, 2021). Moreover, harrisonin (**35**) has anti-inflammatory activity and is found in some *Harrisonia species* (Masila, 2014). Furthermore, skimmianine (**36**) and chaylbemides (A-C) (**37**-**39**) (Fig. 6) are found in *Zanthoxylum* species, particularly *Zanthoxylum chalybeum* (Ochieng *et al.*, 2020). Skimmianine and chaylbemides (A-C) also have an antidiabetic property by inhibiting α-amylase and α-glycosidase (Ochieng *et al.*, 2020).

In addition, skimmianine has a gastroprotective effect by inhibiting *H. pylori* urease, antioxidant protection of gastric mucosa, activating the potassium-ATP (K_{ATP}) channel, and increasing nitric oxide availability (Okagu *et al.*, 2021). Lupeol (**40**) has hepatoprotective activity; it is found in some species, including *Zanthoxylum chalybeum* (Ochieng *et al.*, 2020). Despite non-phenolic compounds (Fig. 6) being limited to a few flora species, their antioxidant, anti-inflammatory activity and modulatory effect on gut microbes play key roles in lowering the risk of developing MDs, including gout and GACs (Gherghina *et al.*, 2022).

Apart from phytochemicals, minerals like Potassium (K), Zinc (Zn), Manganese (Mn), Copper (Cu), Selenium (Se), Iron (Fe), Magnesium (Mg) and Calcium (Ca) also have important biological activities in managing MDs including gout and GACs (García-Montero *et al.*, 2021; McLean & Wang, 2021; Rapa *et al.*, 2019). Potassium can alkalize acidic urine to normal pH (6.5-6.8) and increase the release of NO thereby reducing the risk of developing urolithiasis and hypertension respectively (Barbera *et al.*, 2016; McLean & Wang, 2021). Also, K can slow down osteoporosis by preventing metabolic acidosis thereby preventing kidney stones (McLean & Wang, 2021). The Zn, Mn and Cu are important cofactors of antioxidant enzymes of the superoxide dismutase (SOD) family (Di Fabrizio *et al.*, 2022). The SOD catalyzes the conversion of superoxide ($O_2^{\bullet-}$) to less toxic hydrogen peroxide (H_2O_2).

Likewise, Se is a cofactor for glutathione peroxidases (GSH-Px / GP) (Fig. 7) which catalyze the reduction of H_2O_2 to more safe products: water (H_2O) and oxygen (O_2) (Rapa *et al.*, 2019). Also, GSH-Px catalyzes the reduction of peroxide radicals to alcohols and oxygen (García-Montero *et al.*, 2021). Equally, Fe and Mn are cofactors of catalase (CAT) (Fig. 7) which also catalyze the reduction of H_2O_2 into H_2O and O_2 (Rapa *et al.*, 2019). Furthermore, Zn can stabilize membrane structure, protect protein sulfhydryl groups, enhance metal-binding capacity and prevent iron-initiated lipid peroxidation (Lee, 2018). Also, Zn has anti-inflammatory activity by promoting inhibition of NF-κβ through upregulation of the A20 transcription factor (Prasad, 2014). Besides, Mn can prevent lipid peroxidation through quenching peroxyl radicals (Coassin *et al.*, 1992). Moreover, Mn can enhance the antioxidant and inhibitory activity of flavonoids like luteolin against XO (Dong *et al.*, 2017).

Also, magnesium has an anti-inflammatory activity which involves the reduction of C-reactive protein (CRP); thus, it lowers the risk of developing hypertension and CKD (Rapa *et al.*, 2019). Furthermore, magnesium can enhance vasodilation by acting as a natural calcium channel blocker or increasing the production of prostaglandin E_1; thus, also lowers blood pressure (Houston & Harper, 2008). Besides, magnesium regulates intracellular calcium, potassium, sodium and pH as well as insulin sensitivity; thus, further reducing the risk of developing MDs including diabetes and hypertension (Houston & Harper, 2008). Furthermore, magnesium regulates smooth muscle tone, improving ventilation in diabetic patients with DKA (Moraes & Surani, 2019). In addition, magnesium is a cofactor of enzymes involved in DNA repair mechanisms, maintaining genome stability and fidelity; its adequate dietary intake lowers the risk of developing tumors (Blaszczyk & Duda-Chodak, 2013).

Furthermore, calcium stimulates body antioxidants and mitigates OS associated with lead (Pb) and cadmium (Cd) exposure (Szlacheta *et al.*, 2020). Also, Ca at higher levels within physiological concentration (8.5–10.5 mg/dl) may decrease lipid peroxidation products (Szlacheta *et al.*, 2020). Likewise, calcium can manage secretory and inflammatory diarrheas by activating calcium-sensing receptors (Cheng, 2016; Li *et al.*, 2023). Still, calcium, especially at increased cytosolic concentration, can lead to apoptosis of tumor cells (Zhong & Darmani, 2018). However, mitochondrial calcium overload, which OS causes, can further lead to OS (Szlacheta *et al.*, 2020). Also, increased cytosolic calcium may lead to vomiting (Zhong & Darmani, 2018). The beneficial biological activities of these minerals play a key role in lowering the risk of developing MDs including gout and GACs (García-Montero *et al.*, 2021; Gherghina *et al.*, 2022; McLean & Wang, 2021).

Phytochemicals and minerals with such health benefits are plentiful in natural sources, particularly flora used in TFS and TM (Amarowicz & Pegg, 2019; García-Montero *et al.*, 2021). Conversely, they are less abundant or lacking in the GFS, which has replaced the TFSs of most IPs and escalating MDs, including gout and GACs (Kuhnlein, 2015; Raschke & Cheema, 2008). However, some IPs like the Maasai of Monduli are among the communities integrating flora in their TFS and TM, and they have a low prevalence of MDs, including gout and GACs (Clement *et al.*, 2023; Kuhnlein, 2015). For instance, the odds for hypertension, a GAC, were significantly reduced among Monduli Maasai who integrated fruits in their diets, at an adjusted odds ratio (AOR) of 0.37; 95% CI, 0.18–0.77 (Khamis *et al.*, 2020a). Nevertheless, information (like kind, roles, relative importance, and conservation status) of the flora used in Maasai TFS and TM to manage gout, GACs, and the disease risk factors is not well established. Likewise, the content of minerals and phytochemicals of such flora is not well determined.

Thus, an ethnobotanical survey of flora used in the Maasai TFS and TM against diseases including gout and GACs as well as quantitative analysis of phytochemicals, particularly polyphenols and the minerals in such flora were carried out in this study; they are important in establishing the most potent flora against diseases including the MDs, discovering and developing safe and efficacy nutraceuticals, therapies, or AHAs against the MDs, and promoting conservation and sustainable use of the TFS and TM flora.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Ethnobiological and Ethnobotanical Survey

3.1.1 Description of the Study Area

This study was designed by the researcher (author) in collaboration with the coauthors. It was conducted in Monduli which is among the seven districts of the Arusha region situated between latitude 3°.29′ 59″ south and longitude 36°.45′27″ east in the northeastern part of Tanzania (Fig. 8). The study area was deliberately chosen because the Maasai are the main residents, 97% of the Munduli population size of 227 585 people (Kimaro *et al.*, 2018; URT, 2022). Besides, nearly 70% of the Maasai live in rural areas with available natural resources that support cultural practices in their TFS, TM and livelihood (Khamis *et al.*, 2020b; Roulette *et al.*, 2018).

Monduli has a total area of 6419.0 km^2, of which 6290.6 and 128.4 km^2 are covered by land and water, respectively. The area supports various uses: The 3983.9 km2 is used for grazing, 1055.5 km^2 for agricultural activities and 375.0 km^2 is reserved as forestland. To the North, Monduli is bordered by Longido District; to the West by Ngorongoro and Karatu districts; to the South by Manyara region; and to the East by Arusha Rural District. Moreover, Monduli has a total of 20 wards and 62 villages. This ethnobotanical survey was conducted in seven villages found in four wards: Lepurko, Makuyuni, Monduli, and Mwandeti (Fig. 8); the villages represented highland and lowland climatic zones and had accessible natural resources supporting the Maasai TFS and TM.

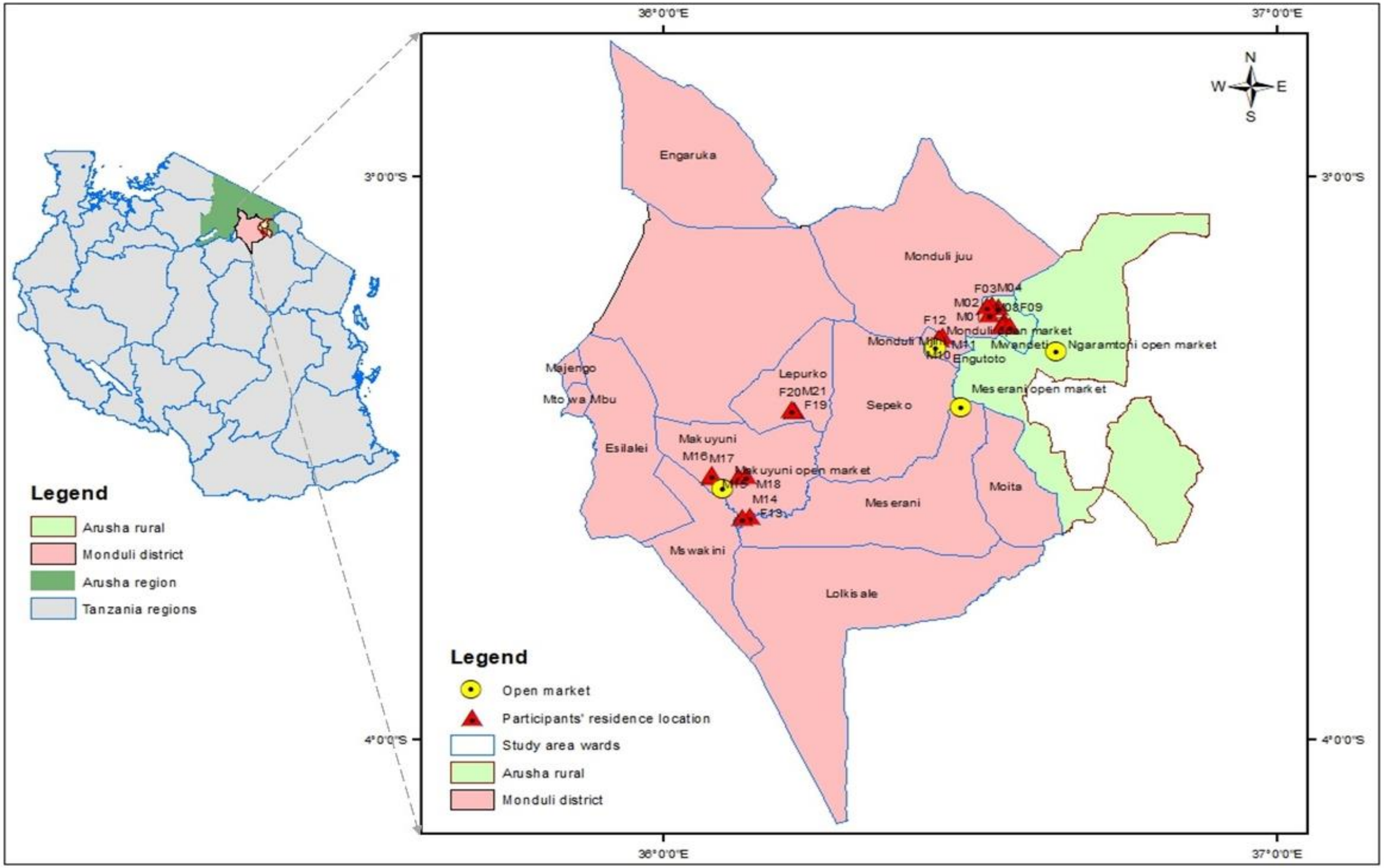


Figure 8: **Participating Maasai traditional practitioners (MTPs) residences and open market locations in chosen study sites in Monduli, Arusha**

The climate of Monduli consists of three zones: Highlands, flat and rolling plains, and rift valleys. Highland has an average altitude of 2000 m, and the lowland (flat and rolling plains) has an altitude ranging from 600-1200 m above sea level. Still, Monduli has a dry climatic condition accompanied by warm temperatures (20-35°C) at low altitudes and cool temperatures (15-19°C) at high altitudes. Its annual rainfall ranges from below 500 mm in the lowlands to 900 mm in the highlands. The Maasai mainly practice livestock keeping and some small-scale farming for their livelihood (Khamis *et al.*, 2020b; Roulette *et al.*, 2018)

3.1.2 Reconnaissance Survey and Informant Selection

The ethnobotanical survey commenced in June 2020 and completed in August 2020. The collection of voucher specimens finished in April 2021. A total of 14 local administrators (A village chairperson and her/his representative from each village) were consulted 2-3 days before face-to-face interviews with MTPs. The theme of the research was first introduced to the administrators for them to recommend suitable MTPs who could best participate and provide reliable information for the study. Bias in choosing participants was avoided by guiding the administrator's recommendations based on the criteria for including or excluding the participants in the study and matching the recommendations provided with the actual qualities possessed by the potential participants before the interview. If the administrators lack knowledge about their villagers, full understanding, and consideration of the set criteria, the choices of the participants would be biased. The recommendation criteria were age and experience from practicing the Maasai TFS and TM; they were based on the aim of the study. The Maasai elders have enormous knowledge and experience in their cultural practices through training organized at different stages of their lives and rituals like "*orpul*" (Makule, 2018; Quinlan *et al.,* 2016). Also, the Maasai populations rely on ancestral knowledge to practice TFS and TM.

At the age of 30 years or above, Maasai men have gathered adequate knowledge and skills on their cultural practices including TFS and TM through learning in different stages of life: Boy (uncircumcised) and "*moran*", marked by circumcisions at the age around 15 years (Quinlan *et al.*, 2016). After the completion of the "*moran*" stage at the age of 30 years, Maasai men qualify for marriage to become "*muruo*" or elders who are capable of family and community responsibilities (Quinlan *et al.*, 2016). After marriage, a man provides a herd of milk cows for his wives to manage for milk and meat consumption in the family (Quinlan *et al.*, 2016). He also takes a herd of cows, goats and or sheep to a distant area for good grazing for their animals especially during dry seasons (Quinlan *et al.*, 2016). This can be supported by the "*moran*" if present in his family. Also, in teamwork with "*moran*", or other elders slaughters the livestock for meat to be consumed at family, cattle camps, or various rituals: Birth, circumcisions, marriage, "*orpul*" (Quinlan *et al.*, 2016; Roulette *et al.*, 2018). The moran harvests and uses the wild flora to prepare foods or medicine used for family or various rituals (Clement *et al.*, 2023).

On the other hand, women acquire knowledge and skills in their cultural practices through interaction with their mothers and grandmothers, and occasionally through "*orpul*" (Roulette *et al.*, 2018). A woman at the age of being married usually after menarche can take on family and community responsibilities (Clement *et al.*, 2023). A married woman "*tɔmɔnɔ́k*" milks the cow and or processes the milk into butter for family consumption or other roles including medicine. She also prepares foods or medicine for consumption by family members or at rituals using various materials: Meat from the livestock slaughtered by men, wild flora, or traditionally cultivated flora harvested by herself, family members, or other community members (Clement *et al.*, 2023; Roulette *et al.*, 2018).

Based on this background, to ensure adequate information about the Maasai TFS and TM is collected, participants with the following qualities were recruited: Aged 30 years or above, the experience of practicing TFS and TM signified by involvement in rituals like "*orpul*" and cultural marriage, and family responsibility as father and mother. These participants were considered experts who practice their TFS and TM; thus, they were referred to as Maasai practitioners (MTPs).

A total of twenty-one MTPs (15 males and 6 females) were identified from seven villages: Engalaoni, Imbibia, Lemiyoni, Lossimingori, Makuyuni juu, Mlimani and Zaburi (Fig. 8). Men were free to decide their participation in the study while women's choice to participate where influenced by consent from their husbands; thus, men were more than women. The MTPs aged between 30-97 years (mean = 66.90: SD = 17.98) were a combination of agro-pastoralist, agro-zero-grazing, traditional healers (TH), and traditional midwives (TMW) who were highly knowledgeable of the TFS and TM (Table 1). During the survey interviews, the knowledge of TFS and TM was shared and recorded at the choice of MTPs.

Table 1: Demographic data of the MTPs in Monduli district, Arusha region, 2021

Demographic data (*N*=21)	**Frequency (%)**			
Gender				
Male	15 (71)			
Female	6 (29)			
Education status				
Nonformal	11 (52)			
Basic reading and writing skills only (adult education)	3 (14)			
Elementary school (STD I - IV/VII)	7 (33)			
Ethnicity				
Maasai	21 (100)			
Occupation of MTPs				
Agro-pastoralist (**AGP**)	18 (86)			
Agro-zerograzing (**AGZ**)	3 (14)			
Traditional healer (**TH**)	2 (10)			
Traditional midwife (**TMW**)	3 (14)			
Years of experience (range)	**AGP**	**AGZ**	**TH**	**TMW**
< 10 years (least experience was 8 years)	1 (5)	0	0	0
10 - 20 years	4 (19)	0	0	0
More than 20 years	13 (62)	3 (14)	2 (10)	3 (14)

3.1.3 Ethnobiological and Ethnobotanical Data Collection

This ethnobiological survey was conducted based on the International Society of Ethnobiology (ISE) Code of Ethics (ISE, 2006), while the ethnobotanical survey considered Bennett's Golden Rule for Ethnobotany Field Work (McClatchey & Gollin, 2005). The surveys started following an official approval (Appendix 2) and a support letter from the Nelson Mandela African Institution of Science and Technology (NM-AIST) administration. The study participants were informed about the benefits of taking part in the present study. To obtain their consent, a brief discussion was held with the MTPs, and the aim of the study was clarified so that they would be clear about the intent of documenting the knowledge regarding the Maasai TFS and TM for academic use, with no commercialization being involved.

It was also made clear that the usual benefits they receive by practicing their TFS and TM will not be affected by giving full information about the Maasai TFS and TM. Verbal consent was obtained from the study participants before the commencement of the study. The costs of travel and time spent were remunerated with modest payments. After clarifying the aim of the study and the criteria for inclusion or exclusion from the study, all participants who provided informed consent were enrolled.

The survey's data was collected by the researcher (author) through open-ended, semi-structured interviews. A checklist of open-ended interview questions (Appendix 1) translated into Swahili was used to interact with the MTPs. However, for the MTPs who could not speak Swahili, a Maasai translator was used. The interview started at the household of each of the MTPs to obtain the available information about TFS and TM. Each MTP was visited and interviewed thrice (at reconnaissance, household and field sample collection) to ensure the consistency of the data provided. The collected data at the household guided the field walks in the local environment of MTPs to obtain more data about the species, particularly flora used in the Maasai TFS and TM. Afterward, all interviews and discussions conducted in the Maasai and Swahili languages were transcribed into English by the researcher.

The interviews at the households of respondents and later in the field walk generated the following data, depending on the survey. The ethnobiological survey provided data about foods (dishes), ingredients or species used in preparing foods, food processing technologies (FPT), cultural reflections guiding the use of foods and their roles or benefits in the Maasai TFS. Also, the ethnobotanical survey provided data about local names of the flora species, growth habitats, habits, part(s) of the flora used, mode of flora preparations or applications, roles of the flora or preparations thereof, and ailments or health conditions managed by the flora.

The data were later subjected to classical ethnobiological and ethnobotanical systematic analysis and a numerical quantitative approach to determine the importance of foods or flora used in the TFS and TM for primary healthcare of the IPs (Amjad *et al.*, 2020; Tuasha *et al.*, 2018). However, the potential bias in data collection could be the involvement of participants who lost their cultural practices in TFS and TM or unevenly geographically distributed in the target study area. While potential barriers and obstacles could be a reluctance to share information or participate in the study by the participants, or limited time for their participation.

3.1.4 Plant Specimen Collection and Identification

Through the guidance and assistance of a botanist and the MTPs during field walks, the researcher collected plant voucher specimens from bushland/shrubland, forest, grassland, savanna and wetland from June 2020 to April 2021. The GPS facility was used to record the coordinates and altitude of places from which specimens were collected. The collected specimens were numbered, assigned Maasai names, pressed and properly dried. Appropriate documentation was made with photographic pictures of the area and the mature individual plant at the site of collection. Identification of the specimens was carried out using Flora of Tropical

East Africa (FTEA [Flora of Tropical East Africa] 1952-2012, 2012) with the assistance of the botanist and his team members at Tanzania Plant Health and Pesticides Authority (TPHPA) in the National Herbarium section. Specimens with labels were finally deposited at TPHPA in the National Herbarium section.

3.1.5 Data Analysis

Data analysis was conducted using the classical ethnobiological and ethnobotanical systematic investigation and a numerical quantitative approach (Amjad *et al.*, 2020; Tuasha *et al.*, 2018). The quantitative analysis was achieved through the following ethnobiological and ethnobotanical indices:

(i) Use Categories

Species used in the TFS were grouped into various use categories as found in the TFS. The method described by Cook (1995) and later by Issa *et al.* (2018) was adopted with some modifications to formulate the use categories. Each time a species was mentioned as "used" by an informant it was counted as one (1) 'use report'. Also, when an informant used a species for more than one role in a use category e.g. "the animal slaughtering process" for "holding animal meat" and or "dissolving its blood"; or "respiratory system" for treating "cough", and or "tonsillitis", for each case it was still counted as one "use report" (Issa *et al.*, 2018).

(ii) Use Value (UV) Index

It is a quantitative measure that facilitates the evaluation of the relative importance of each species; it is based on the known local uses of each species among informants, and it is expressed by the following equation (Amjad *et al.*, 2020):

$$\mathrm{UV} = \frac{\sum U_{\mathrm{i}}}{\mathrm{N}}$$

Whereby, U_{i} represents the number of use reports cited by each informant for a given species, and N denotes the total number of informants. Although it is used to evaluate the relative importance of species, UV does not distinguish between a single or multiple uses of a plant species. This is because the frequency a species is cited for a particular use varies from one use to another, depending on users' choices; thus, a species can have a high frequency of citation (use reports) and hence UV from a single reported use or multiple reported uses and vice versa

(Amjad *et al.*, 2020). The importance of each species is a function of the increase in UV values. Higher values suggest that the species is highly valuable and vice versa.

(iii) Informant Consensus Factor (ICF)

The knowledge homogeneity among informants was measured using the ICF technique expressed *vide infra*, see below (Tuasha *et al.*, 2018):

$$\text{ICF} = \frac{N_{\text{ur}} - N_{\text{s}}}{N_{\text{ur}} - 1}$$

Whereby, N_{ur} denotes the total number of use reports for all species cited in a use category, and N_{s} denotes the number of species mentioned by informants in that use category. When ICF is close to or equal to zero (0), it suggests random selection of species; there is no exchange of information among informants about species in a given use category; and there is strong disagreement among informants due to different experiences and strict secrecy on information keeping (Issa *et al.*, 2018; Tuasha *et al.*, 2018). However, when ICF approaches or is equal to one, it signifies a systematic, well-defined selection of species; there is a clear exchange of information among informants; and the majority of informants provide information on a few species (Issa *et al.*, 2018; Tuasha *et al.*, 2018).

(iv) Fidelity Level (FL)

The ratio of informants who independently "report the uses of a species or ingredient or food" or "cite a health condition" for the same "use category" or "disease category" to the total number of informants who "mention the species or ingredient or food for any use" or "cite the disease category of the health condition" respectively is determined by FL expressed below (Tuasha *et al.*, 2018):

$$\text{FL (\%)} = \frac{N_p}{\text{FC}} \times 100$$

Whereby, N_p is the number of informants who "claim the use of a species or ingredient or food for a particular purpose" (e.g., treating skin disorders) or "cite a health condition" (e.g., boil); and FC is the total number of informants that "use the species or ingredient or food for any use" or "cite the disease category of the health condition" respectively (Tuasha *et al.*, 2018).

(v) Relative Frequency of Citation (RFC)

It showed to what extent “a species or ingredient or food” or “a health condition” was cited “for any use” or “among health conditions” respectively by the participants of the study:

$$\mathrm{RFC} = \frac{\mathrm{FC}}{\mathrm{N}}$$

The FC is the number of informants “reporting the uses of a particular species or ingredient or food” or “citing a health condition”, and N is the total number of informants (Amjad *et al.*, 2020).

(vi) Specific Relative Frequency of Citation (RFCs)

This study ought to determine and compare the relative importance of using a plant species or ingredient, or a food for a specific purpose. Therefore, **RFC*s*** were computed through the following formula:

$$\mathrm{RFC}_S = \mathrm{FL} \times \mathrm{RFC} = \frac{N_p}{\mathrm{FC}} \times \frac{\mathrm{FC}}{\mathrm{N}}$$

Thus, a species or ingredient or food is important and mostly preferred by informants to treat an ailment or perform a particular role in the area when FL and RFC*s* are high, and vice versa.

3.2 Antioxidant Capacity and Mineral Content Determination for Flora Used in Maasai TFS and TM Against Diseases, Including Gout and GACs

3.2.1 Chemical Reagents

Chemical reagents were purchased from various manufacturers (Table 2) and used to determine antioxidant capacity and mineral contents of the selected most commonly used flora against gout and GACs.

Table 2: Chemical reagents used in antioxidant capacity and mineral content determination

Chemical	Molecular formula	Specific gravity	Assay (%)	Manufacturer
Aluminium chloride	$AlCl_3$		99.5	Sigma-Aldrich
Calcium oxide	CaO		98.0	Uni-chem
Ethanol	C_2H_5OH		99.7	Griffchem
Ethylene diamine tetraacetic acid disodium salt	Na_2EDTA		96.0	Loba Chemie PVT. LTD
Folin-Ciocalteu reagent				Prepared at ATC
Gallic acid	$C_7H_6O_5.H_2O$		99.5	Loba Chemie PVT. LTD
Hydrochloric acid	HCl	1.18 g	35.4	Loba Chemie PVT. LTD
Hydrofluoric acid	HF		40.0	Merck
Iron (Metal) Fillings	Fe		100	Loba Chemie PVT. LTD
Magnesium oxide	MgO		96.0	Loba Chemie PVT. LTD
Manganese metal	Mn		99.9	Hopkin & Williams
Methanol	CH_3OH	0.791	99.8	Griffchem
Nitric acid	HNO_3	1.41 g	69.0	Loba Chemie PVT. LTD
Potassium chloride	KCl		99.0	Griffchem
Quercetin	$C_{15}H_{10}O_7$		95.0	Sigma-Aldrich
Sodium carbonate	Na_2CO_3		99.5	Trust Chemical Laboratories (TCL)
Strontium chloride hexahydrate	$SrCl_2.6H_2O$		99.0	Loba Chemie PVT. LTD
Zinc metal	Zn		100	Fisher Scientific, USA.

3.2.2 Plant Material

A total of 35 species, which comprised 43 samples of the most commonly used plant parts, were collected, step 1 (*S-1*), (Fig. 9) from Monduli District, Arusha, Tanzania. The botanist identified the species, and their voucher specimens were deposited at the Tanzania Plant Health and Pesticides Authority (TPHPA) in the National Herbarium section. Detailed information for each voucher species can be found through its collection number indicated against each species. The collected samples were transported to the research institution in a cool and dry atmosphere and then air-dried, step 2 (*S-2*), under the shade (Fig. 9). The air-dried samples were pulverized, step 3 (*S-3*), to 850 µm particle size of the powder (Fig. 9) and then stored in an air-tight package, below 10°C in a dark environment to the integrity of samples (Paul *et al.*, 2017).

3.2.3 Extraction of Plant Samples for Total Phenolic and Flavonoid Content Determination

Acurately, 10.000 g of the pulverized sample of each used plant part was extracted with 99.7% ethanol. Exactly 75 mL of the ethanol was mixed with the weighed pulverized sample in the 250 mL conical flask. The mixture in the conical flask was left for 10 minutes to extract the sample at room temperature. After that, the formed extract solution was decanted into another container. The extraction of the sample was repeated thrice: each time, the sample was extracted with fresh 75 mL of ethanol for 10 minutes. Total volume, approximately 225 mL of the decanted extract solution, was collected into the container ready for concentration, step 4 (*S-4*) (Fig. 9). The extract solution for each sample was concentrated by a rotary evaporator (Fig. 9) under reduced pressure at 40°C. The obtained extract was placed into the container and then stored in cool and dry conditions; it was ready for further use.

(i) Sample Preparation for Total Phenolic and Flavonoid Content Determination

The weight of each sample was measured between 10-50 mg of ethanolic extract, and then it was dissolved in 5 mL of Methanol (99.8%). The mixture was subject to the vortex mix until the sample extract dissolved completely. The formed solution mixture was centrifuged at 3300 rotations per minute (RPM) for 30 minutes. The formed supernatant (stock sample) was transferred into the amber bottle for storage to protect the analyte from any reaction if exposed to light.

(ii) Total Phenolic Content

The total phenolic content (TPC) was determined using the modified Folin-Ciocalteu method (Adewusi & Steenkamp, 2011a). Exactly 1 mL of the supernatant of each sample from the amber bottle was mixed with 5 mL of Folin-Ciocalteu and 4 mL of saturated sodium carbonate (7% Na_2CO_3) in the amber container. The mixture was vortexed for 15 seconds and then incubated in the water bath for 30 minutes at 40°C for color formation, step 5 (*S-5*) (Fig. 9). Absorbance was measured at 765 nm using the UV-Vis spectrophotometer (Fig. 9). When the absorbance (Abs) of a sample reached the maximum value (in this study it was 4.00) the instrument could read, the supernatant (1 mL) of that sample was further diluted to 5 mL again in the methanol. Exactly 1 mL of the diluted sample was treated in the same way as the first measured sample before dilution, and its absorbance was remeasured to compute the total phenolic content of the sample. Total phenol content was calculated as mg gallic acid equivalent GAE/g of dry plant material based on the standard curve of gallic acid (1.00 - 7.5 mg/L, $\boldsymbol{C}$ = 0.6311 + 7.2855$\boldsymbol{Abs}$, R = 0.991285). All determinations were carried out in a tetraplicate: The instrument measured, a sample four times, and the average and standard deviation thereof are shown in the results (Appendix 6). The total phenolic content (TPC) expressed as mg GAE/g of the extract was computed by the equation below:

$$TPC = \left(\frac{C_m \times V_t}{V_s} \times V_{st}\right) \div M_{ex} \qquad (1)$$

$$V_t = V_S + V_{FC} + V_{SC} \qquad (constant) \qquad (2)$$

Where:

TPC = total content of phenolic compounds in mg GAE/g of extract

C_m = concentration of gallic acid (mg/L) established from the calibration curve

V_s = volume of extract (constant)

V_{st} = volume of extract stock sample (constant)

M_{ex} = weight of pure plant ethanolic extract, which was dissolved in the methanolic stock sample

V_{FC} = volume of Folin-Ciocalteu (constant)

V_{SC} = volume of saturated sodium carbonate (constant)

Note: If the extract stock sample required further dilution to determine its concentration within the working range of the calibration curve, dilution law was applied to compute its TPC.

(iii) Total Flavonoid Content

The total flavonoid content (TFC) of each sample was determined by the aluminum chloride colorimetric method (Chandra *et al.*, 2014). Quercetin was used to make the standard calibration curve for determining total flavonoid content. Stock quercetin solution was prepared by dissolving 5.0 mg quercetin in 1.0 mL methanol, then the standard solutions of quercetin were prepared by serial dilution using methanol (5-200 mg/L). An amount of 0.6 mL diluted standard quercetin solution or extract was separately mixed with 0.6 mL of 2% aluminum chloride ($AlCl_3$) followed by 2 mL of methanol. After mixing, the solution was incubated for 60 minutes at room temperature. The absorbance of the reaction mixtures, step 6 (*S-6*), (Fig. 9) was measured against a blank at 420 nm wavelength with a UV-Vis spectrophotometer (Fig. 9). The concentration of total flavonoid content was measured in mg quercetin equivalent QE/g of extract based on a standard calibration curve of quercetin (1.425

– 7.125 mg/L, ***C*** = 0.1507 + 20.0090***Abs***, *R* = 0.998684). The total flavonoid content (TFC) expressed as mg QE/g of extract was computed by the Equation 3:

$$TFC = \left(\frac{C_m \times V_t}{V_Q} \times V_{st}\right) \div M_{ex} \qquad (3)$$

$$V_t = V_Q + V_{AC} + V_M \qquad (constant) \qquad (4)$$

Whereby:

TFC = total content of flavonoids in mg QE/g of extract

C_m = concentration of quercetin (mg/L) established from the calibration curve

V_Q = volume of extract

V_{st} = volume of extract stock sample (constant)

M_{ex} = weight of pure plant ethanolic extract, which was dissolved in the methanolic stock sample

V_{AC} = volume of aluminum chloride (constant)

V_M = volume of methanol

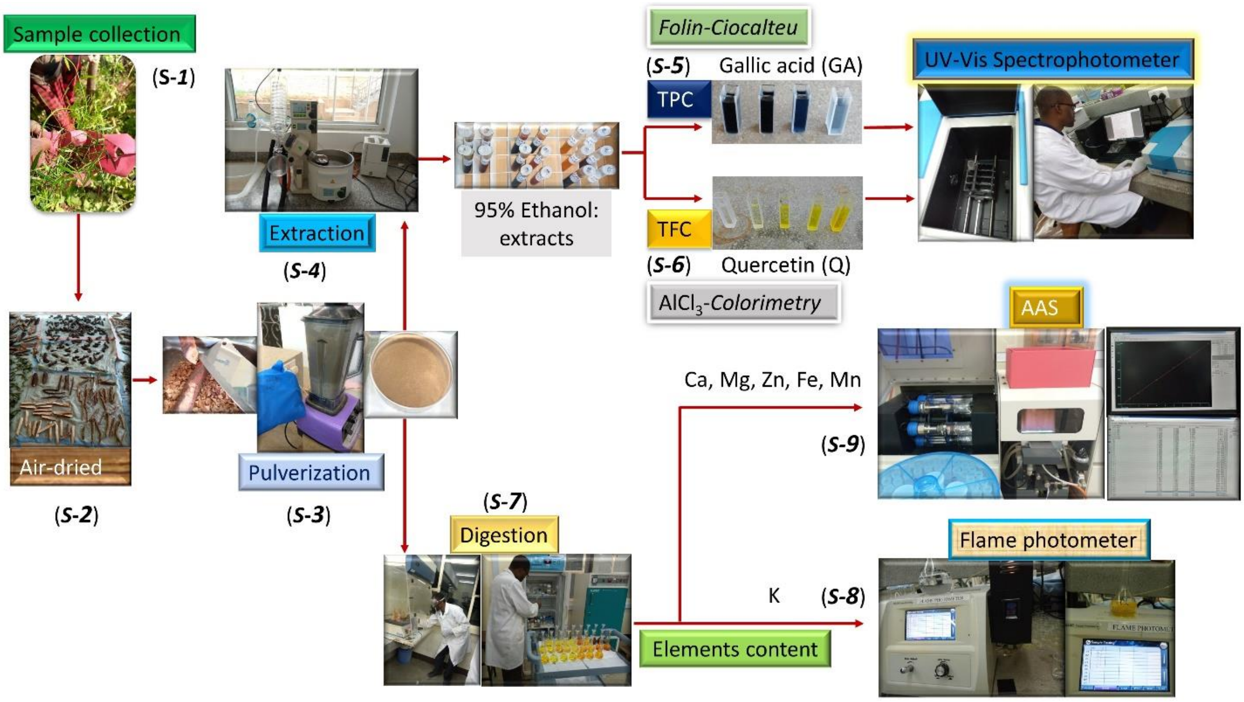


Figure 9: The main steps (*S*) for determining total phenol (TPC), flavonoid (TFC), and mineral contents of flora used in Maasai TFS and TM against gout and GACs

3.2.4 Sample Preparation for Mineral Content Determination

Before digestion, each pulverized sample, step-3 (*S-3*), (Fig. 9) was further dried at 80°C (176°F) for 48 hours in the oven to remove the remaining moisture while avoiding the thermal decomposition of the sample (Paul *et al.*, 2017). Then the sample was removed from the oven, followed by cooling the dried sample in the desiccator at room temperature for 30 min, and after that weight of each sample was measured before digestion.

(i) Digestion of Plant Samples for Mineral Content Determination

The wet acid-digestion method was adopted as described by Huang *et al.* (2004) with some modifications. The HNO_3/HF digestion was performed in this study. Hydrofluoric acid (HF) was used instead of hydrogen peroxide to ensure complete digestion of the samples (Gruyter, 2015; Lavilla *et al.*, 1999). Acurately 1.6 g of the dry-cooled sample from the desiccator was measured on the analytical balance. The measured sample was digested at 3:1 (HNO_3: HF). The volume of 4 mL of hydrofluoric acid (HF) followed by 12 mL of concentrated acid (HNO_3) was measured into a 250 mL Pyrex glass conical flask. While in the fume chamber, the conical flask containing the sample was heated at 100°C on the hot plate for 15 minutes until all brown fumes disappeared and left a solution mixture. The solution mixture was left to cool and then filtered into a 100 mL volumetric flask. The digested solution in the volumetric flask was diluted with distilled water up to the mark. These procedures were done for each sample. The blank sample (1.600 g of distilled water) was digested following the same procedures as described earlier. Each diluted sample in the volumetric flask was stored in the fridge at 4°C, ready for nutrient elemental analysis by a spectroscopic method.

(ii) Instrument Conditions for Calibration Curve and Mineral Content Determination

Potassium (K) content in the plant samples was measured using the FP6440 Flame photometer, while zinc (Zn), manganese (Mn), iron (Fe), magnesium (Mg) and calcium (Ca) contents were measured using the Atomic Absorption Spectrophotometer (AAS). The instrument conditions for measurement were set for each nutrient element as shown in Table 3.

Table 3: Instrument's conditions used to determine nutrient element contents

Analyte	λ (nm)	Slit (nm)	PMT (V)	Lamp current (mA)	Observe height (mm)	Acetylene flow (L/min)
K						
Zn	213.9	0.4	341	3.00	7.0	1.0
Mn	279.5	0.2	307	3.00	7.0	1.7
Fe	248.3	0.2	433	3.00	6.0	1.7
Mg	285.2	0.2		3.00	6.0	1.6
Ca	422.7	0.4		3.00	6.0	1.7

(iii) Preparation of Potassium Standard Solution and Calibration Curve

Standard solutions of potassium were prepared for calibration of the FP6440 flame photometer. A weight of 5.00 g potassium chloride, KCl (Assay: 99.0%), in a glass petri dish was measured and heated in the oven at 140°C for two (2) hours to remove any hydrating water from the salt (Archer, 1999). The heated sample was cooled in the desiccator at 23°C. Exactly 93.19 mg of the dry-cooled KCl was measured on the analytical balance and then put into a 100 mL beaker. The salt in the beaker was dissolved in distilled water and then poured into a 500 mL volumetric flask. Distilled water was used to rinse the beaker while diluting the solution mixture in the volumetric flask to the mark, forming a potassium standard mother liquor of 2.5 mmol/L. Standard series of 0.5, 1.0, 1.5, and 2.5 mmol/L were prepared from the standard mother liquor using distilled water as a diluent, forming 100 ml of each standard series. The calibration curve for potassium (Table 4) was plotted using the standard series; it was used with the flame photometer to measure the K content in the samples.

Table 4: Calibration curves used to determine nutrient element content of the flora

Analyte	Concentration (C) range	Calibration curve equation	Correl ($\boldsymbol{R}$)	D. L. (µg/mL)	CO (µg/mL)
K	0.5-2.5 mmol/L	$\boldsymbol{C} = 0.0035\boldsymbol{S} - 1.2021$	1.000000		
Zn	1.0-5.0 µg/mL	$\boldsymbol{Abs} = 0.1787\boldsymbol{C} - 0.0229$	0.992916	0.0317	0.0244
Mn	1.0-4.0 µg/mL	$\boldsymbol{Abs} = 0.1067\boldsymbol{C} - 0.0197$	0.998283	0.0210	0.0409
Fe	1.0-4.0 µg/mL	$\boldsymbol{Abs} = 0.0526\boldsymbol{C} + 0.0028$	0.999371	0.2390	0.0830
Mg	0.1-0.5 µg/mL	$\boldsymbol{Abs} = 0.2702\boldsymbol{C} + 0.0047$	0.997163	0.0108	0.0161
Ca	1.0-10.0 µg/mL	$\boldsymbol{Abs} = 0.007\boldsymbol{C} - 0.0009$	0.999367	0.0514	0.6216

(iv) Preparation of Zinc Standard Solution and Calibration Curve

A zinc (Zn) standard solution, 100 µg/ml, was prepared. Accurately 0.025 g of pure metal zinc (Assay: 99.9%) was measured and put into a 250 ml beaker. After that, 5 ml hydrochloric acid was added to the beaker while swirling to dissolve the metal. Then 30 ml of de-ionized water was added and the beaker heated on the hot plate until the sample completely dissolved and evaporated almost to dryness. Next, the mixture was transferred to a 250 ml volumetric flask and diluted to the mark with deionized water while swirling it up uniformly. The resulting solution was 1 ml = 100 µg Zn.

Standard series of 0.0, 1.0, 2.0, 3.0, 4.0 and 5.0 µg/ml were prepared by measuring 0.0, 1.0, 2.0, 3.0, 4.0 and 5.0 ml of the standard solution respectively and each mixed with 2% hydrochloric acid then diluted with de-ionic water to 100 ml in the volumetric flask. The AAS instrument conditions for zinc determination (Table 3) were set, and the corresponding calibration curve (Table 4) was generated using the series.

(v) Preparation of Manganese Standard Solution and Calibration Curve

A manganese (Mn) standard solution, 100 µg/ml, was prepared. Accurately 0.103 g of pure metal manganese (Assay: 99.9%) was measured and put into a 250 ml beaker. A 20 ml (1+1) nitric acid was added to the beaker containing the standard sample and then heated on the hot plate until the sample dissolved and evaporated almost to dryness. After that, 20 ml of hydrochloric acid was added to dissolve the salt with heating. Then the mixture was transferred to a 1000 ml volumetric flask and diluted to the mark with deionized water while swirling it up uniformly. The resulting solution was 1 ml = 100 µg/ml.

Standard series of 0.0, 1.0, 2.0, 3.0, 4.0 and 5.0 µg/ml of Mn were prepared following the same procedures as for the zinc standard series. The AAS instrument conditions for manganese determination (Table 3) were set, and the corresponding calibration curve (Table 4) was generated using the series.

(vi) Preparation of Iron Standard Solution and Calibration Curve

An iron (Fe) standard solution, 100 µg/ml, was prepared. Accurately 0.014 29 g ferric oxide (99.999%), oven-dried at 300°C, was measured and put into a 250 ml beaker. A 20 ml (1+1) hydrochloric acid was added to the beaker containing the standard sample and then heated until the sample dissolved and evaporated to a small volume (5 ml). After cooling it down, 5 ml of hydrochloric acid was added to dissolve the salt with heating. Then the mixture was transferred to a 100 ml volumetric flask and diluted to the mark with deionized water while swirling it up uniformly. The resulting solution was 1 ml = 100 µg/ml.

Standard series of 0.0, 1.0, 2.0, 3.0, 4.0 and 5.0 µg/ml of Fe were prepared following the same procedures as for the zinc standard series. The AAS instrument conditions for iron determination (Table 3) were set, and the corresponding calibration curve (Table 4) was generated using the series.

(vii) Preparation of Magnesium Standard Solution and Calibration Curve

A magnesium (Mg) standard solution of 1000 µg/ml was prepared. Accurately, 1.728 g magnesium oxide (assay: 96 %), combusted at 800°C, was measured and put into a 250 ml beaker. A small amount of de-ionized water was added to wet the beaker, followed by 10 ml (1+1) hydrochloric acid, and then the beaker was placed on the hot plate at a low temperature until the salt was fully dissolved. After cooling down, the mixture was transferred to a 1000 ml volumetric flask and diluted to the mark with deionized water while swirling it up uniformly. The resulting solution was 1 ml = 1000 µg Mg.

Standard series of 0.0, 0.1, 0.2, 0.3, 0.4 and 0.5 µg/ml were prepared in the following steps: First, 10 ml of the standard solution (1000 µg/ml) was measured into 100 ml volumetric flask followed by additional of 2 ml HCl and dilution with de-ionic water to the mark. This diluted solution was again diluted in this second step, as in the first step, forming a standard solution of 10 µg/ml. Then in the next step, the standard series was prepared by measuring 0.0, 1.0, 2.0, 3.0, 4.0 and 5.0 ml of 10 µg/ml standard solution, respectively each into a separate 100 ml volumetric flask. After that, into each volumetric flask, 2 ml of hydrochloric acid and 4 ml of 5% strontium chloride were added and diluted with de-ionized water to the mark. The AAS instrument conditions for magnesium determination (Table 3) were set, and the corresponding calibration curve (Table 4) was generated using the series.

(viii) Preparation of Calcium Standard Solution and Calibration Curve

A calcium (Ca) standard solution of 100 µg/ml was prepared. Accurately 0.143 g calcium oxide (assay: 98%) was measured and put into a 250 ml beaker, followed by 5 ml HCl, and heated on the hot plate at a low temperature until the salt was fully dissolved. After cooling down, the mixture was transferred to a 1000 ml volumetric flask and diluted to the mark with deionized water while swirling it up uniformly. The resulting solution was 1 ml = 100 µg Ca.

Standard series of 0.0, 1.0, 2.0, 4.0, 6.0 and 10 µg/ml were prepared by measuring 0.0, 1.0, 2.0, 3.0, 4.0 and 5.0 ml of 10 µg/ml standard solution, respectively each into a separate 100 ml volumetric flask. After that, into each volumetric flask, 1 ml of 20% strontium chloride, 1 ml of 0.1M EDTA, and 2 ml of hydrochloric acid were added and diluted with deionized water to the mark. The AAS instrument conditions for calcium determination (Table 3) were set, and the corresponding calibration curve (Table 4) was generated using the series.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 The Ethnobiological Link Between Health Benefits and Qualities of the Maasai Traditional Food System

An ethnobiological survey revealed that the Maasai traditional food system (TFS) had a variety of 19 dishes and a diversity of 78 flora species. The diversity of dishes and species had various potential health benefits: Nutrition like Fe and Vitamin A; therapeutic and protective effects against ailments including metabolic diseases (MDs) like gout, pressure, indigestion and kidney disorders. Some food processing technologies (FPT), like nixtamalization and meat roasting, had potential protective effects against the MDs (Kirui, 2016; MacDonald & Reitmeier, 2017; Muñoz Cano *et al.*, 2013; Oberleithner *et al.*, 2009). Cultural preferences and restrictions (CPR) for the food selection ensured individual nutritional and health needs were met, and reinforcement of Maasai socio-structure and cohesion (Fig. 10).

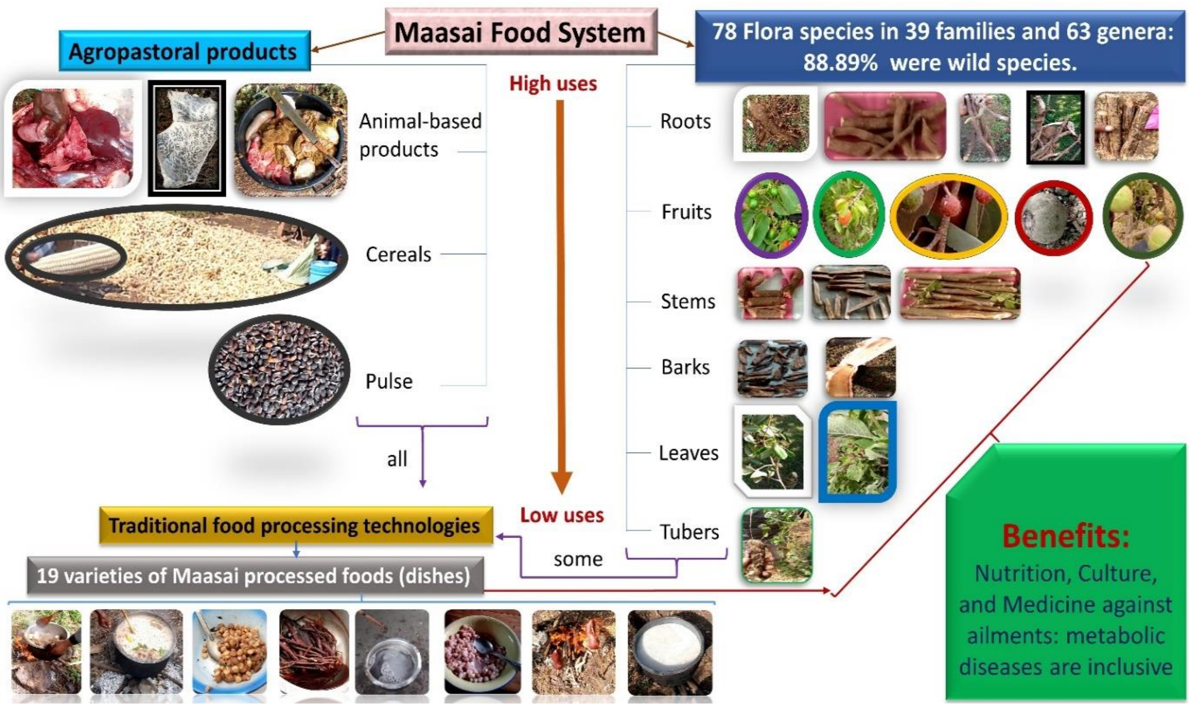


Figure 10: Graphical summary of objective one results

4.1.1 Food Variety and Diversity of Species in the TFS Used by the MTPs

This study recorded 19 varieties of Maasai foods (dishes) (Fig. 11), which were prepared from various ingredients (Appendix 3). Also, 78 flora species distributed in 39 families and 63 genera were used as food ingredients (Appendix 3), direct food sources, and food processing materials (Appendix 4). Most of the flora (57 species) were claimed to have medicinal roles in addition to nutritional and processing roles (Appendix 4). Still, most of the flora (88.89%) were sourced from the wild habitat (Fig. 12a) while trees accounted for the highest proportion (51.85%) of the flora species (Fig. 12b). Roots (Rt) followed by fruits (Ft) / Seeds (Sd) had the highest proportion of uses (Fig. 13). Non-plant ingredients were also used in preparing the Maasai foods (Appendix 3).

Amongst the foods (Fig. 11), "*Oloshoro*" or "*irpaek lekule*", followed by "*ingiring-naapejo*", "*olchani-imotori*", and "*irmakuku*" or "*ngararumu-ombenek*" had the highest RFC (>90%) (Fig. 11). Furthermore, fats, milk, maize, salt, beans, meat and *Olea europaea* subsp. *africana* were the ingredients with a high frequency of use in preparing the topmost consumed foods: They were respectively found in 7, 7, 6, 5, 4, 4 and 4 of the 10 topmost foods with the highest RFC (Fig. 11). Finger millet, rice, soda "magadi", *Lablab purpureus*, tomatoes, banana, Irish potatoes, onion, *Solanum villosum* and carrot were integrated into some of the Maasai foods (Appendix 3) though.

On the other hand, *Vangueria infausta* (African wild medlar), followed by *Ximenia caffra* (African sour plum) and *Dovyalis abyssinica* (African gooseberry), each had the highest values of FL and RFC of 1.00 and ≥ 0.52, respectively, amongst the direct food source flora (Fig. 14). Most of the food source flora, 24 species (82.8%) their fruit consumed as foods; for example, *Vangueria infausta*, *Ximenia caffra* and *Dovyalis abyssinica* (Fig. 14). Some of the species such as *Croton machrostachyus* (broad-leaved croton) and *Embelia schimperi* (Ethiopian olivelike), have their leaves cooked as a vegetable and chewed as edible parts, respectively. *Embelia schimperi* leaves were not consumed by women before menopause, as it was reported to induce abortion and excess menstrual flow. *Ficus thonningii* (Strangler fig) roots' bark (the inner part) and *Vigna parkeri* (creeping vigna) tuber were mainly chewed as sources of water (Appendix 4).

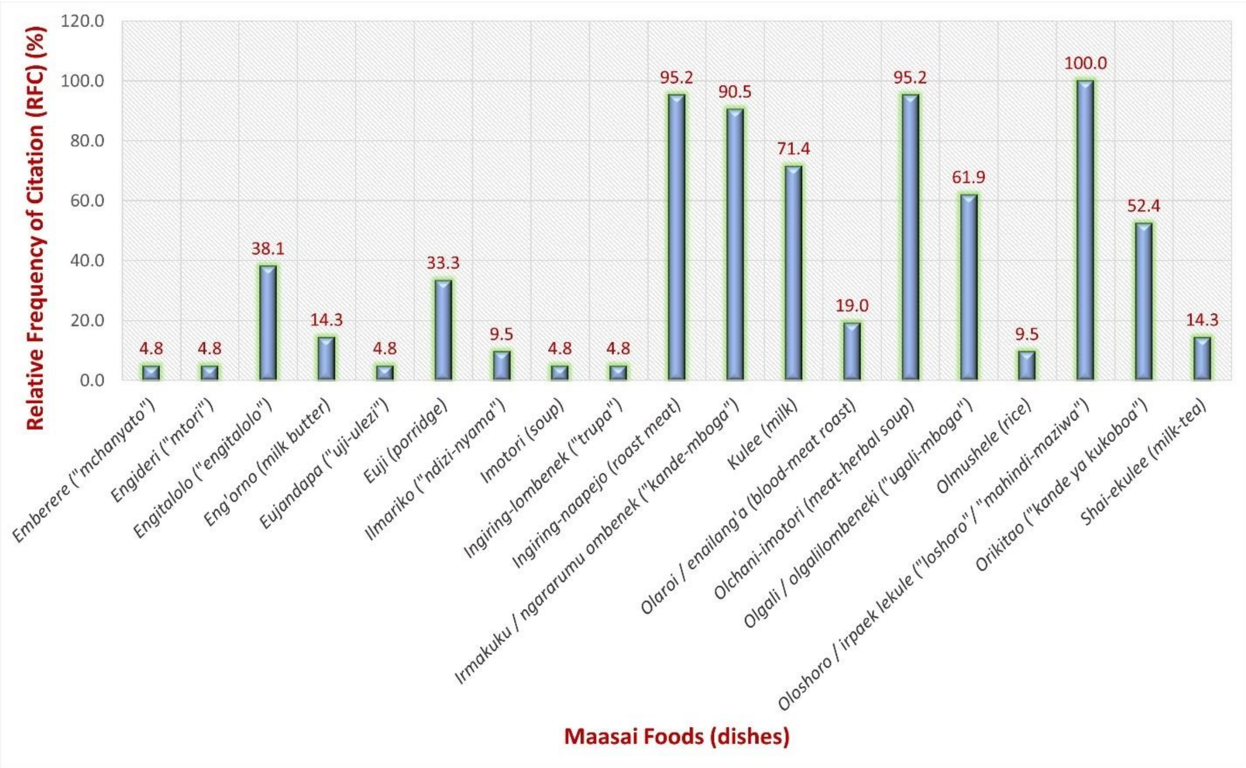


Figure 11: **The RFC (%) of Maasai Foods prepared from various ingredients**

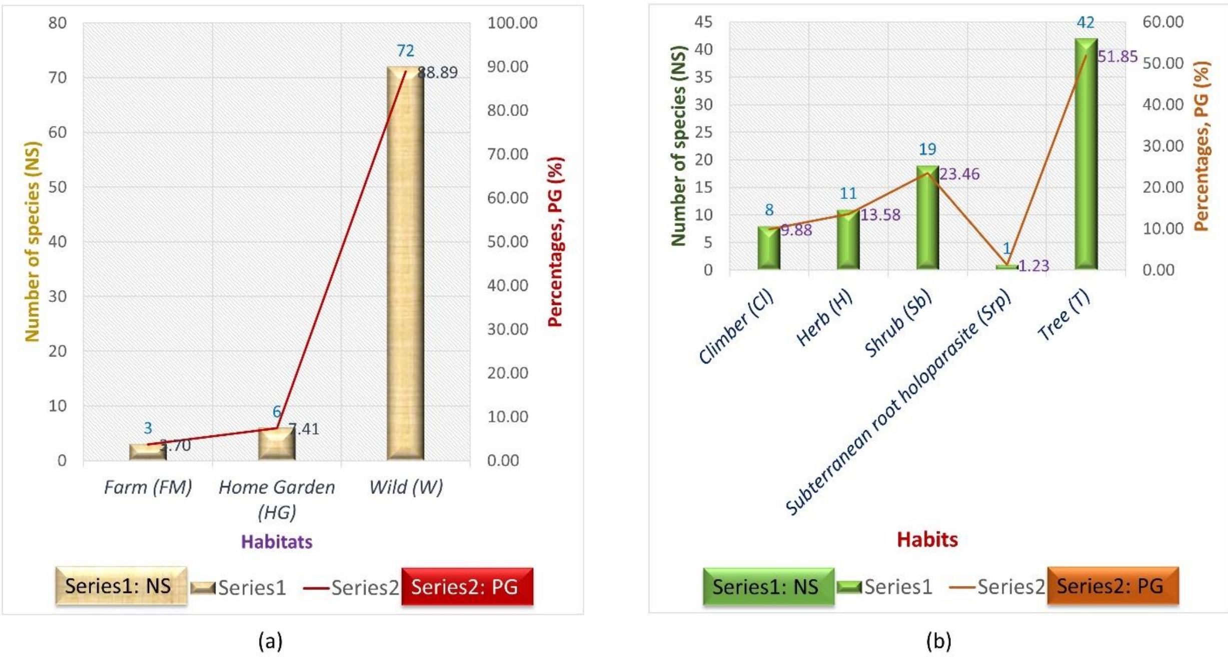


Figure 12: **Proportions of flora species on habitat (a) and habits (b)**

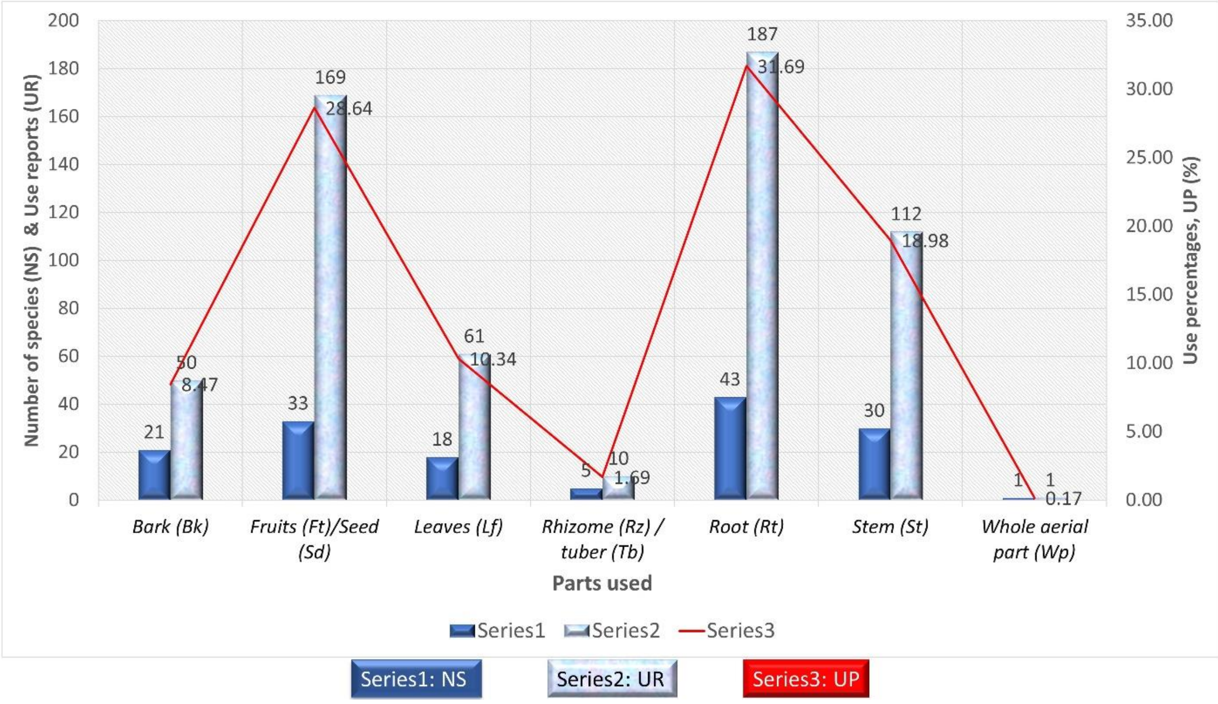


Figure 13: **Proportions of uses on parts of the flora species**

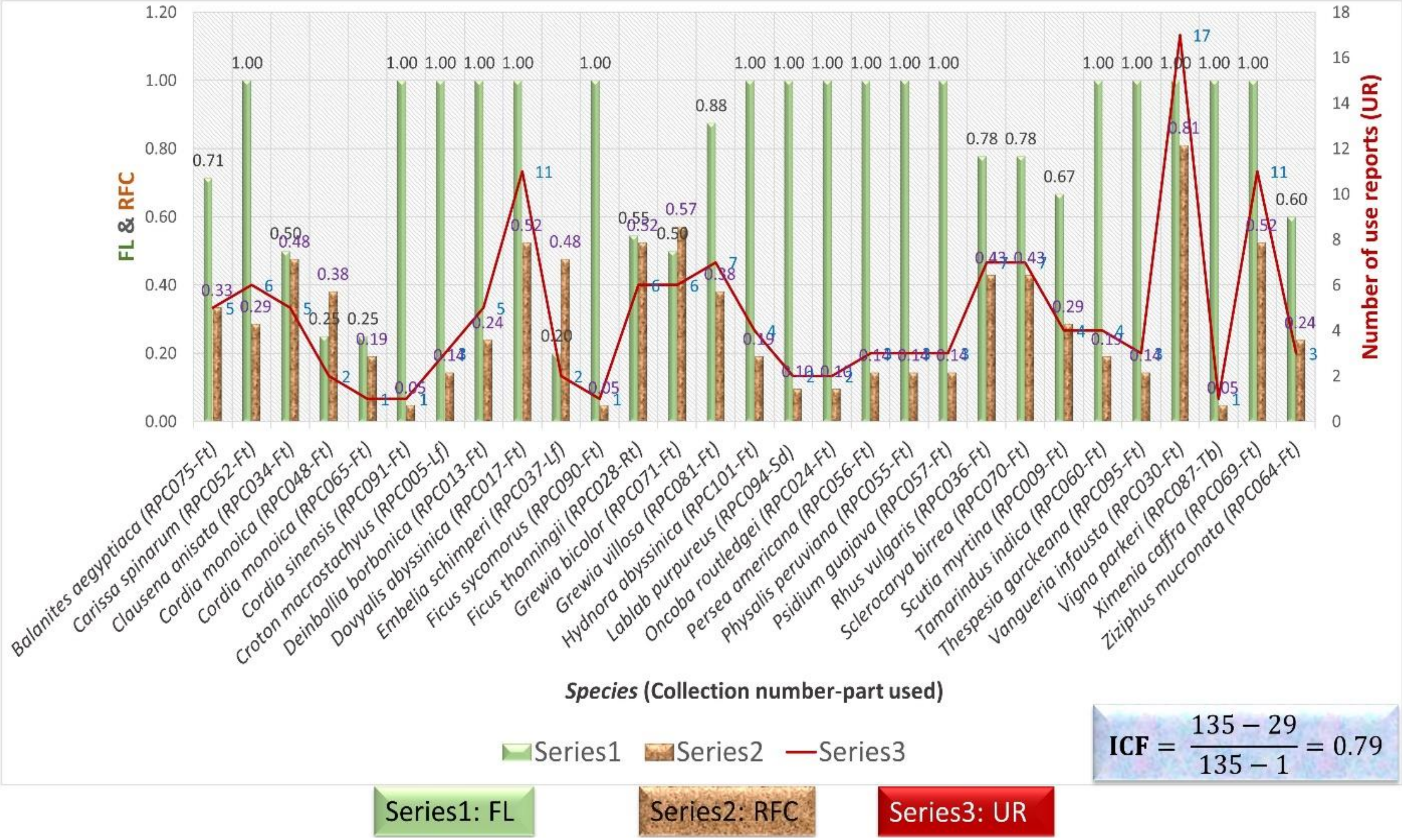


Figure 14: **The FL, RFC, UR, and ICF of flora species used as direct food sources**

4.1.2 Ingredients and Processing Technologies of the Maasai Foods

This section reports the foods' ingredients and FPT developed by the Maasai to prepare each food. But, the proportions and roles of the ingredients and the proportions and frequency of use for each food are more detailed in Appendix 3 and 4. Foods (dishes) described here are of specific nutritious value because the ingredients for their preparation, their FPT, perceived advantages and health benefits, and CPR made for their choices constitute important characteristics of food security and the resulting health impacts associated with the Maasai TFS.

(i) "*Emberere*"

This food is prepared using the ingredients described here. Each of the ingredients had an FL of 1.00 (Appendix 3). Fresh or dry whole maize grains are added into the water in the pot (Fig. 15), and placed on fire followed by the addition of soda "magadi" to soften maize grains. Then, bean seeds or peeled green bananas are added to the pot and left to boil till the resulting mixture is softened. Thereafter milk is added to the mixture while thoroughly stirring to form "*emberere*". This liquid food before its consumption is stored and preserved in the calabash (Fig. 16) which was decontaminated by smoke and ashes of *Olea europaea* subsp. *africana* and cleaned by brush ("*esosian*") made from the roots of either of the plant species (Fig. 17). The smoke and ashes from the species provide aroma and taste to the food. The food was reported to be used for nutrition and energy purposes.

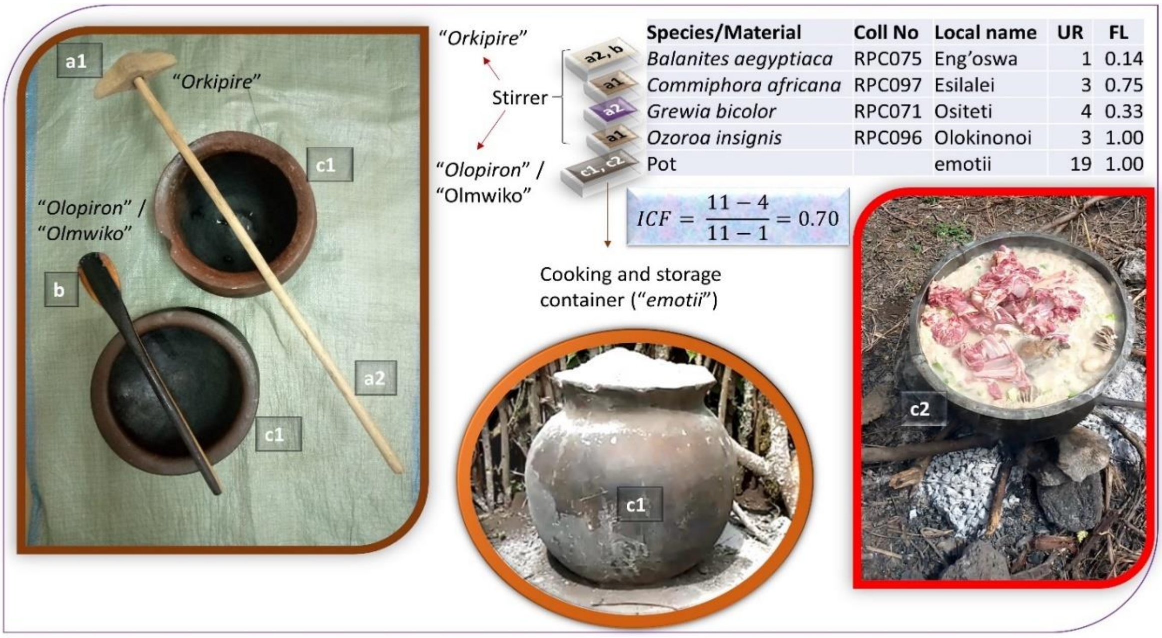


Figure 15: Stirrers and pots used in the cooking process

Species/Material	Coll N0	Local name	UR	FL
Lagenaria siceraria	RPC093	oltulet/engotii	15	1.00

$$ICF = \frac{15-1}{15-1} = 1.00$$

Figure 16: Calabash, as a storage container or funnel directing liquid foods into the container

Species/Material	Coll N0	Local name	UR	FL
Albizia anthelmintica	RPC062	emukutan	4	0.36
Ficus thonningii	RPC028	oreteti	11	1.00
		oitii	1	1.00
		oluayi/olearai	2	1.00
		ortepes	3	1.00

$$ICF = \frac{21-5}{21-1} = 0.80$$

Figure 17: Brush ("*esosian*") used in the decontamination and cleaning of the calabash

(ii) *"Engideri"*

The food is being prepared by the ingredients described here. Each of the ingredients had an FL of 1.00 (Appendix 3). Green bananas (ndizi ng'ombe) are peeled and added to water contained in the pot which is on fire. The bananas are left to boil till softened and then the fresh or yogurt milk is added to the bananas while stirring to form "*Engideri*". This liquid food before its consumption is stored and preserved in the calabash (Fig. 16) which is treated by ashes and smoke of *Olea europaea* subsp. *africana* as described earlier.

"*Engideri*" was preferred by some users because of its claimed roles: Stops diarrhea especially when fresh milk is used, increases milk production for lactating mothers and increases body fluid.

(iii) ***"Engitalolo"***

This food is prepared by the ingredients shown in Fig. 18. The ingredients had FL ranging from 0.13-1.00. Soda, *Solanum villosum* ("mnavu"), water, and whole maize grains had the highest FL of 1.00 each (Fig. 18). Whole maize grains are added to water in the pot set on fire, and then it is followed by soda ("magadi"). Fresh/dry bean seeds or peeled green bananas can be added to the formed mixture. Thereafter chopped fresh leaves of *Solanum villosum* are added to the later mixture. The resulting mixture is left to boil till is fully cooked. Fresh/yogurt milk or separately cooked milk-porridge is added to the cooked mixture. Then clean cold water is added while stirring the whole mixture to form light-viscous food. Burning stick of *Olea europaea* subsp. *africana* stem is added into the lighter-viscous food, and then it is left for night (evening-morning) to give a sour taste to the food. At this stage "*Engitalolo*" is ready for consumption.

This food is culturally eaten by females and uncircumcised boys who are usually aged 12 years and below. Circumcised men don't consume the food because they regard leafy vegetables like *Solanum villosum* as animal foods. Foods containing leafy vegetables when consumed by men, culturally lower their status of being men and wealthier with livestock which could provide food for them instead of leafy vegetables. This reflects what four respondents said. "But the restriction for men to consume the leafy vegetable food is no longer apply to all Maasai men. It is evident by a respondent who said, "I started to eat "*Engitalolo*" since 1966". "*Engitalolo*" is reported to provide good health, increase appetite and milk production for pregnant and lactating mothers respectively, improve sight and increase body fluid.

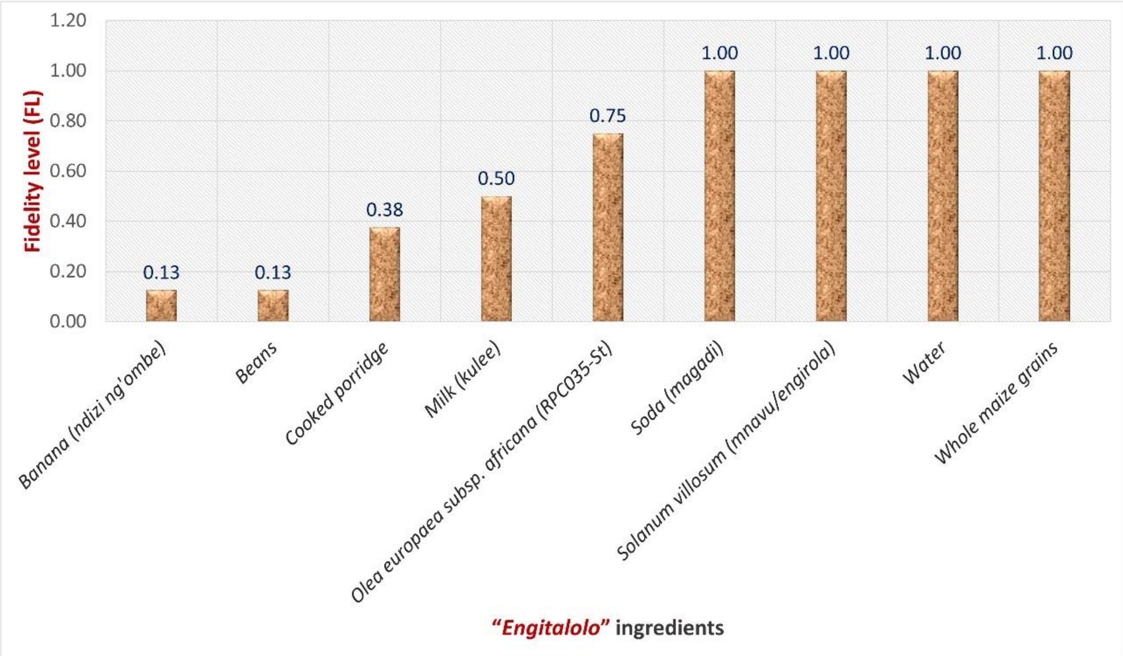


Figure 18: The FL of "*Engitalolo*" ingredients

(iv) *"Eujandapa"*

The food is prepared using the ingredients described here. Each of the ingredients had an FL of 1.00 (Appendix 3). While stirring water in the pot set on fire, the finger millet flour is added into the water. Thereafter fresh or yogurt milk is added followed by sugar and fats while continue stirring. The added fats can be in the form of ghee or tallow from the animals: Cow, goat and sheep. The resulting mixture is left to boil until is fully cooked and ready for consumption.

(v) *"Euji" (porridge)*

The preparation of this food involves the ingredients in Fig. 19. The ingredients had FL ranging from 0.29-1.00. Whole maize grain flour and water followed by milk and *Olea europaea* subsp. *africana* had the highest FL (Fig. 19). The flour is added to boiling water in the pot (Fig. 15) while stirring the mixture. The stirring process continues for 30 minutes up to 2 hours to form the porridge. If the porridge is used shortly after preparation, salt and or fat (ghee/tallow) are added to the boiling porridge during stirring. Thereafter, fresh milk, the most preferred or yogurt milk is added to the boiling or cooled porridge, then the mixture is stirred thoroughly to form "*Euji*". Fat, salt and yogurt are not used in the preparation if the porridge is to be stored and used for longer time. This avoids fermentation of the porridge that would result in the heartburn. The porridge ready for storage and longer consumption is put into the calabash (Fig.

16) which was decontaminated by smoke and ashes of *Olea europaea* subsp. *africana* and cleaned by the brush (Fig. 17).

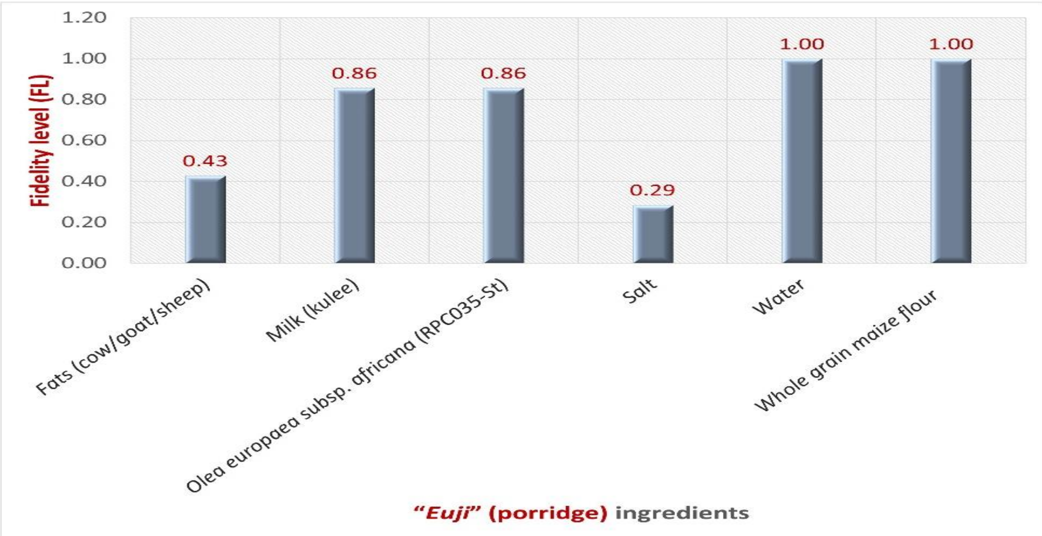


Figure 19: The FL of "*Euji*" (porridge) ingredients

"*Euji*" is preferred for quenching thirst, cleaning and relaxing blood vessels, stopping chilling in cold weather, and removing tiredness. This reflects what two respondents said. It is also consumed as a meal starter, especially by men before consumption of a lunch. Furthermore, it was reported that some "*Euji*" materials particularly whole maize grain flour and salt when mixed in cold water and drunk by unconscious alcohol ("*enemasher*") drunker, induce vomiting and relieve the alcoholism.

(vi) *"Ilmariko"*

This food is prepared by the ingredients described here. Each of the ingredients had an FL of 1.00 (Appendix 3). Clean tomatoes and onion are chopped and then added into the pot containing boiling fats (ghee/tallow). The mixture is roasted for a while. Then trimmed meat is added to the roast while stirring. Thereafter peeled green bananas, either hard ("mshale") or soft ("uganda"), and peeled Irish potatoes are added to the roast. Next, water followed by salt is added to the later mixture while stirring. Occasional stirring continues until the food is fully cooked. "*Ilmariko*" is reported to provide nutrition and energy.

(vii) *"Imotori"*

The preparation of this food involved the ingredients described here. Each of the ingredients had an FL of 1.00 (Appendix 3). The "*Imotori*" can be prepared in two ways. In the first preparation, whole maize grains are ground using mortar ("*engiuri*") and pestle ("*emushi*") made from either of the species shown in Fig. 20. Then, small pieces of the trimmed meat are added to the water contained in the pot (Fig. 15) set on fire. Thereafter, cleaned ground maize grains or peeled green bananas are added into the pot containing the meat, and the resulting mixture is left to boil while occasionally stirred until the mixture is fully cooked and softened. This viscous food is ready for consumption.

Alternatively, instead of using small pieces of trimmed meat, large pieces are used and the food is prepared using the same materials as in the first preparation. Once the food is fully cooked and form soup, the large pieces of meat are removed from the soup. The cooked meat and soup are consumed separately.

The "*Imotori*" is consumed by females as it contains meat parts which are culturally believed to have some roles to them. For instance, spine-tail meat is believed to restore the health of spine of women post-delivery. Men are culturally restricted from eating the food because gastrointestinal meat particularly large intestine in the food is believed to weaken scalp hair or cause sculptor in men.

Species/Material	Coll No	Local name	UR	FL
Balanites aegyptiaca	RPC075	Eng'oswa	1	0.14
Dalbergia melanoxylon	RPC074	Oltiasika	1	0.33
Eucalyptus saligna	RPC044	Orkelebu	1	0.50
Mystroxylon aethiopicum	RPC029	Olodong'anayo	3	1.00

$$ICF = \frac{6-4}{6-1} = 0.40$$

Species/Material	Coll N0	Local name	UR	FL
Commiphora africana	RPC097	Esilalei	2	0.50
Cordia africana	RPC042	Ormuringiringa	3	1.00
Dovyalis abyssinica	RPC017	Emaduai	2	0.18
Ekebergia capensis	RPC022	Ormukuna	3	1.00
Sclerocarya birrea	RPC070	Ormang'uai	2	0.22

$$ICF = \frac{12-5}{12-1} = 0.64$$

Figure 20: Mortar ("*engiuri*") and pestle ("*emushi*") used to grind foodstuffs

(viii) "Ingiring-lombenek"

This food is prepared using the ingredients described here. Each of the ingredients had an FL of 1.00 (Appendix 3). Trimmed meat pieces from either cow, goat, or lamb are put into water contained in the pot (Fig. 15) set on fire. The pieces are left to boil until they are fully cooked. Thereafter, using rendered fats from the animals, the cooked meat is roasted together with chopped onion and tomatoes until fully cooked. "*Ingiring-lombenek*" prepared in this way is often consumed with stiff porridge ("*olgali*"/ "ugali").

Alternatively, the pieces of trimmed meat from either of the animals are put into water in the pot on fire and left to boil. Then, while the meat is boiling, chopped bananas, tomatoes and oil from the rendered fat are added, and they are left to boil together until fully cooked. Salt can be added to the food. This form of "*Ingiring-lombenek*" is preferred by females including lactating mothers.

(ix) ***"ingiring-naapejo"***

This food is prepared using meat ("*ingiring*") from cows, goats and sheep. The kind of meat and how it is prepared depends on its use purposes: For household ("*ronjo*") use, "*orpul*" festival, ceremony, gender identity (father/mother), and health status (sick/post-delivery). Goats and sheep are the common sources of meat used in a household ("*ronjo*"). Also, goats are culturally used as gift meat for men while sheep are the source of gift meat for women. Cows are used as the main source of meat in addition to goats and sheep for "*orpul*" festivals or ceremonies.

An animal of choice is slaughtered before proceeding with other roasting processes. Culturally slaughtering process is done away or a bit far from home by Maasai men particularly "*morans*" to avoid being seen by women. The animal to be killed for meat source is laid over holding leaves ("*enaraa*") which are from either of the plant species shown in Fig. 21. The leaves prevent contamination and provide aroma and taste to the meat. Also, the leaves together with the rope from *Abutilon longicuspe* can be used to wrap meat from the animals for a gift to the father and mother-in-laws.

The killing of the animals can either be through hanging or slaughtering by knife. Killing through hanging is preferred as it is easier to collect much blood from the animal, leaving the animal's flesh with little blood. The blood is collected shortly after hanging when the animal's heart is pierced by a knife that allows the blood to drain into the stomach. When the skinning is done and the stomach is opened, the coagulated blood is dissolved or thinned using leaves from either of the species shown in Fig. 21. The thinned blood is collected using hands or any vessel into a container; it is ready for use. Also, hard fat ("*engurinyi*") which encloses visceral organs is separated from the organs and spread over a clean place to dry a bit under the sun. This fat can be used to cover meat especially the liver ("*emonywa*") in the roasting process, or it can further be molded into a size of a fist that is ready for use in the preparation of meat-herbal soup ("*olchani-imotori*"). Meat ("*ingiring*") to be roasted is trimmed or portioned into different parts (Fig. 22). These parts had FL of 1.00 each.

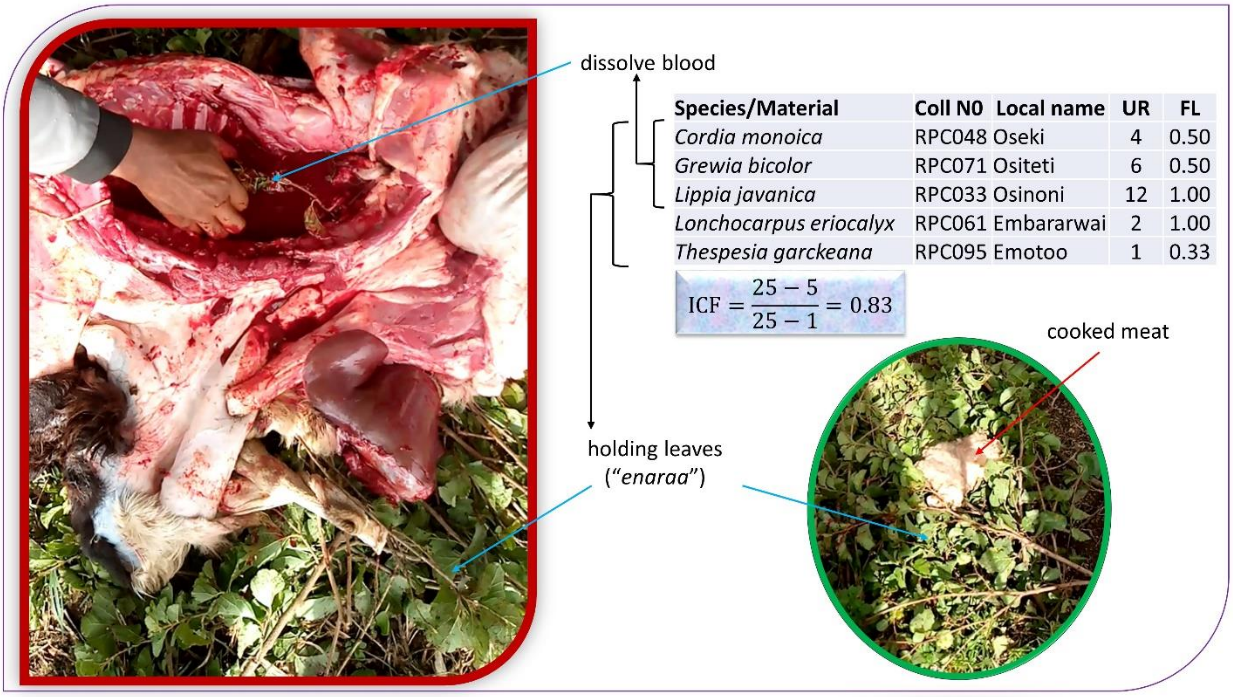


Figure 21: **Plant species whose leaves are used for holding animals in the slaughtering process and dissolving (thinning) the coagulated blood of the slaughtered animals**

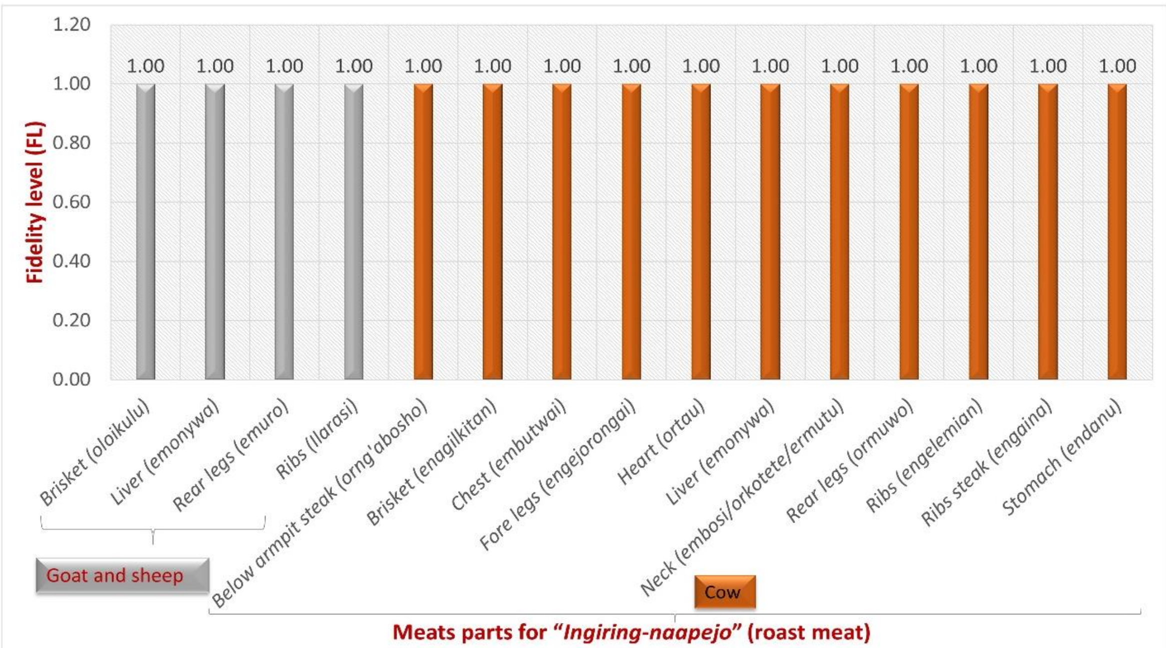


Figure 22: **The FL of meat's parts used for "*ingiring-naapejo*" (roast meat)**

The prepared meat parts are spread using the holding sticks ("*orjibet*") from either of the species shown in Fig. 23. The species are used for making sticks because they are not bitter or poisonous. Moreover, they provide good aroma and taste to the meat, and they increase appetite. The sticks with meat are erect on the ground beside the fire (Fig. 23), and they are occasionally turned around until the meat is fully cooked. The sticks can also be used to hold the cooked meat from boiling soup (Fig. 23). Alternative to the sticks ("*orjibet*"), wire mesh (very rarely), or firewood are used especially by women to roast meat.

It was noted that no salt is added to the roast meat due to various reasons. Water in the meat itself has salt. This was reflected by four respondents. Also, consumption of roast meat with added salt can cause gout (inflammation and pain in the knees and ankles) and increase the heartbeat of consumers. This was reflected by two respondents. Likewise, "eating roast meat with added salt encourages lions to kill the consumers and eat their salty flesh", a respondent said. Still, another respondent said, "Added salt to the roast meat causes thirst and thinness to consumers".

When the roast meat ("*ingiring-naapejo*") is ready for consumption, "*orjibet*" with the meat is usually erect on the ground (Fig. 23). A consumer with a knife cuts the meat, and he/she eats the meat before distributing it to others. "*Ingiring-naapejo*" is usually eaten along with other foods such as ugali ("*olgali*"). It is also consumed along with medicinal preparations such as meat-herbal soup and herbal decoctions.

Species/Material	Coll N0	Local name	UR	FL
Abutilon longicuspe	RPC020	Oldadai	2	1.00
Clausena anisata	RPC034	Ematasia	8	0.80
Combretum zeyheri	RPC098	Ormaroroi-oibor	1	0.20
Cordia monoica	RPC048	Oseki	4	0.50
Cordia monoica	RPC065	Ordoko	2	0.50
Dombeya kirkii	RPC066	Orporokwai	1	0.25
Eucalyptus saligna	RPC044	Orkelebu	1	0.50
Grewia bicolor	RPC071	Ositeti	9	0.75
Lippia javanica	RPC033	Osinoni	4	0.33
Olea europaea subsp. *africana*	RPC035	Oloirien	1	0.05
Thespesia garckeana	RPC095	Emotoo	1	0.33
Vepris simplicifolia	PRC011	Olgilai	3	0.38
		emandila	3	1.00
		osendu	3	1.00
		Eiri	1	1.00

$$\mathrm{ICF} = \frac{44 - 15}{44 - 1} = 0.67$$

Figure 23: Plant species whose stems are used as holding sticks (“*orjibet*”) in meat roasting and cooking

The meat part eaten by a consumer depends on his/her cultural identity in the Maasai society. For instance, rear legs are culturally eaten by “*morans*”. Neck, head, kidney and liver are eaten by elders as they are believed to be more nourished. “Large intestine is consumed by women, but men do not consume for it is believed to weaken scalp hair or cause sculptor when eaten by them”, said two respondents. The spine-tail meat is consumed by women as it is thought to strengthen their spine and restores the health of the spine post-delivery. The spine-tail meat is also used as a gift to elderly women to show honor to them. Brisket meat is consumed by uncircumcised boys. Liver of sheep is consumed by females while that of goat is consumed by males. Males consume liver of the goat because the animal eats variety of herbs compare to sheep.

When a woman has a special occasion in her household, she may give the rear legs or stomach of a goat or sheep to honor her co-wife or female neighbors. Also, a woman can give thigh meat to her mother-in-law or great co-wife to honor them. Forelegs and ribs of the animals are consumed by the woman of the household with whom the occasion or ceremony is concerned.

(x) “Irmakuku” (“ngaramumu”) or “Ngararumu ombenek”

This food is prepared using the ingredients in Fig. 24. Whole maize grains, water, soda, salt and beans had the highest FL (Fig. 24). Whole maize grains are added to water in the pot set on a fire. This is followed by the addition of soda to soften the maize grains. Fresh or dry seeds of beans or *Lablab purpureus* ("*ngwara*") are added to the later mixture and left to boil until fully cooked. Then the formed soup in the resulting mixture can be filtered or left to boil until the food is semi-dry. After that, salt, fat (ghee/tallow) or dry banana pieces ("*irmakosho*") can be added to the semi-dried mixture while stirring until the final mixture becomes stiff which is called "*irmakuku*". Dry banana pieces are prepared from any banana fruit which is close to ripening with exceptional to "mshale". The bananas are hanged over the fire in the kitchen until they dry thereby forming "*irmakosho*". "*Irmakosho*" is used in place of salt to provide taste to the food. If the food is for females alone, *Solanum villosum* ("mnavu") can be mixed with the other components during boiling, before stirring to stiffness starts. So, the resulting food is called "*Ngararumu ombenek*".

Alternatively, chopped tomatoes and or onion are separately roasted with fat (ghee/tallow) from the animals. This roast is mixed with the other components of "*irmakuku*" or "*Ngararumu ombenek*" while stirring the food to stiffness. Additional of these materials particularly tomatoes are done when the food is consumed soon after preparation to avoid fermentation of the food if they are to be stored for a longer time.

"*Irmakuku*" or "*Ngararumu ombenek*" can be consumed along with other foods such as fresh milk, tea or milk tea. This food provides nutrition and energy as well as it gives longer satiation when it is eaten. Young babies and older people are restricted to consume this food because its stiffness may result into a hard stool which is difficult to excrete.

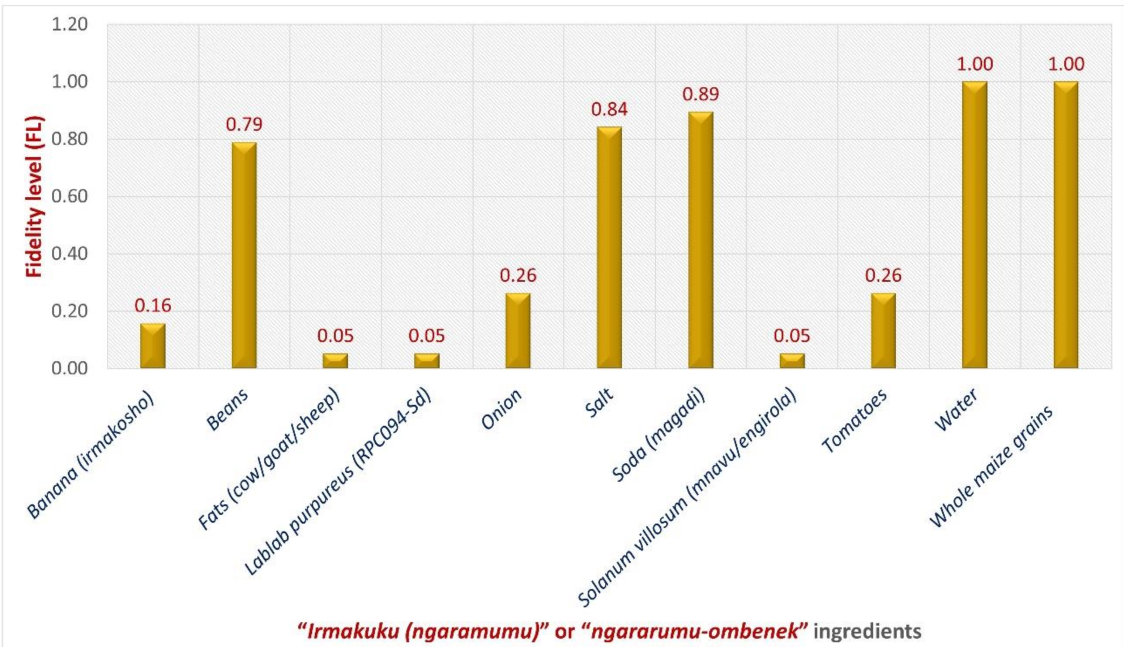


Figure 24: The FL of "*irmakuku*" or "*ngararumu-ombenek*" ingredients

(xi) *“Kulee” (milk)*

The main source of milk is a cow. Species in Fig. 25 are the most common additives to the milk when it is processed for common uses. The clean teats of the cow are milked to give the milk which is then put into the calabash (Fig. 16) which was treated by smoke and ashes of *Olea europaea* subsp. *africana* and cleaned by brush from either of the species (Fig. 17). The species makes milk fresh for up to twenty-four hours. This additive provides aroma and taste to the food. It also prevents stomach bloating which would occur if the calabash was not treated with the species. Milk stored in the calabash treated by smoke and ashes of *Olea europaea* subsp. *africana* can be preserved for up to seven days. *Albizia anthelmintica* powder can be added to the milk in the calabash and stay for up to four days. The latter species increases body heat and treats worms when consumed with milk. The milk in the calabash is shaken well shortly before its consumption.

If there is plenty of milk, women usually after three days thoroughly shake the stored milk in the decontaminated calabash to form milk butter. The milk is separated from milk butter using spoon or calabash cap, and it is poured into another container. The milk butter is put into a pot set on fire and it is heated to form ghee (“*eng’orno*”).

The milk separated from milk butter can be used in preparing other foods as described in this work. It can also be consumed along with other foods such as “*olgali*” and “*irmakuku*”. Ghee is used for feeding children to build their bodies. Pregnant women are restricted from using milk products containing *Albizia anthelmintica* as it is claimed to induce abortion.

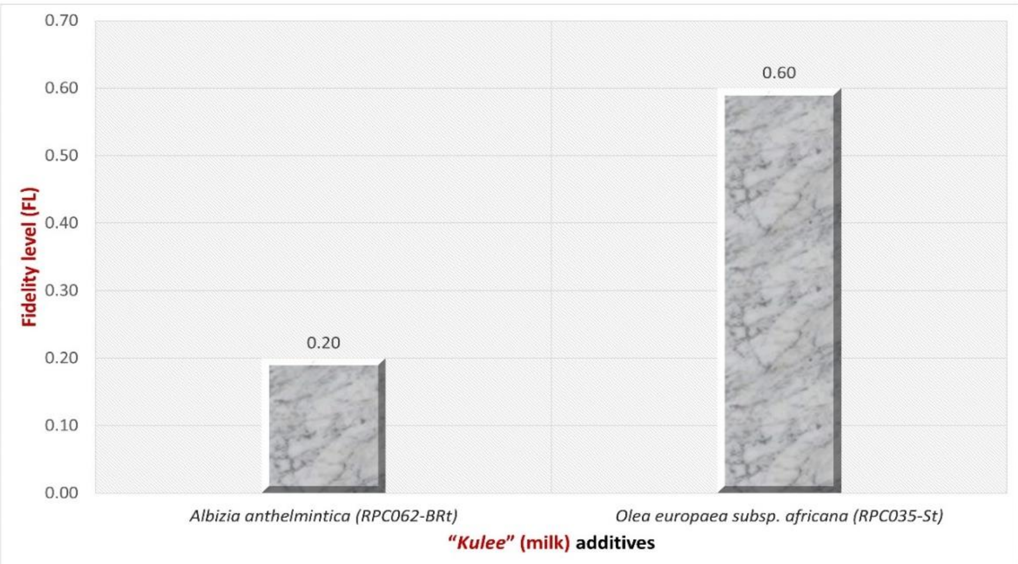


Figure 25: The FL of “*kulee*” (milk) additives

(xii) *"Olaroi" or "Enailang'a"*

These blood-based foods are prepared using the ingredients in Fig. 26. Blood had the highest FL (Fig. 26). Blood is obtained from either of the animals: Cow, goat and sheep. When blood is obtained from a live cow, the animal is tied with a rope around the neck to locate the main vein from which the blood is drained. A small arrow is used to pierce the vein, and then blood is drained into a container such as the calabash. Alternatively, the blood can be obtained from the animals after being slaughtered as described earlier (Fig. 21).

The freshly collected blood can thoroughly be mixed with fresh milk to form "*Olaroi*" which is ready for consumption. Otherwise, meat with soft fat is mixed with small amount of fat (ghee/tallow) which is contained in the pot set on fire. The meat is left to boil to give more fat until it dries. The liquid fat (tallow) is drained into another container to remain with the dry meat. Then, the fresh blood is added to the dry meat in the pot. Blood and the dry meat are heated while stirring until they are fully cooked thereby forming "*enailang'a*".

"*Olaroi*" specially made from the blood of a live animal (cow) is preferred for consumption when a person is far from home ("*ronjo*" / "boma") specifically when herding animals in the bushes where cooking is difficult. "*Olaroi*" also, serves as a source of food during hunger. "*enailang'a*" was regarded as the must food for pregnant women and post-delivery mothers as it is believed to increase and restore blood during pregnancy and after delivery respectively. This food causes thirst; it is often consumed along with meat soup, tea or porridge. These blood-based foods can also be consumed by sick or anemic people to improve their health.

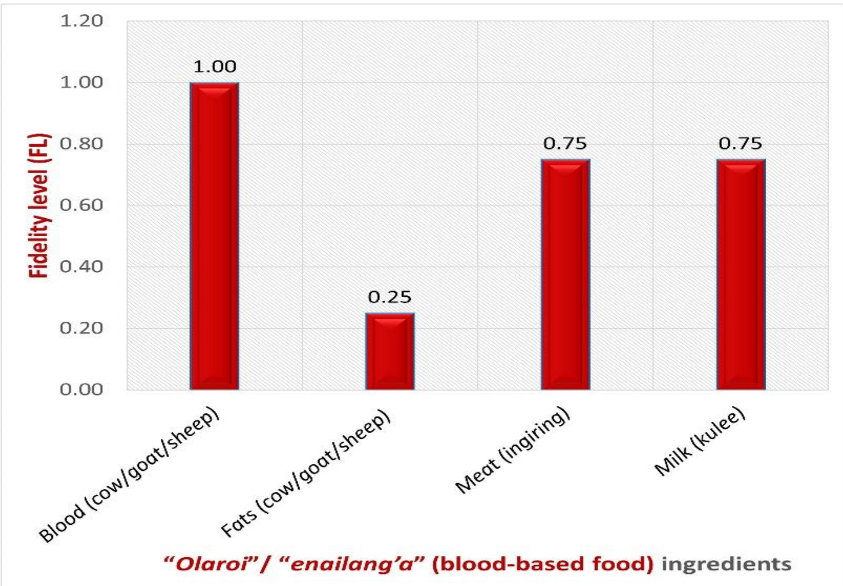


Figure 26: The FL of "*Olaroi*" or "*Enailang'a*" ingredients

(xiii) *"Olchani-imotori"*

This food is prepared using the materials in Fig. 27. The materials had FL ranging from 0.32-1.00. The trimmed meat pieces from either of the meat parts (Fig. 27) are put into water contained in the pot set on fire. The meat is left to boil until fully cooked and forms soup ("*imotori*"). The cooked meat pieces are removed from the pot and placed on holding leaves, "*enaraa*" (Fig. 21) by using holding sticks ("*orjibet*") made from either of the plant's species (Fig. 23). The remaining meat broth or stock in the pot is ready for mixing with hard fats ("*engulaa*/*engurinyi*") and the herbal decoction.

The herbal decoction can be prepared from a combination of the plant's species among the 44 species (Fig. 28) which are commonly used in the preparation of "*olchani-imotori*". Different plants' parts, fresh or dry are chopped into small pieces, and they are mixed in a desired combination depending on the need. The pieces are added to water in the pot set on fire. The plant parts are boiled until no more color change is observed. The plants' parts are removed from the formed decoction. This decoction is mixed with the meat broth or stock into which the hard fats ('*engulaa*/*engurinyi*') may have been added. The decoction is added in portions while thoroughly stirring the mixture using a stirrer ('*orkipire*') made from either of the species (Fig. 15) to form "*olchani-imotori*". This liquid food is ready for consumption usually along with cooked meat or roast meat. "*Olchani-imotori*" have disease prevention and treatment roles as well as nutritional function (Appendix 3 & 4).

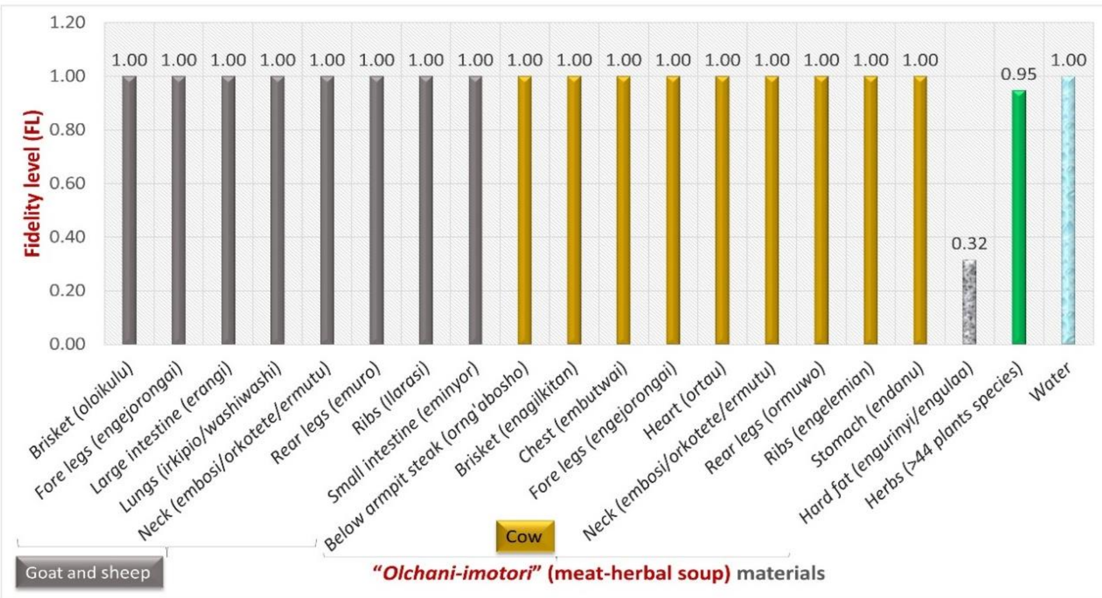


Figure 27: The FL of "*Olchani-imotori*" materials

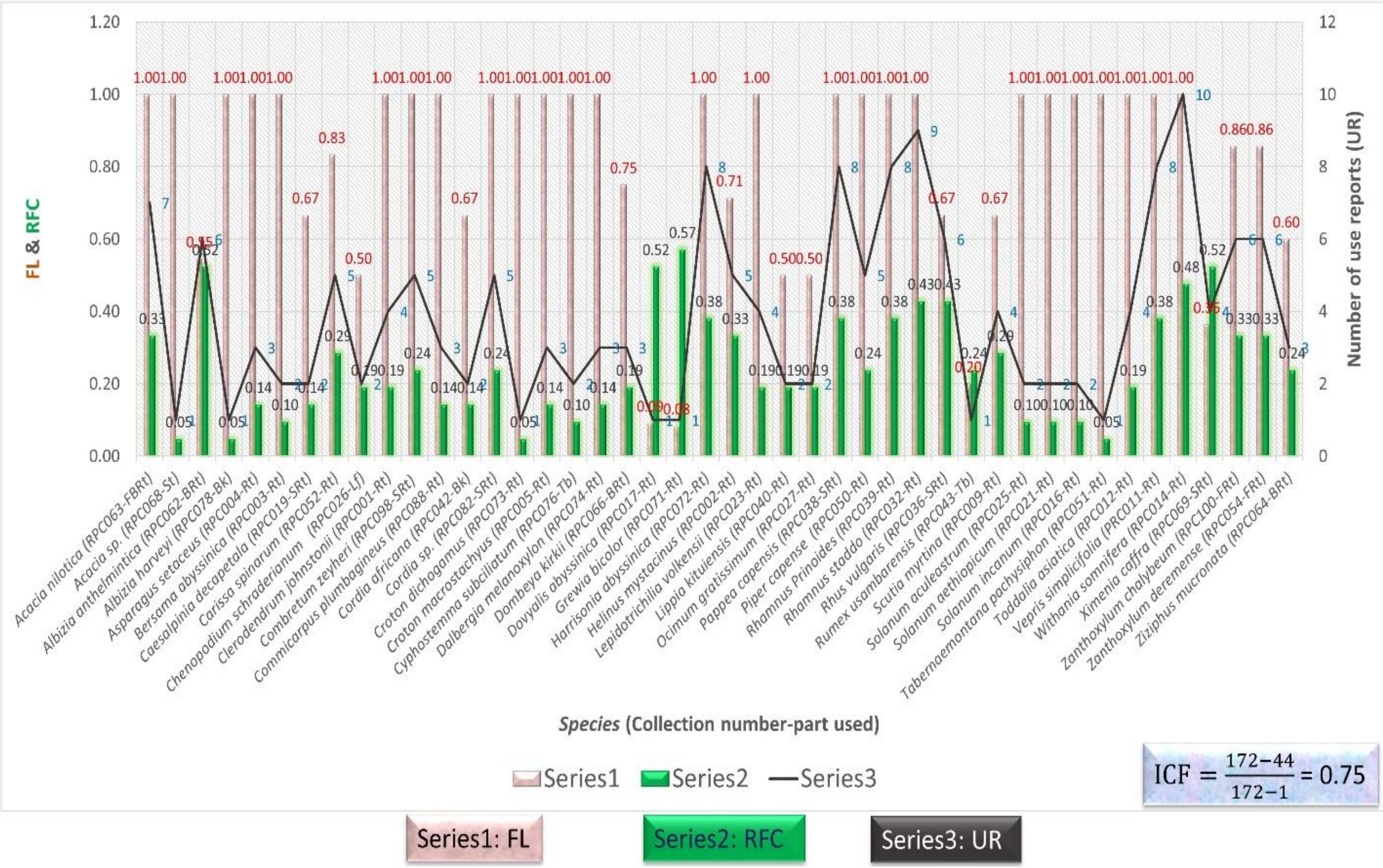


Figure 28: The FL, RFC, and ICF of flora species used to prepare "*olchani-imotori*"

(xiv) *"Olgali" or "Olgali-lombenek"*

The food is prepared using the ingredients in Fig. 29. Whole grain maize flour and water had the highest FL of 1.00 (Fig. 29). Whole grain maize flour is added to boiling water while stirring using the stirrer ("*Olopiron*"/ "Olmwiko") made from either of the species (Fig. 15). The stirring continues until the mixture in the pot become stiff thereby forming "*olgali*". Salt or fats/tallow ('*rongiana*') or the mixture of fats, hot water, and salt can be added to the boiling water and flour mixture during stirring to provide taste and soften "*olgali*". This food is ready for consumption along with beans or vegetables, particularly *Solanum villosum* ("*engilora*"/ "mnavu"): each of them is usually roasted with onion, carrot, tomatoes, fats, and salt.

Fats (ghee/tallow) is added into the pot set on fire. Then clean chopped onion is added into the boiling fats and roasted for a while. Thereafter, chopped tomatoes and carrots are added to the onion while stirring, and they are left to boil in the pot while closed. The resulting mixture is occasionally stirred while boiling to form the semi-cooked mixture. Clean chopped *Solanum villosum* is added to the later mixture while stirring. The resulting mixture is left to boil with occasional stirring until is fully cooked thereby forming "*mbenek*" which is ready for consumption along with "*olgali*". "*Olgali*" prepared and eaten along with the "*mbenek*" is referred to as "*olgali-lombenek*". Beans can be used in place of *Solanum villosum*, and it is cooked like a vegetable that can be eaten along with "*olgali*". "*Olgali*" is also preferred to be consumed along with milk (fresh/yogurt). Consumption of "*olgali*" provides nutrition and energy. It is also believed to increase blood, improve sight, and prevent diseases especially when consumed along with the cooked *Solanum villosum*.

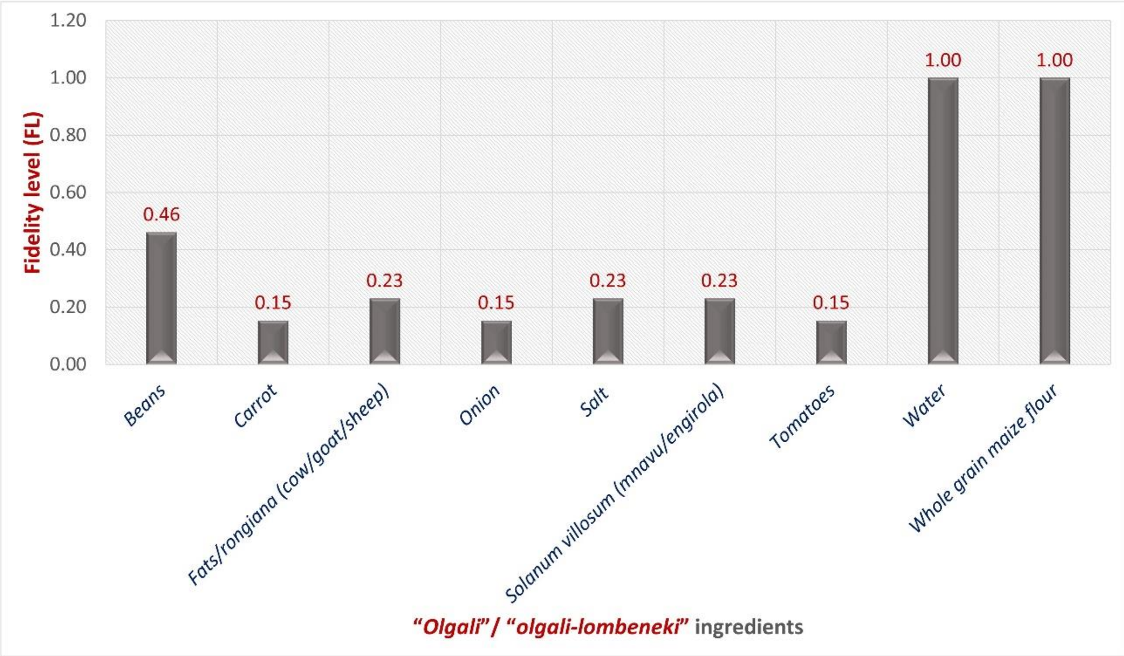


Figure 29: The FL of "*Olgali*" or "*Olgali-lombenek*" ingredients

(xv) *"Olmushele"*

This food is prepared by the ingredients described here. Each of the ingredients had an FL of 1.00 (Appendix 3). Fat (ghee/tallow) is added to the boiling water in the pot set on fire. Then, clean and washed rice is added to the boiling mixture while stirring. Immediately after the addition of rice, salt is added while stirring to have the required taste of the food. The later mixture is left to boil with occasional stirring until its liquid starts to dry. The pot containing the semi-dried mixture while it is covered by a lid, it is taken out of fire or set at low heat. This is followed by the addition of burning charcoal on top of the lid and left for some time until the food is fully cooked thereby forming "*Olmushele*". This food is often ready for consumption along with other foods particularly vegetables, fruits-vegetables, and meat which are independently prepared.

The fat is added into the pot which is set on fire. It is left to boil for a while and then chopped onion is added to the fats to be roasted for a while. Thereafter, pieces of trimmed meat or chopped *Solanum villosum* are added to the roasting onion and mixed thoroughly. This is followed by additional of chopped pieces of Irish potatoes, carrots, and tomatoes while stirring the resulting mixture. Water, followed by salt is added into the later mixture while stirring. This mixture is left to boil while the pot is covered with its lid, and it is occasionally stirred while adjusting the amount of water till the food is fully cooked. The cooked vegetables and meat are ready for consumption along with "*Olmushele*".

Consumption of "*Olmushele*" along with cooked vegetables or meat, provides nutrition and energy. "*Olmushele*" is taken as normal food (not traditional), and it started to be eaten as food since 1988, then it spread in the Maasai community of Monduli," said one of the respondents. This food is preferred for consumption during a ceremony.

(xvi) ***"Oloshoro" or "irpaek-lekule"***

This food is prepared by the ingredients in Fig. 30. Ground maize grains, milk, and water had the highest FL of 1.00 each. They were followed by *Olea europaea* subsp. *africana* with an FL of 0.81. Ground maize grains were obtained by grinding the wetted dry whole maize grains using a mortar and pestle which were made from either of the plant species (Fig. 20). Grinding of the maize grains was rarely made by electrical machines in the peri-urban Maasai community.

The clean ground maize grains are added into water contained in the pot set on fire. Then, peeled and chopped pieces of banana ('ndizi ng'ombe') can be added into the pot and left to boil together with the maize grain until they are fully cooked. Alternatively, the ground maize grains in the pot are left to boil to fully cooked, and then after cooling it is mixed with the porridge "*euji*" which is prepared with the components (Fig. 19) as described earlier. But salt, fats, and yogurt are not included in the porridge for longer use and storage of "*Oloshoro*". The cooked ground maize grains can stay overnight before mixing with the porridge. Thereafter, fresh milk is added to either of the mixture, cooked ground maize grains and banana or cooked ground maize grains and the porridge. The later mixture is stirred thoroughly by the stirrer made from either of the species (Fig. 15) to form "*Oloshoro*". "*Oloshoro*" can also be formed by the mixture of cooked ground maize grains and fresh milk only thereby it is referred to as "*Irpaek-lekule*". Before its consumption, this liquid food is poured through the funnel into the calabash (Fig. 16) which is decontaminated by smoke and ashes from either of the species whose names, collection numbers, and parts used are shown in Fig. 30. The brush made from either of the species (Fig. 17) are used in decontamination and cleaning of the calabash which is to store the food. The used species provide preservation, taste, and aroma to the food. "*Oloshoro*" can be renewed by adding fresh milk for continuing consumption for up to three weeks.

Consumption of "*Oloshoro*" increases or restores appetite, and energy, softens feces, quenches thirst, increases body fluid and induces diuresis (cleansing kidney). "*Oloshoro*" culturally must be available at all times in the house of a man for consumption as a meal starter before his wives prepare a lunch. This food is preferred for consumption during the day instead of night due to its diuresis effect. "*Oloshoro*" as '*Irpaek-lekule*' can be consumed even in a ceremony.

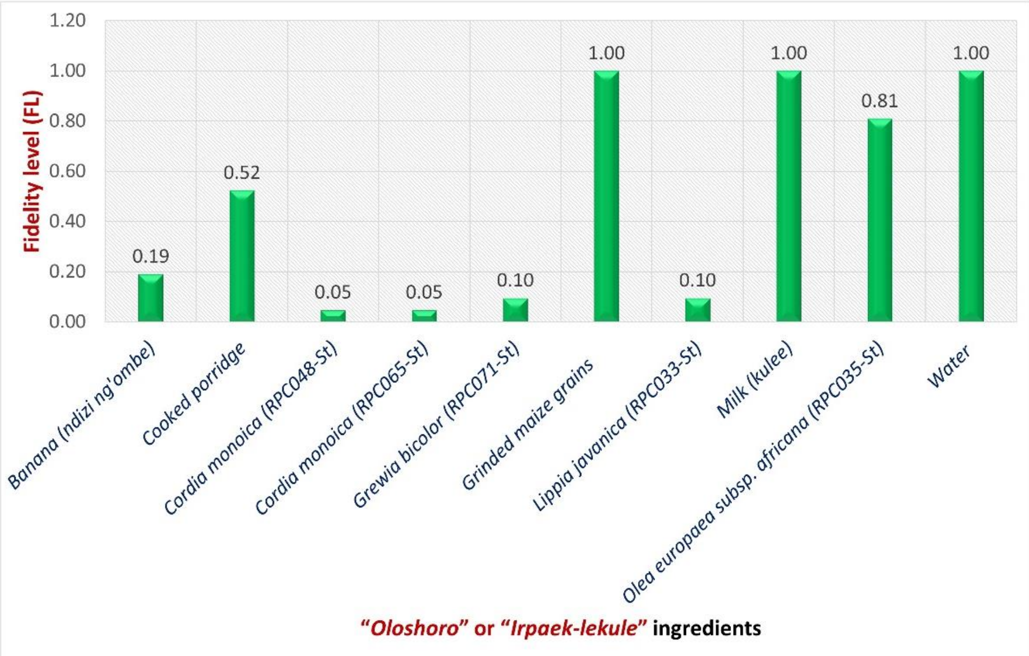


Figure 30: The FL of "*Oloshoro*" or "*Irpaek-lekule*" ingredients

(xvii) *"Orikitao"*

This food is prepared by the ingredients in Fig. 31. Beans, ground maize grains, and water had the highest FL of 1.00 each. Again, ground maize grains were obtained by grinding the dried whole maize grains using the tools (Fig. 20) described earlier.

The ground maize grains are added to water contained in the pot set on fire. Then, fresh or dry seeds of beans or *Lablab purpureus* are mixed with the maize grains in the pot, and they are left to boil together until fully cooked. Soda, "magadi" may be added to the mixture during cooking to soften beans and reduce stomach gas that would occur when this food without soda is consumed. Salt may also be added to the mixture during cooking for the taste of the food. Once the mixture of the maize grains and beans or *Lablab purpureus* is fully cooked, its fluid can be left or filtered out and then stirred thoroughly to respectively forms viscous or stiff "*Orikitao*" which is ready for consumption.

Alternatively, to the boiling mixture of grinded maize grains and beans or *Lablab purpureus*, pieces of trimmed meat, carrots, potatoes, onion, tomatoes are added. The fat/oil (Fig. 31) followed by the salt are added to the later mixture while stirring, and they are left to boil with occasional stirring to form another version of fully cooked viscous or stiff "*Orikitao*". Also, independently prepared roast which is made from meat, carrot, potatoes, onion, tomatoes, fats/oil and salt can be mixed with the cooked mixture of ground maize grains and beans or *Lablab purpureus* to form another type of "*Orikitao*" which may be viscous or stiff.

Consumption of "*Orikitao*" provides nutrition and energy. This food is often consumed along with other foods, particularly tea. It is preferred for consumption during farming as it is believed to provide enough energy and longer satiation.

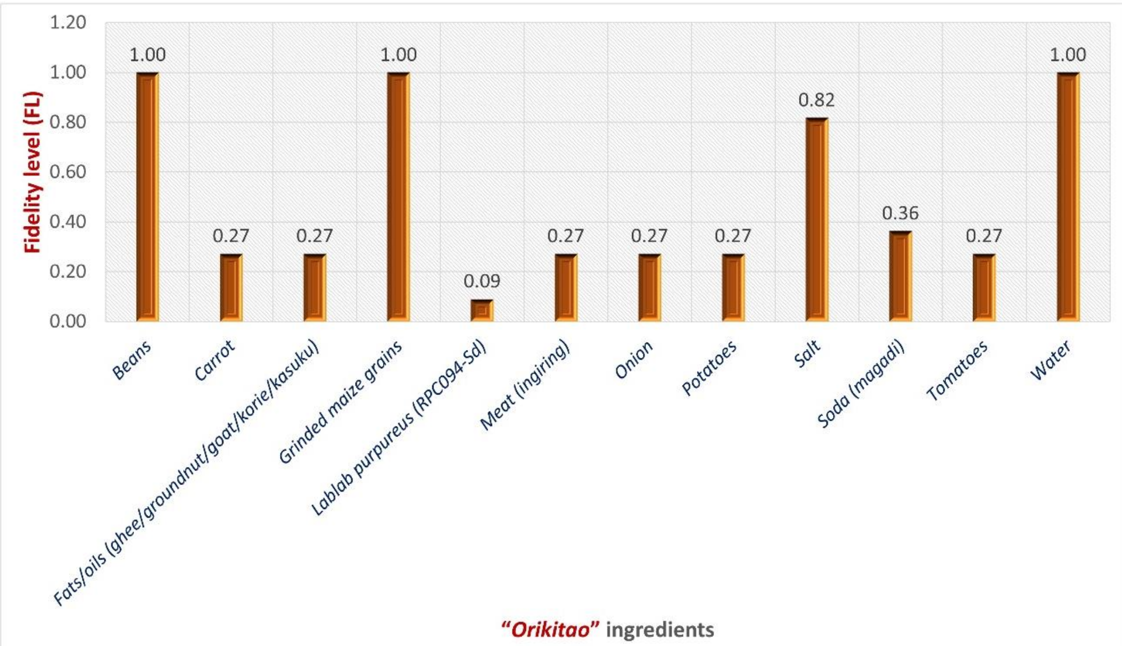


Figure 31: The FL of "*Orikitao*" ingredients

(xviii) *"Shai-ekulee"*

This food is prepared using the ingredients in Fig. 32. Milk had the highest FL of 1.00. Milk, some amount of water, tea leaves, and spices like ginger or cardamom are added into the pot set on fire. The mixture is left to boil for about 15 minutes, then sugar may be added into the boiling mixture to form "*Shai-ekulee*". Powder of the plant's species whose names, collection numbers and parts used are shown in Fig. 32, were additives used as the substitute for tea leaves or spices to prepare the tea. The powder of the plants' species is obtained by grinding the chopped dried plants' parts using the tools (Fig. 20). Exceptional to *Sphaeranthus bullatus*, the fresh parts thereof are used instead of its powder to prepare "*Shai-ekulee*" without sugar. The food additives provided aroma, taste and appetite for "*Shai-ekulee*". Furthermore, the additives had medicinal roles against disorders of gastrointestinal, gynecological, musculoskeletal and respiratory systems (Appendix 4). "*Shai-ekulee*" was preferred for nutrition and sometimes for its medicinal roles.

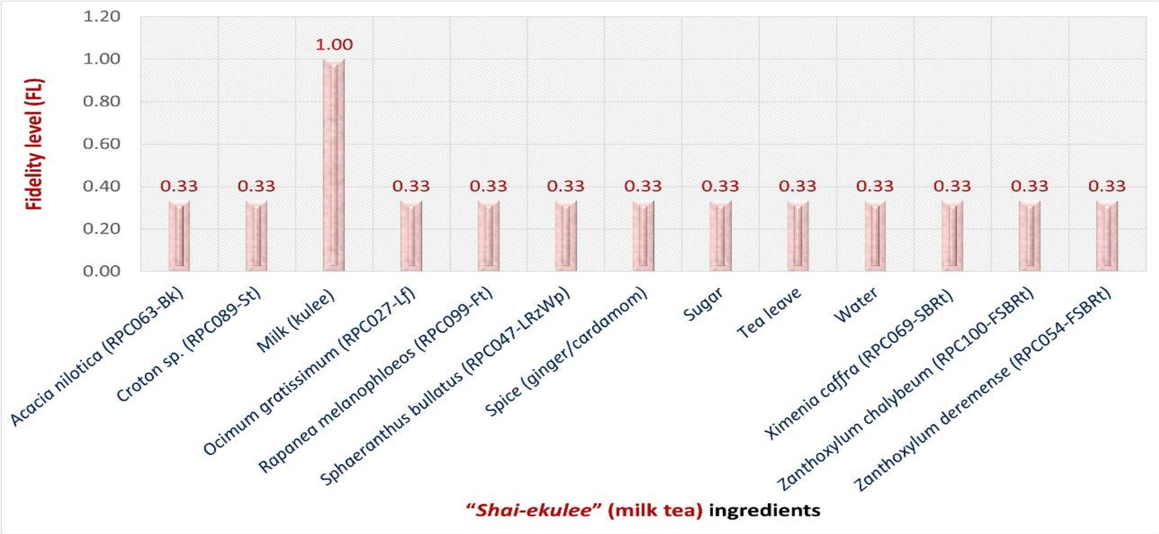


Figure 32: The FL of "*Shai-ekulee*" ingredients

4.1.3 Roles of Ingredients and Species Used by MTPs in the Maasai TFS

The TFS used by Maasai in the study area had a rich diversity of 19 foods (dishes) prepared from various ingredients, and it had 78 flora species distributed in 63 genera and 39 families that were used as direct food sources, food ingredients, and foods' processing materials. About 88.89% of the flora were sourced from the wild habitat (Fig. 12a). The variety of dishes and diversity of species which were mostly found in the natural environment make part of the typical qualities of a TFS (Kuhnlein, 2015; Lambden *et al.*, 2007). The qualities provide an understanding of the vast diversity of food available and how many different dietary patterns can provide complete human nutrition and other associated benefits (Kuhnlein, 2015). Some dishes and most flora integrated in the TFS had medicinal roles in addition to nutrition and social-cultural roles (Appendix 3 & 4).

The most frequently consumed foods in the study area were "*Oloshoro*" or "*irpaek lekule*", followed by "*ingiring-naapejo*", "*olchani-imotori*", and "*irmakuku*" or "*ngararumu-ombenek*": they had the highest RFC (>90%) (Fig. 11). Moreover, the most frequently used ingredients in preparing the top most frequently consumed foods were fats, milk, maize, salt, beans, meat and *Olea europaea* subsp. *africana*: Each was found in 4-7 of the 10 top most consumed foods, which had the highest RFC (Fig. 11). Cow, goat, and sheep kept by the Maasai in the study area were the source of fat, milk and meat. The common use of animal products in the Maasai TFS is strongly supported by Quinlan *et al.* (2016) who also reported that the Maasai dietary structure is based on milk and meat from the kept livestock. Moreover, the common use of cereals like maize and pulse like beans is not only integrated in the Maasai TFS, but it is also common in other TFSs of indigenous people (Mamiro *et al.*, 2011).

The animal-based food items, such as meat and milk, have high levels of proteins, fats, minerals and B vitamins (Li *et al.*, 2021). But a high level of fats has been associated with oxidative stress, which results in MD (Li *et al.*, 2021). Conversely, the consumption of whole-grain cereals and bean-based foods has been associated with a low risk of acquiring non-communicable diseases (Arjmandi & Mullins, 2021; Muñoz-Cano *et al.*, 2013). Maize, particularly whole grains, has been found to decrease the risk of developing MDs (Muñoz-Cano *et al.*, 2013). The capacity of maize to decrease the risks could be supported by the antioxidant activities of phenolic compounds, which are present in whole grains (Adom & Liu, 2002). Antioxidants present in whole maize grains can support the claim that "*Euji*" (Fig. 19) was preferred for cleaning and relaxing blood vessels: Antioxidants can prevent arteriosclerosis (Bandeali & Farmer, 2012; Sardesai, 1995).

Moreover, the consumption of whole maize grains is linked to the prevention of colon, digestive, breast and prostate cancers (Adom & Liu, 2002). Furthermore, beans are also known to have phenolic compounds, which exhibit a range of bioactive functions such as cardiovascular, cancer and metabolic protection (Arjmandi & Mullins, 2021). The bioactivities against cardiovascular diseases and tumors, like colon cancer, lower the risk of acquiring other diseases, such as gout. So, the frequent use of beans and cereals, particularly whole maize grains, in the Maasai TFS may justify the low prevalence of the MDs in such communities.

Amongst the ingredients used to prepare the Maasai foods (Fig. 11), some were used as non-plant while others were used as plant food additives. Salt, soda ("magadi") and fat (ghee and tallow) were the common non-plant additives. These additives had various roles at varying proportions of the foods (Fig. 33). Most foods required non-plant additives for taste, followed by softening of grains: Maize and beans (Fig. 33 & Appendix 3).

Soda, "magadi" was used to soften whole maize grains and beans as well as prevent stomach bloating that would occur when the food containing the grains without soda is consumed. This additive is reported elsewhere to be used in preparing hard-to-cook legumes and it can reduce the anti-nutritive effect of tannins and increase the digestibility of organic matter and starch in grains (Monyo *et al.*, 1992; Muindi *et al.*, 1981). Moreover, its capacity to reduce stomach bloating could be due to its neutralizing effect toward acid which may be associated by the consumed food (Mamiro *et al.*, 2011; Monyo *et al.*, 1992). Soda, "magadi" can lower the uptake of minerals like iron and zinc, though (Mamiro *et al.*, 2011).

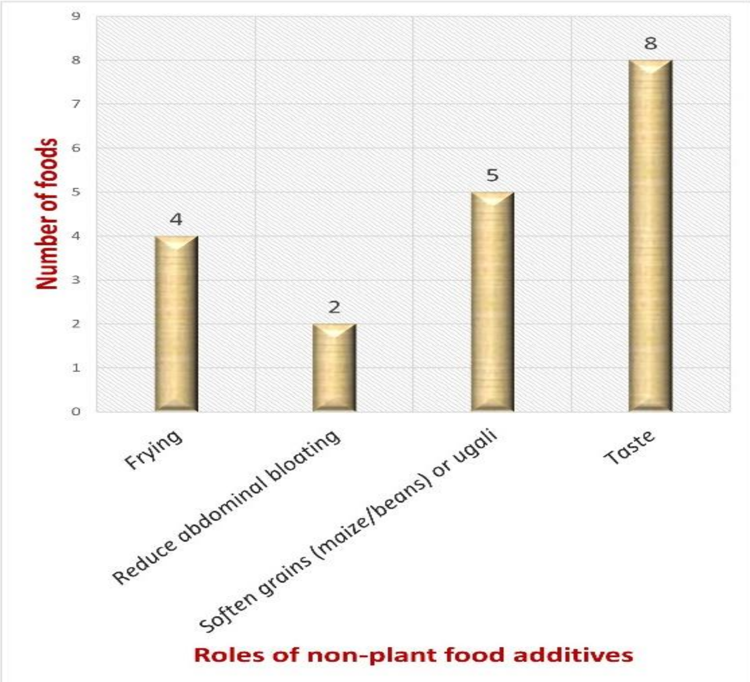


Figure 33: **Proportions of foods against roles of non-plant food additives**

On the other hand, a diverse of flora species was used as food additives. The plant food additives had various roles at varying proportions of the foods (Fig. 34). High proportions of the Maasai foods required additives from the flora for aroma, taste, and preservation (Fig. 34). *Olea europaea* subsp. *africana* was the most common plant food additive: It was common in "*emberere*", "*engideri*", "*engitalolo*", "*euji*", "*kulee*", and "*Oloshoro*" at FL ranging from 0.60-1.00. This additive was used for the aroma, taste and preservation of the foods.

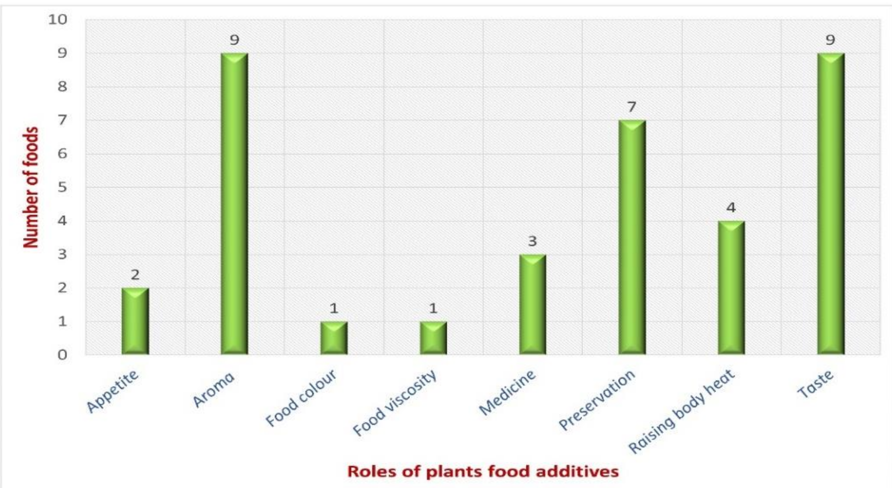


Figure 34: **Proportions of foods against roles of plant additives**

Also, the additives which were included in the food (Fig. 30) during the decontamination process had the same roles as *Olea europaea* subsp. *africana*. The aroma, taste and preservation roles of the species could be attributed by phenolic compounds which are present in the species like *Olea europaea* subsp. *africana* (Hashmi *et al.*, 2015; Simelane & Msomi, 2017). Indeed, phenolic compounds are associated with smoked aroma characteristics and they have antioxidant properties, which have potential for food preservation (Hashmi *et al.*, 2015; Wang *et al.*, 2018).

Although a diverse of flora species were available as food additives in preparing the Maasai foods, most of the species except *Olea europaea* subsp. *africana* were integrated into relatively few foods like "*olchani-imotori*" (Fig. 28) "*Oloshoro*", (Fig. 30), and "*Shai-ekulee*" (Fig. 32). These species had various roles in addition to the aroma and taste of the foods (Appendix 4). For instance, some species used in preparing "*olchani-imotori*" provided color, viscosity, and appetite for the food while some raised body temperature and others used as medicine through the consumption of the food (Appendix 4).

The most common plant additives used in preparing "*olchani-imotori*" were *Withania somnifera*, followed by *Rhamnus staddo*, *Harrisonia abyssinica*, *Pappea capensis*, *Rhamnus prinoides*, *Vepris simplicifolia* and *Acacia nilotica* (Fig. 28). These species were believed to have preventive and therapeutic roles against various ailments (Appendix 4). For instance, all the most commonly used additives except *Vepris simplicifolia* were among the species used against joint pain, while *Withania somnifera*, *Rhamnus staddo* and *Harrisonia abyssinica* were among the species used against both pain and inflammation of joints (Appendix 4). Moreover, *Withania somnifera*, *Rhamnus staddo*, *Rhamnus prinoides* and *Vepris simplicifolia* were among the species used to cleanse kidneys through their diuretic effect (Appendix 4). *Acacia nilotica* was used to facilitate food digestion, while *Ocimum gratissimum* was used against constipation and stomach bloating (Appendix 4).

Pain and inflammation of joints are among the symptoms of gout (So & Martinon, 2017). Moreover, constipation, indigestion and stomach bloating are the symptoms of hyperchlorhydria, which is a marked condition in gout patients (Stockton, 1897). Hyperchlorhydria has various underlying causes: Gastrinoma (Zollinger-Ellison syndrome), *Helicobacter pylori* infection, colorectal carcinoma and diminished renal or hepatic function (Alter, 2020; Shulkes & Baldwin, 2013). So, the plant additives integrated into "*olchani-imotori*" have potential roles in preventing and treating conditions associated with oxidative stress and inflammation including gout, cancer and kidney disorders (Alter, 2020; Shulkes & Baldwin, 2013; Stockton, 1897) in the Maasai communities. Some of the plant food additives integrated into "*olchani-imotori*" were also used in preparing "*Shai-ekulee*", and they had the same medicinal roles (Appendix 4 & Fig. 32). The uses of the species against the conditions are also supported by the findings of other studies (Ali *et al.*, 2012; Chen *et al.*, 2020; Dar *et al.*, 2015; Madivoli *et al.*, 2018; Shirwaikar *et al.*, 2009).

Withania somnifera, *Rhamnus prinoides*, and *Harrisonia abyssinica* have antioxidant and anti-inflammatory activities (Chen *et al.*, 2020; Dar *et al.*, 2015; Madivoli *et al.*, 2018). Moreover, *Acacia nilotica* and *Ocimum gratissimum* are reported to have antioxidant, antidiabetic, anticancer, antihypertensive and hepatoprotective effects (Ali *et al.*, 2012; Shirwaikar *et al.*, 2009). Integration of species with such bioactivities in a TFS contributes to the low incidence of such inflammatory conditions in the communities that consume the species (Kimondo, 2020).

Apart from flora species being used as food additives in preparing the Maasai foods, some flora species were used as direct food sources (Fig. 14). The most commonly used flora was *Vangueria infausta*, followed by *Ximenia caffra* and *Dovyalis abyssinica* (Fig. 14). The fruits of these species were the food source. *Vangueria infausta* is a well-known nutraceutical plant with plant parts valued in several cultures in East and South Africa for its medicinal roles (Maroyi, 2018). The fruit of this species is a source of carbohydrates, Fe, vitamin C and many other nutrients required for human nutrition and health (Maroyi, 2018). Although in this study, *Vangueria infausta* fruit was used as the food source, the fruit is reported elsewhere to have ethnomedicinal uses against menstrual problems and parasitic worms (Amri & Kisangau, 2012; Maroyi, 2018).

Likewise, in addition to being a food source plant, Ximenia caffra is used to treat mental illnesses, such as hallucinations, while *Dovyalis abyssinica* has antidiabetic properties (Kamau, 2018; Samuelsson *et al.*, 1983). Although fruits accounted for a high proportion (82.8%) of the flora species used as direct food sources, other flora parts were used as food sources. For instance, leaves of *Croton machrostachyus* and *Embelia schimperi* were cooked as vegetables and chewed for nutrition, respectively. In addition, the inner part of *Ficus thonningii* roots, bark and tuber of *Vigna parkeri* were mainly chewed as a source of water. So, the flora species, particularly the most commonly used ones, have a great role in the nutrition and health of the Maasai community.

4.1.4 Roles of Food Processing Technologies Used by the MTPs

This study documented various materials and technologies used in processing the foods (Fig. 11). Most of the materials were plants (31 species), and they were used in various technologies to prepare the foods (Fig. 15-17, Fig. 20, 21, & 23). But non-plant materials such as pots (Fig. 15) were also involved in the processing of the foods. These materials had various roles (Fig. 35) in processing the foods. Varying proportions of the foods required these materials to attain the roles (Fig. 35). High proportions of foods (16 foods) required the materials (Fig. 15) for boiling/cooking and stirring. This was followed by 14 foods that required the materials (Figs. 15 & 16) for storage.

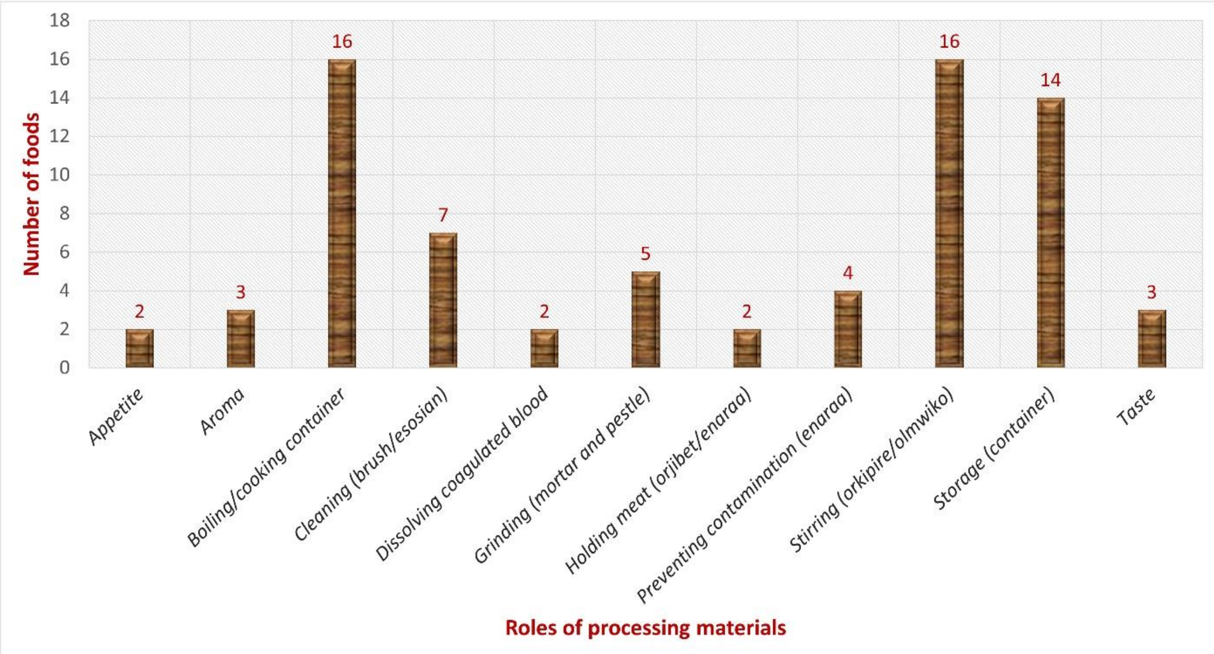


Figure 35: Proportions of foods against the roles of processing materials

Some of the processing materials had additional roles that improved the quality of the foods. For instances, flora used in dissolving coagulated blood and holding meat (Fig. 21 & 23) improved aroma and taste as well as the appetite for the prepared foods (Appendix 4). The most commonly used flora of which its leaves were used to hold meat and dissolve the coagulated blood was *Lippia javanica* followed by *Grewia bicolor* (Fig. 21). Likewise, the most common flora whose stems were used to hold the meat was *Grewia bicolor* followed by *Clausena anisata* (Fig. 23). *Lippia javanica* is traditionally used as a food additive and improves the sensory properties of foods in addition to its various pharmacological activities (Chawafambira, 2021; Maroyi, 2017). This could support its application in the current study to improve the aroma, taste and appetite for the meat and blood which are processed using its leaves. The wood of *Grewia bicolor* has anti-helminthic properties while the bark treats inflammation of the intestines (Nyakudya *et al.*, 2015). So, the use of its stem in holding the meat could have medicinal value against digestive problems apart from the aroma, taste and appetite it provides for the food. *Clausena anisata* is traditionally used to manage various diseases (Songue *et al.*, 2012). Its stem is reported to contain alkaloids and peptide derivatives which have anticancer and anti-inflammatory activities (Songue *et al.*, 2012). So, *Clausena anisata* stem, apart from its roles in aroma, taste and appetite for the food, has a potential medicinal benefit against the MDs which may be associated with the consumption of the meat.

Moreover, in some food processing materials, the same plant parts were used as food additives, and they had medicinal roles. For instance, *Albizia anthelmintica* roots were used as an additive in preparing *olchani imotori* (Fig. 28) and as a brush (Fig. 17) for cleaning calabash (Fig. 16). Also, the *Combretum zeyheri* stem was used as a food additive (Fig. 28) and as a stick for holding roast meat (Fig. 23). These species had medicinal roles (Appendix 4). Consistent with this study it was reported that *Albizia anthelmintica* is traditionally used against stomach worms while *Combretum zeyheri* is used against pain and inflammation of joints (Nankaya *et al.*, 2019; Ngowi, 2015). So, the medicinal roles of the same plant parts used in processing the foods may potentially be induced in the processed food against the same conditions.

Equally, some FPT were claimed to prevents some diseases or protecting human from being preyed by animals like lion. The roasting of meat (Fig. 23 a & c) did not involve the addition of salt, which contain sodium. This was claimed to prevent gout and increased heartbeats. This may hold the truth because blood pressure is directly related to sodium intake (MacGregor & He, 2001). Also, sodium is involved in the formations of monosodium urate crystals which result into gouty arthritis (Werber, 2013).

Also, consumption of the roast meat with no salt was claimed to make human flesh less salty. This is claimed to prevent humans from being preyed on by lions which are appealed to the salty human flesh of any who consume roast meat with added salt. The link of salty taste of human flesh and preying human by lions because of eating the salty meat is not clear. But lions can indeed develop a taste for humans, and the behavior of preying humans can be passed through generations of lions (Kerbis-Peterhans & Gnoske, 2001). Although, reasons for preying on lions depend on the conditions of lions and ecological changes (Yeakela *et al.*, 2009).

Likewise, the meat roasting technology was claimed to prevent thirst and thinness to consumers that would occur if the meat roasted with salt is consumed. This may hold the truth because increased sodium intake is an intrinsic part of thirst response especially during and after exercise (Stachenfeld, 2008). Also, the excretion of salt requires urea which demands more energy for its synthesis (Dürfeld, 2017); thus, consuming roast meat with more salt may lead to thinness.

4.1.5 Roles of the Maasai Foods and Criteria Developed by MTPs for Food Selection

Ingredients and processing materials used to prepare the Maasai foods had various nutritional and medicinal benefits. But some of these benefits were also reflected in the roles of foods as perceived by the MTPs in this study (Fig. 36). Varying proportions of the foods were perceived to have different roles (Fig. 36).

All foods were used for nutrition and energy purposes. But some foods had very specific roles (Fig. 34) depending on the ingredients used. For instance, foods prepared from African nightshade "mnavu" (*Solanum villosum*) and animal blood were perceived to increase blood. Mshanga *et al.* (2020) reported the use of African nightshade and meat-based foods by Maasai pregnant women for the same roles. Moreover, foods containing *Solanum villosum* were perceived to improve sight, prevent sickness and increase milk for lactating mothers. The benefits of *Solanum villosum* could be linked to its richness in protein, vitamin A, iron, Ca and phytochemicals and its capacity to boost the body's immunity (Mwai *et al.*, 2007; Zahara *et al.*, 2019).

Moreover, some foods especially those containing ingredients with healing properties were used as medicine apart from providing nutrients and energy (Appendix 3 & 4). "*Kulee*", "*Shai-ekulee*" and "*Olchani-imotori*" were used to prevent and treat diseases that were linked by the medicinal property of their ingredients (Appendix 4).

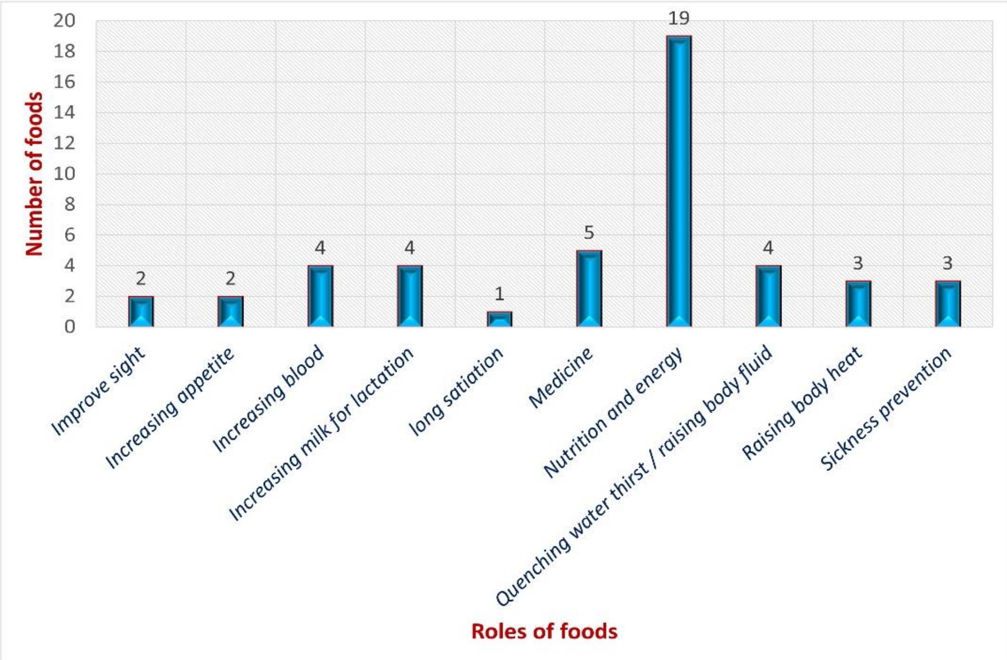


Figure 36: Proportions of foods against their roles

Furthermore, in consideration to the perceived roles of the foods, some criteria for food selection were set by the MTPs. These criteria were based on gender, age, health status, cultural beliefs and nutritional values attached to the foods. The criteria guided preferences (Fig. 37) and restrictions (Fig. 38) in using the Maasai foods.

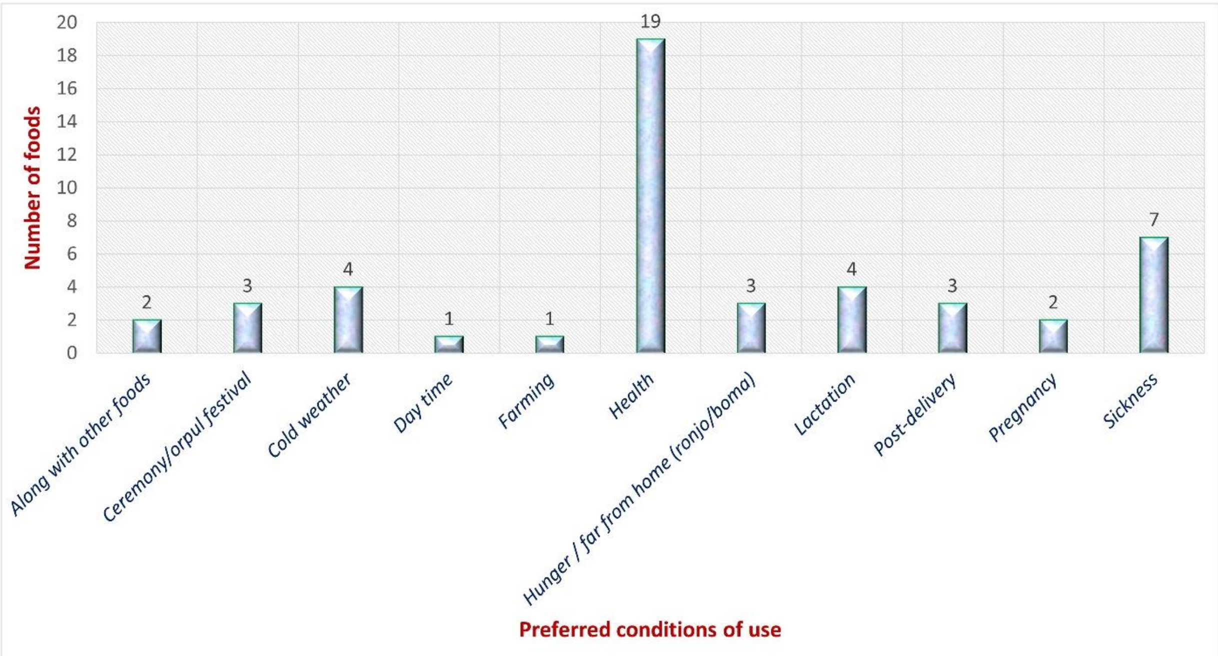


Figure 37: Proportions of foods against the preferred conditions of use

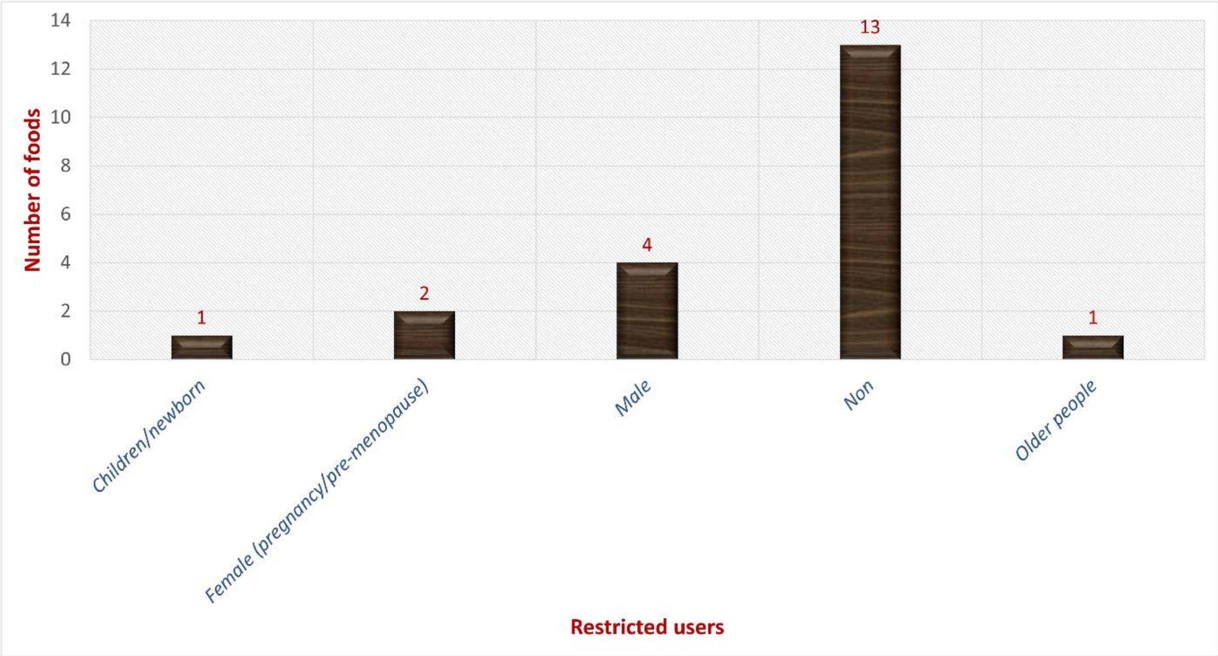


Figure 38: Proportions of food against restricted users

All foods were preferred for promoting health. But certain foods were mostly preferred to be used under particular conditions (Fig. 37). For instance, foods which were prepared from *Solanum villosum*, blood and meat were perceived to increase blood; thus pregnant, post-delivery women and anemic individuals preferred such foods. Moreover, foods which were believed to raise body temperature were preferred in cold weather. Foods which had plenty of fluid or believed to raise body fluid were preferred for consumption during the day time and thirst. Also, foods with medicinal properties were preferred for disease treatment and prevention. Moreover, food like "*irmakuku*" which gives long satiation was preferred during farming activities. It was also eaten along with other foods.

Conversely, some foods had restrictions for particular users while other foods had no restrictions (Fig. 37). Food like "*irmakuku*" which was hard to digest was restricted from being used by children and older people to avoid digestion complications associated with the hard texture. Moreover, foods that comprise species like *Albizia anthelmintica* and *Embelia schimperi* were restricted from being used by pregnant women because the species were believed to induce abortion. *Embelia schimperi* was also supposed to induce excess menstrual flow; thus, pre-menopause women were restricted. The antifertility effects of these species are reported elsewhere (He *et al.*, 2020; Pawlos *et al.*, 2022).

Likewise, foods that were prepared from vegetables such as *Solanum villosum*, were culturally restricted from being consumed by men especially those who were circumcised. This restriction signified the status of being men and wealthier with livestock. Moreover, men were also culturally restricted from consuming foods prepared from large intestine meat of the animals because the meat is believed to weaken scalp hair or cause sculptor to men. Micronutrients like zinc, iron and vitamins (B, C, and D) ensure a normal hair follicle cycle (Almohanna *et al.*, 2019). But their deficiency can result in alopecia (Almohanna *et al.*, 2019). The micronutrient concentrations in meat vary between types of animals and meat parts thereof (Seong *et al.*, 2014; Wood, 2017). For instance, a pork's liver, heart and pancreas are richer in the required nutrients than other parts including the large intestine (Seong *et al.*, 2014). Also, the beef liver is rich in zinc and iron than other parts of beef meat and the liver of chicken (Wood, 2017). The variation of the nutrients especially between meat parts of an animal may explain why Maasai men avoid consumption of the large intestine which may have low concentration of the required nutrients to prevent alopecia.

So, the restrictions and preferences set on the foods may have cultural and health benefits. But the restrictions may sometimes deprive restricted users from nutrients and health benefits associated with restricted foods, particularly those with no negative effects on their health. For instance, eating foods based on leafy vegetables such as *Solanum villosum* were culturally restricted from being used by men. But in the present day, some Maasai men benefit from the nutrition and health benefits of such foods.

Furthermore, animal-based foods had some restrictions and preferences which were based on cultural meaning attached to the foods. Different animals and their meat parts as described earlier were culturally preferred and restricted among members of the society to recognize and honor them as per positions they held in their community. The positions identified and honored by the animal-based food were man, woman, woman bearing children, elder, '*moran*', uncircumcised boy, co-wife and neighbor. Moreover, these foods were preferred for consumption in ceremonies, "*orpul*" festivals, or special occasions. So, these animal-based foods are important in reinforcing the very structure of Maasai society and their social cohesion (Fontefrancesco & Lekanayia, 2018).

Indeed, the CPR set for food selection ensures individual nutritional and health needs are met as well as the socio-cultural needs are fulfilled. The CPR may ensure variations of nutritional content received by consumers of foods under consideration. This may favor their individual nutritional and health needs. But CPR may deprive consumers from certain nutrients especially when nutritional needs are not considered. However, foods without CPR considerations provided equal opportunities to all MTPs for nutritional and health benefits.

Certainly, the Maasai TFS qualities constitute a diversity of dishes and flora species, food processing and technologies (FPT), and cultural preferences and restrictions (CPR) for food selection linked to enormous health benefits against ailments including MDs like gout. However, the kind, roles, relative importance and conservation status of the flora used in Maasai TFS and TM to manage gout, GACs and the disease risk factors must be well-established.

4.2 Flora Used in the Maasai Food System and Traditional Medicine Against Diseases, Including Gout and Associated Conditions

An ethnobotanical survey revealed that the study area had 101 flora species distributed in 84 genera and 42 families. About 79% of the species were used as medicine; some were for food or processing thereof. The medicinal plants (MPs) managed 69 health conditions, including gout, "*Olgila*" and gout-associated conditions (GACs). The MPs had potential nutritional and antioxidant agents against diseases, including MDs, like gout. The root parts of the flora species (54%) were exploited the most, while most flora (94%) were non-cultivated, sourced from wild habitats (Fig. 39).

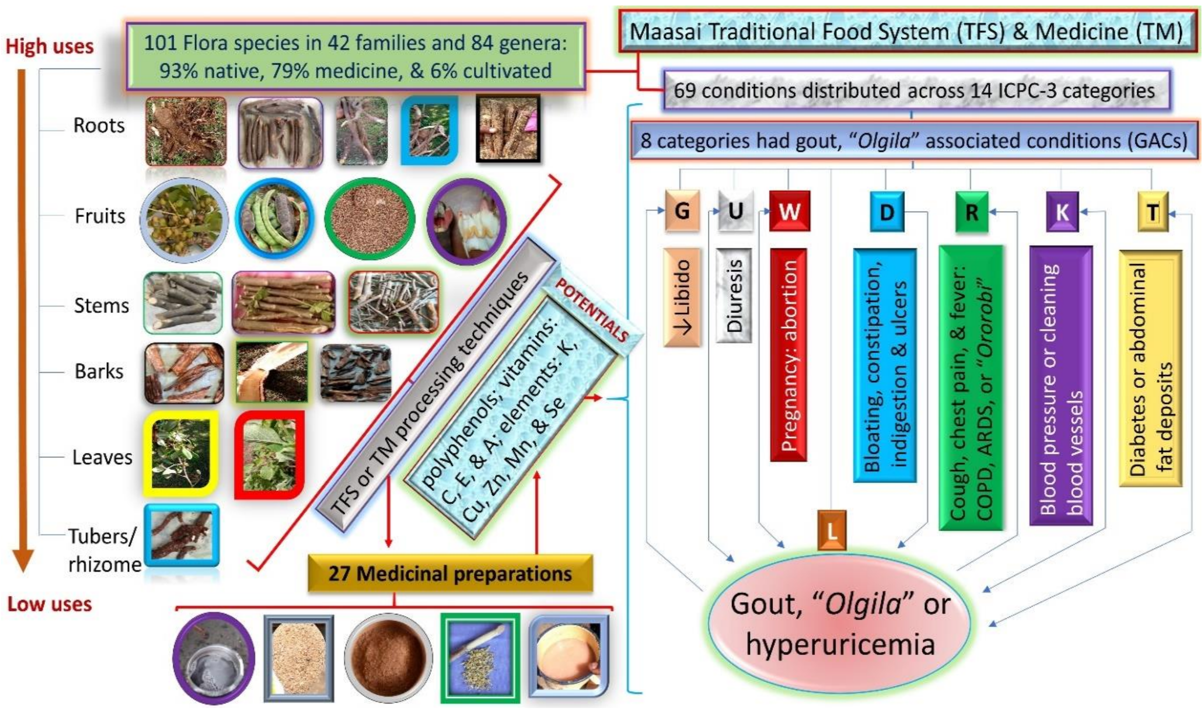


Figure 39: **Graphical summary of objective two results**

4.2.1 Flora Used in Maasai TFS and TM

This study recorded 101 flora species distributed in 42 families and 84 genera (Appendix 4). The most represented families were Fabaceae, followed by Euphorbiaceae, Rutaceae and Solanaceae: They had the highest number of species (Appendix 4). The flora species grow in various habitats at varying percentages of species: Forest (52%), savanna (33%), bushland/shrubland (10%), grassland (7%), and wetland (2%) (Appendix 4). Likewise, the flora had various habits with varying percentages of species: Tree, T (47%); shrub, Sb (25%); herbs, H (22%); and climber, Cl (9%) (Appendix 4). Moreover, the flora consisted of native (93%) and alien species (7%): Introduced and naturalized in the study area (Appendix 4). Six percent of the flora species were cultivated in farms, home gardens or synanthropic, growing around MTPs' home environment (Appendix 4). Moreover, 58% of flora species were present in the International Union of Conservation of Nature (IUCN) red list, and the Least Concern (LC) category thereof had the highest number of species (57) (Appendix 4). The species in the LC category have healthy and stable populations as well as do not currently face a high risk of extinction. On the other hand, the near-threatened (NT) and vulnerable (VU) categories had one species each (Appendix 4).

Besides, the flora of the study area had various uses with varying species' percentages and use reports (UR) respectively: Medicine, 79% (276); food processing/storage materials, 32% (169); food, 29% (135); and other uses, 8% (17) (Appendix 4). Among the flora species investigated in this study, *Withania somnifera* (L.) Dunal had the highest use value (**UV**) of 2.67 (Appendix 4). Furthermore, the flora uses were achieved by various floral parts in powder or small pieces at varying species' percentages and use reports (UR) respectively: Roots (Rt), 54% (213); fruits (Ft)/ seeds (Sd), 35% (171); stem (St), 31% (112); bark (Bk), 25% (59); leaves (Lf), 23% (71); rhizome (Rz)/ tuber (Tb), 5% (10); and whole aerial parts (Wp), 5% (6) (Appendix 4). The floral parts were prepared or applied in various ways such as mixing floral part(s) with or without food substances, minerals, and or fluid (Fig. 40). A decoction in meat broth or stock ("*olchani-imotori*") had the highest percentage of species prepared in that form (Fig. 40).

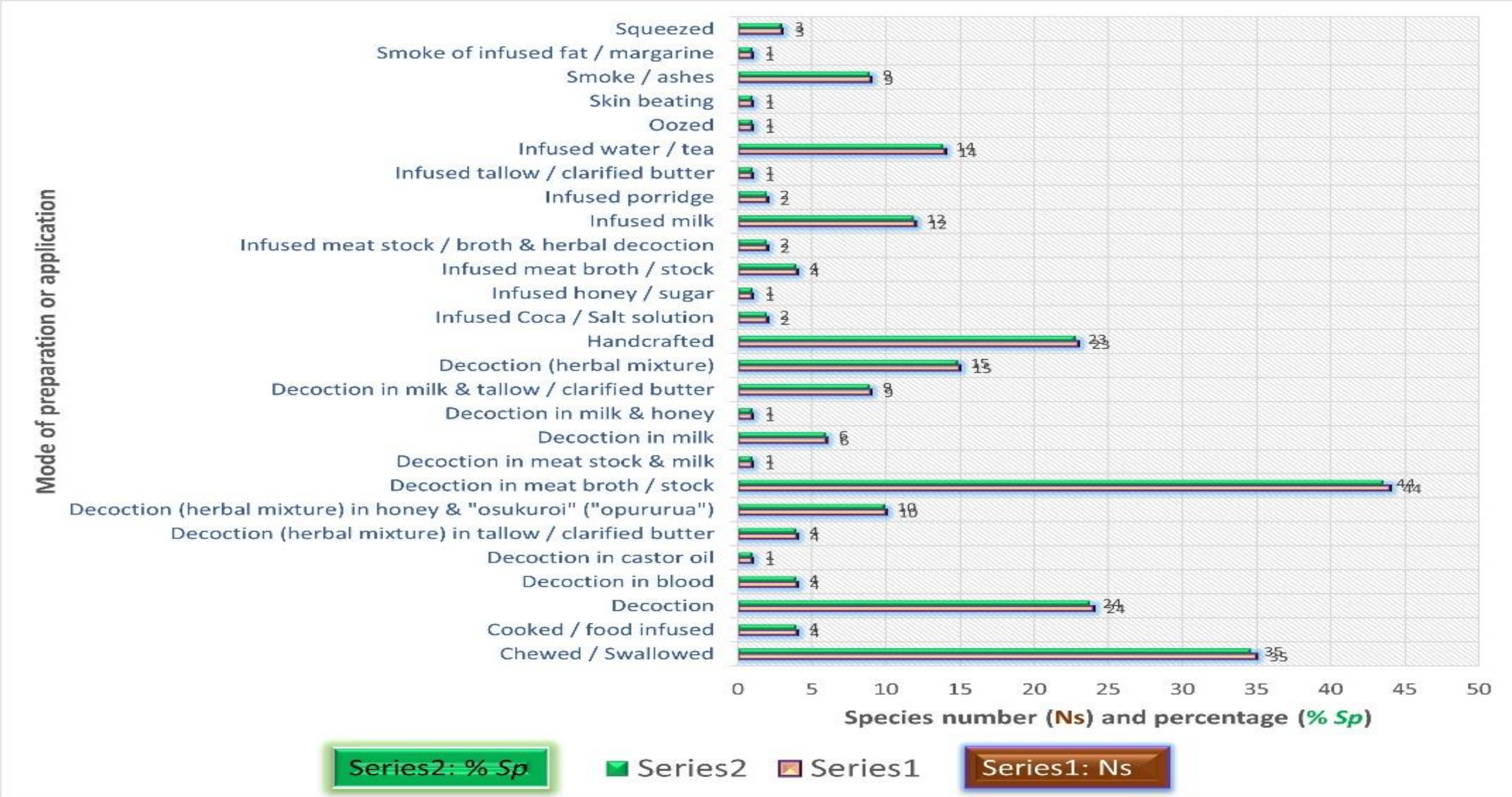


Figure 40: **Proportions of flora species across modes of preparation or application**

Besides, a decoction or an infusion was prepared from a mixture of different floral parts to mainly target multiple roles, including nutrition and prevention/therapies against ailment(s) (Appendix 4). Conversely, a decoction or an infusion was prepared from a floral part to target, often a specific role. The reason(s) for mixing a decoction or preparing an infusion with food substance(s) or other fluid (Fig. 40) was to attain the following: Dissolve fats, add taste or flavor, increase mixture viscosity, reduce plant side effects, enhance diffusion into the body, and or increase efficacy in performing its role(s) (Appendix 4). "*Opururua*" usually combines honey, a decoction from floral parts, and infusion of especially "*Osukuroi*" roots and some floral parts retained in the resulting mixture, "*Opururua*" (Fig. 40 & Appendix 4). Handcrafted floral parts were often used to process or store medicines or foods (Appendix 4). Furthermore, the preparations of the flora parts used in the study area were taken through various delivery routes at varying species' percentages: Oral (Or), 91%; nasal (Na), 8%; dermal (De), 7%; and ocular (Oc), 1% (Appendix 4). Moreover, the floral preparations were administered at varying dosages based on sex, age, body fitness, health history, duration of the sickness, pregnancy and menstruation or menopause status (Appendix 4). The common dosage measurements of the preparations were drops, palm length or volume, teaspoon, tablespoon, "*Mollel*" (~¼ Liter), "*Neing'asha*" or "*Laiser*" (~½ Liter), "*Leseri*" or "*Tumberi*" (~1 Liter).

4.2.2 Health Conditions or Ailments Managed by Flora of the Study Area

A total of 69 health conditions or ailments managed by the flora of the study area were recorded (Appendix 4). Classification of the conditions or ailments through the International Classification of Primary Care (ICPC-3) resulted in fourteen (14) ICPC-3 categories (Fig. 41). The categories' informant consensus factor (ICF) ranged from 0.000 to 0.714 (Fig. 41).

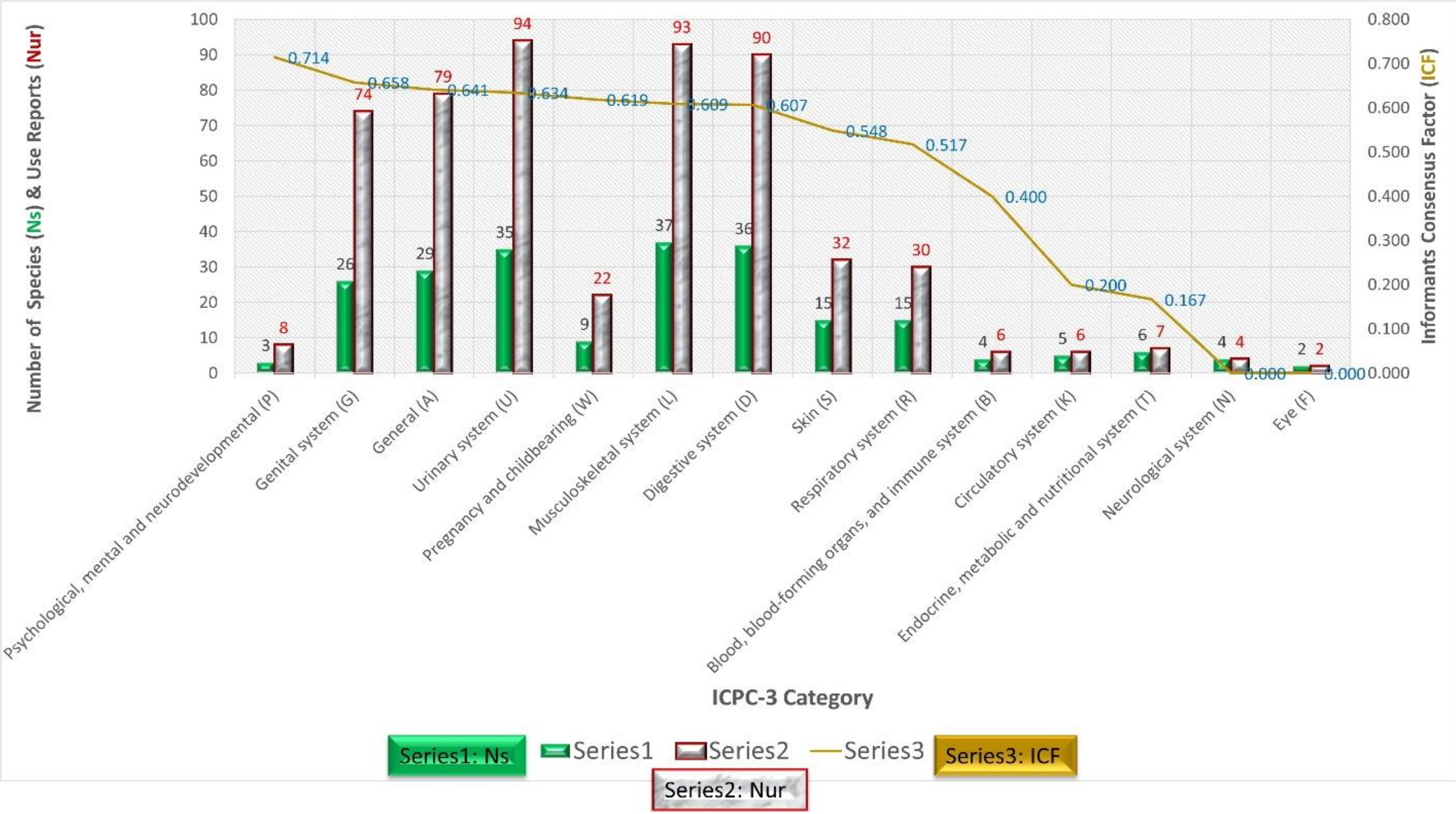


Figure 41: **The Ns, Nur, and ICF for ICPC-3 categories recorded in the study area**

Some health conditions across the ICPC-3 categories had Maasai names and some were grouped into categories classified traditionally (Appendix 4). Hernia, signified by stomach grumbling and pain on the umbilical cord was known as "*Enarposeseni*" (Appendix 4), representing the digestive system (**D**) conditions with codes DD75 and DD76. Increased confidence or angriness was referred to in Maasai as "*Mori* or *Emboshona*" (Appendix 4), representing conditions of the psychological, mental and neurodevelopmental (**P**) category (Fig. 41). Furthermore, some diseases or health conditions were classified traditionally into local categories: "*Osupetai*", "*Olgila*", and "*Ororobi*" (Appendix 4).

"*Osupetai*" had the health conditions constituted in general (**A**), digestive (**D**), genital (**G**), circulatory (**K**), musculoskeletal (**L**), neurological (**N**), and respiratory (**R**) systems as well as skin (**S**) ICPC-3 categories (Fig. 42 & 43). Gonorrhea, boil, followed by back (waist) pain, bone pain, joint pain and swollen joints like finger and knee had the highest **FL** and **RFC** (Fig. 42). "*Osupetai*" had various causes or risk factors (Fig. 43). Sexual intercourse or blood contact followed by eating foods without cleaning (detoxifying) the body or taking herbs had the highest **FL** and **RFC** (Fig. 43). "*Osupetai*" was further classified into sub-categories based on effects or affected body parts: Bones ("*loloik*"), muscles, joints, and reproductive system (e.g., gonorrhea) "*Osupetai*" (Appendix 4). The flora species (Fig. 44 and Appendix 4) were used to manage "*Osupetai*" health conditions (Fig. 42).

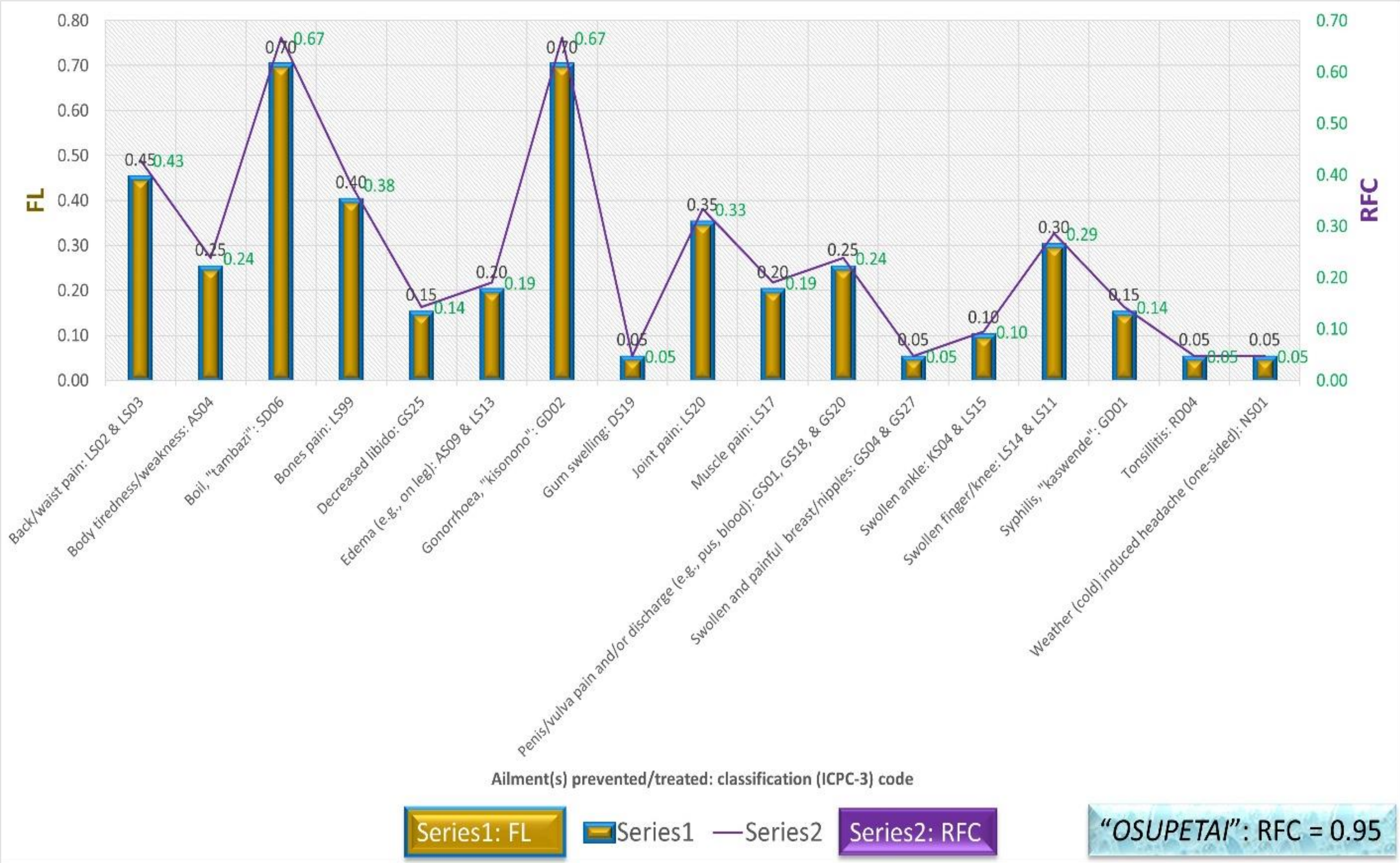


Figure 42: **The FL & RFC of ailments(s) prevented/treated in "*Osupetai*" by flora (Fig. 44)**

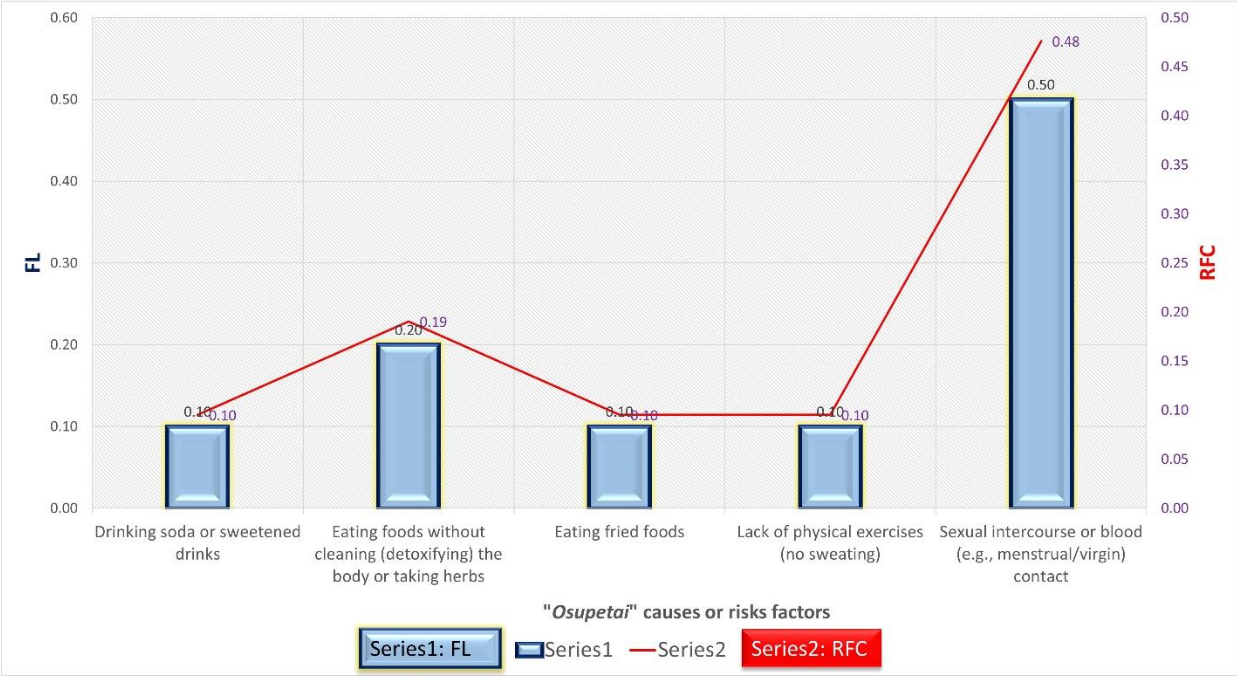


Figure 43: The FL & RFC "*Osupetai*" causes or risk factors

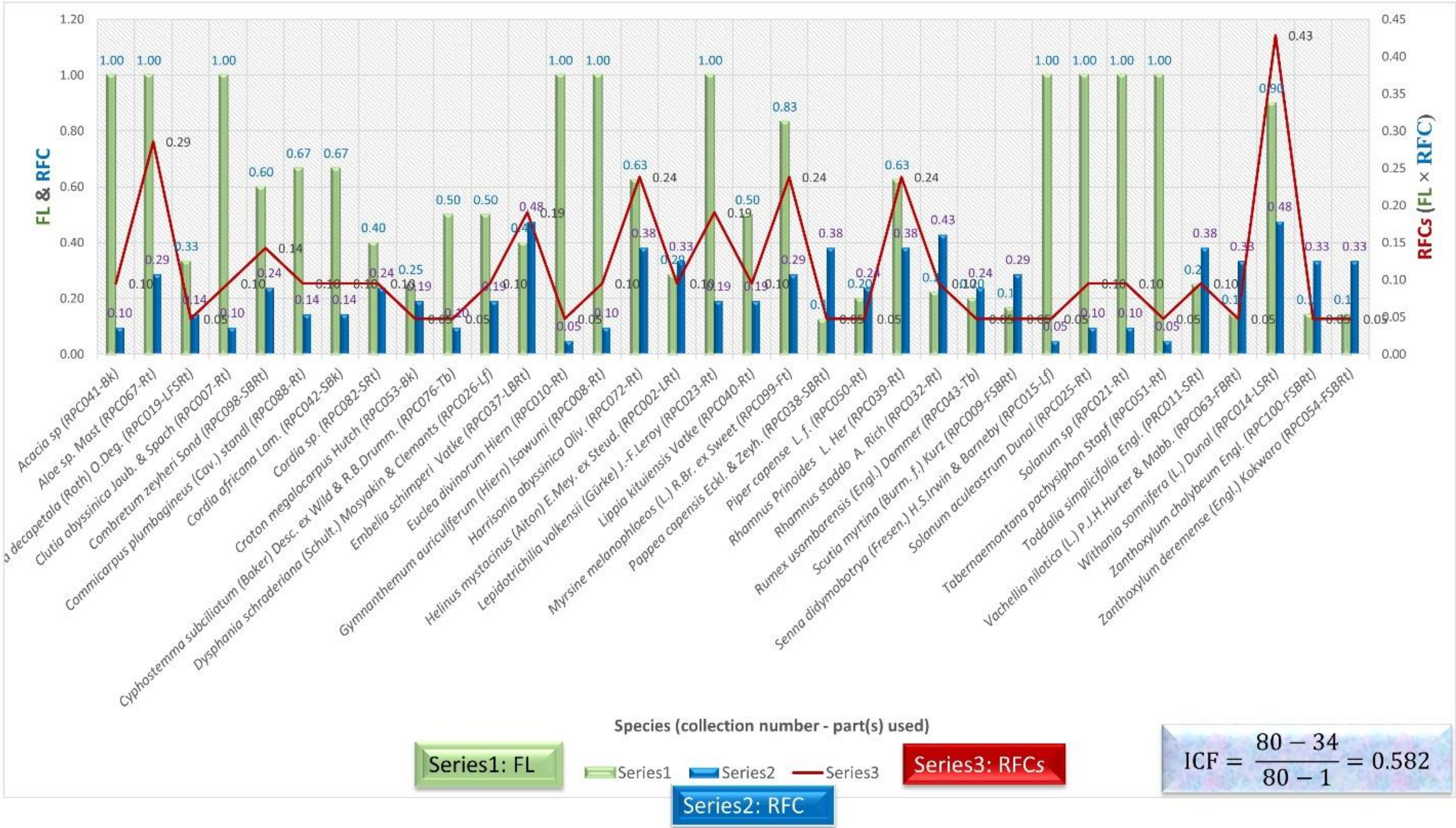


Figure 44: The FL, RFC, and RFC*s* of the flora that manage the "*Osupetai*" health conditions

“*Olgila*” had health conditions in the **A**, **G**, **K**, and **L** ICPC-3 categories (Fig. 45a); most of them were part of **L** conditions (Fig. 45b). Joint pain followed by body tiredness or weakness, and walking difficulties had the highest **FL** and **RFC** (Fig. 45a). “*Olgila*” had various causes or risk factors (Fig. 46). Eating without working or cleaning the body followed by eating meat with added salt, and less or lack of physical activities had the highest **FL** and **RFC** (Fig. 46). Besides, “*Olgila*” was sometimes used to refer to gout. This reflects what six respondents said. Also, “*Olgila*” was sometimes used to refer to “*Osupetai*”. This reflects what seven respondents said. “*Olgila*” and **L** conditions were managed by the flora species (Fig. 47 and Appendix 4).

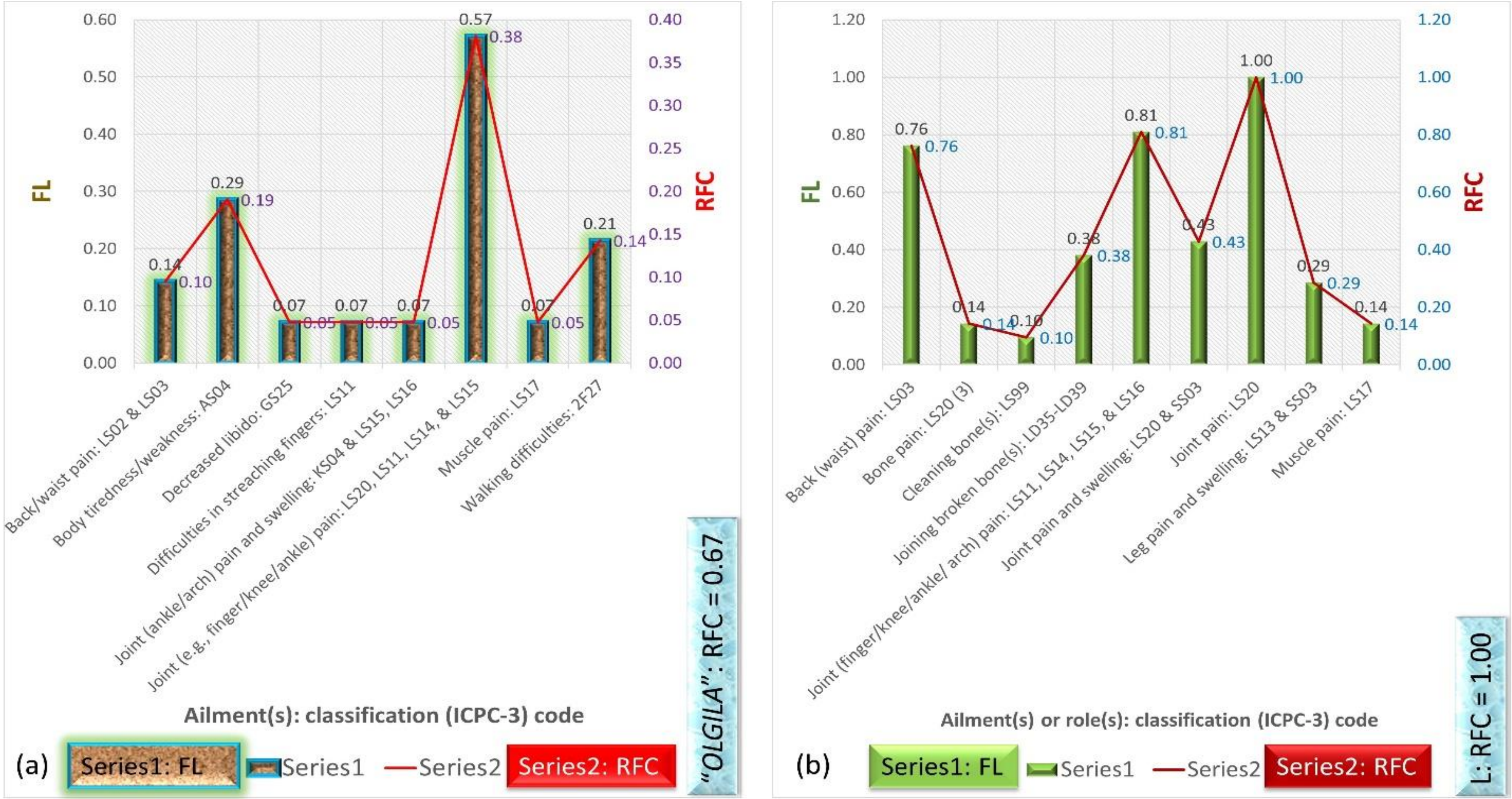


Figure 45: The FL & RFC of ailments(s) or health conditions in "*Olgila*" (a) and L (b)

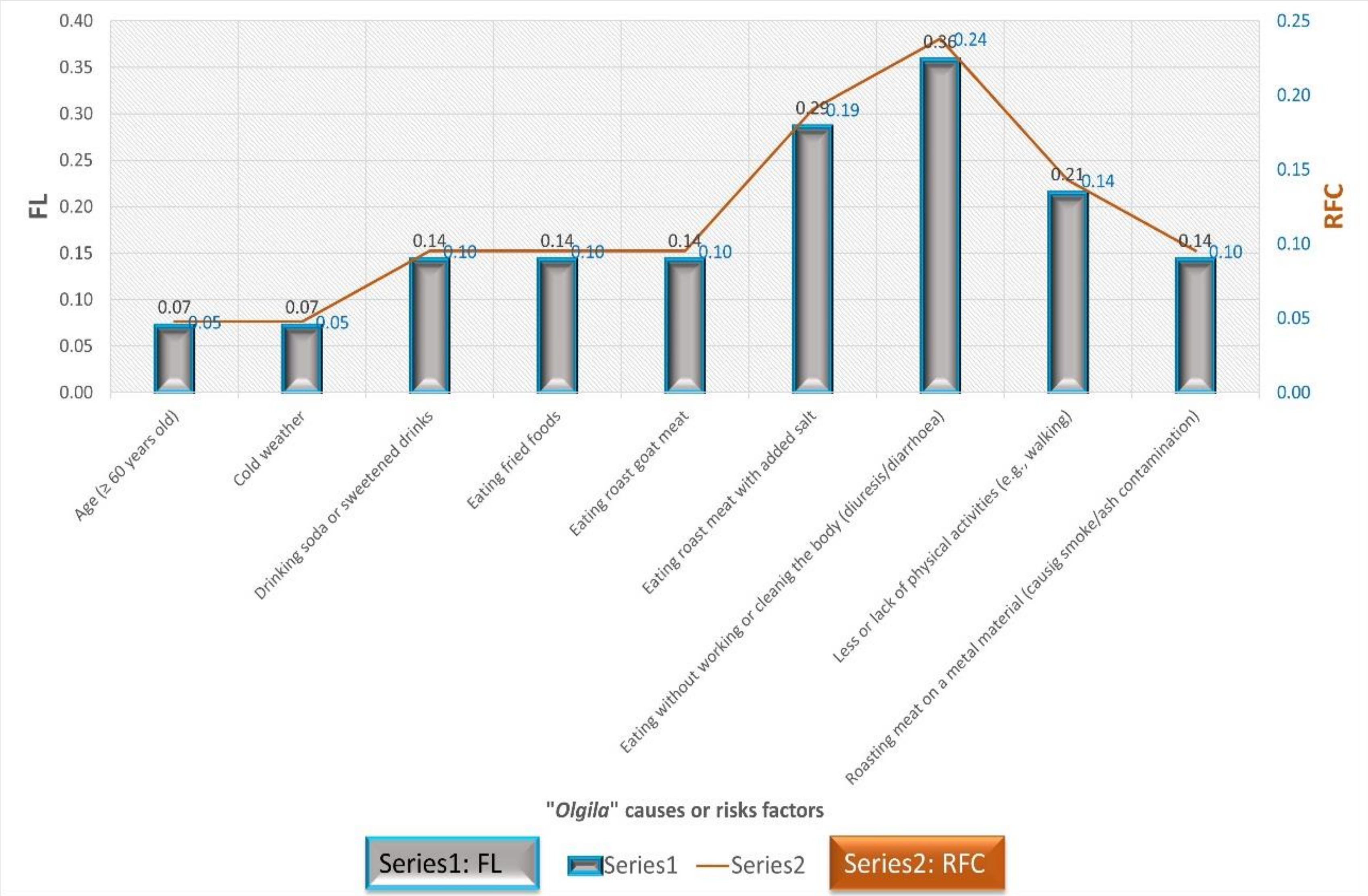


Figure 46: **The FL & RFC "*Olgila*" causes or risk factors**

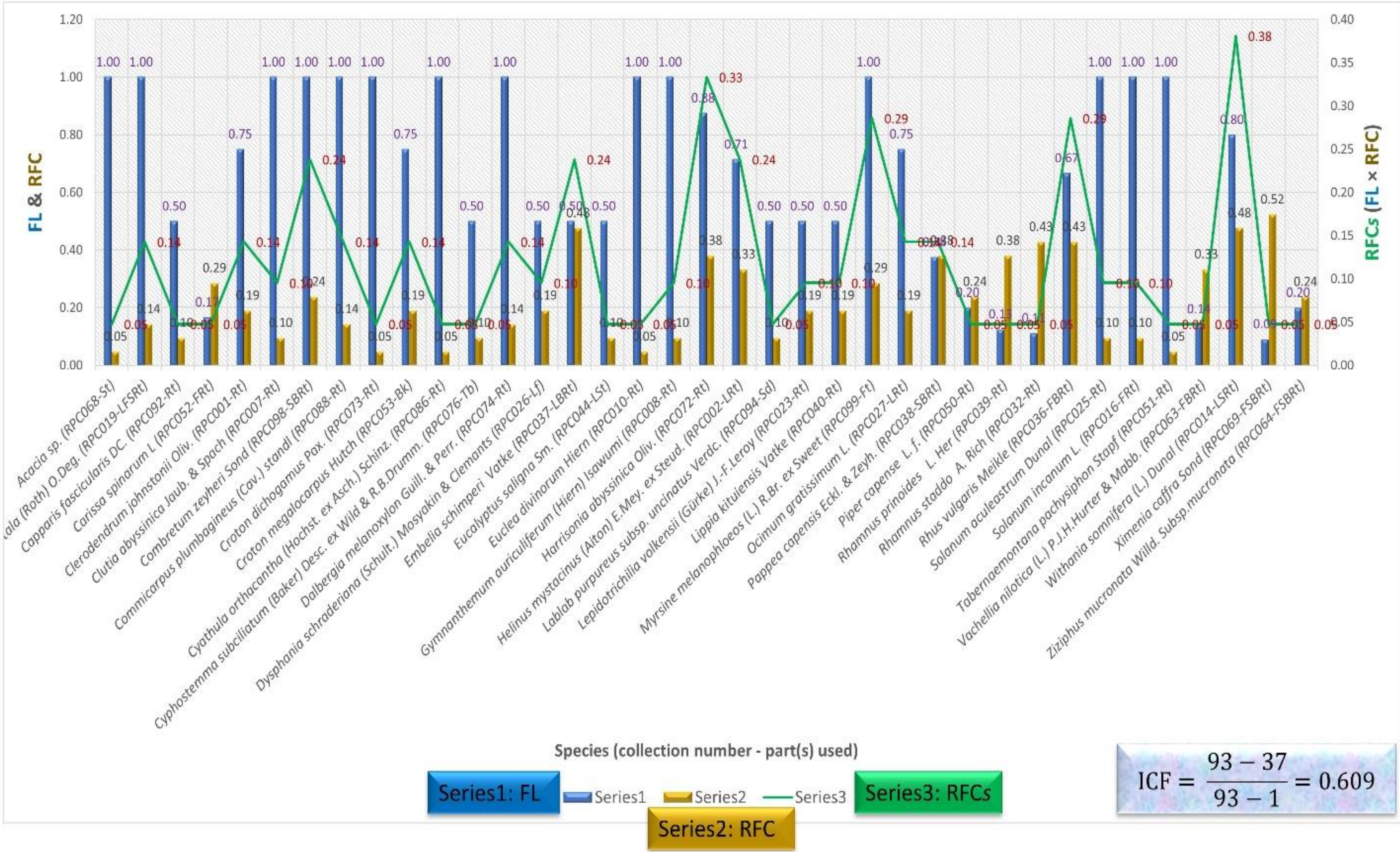


Figure 47: The FL, RFC, and RFC*s* of the flora that manage the "*Olgila*" and L health conditions

"*Ororobi*" had health conditions in the **A** and **R** ICPC-3 categories: **A** conditions were fever (AS03) or malaria (AD 16), and chest pain (AS12) while the **R** conditions were cough (RS07), influenza (RD07), and pneumonia (RD09) or respiratory pain (RS01) (Appendix 4). Some flora used to manage "*Osupetai*" or "*Olgila*" were also used against "*Ororobi*" health conditions (Figs. 44 - 47 & Appendix 4).

4.2.3 Flora Used in the Maasai TFS and TM that are Available in the Open Markets

Market observation of the flora used in the Maasai TFS and TMs was conducted in common open markets (Fig. 8). The flora species (Appendix 5) observed on the open markets were also cited in the interviews conducted in the respondents' households. For 67% of the flora, their voucher specimens were deposited at the National Herbarium, TPHPA. Moreover, parts of the observed flora were mainly sold for medicinal purposes. Also, the medicinal uses of the observed flora were the same as were reported in the interviews, except *Acacia nilotica* was sold for the additional role of cleaning blood (Appendixs III & IV). Some flora species were sold for gout, "*Olgila*" (Appendix 5).

4.2.4 Diversity of Flora Used in the Study Area

The flora used in traditional TFS and TM by Maasai in the study area had a rich diversity of 101 species distributed in 84 genera and 42 families. The most represented families were, Fabaceae, followed by Euphorbiaceae, Rutaceae, Solanaceae, Boraginaceae, Lamiaceae, Malvaceae, Rhamnaceae and Anacardiaceae: They had 4-10 species each (Appendix 4). These families are among the topmost families comprising flora used in Tanzania (Hilonga *et al.*, 2018). Moreover, most flora species were sourced from the forest followed by savanna (Appendix 4). Furthermore, the most common habit was a tree that accounted for the most species (Appendix 4). Consistency with this study, Kimondo (2020) reported a high proportion of species being used as trees by Ilkisonko Maasai of Kajiado County, Kenya. This consistency could be due to the same Maasai cultural reflections and patterns of growth forms in their communities.

4.2.5 Benefits of Flora Used in Maasai TFS and TM

Flora used in the traditional TFS and TM have a wide range of benefits in promoting the health and well-being of people, especially those who strongly uphold their cultural practices (Kimondo, 2020). The flora of this study was used for medicines, food sources and food or medicine processing/storage (Fig. 40 & Appendix 4) thereby it has a potential contribution toward achieving SDGs 2 and 3 (United Nations, 2015). The flora had other additional uses though (Appendix 4). Medicines accounted for the highest species proportion and use reports (Appendix 4). So, most flora were medicinal plants (MPs).

(i) Health Conditions and Disease Categories

A total of sixty-nine (69) health conditions distributed across fourteen (14) ICPC-3 categories (Fig. 41) were managed by the MPs. The categories had ICF ranging from 0.00-0.714 while category **P** followed by **G** had the highest ICF (Fig. 41). Also, nine (9) categories had ICF > 0.500 (Fig. 41). Higher ICF values suggest a systematic and well-defined selection of MPs in managing the health conditions for each category including "*Osupetai*", "*Olgila*" and **L** (Fig. 44 & 47). Also, there is a clear exchange of information among informants regarding the use of MPs against health conditions (Issa *et al.*, 2018; Tuasha *et al.*, 2018). But five (5) categories had ICF < 0.500 (Fig. 41). Categories **N** and **F** had the lowest ICF of 0.00 (Fig. 41). Lower ICF values could suggest the following: There is a random selection of MP species used against health conditions in each of the categories; there is no exchange of information among informants about MPs used in each category; and there is strong disagreement among informants due to different experiences and strict secrecy on information keeping (Issa *et al.*, 2018; Tuasha *et al.*, 2018).

(ii) Health Conditions Related to Gout and Managing MPs Thereof

"*Olgila*" sometimes known as gout, was among the conditions managed by the MPs of the study area. Most of the "*Olgila*" health conditions particularly joint pain and swelling, difficulty in stretching fingers, decreased libido, and walking difficulties (Fig. 45a) relate to gout (Dehlin *et al.*, 2020a). All the "*Olgila*" conditions except body weakness or tiredness and reduced libido constitute the conditions of the musculoskeletal system (Fig. 45). So "*Olgila*" is closely related to gout by sharing its musculoskeletal conditions with that of gout. Still, most causes or risk factors of "*Olgila*" (Fig. 46) are similar to those of gout (Dehlin *et al.*, 2020b; Li *et al.*, 2021). The similarities and close relationships agree with the use of the term, "*Olgila*" by some respondents to mean gout.

Besides, "*Olgila*" (Fig. 45a) makes up a portion of "*Osupetai*" health conditions (Fig. 42). Moreover, all causes or risk factors of "*Osupetai*" except sexual intercourse or blood contact (Fig. 43) are the same as those of "*Olgila*" (Fig. 46). So, "*Olgila*" or gout shares health conditions and causes or risk factors with "*Osupetai*". But "*Osupetai*" has health conditions and causes or risk factors more than those of "*Olgila*" or gout (Fig. 42, 43, 45a & 46). Indeed, analysis of its conditions and causes or risk factors clearly shows that "*Osupetai*" constitutes communicable and non-communicable diseases with various causes: bacteria, viruses, parasitic worms, arthritis and damage to tissues, weather changes, endocrine and neuron system disorders (Clement *et al.*, 2021). These causes can justify its further classification into "*Osupetai*" of bones, muscles, joints, and the reproductive system. Moreover, they support the relationship that "*Olgila*" or gout, a non-communicable disease, is a part of "*Osupetai*" health conditions.

"*Olgila*" or gout health conditions were prevented or treated by various MPs (Fig. 47). Pain and swelling of fingers, knees and ankles were the most frequently cited conditions of the musculoskeletal system, **L** (Fig. 45). These conditions are among the symptoms of gout, a consequence of hyperuricemia, an elevated serum uric acid level (Gherghina *et al.*, 2022). Xanthine oxidoreductase (XOR) is converted from xanthine dehydrogenase (XDH) into its isoform xanthine oxidase (XO) under hypoxic/ischemic and inflammatory conditions (Bortolotti *et al.*, 2021; David *et al.*, 2015). The conversion can be irreversible if the conditions are prolonged (Bortolotti *et al.*, 2021). Increased activity of XO leads to hyperuricemia along with generations of reactive oxygen species (ROS): Superoxide and hydrogen peroxide (Bortolotti *et al.*, 2021). The increased levels of ROS cause OS while hyperuricemia can cause the precipitation of uric acid into monosodium urate crystals in tissues (Bortolotti *et al.*, 2021). The crystals trigger inflammation and pain in joint tissues like that of fingers, knees and ankles (Allegrini *et al.*, 2022).

Withania somnifera followed by *Harrisonia abyssinica*, *Myrsine melanophloeos*, *Combretum zeyheri*, and *Embelia schimperi* were the most frequently used MPs against health conditions of "*Olgila*" and **L**, particularly joint pain and swelling (Fig. 47 & Appendix 4). These species contain various phytochemicals including quercetin, alloptaeroxylin, embelin, procyanidin B3 and epicatechin respectively (Akram *et al.*, 2014; Caruso *et al.*, 2020; Fyhrquist *et al.*, 2020; Masila, 2014); they have antioxidant and anti-inflammatory activities (Amarowicz & Pegg, 2019; Caruso *et al.*, 2020). All the phytochemicals except embelin are phenolic compounds; phenolic compounds and embelin can scavenge free radicals (Amarowicz & Pegg, 2019; Caruso *et al.*, 2020). In addition, flavonoids like quercetin, procyanidin B3 and epicatechin as secondary antioxidants can prevent free radicals generation through chelating oxidative metals (Amarowicz & Pegg, 2019).

Also, such flavonoids can prevent inflammation by inhibiting cyclooxygenase enzymes (Amarowicz & Pegg, 2019). Still, quercetin can inhibit XO (Ayyappan & Nampoothiri, 2020). These biological activities of the phytochemicals lower the risk of developing hyperuricemia, gout and GACs (Gherghina *et al.*, 2022; Li *et al.*, 2021). This explains why MPs are extensively used in TM against various inflammatory disorders (Kimondo, 2020; Kougan *et al.*, 2013). Therefore, the MPs used against joint pain and swelling (inflammation) (Figs. 44 - 47 & Appendix 4) are potential sources of antioxidant, anti-inflammatory and AHAs against gout and GACs. Also, using these MPs by Maasai in their TFS and TM while they are healthy and sick could support the claim that inflammatory conditions like gout have a low incidence in Maasai communities (Kimondo, 2020).

On the other hand, increasing evidence has shown that gout or hyperuricemia may predispose to chronic kidney disease CKD, cardiovascular disease, metabolic syndrome, diabetes mellitus and erectile dysfunction (Dehlin *et al.*, 2020b; Gherghina *et al.*, 2022). The predisposition occurs due to the prooxidative and or proinflammatory roles of hyperuricemia (Gherghina *et al.*, 2022). Conversely, some of these MDs, like hypertension, hyperlipidemia and renal diseases, can also predispose to hyperuricemia and or gout (Dehlin *et al.*, 2020a). So, MPs used against gout could lower the risk of getting MDs predisposed by gout. Also, the MPs used against the MDs predisposing to gout could lower the risk of getting gout and the resulting burden of its comorbidities. The MPs of the study area can potentially manage most of the MDs associated with gout: They are claimed to prevent or treat reported gout-associated health conditions and or risk factors (Appendix 4).

Decreased libido was among the health conditions of gout; "*Olgila*" and "*Osupetai*" (Figs. 42 & 45a). Such sexual inappetence is among the known comorbidities associated with gout (Dehlin *et al.*, 2020a). But, improving erection or increasing libido was the most common role achieved by the MPs for promoting the health of the genital system, **G** (Appendix 4). *Pappea capensis* (Figs. 44 & 47) was among the species commonly used to improve erection or libido (Appendix 4). Consistent with this study the species was reported elsewhere to be used for fertility or aphrodisiac function (Kimondo, 2020; Makule, 2018). *Pappea capensis* contains zinc, vitamins C and E and phenolic compounds like apigenin, kaempferol and quercetin (Karau *et al.*, 2012a; Muruthi *et al.*, 2023a). The Zinc is a cofactor of antioxidant enzymes and insulin, while vitamins C and E prevent lipid peroxidation and inflammation (Karau *et al.*, 2012a). Also, apigenin, kaempferol and quercetin can inhibit XO (Ayyappan & Nampoothiri, 2020). Thus, *Pappea capensis* can prevent hyperuricemia, gout and GACs like decreased libido (Dehlin *et al.*, 2020b; Gherghina *et al.*, 2022).

Kidney disorders are predisposing conditions to gout and vice versa as explained earlier. Inducing diuresis was among the most common approaches to cleaning the body, kidneys and urine (Fig. 46 & Appendix 4). Diuresis has been used against heart failure, liver, gout and kidney disorders that cause fluid retention (edema) in the body (Hedaoo & Bodhankar, 2019). However, diuresis, especially when induced by conventional diuretics, can lead to an upset of bloodstream salt balance, worsening diabetes and gout conditions (Hedaoo & Bodhankar, 2019). *Withania somnifera* followed by *Rhamnus prinoides* were among the most common MPs used to induce diuresis (Appendix 4). Yet, no side effects associated with diuresis were reported by MTPs when using the MPs (Appendix 4).

This is strongly supported by the fact that natural diuretics, mainly vegetables and fruits, are high in water and potassium (and some in magnesium and calcium), thereby offsetting vascular stiffness, which would occur at low potassium and high sodium levels (Hedaoo & Bodhankar, 2019). Diuresis and water properties of the MPs might have been enhanced by plenty of fluid that was used in making their preparations like decoction and '*opururua*', though (Fig. 40). Decoction in meat broth or stock was the most frequently used preparation (Fig. 40). Furthermore, high potassium intake especially as alkaline salt provides an anti-urolithiasis effect which can dissolve kidney stones associated with uric acid (Barbera *et al.*, 2016). So, this could support the additional use of these diuretic MPs against gout symptoms, joint pain and swelling (Fig. 44 - 47, & Appendix 4) with no reported side effects as opposed to conventional diuretics.

Consistent with this study *Withania somnifera* was elsewhere reported to be used as a diuretic agent (Gaurav *et al.*, 2023). Still, *Withania somnifera* and *Rhamnus prinoides* are elsewhere used against arthritis (Kimondo, 2020). These species contain flavonoids (quercetin, apigenin and kaempferol), triterpenoids (withaferin A), and saponins (sitoindosides *VII-X*) (Chen *et al.*, 2020; Saleem *et al.*, 2020); the compounds are among the polar compounds with diuretic properties (Aswini *et al.*, 2020). Moreover, the compounds have antioxidant properties while the flavonoids have inhibitory activity against XO (Ayyappan & Nampoothiri, 2020; Saleem *et al.*, 2020). Thus, using such MPs to clean kidneys and urine through diuresis, could promote the health of kidneys and lower the risk of developing gout and the GACs.

Gout is known to be associated with pregnancy (Horta-baas *et al.*, 2017). Gout during pregnancy or the reproductive age of women is not common, though (Horta-baas *et al.*, 2017). However, pregnant women with gout are at increased risk of having maternal complications including renal damage, preeclampsia, postpartum uremia, anemia and rarely abortion (Horta-baas *et al.*, 2017). These adverse effects are linked to OS associated with pregnancy (Di Fabrizio *et al.*, 2022). Although reactive oxygen species (ROS) and antioxidants are important in regulating reproductive processes, elevated level of ROS induces OS that lead to such pregnancy outcomes associated with gout (Al-Gubory *et al.*, 2010; Di Fabrizio *et al.*, 2022). Pregnancy is associated with hypoxic/ischemic and reperfusion conditions, which convert XOR from xanthine dehydrogenase into its isoform XO (Di Fabrizio *et al.*, 2022). Thus, the increased XO activity leads to hyperuricemia, along with the generation of ROS, particularly superoxide free radical, thereby causing gout and preeclampsia associated with pregnancy (Di Fabrizio *et al.*, 2022).

Besides, OS promotes spontaneous abortion, especially before the end of the first trimester (Al-Gubory *et al.*, 2010). Conversely, stopping bleeding (WS03) and abortion (WD65), particularly in early pregnancy, were among the common roles or conditions in pregnancy and childbearing (**W)** (Fig. 41 & Appendix 4) managed by the MPs (Appendix 4). *Grewia villosa*, *Lannea schweinfurthii*, and *Ximenia caffra* were used against bleeding and abortion (Appendix 4). The presence of *p*-coumaric acid, catechin, kaempferol, quercetin and ursolic acid with antioxidant, anti-inflammatory and anti-hyperuricemia activities in these species (Ayyappan & Nampoothiri, 2020; Maroyi, 2016, 2019; Sanvitha *et al.*, 2022) can support their use against the pregnancy outcomes associated with gout (Di Fabrizio *et al.*, 2022). *Grewia villosa* is used elsewhere against rheumatism (Kimondo, 2020) while *Lannea schweinfurthii* and *Ximenia caffra* are used against anemia and abortion (Maroyi, 2016, 2019). *Ximenia caffra* is also used against "*Olgila*" (Fig. 47). So, these species have potential uses against the pregnancy outcomes associated with gout.

Gout is also associated with digestive system (**D**) disorders. Components of **D,** particularly the intestinal tract, have a role in eliminating one-third of uric acid through the uricolysis process, which is supported by intestinal flora, thereby reducing the risk of gout (Sorensen, 1965). Uricase is not present in human tissues (Sorensen, 1965). Thus, any **D** disorder that impairs the excretion of uric acid, constitutes gout risk factors. Hyperchlorhydria, a high stomach acid, is one of the marked conditions in gout patients (Stockton, 1897). Hyperchlorhydria results from gastrinoma (Zollinger-Ellison syndrome), *Helicobacter pylori* infection, colorectal carcinoma and diminished renal or hepatic function (Alter, 2020; Shulkes & Baldwin, 2013). Moreover, it can lead to peptic ulcers, thickening of the gastrointestinal mucosa, delayed starch digestion, stomach bloating or flatulence and liver enlargement, which leads to impaired renal uric acid excretion (Shulkes & Baldwin, 2013; Stockton, 1897). Also, glycogen storage disease type Ia can affect the liver through a defective enzyme and it is the main cause of gout, particularly in premenopausal patients (Zhang & Zeng, 2016). Thus, **D** disorders can lead to impaired excretion of uric acid in both the intestinal tract and kidney thereby increasing the risk of developing gout.

Constipation (DS12), indigestion (DS99), stomach bloating (DS08) and stomach ulcer (DD70) which are hyperchlorhydria symptoms, were among the **D** conditions managed by the MPs (Fig. 41 & Appendix 4). *Biancaea decapetala* (Appendix 4) with the synonym *Caesalpinia decapetala* (Roth). Alston was used against constipation (Appendix 4). Moreover, its use against gastrointestinal disorders is reported elsewhere (Bhadoriya *et al.*, 2012). *Biancaea decapetala* has various compounds including gallic acid, lupeol, resveratrol and quercetin with antioxidant activity thereby supporting its use against gastrointestinal inflammations including peptic ulcers, which are associated with OS (Bhadoriya *et al.*, 2012). Likewise, the use of *Withania somnifera* and *Ximenia caffra* against stomach ulcers (Appendix 4), is supported by their antioxidant and anti-inflammatory compounds including quercetin and kaempferol (Gaurav *et al.*, 2023; Maroyi, 2016).

Furthermore, resveratrol and quercetin promote gut commensal microbiota and keep gut epithelial barrier integrity (García-Montero *et al.*, 2021). Also, kaempferol and quercetin have anticancer activity (Al-Nour *et al.*, 2019); they are also present in *Vachellia nilotica* (Fig. 44 & 47) with the synonym *Acacia nilotica* (L.) Wild ex Delile (Appendix 4) and *Ocimum gratissimum* (Ajayi *et al.*, 2017; Al-Nour *et al.*, 2019). Thus, the biological activities of these compounds support the uses of the species against the hyperchlorhydria symptoms, in facilitating food digestion and against "*Olgila*" (Fig. 44 - 47, & Appendix 4). Such species can lower the risk of developing gout and its marked condition, hyperchlorhydria: *Ocimum gratissimum* is used elsewhere against rheumatism (Ajayi *et al.*, 2017).

Besides, gout or uric acid is also associated with some respiratory system (**R**) disorders (Horsfall *et al.*, 2014; Peng *et al.*, 2022; Wang *et al.*, 2013). A low level of serum uric acid is associated with higher rates of chronic obstructive pulmonary disease (COPD) and lung cancer in current smokers (Horsfall *et al.*, 2014). Still, hyperuricemia or gout is among the high-risk factors of Acute Respiratory Distress Syndrome (ARDS) which is associated with **R** diseases including severe pneumonia, tuberculosis or COVID-19 (Peng *et al.*, 2022; Wang *et al.*, 2013). Also, malaria can induce ARDS (Taylor *et al.*, 2012). Conversely, ARDS may lead to hypoxia (Taylor *et al.*, 2012), a risk factor for hyperuricemia and gout (Bortolotti *et al.*, 2021). "*Ororobi*" health conditions: Fever, cough, chest pain, influenza and pneumonia (Appendix 4) are the **R** diseases symptoms (Horsfall *et al.*, 2014; Peng *et al.*, 2022; Wang *et al.*, 2013). *Zanthoxylum chalybeum* and *Zanthoxylum deremense* were among the most common species used against "*Ororobi*" (Appendix 4). Also, they were used against malaria (Appendix 4). These species contain phenolic compounds like ailanthoidol and 6-acetonyldihydrochelerythrine (Ochieng *et al.*, 2020).

Also, in addition to the latter compound other alkaloids, skimmianine and chalybemide A, B and C are also present in the species (Ochieng *et al.*, 2020). Phenolic compounds have antioxidant activities against OS which may be induced by hypoxic/ischemic conditions (Amarowicz & Pegg, 2019; Bortolotti *et al.*, 2021). Moreover, alkaloids possess antibacterial and antiplasmodic properties (Mbunde *et al.*, 2017). Thus, such biological activities support the traditional use of the species against respiratory conditions and malaria in the current study (Appendix 4) and elsewhere (Mbunde *et al.*, 2017). Also, these species can be used against gout and the associated respiratory conditions.

Gout or hyperuricemia is associated with some circulatory system (**K**) disorders including vascular disease and hypertension (Gherghina *et al.*, 2022). Hyperuricemia through its pro-inflammatory and pro-oxidative effects has the role of initiating vascular stiffening which leads to **K** disorders and chronic kidney disease, CKD (Gherghina *et al.*, 2022; Ramirez-Sandoval *et al.*, 2017). Blood pressure, swollen ankle and blood vessel cleaning, signified by increased body strength and absence of heart tightness (Fig. 42 - 45a, & Appendix 4), were among the **K** conditions managed by the MPs (Appendix 4). *Pappea capensis* and *Harrisonia abyssinica* were among the most common species used in cleaning blood vessels and swollen ankles respectively (Appendix 4). *Pappea capensis* contains apigenin, kaempferol and quercetin with antioxidant and inhibitory activity against XO; thus, preventing hyperuricemia and OS (Ayyappan & Nampoothiri, 2020; Muruthi *et al.*, 2023a). Also, *Pappea capensis* has vitamins C and E with antioxidant properties that prevent lipid peroxidation and atherosclerosis (Gherghina *et al.*, 2022; Karau *et al.*, 2012a).

Moreover, this species probably contains potassium, which softens endothelial cells by enhancing the release of nitric oxide (NO); thus, preventing the consequences associated with vascular stiffness (Oberleithner *et al.*, 2009). Besides, *Harrisonia abyssinica* contains alloptaeroxylin and harrisonin (Masila, 2014), polar compounds with diuretic properties that can relieve ankle swelling (Aswini *et al.*, 2020). So, such biological properties support the uses of these species against the conditions (Appendix 4).

Still, *Asparagus setaceus*, *Tragia ukambensis,* and *Hydnora abyssinica* (Appendix 4) were used against blood pressure (Appendix 4). Some species like *Hydnora abyssinica* contain protocatechuic acid and catechin with antioxidant and anti-inflammatory properties (Al-Fatimi *et al.*, 2016; Amarowicz & Pegg, 2019); thus, preventing OS and inflammatory conditions including hypertension (Gherghina *et al.*, 2022). So, these MPs are not only important in managing the **K** disorders and CKD but, also in gout predisposed by or predisposing to the conditions (Gherghina *et al.*, 2022; Ragab *et al.*, 2017). This concurred with some species being used against "*Olgila*" (Fig 44 & 47).

Gout or hyperuricemia is also associated with diabetes mellitus, an endocrine, metabolic, and nutritional system (**T**) disorder (Lv *et al.*, 2013; Ragab *et al.*, 2017). Gout or hyperuricemia can cause OS-associated damage to beta cells, leading to insulin deficiency and the consequent diabetes mellitus (Lv *et al.*, 2013). Conversely, diabetes mellitus through hyperglycemia, ketoacidosis, osmotic diuresis and pro-inflammatory effect leads to elevated uric acid level, loss of potassium and impaired renal excretion of uric acid thereby resulting in hyperuricemia and or gout (Barbera *et al.*, 2016; Dhatariya *et al.*, 2020; Oguntibeju, 2019). Diabetes was among the conditions of **T** managed by the MPs (Appendix 4). Again, *Asparagus setaceus*, *Tragia ukambensis* and *Hydnora abyssinica* were in combination used against diabetes (Appendix 4). Antioxidant activity of these species could support their use against diabetes: antioxidants can prevent or suppress such OS or inflammation associated with diabetes (Asmat *et al.*, 2016). Moreover, these species may potentially have high potassium content enough to improve the excretion of uric acid and insulin hormone (Barbera *et al.*, 2016; MacGregor & He, 2001).

Diabetes mellitus predispositions include obesity or high fat deposits in adipose tissues that may undergo lipid peroxidation leading to inflammation and damage of beta cells; thus, insulin deficiency (Oguntibeju, 2019). Preventing or dissolving abdominal fat deposits was achieved by using *Ziziphus mucronata* and *Dombeya kirkii* (Appendix 4). *Ziziphus mucronata* has phenolic compounds and cyclopeptide alkaloids with antioxidant and antidiabetic properties respectively (Da Costa-Mousinho *et al.*, 2013). Antidiabetic properties of the alkaloids involve inhibition of α-amylase and α-glucosidase, and increasing glucose uptake (Da Costa-Mousinho *et al.*, 2013). These biological properties support the use of such species in lowering the risk (abdominal fat deposit) for developing diabetes mellitus and consequently gout or hyperuricemia. Thus, *Ziziphus mucronata* is also used against "*Olgila*" (Fig. 47).

(iii) Potential Roles of Flora on Causes or Risk Factors of Gout, "Olgila" and GACs

Apart from MPs used in managing various health conditions, this study documented the roles of flora on causes and risk factors for some diseases including gout, "*olgila*" and GACs (Fig. 43 & 46). Eating foods without working or cleaning the body and or taking herbs, followed by eating meat with added salt and less or lack of physical activities were the most common causes and risk factors of diseases including gout, "*olgila*" (Fig. 43 & 46). Consumption of purine-rich, high-fat, and high-carbohydrate foods poses the risk of developing hyperuricemia and gout, along with their inflammatory effects (Gherghina *et al.*, 2022; Li *et al.*, 2021). The purine-rich and high-fat foods were the most common in medicinal preparations and among food sources (Fig. 40 & 46). Thus, consuming such food sources without integrating substances that prevent OS and inflammation associated with those foods is expected to raise the risk of developing diseases like gout and GACs in consumers. However, MPs of this study with reported or potential biological activities against the diseases were used. A low prevalence of diseases like gout and GACs is reported in IPs like the Maasai community which integrate MPs in their TFS and TM (Kimondo, 2020). This supports the claim that eating food without integrating herbs is a risk factor for developing such diseases (Fig. 43 & 46).

Still, eating roast meat with added salt was also a risk factor for developing gout, "*olgila*" (Fig. 46). This can be supported by the fact that meat especially beef, lamb, or goat is rich in purine which can elevate serum uric acid levels precipitating with sodium to form monosodium urate crystal leading to gout and GACs (Gherghina *et al.*, 2022; So & Martinon, 2017b). Also, sodium intake may lead to high plasma sodium concentration which stiffens endothelial cells by reducing nitric oxide release (Oberleithner *et al.*, 2009); thus, it leads to hypertension, a risk factor for gout (Ragab *et al.*, 2017). Hence, to avoid the consequence of such risk, MTPs more often do not add salt in roasting their livestock meat for consumption as described earlier (Fig. 23).

Drinking soda or sweetened drinks was also a risk factor for developing diseases including gout, "*olgila*" (Fig. 43 & 46). Indeed, such drinks contain a high amount of sugar especially fructose which requires a great deal of energy, ATP (adenosine triphosphate), and intracellular phosphate consumption for its metabolism (Gherghina *et al.*, 2022). This causes increased purine degradation and uric acid synthesis, leading to hyperuricemia or gout (Gherghina *et al.*, 2022). So, this could explain why MTPs do not often use such drinks or rarely use them especially along with herbs (Fig. 40) to treat certain diseases (Appendix 4).

Less or lack of physical activity was another risk factor for developing diseases including gout, "*olgila*" (Fig. 43 & 46). Physical activities increase insulin sensitivity, glucose uptake by the contracting skeletal muscles, and blood flow in the muscle cells that promote glucose transport into the cells (Oguntibeju, 2019). Also, physical activities decrease fat in adipose tissues (Oguntibeju, 2019). Thus, physical activities lower the risks of developing MDs including diabetes mellitus, hypertension, CKD and gout (Oguntibeju, 2019; Ragab *et al.*, 2017). Physical activities like walking (Fig. 46) and agropastoral works which were carried out by more than 86% of the MTPs (Table 1) may explain the low prevalence of such MDs in their communities (Kimondo, 2020).

Consumption of fried foods or meat roasted on a metal material which enhances smoke and ash contamination on meat, were other risk factors for developing gout, "*olgila*" (Fig. 46). Inappropriate food processing methods such as baking, frying, grilling, roasting and smoking are the main sources of polycyclic aromatic hydrocarbons (PAHs) in foods (Pang *et al.*, 2020). Also, the cooking methods especially roasting and frying lead to high levels of protein oxidation and lipid-oxidation products (Hu *et al.*, 2017). Malondialdehyde (MDA) and 4-hydroxynonenal (HNE), the toxic and most common secondary products of lipid oxidation, can enhance further protein oxidation, which can lead to advanced glycation end products (AGEs) in processed meat (Hu *et al.*, 2017; Zhu *et al.*, 2023). AGEs and PAHs induce OS; but, PAHs are carcinogenic to humans (Barreira, 2007). In addition to OS, AGEs in humans can lead to inflammation, resulting in MDs including diabetes and its complications (Heidari *et al.*, 2020; Kim *et al.*, 2015).

The effect of metal material usually made of iron on meat processing is less understood. But heme iron, a pro-oxidant from processed meat can be released from its porphyrin ring and accelerates the oxidative deterioration of protein and lipids in the processed meat (Hu *et al.*, 2017). Also, iron in the human body can cause cellular OS and lead to diseases like diabetes

(Kim *et al.*, 2015). Thus, if iron from the metal material can get access into the processed meat or human body, it may enhance the production of AGEs in both processed meat and the human body thereby leading to diabetes which is among the gout's risk factors. Therefore, consuming fried foods and meat roasted on metal material especially made of iron, can be a risk factor for developing MDs including gout, "*olgila*". This can explain why MTPs always roast their livestock meat using special sticks "*orjibet*" made from plants like *Combretum zeyheri* instead of metal materials (Fig. 23). *Combretum zeyheri* is also used in preparing "*Olchani-imotori*", a plants' decoction mixed with meat broth or stock (Fig. 40) that is always consumed along with cooked foods especially boiled or roast meat (Appendix 3). *Combretum zeyheri* has compounds like protocatechuic acid and procyanidin B3 with antioxidant properties (Fyhrquist *et al.*, 2020). Flavonoids like procyanidin B3 can also chelate the iron while processing or consuming meat, preventing the formation of AGEs and OS; thus, lowering the risk of the MDs associated with processed meat (Hu *et al.*, 2017). This can support the uses of *Combretum zeyheri* as "*orjibet*" and in preparing "*Olchani-imotori*".

(iv) Preparation, Doses, and Route of Delivery

Flora species of this study were used alone or in different preparation forms (Fig. 40) to mainly attain nutrition, food quality, therapeutic effect and safety roles. The food substances like fat or tallow, milk, blood, meat broth, or stock in the preparations (Fig. 40) had various roles including increasing therapeutic efficacy and reducing side effects associated with the flora (Appendix 4). The use of such food substances elsewhere in management or reducing overdose symptoms associated with herbal remedies (Makule, 2018) supported their use in reducing possible side effects of the flora in this study. This may explain why the flora decoction in meat broth or stock, "*Olchani-imotori*" was the most common preparation (Fig. 40). Likewise, "*Olchani-imotori*" was more often used along with food substances especially roast or cooked meat for preventive or therapeutic roles against diseases (Appendix 3 & 4) as is reported elsewhere (Clement *et al.*, 2023).

Still, different parts of the flora were used in achieving various modes of preparations (Fig. 40), but the most common was the root (Appendix 4). This could be explained by the fact that most flora were used as medicine (Appendix 4), and Maasai, through their experience with their cultural practices, have been able to ascertain that roots are more effective than other parts. Consistently, Maasai elsewhere cited roots as the most commonly used part; roots are known to have highly potent compounds that remain stable for a longer time, than compounds in other parts of the plant, after harvesting (Kimondo, 2020).

Moreover, although the amounts or dosages of preparations varied among informants, they were given based on age, sex and health conditions to attain their targeted role and avoid possible side effects as described earlier, thereby showing a good sense of effectiveness, efficacy and safety in using the preparations. For instance, preparations involving *Embelia schimperi* were not used by pre-menopause women; they induced excessive menstrual flow and pregnancy abortion (Appendix 4). Besides, most flora species were administered through the oral root (Appendix 4). This suggests that most of them were edible.

(v) Conservation Status

The conservation of flora or natural resources has been influenced by factors like anthropogenic activities, climatic changes and conservation strategies (Makule, 2018). In this study, most flora was native and harvested from wild areas, the natural habitats; used as medicine; used in the form of roots (Appendix 4); and some were sold in open markets (Fig. 8 & Appendix 5). The dependency on MPs for treating diseases and overuse by vending them in the open markets for economic purposes threatens the environment, flora diversity and traditional knowledge thereof (Makule, 2018; Tuasha *et al.*, 2018). For instance, *Dalbergia melanoxylon* Guill. & Perr. and *Zanthoxylum deremense* were in the near threatened (NT) and vulnerable (VU) categories of the IUCN red list respectively (Appendix 4). But, most of the flora species in the IUCN red list are in the LC category (Appendix 4).

Also, the concern of flora protection is understood by MTPs in the study area: Six percent (6%) of flora species were cultivated in home gardens or farms or left to grow as synanthropic flora by MTPs (Appendix 4). Therefore, to realize sustainability of the TFS and TM, the local conservation practices of the flora and health benefits thereof need to be aligned with SDG 13: Climate Action and SDG 15: Life on land, through adopting transformational strategies that ensure integrated sustainable conservation and use of the natural resources (Carpentier & Braun, 2020).

Surely, the Maasai TFS and TM had diverse flora species used for medicine, food and food processing. Most of the flora species (79%) were used as MPs to manage health conditions including gout, "*olgila*" and GACs: Some disorders of genital, urinary, digestive, respiratory, circulatory and endocrine systems as well as some pregnancy disorders. High use of flora particularly MPs in processing foods like roasting meat or along with other foods or in making preparations like "*Olchani-imotori*" with both nutritional and medicinal roles had potential roles in reducing risk factors for developing gout, "*olgila*" and GACs. Also, the MPs had potential antioxidant, anti-inflammatory, and anti-hyperuricemia activities against gout, "*olgila*" and GACs. However, the content of the phytochemicals particularly polyphenols, which are responsible for biological activities needs to be known for estimating the antioxidant capacity of the MPs.

4.3 Antioxidant Capacity of Flora and Health Benefits thereof in Maasai TFS and TM

Ultraviolet-visible spectrophotometric analysis of flora parts commonly used in the Maasai TFS and TM revealed that the ethanolic extracts of the floral parts had varying total phenolic content (TPC) with the highest being of *Rhus vulgaris* root and the lowest was of *Zanthoxylum chalybeum* root. Likewise, *Dalbergia melanoxylon* root heartwood (black parts) had the highest total flavonoid content (TFC) and *Lepidotrichilia volkensii* root had the least TFC. TPC and TFC suggest the presence of phenolic and flavonoid compounds respectively: They have antioxidant, anti-inflammatory, anti-hyperuricemia, anticancer and or gut barrier integrity-keeping properties. The flora parts, particularly those with high antioxidant capacity (TPC and TFC), support their traditional use against gout, "*Olgila*" and GACs (Fig. 48).

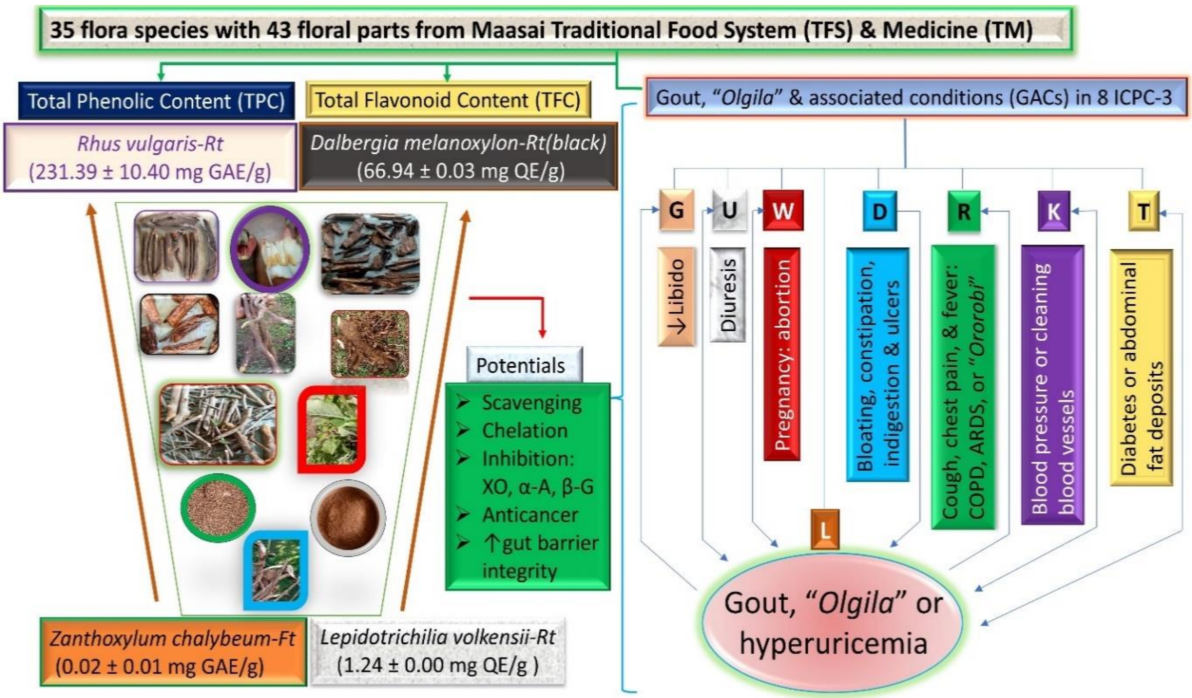


Figure 48: Graphical summary of objective three results

4.3.1 Total Phenolic and Flavonoid Content of the Flora and its Health Benefits

The antioxidant capacity of 43 floral parts from 35 species (Fig. 49) frequently used in the Maasai TFS and TM (Fig. 14, 28, 44 - 47 and Appendix 4) was determined by the UV-Vis spectrophotometric method; it was measured in terms of total phenolic content (TPC) and total flavonoid content (TFC). The floral parts from which the antioxidant capacity was determined included bark (*Bk*), fruit (*Ft*), or pod (*Pd*), leaf (*Lf*), root (*Rt*), rhizome (*Rz*), stem (*St*), and whole aerial part (*Wap*). The percentage yield of floral parts ethanolic extracts ranged between 2.26 and 37.87% (Fig. 49). The TPC of the extract ranged between 0.02 ± 0.01 mg GAE/g (*Zanthoxylum chalybeum* Engl. fruit) and 231.39 ± 10.40 mg GAE/g (*Rhus vulgaris* Meikle root) as seen in Fig. 50. Moreover, TFC ranged between 1.24 ± 0.00 mg QE/g (*Lepidotrichilia volkensii* root) and 66.94 ± 0.03 mg QE/g (*Dalbergia melanoxylon* Guill. & Perr. root heartwood, *Rt-H*: black part) as shown in Fig. 51.

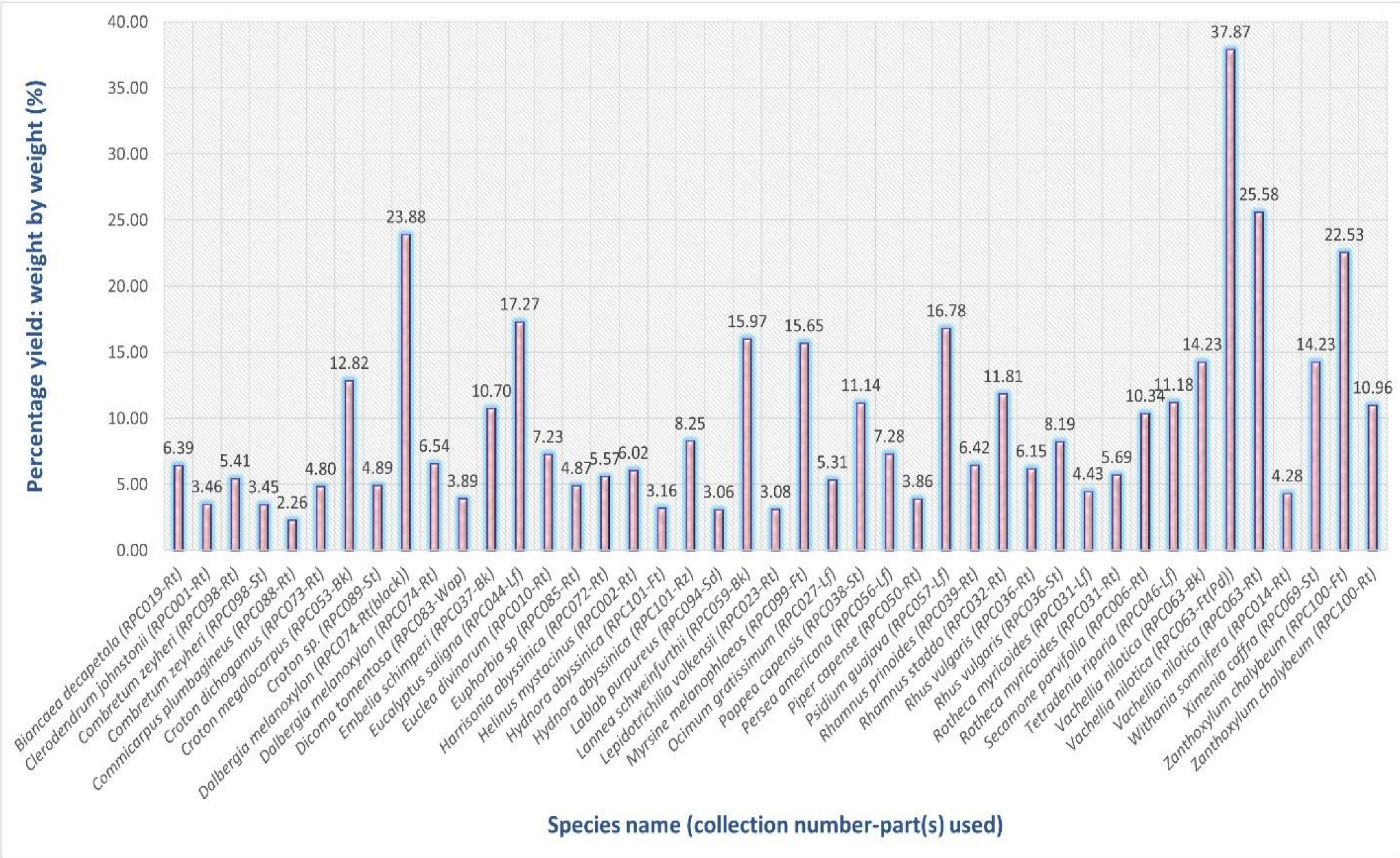


Figure 49: **The percentage yield of ethanolic extracts of floral parts commonly used in the TFS and TM**

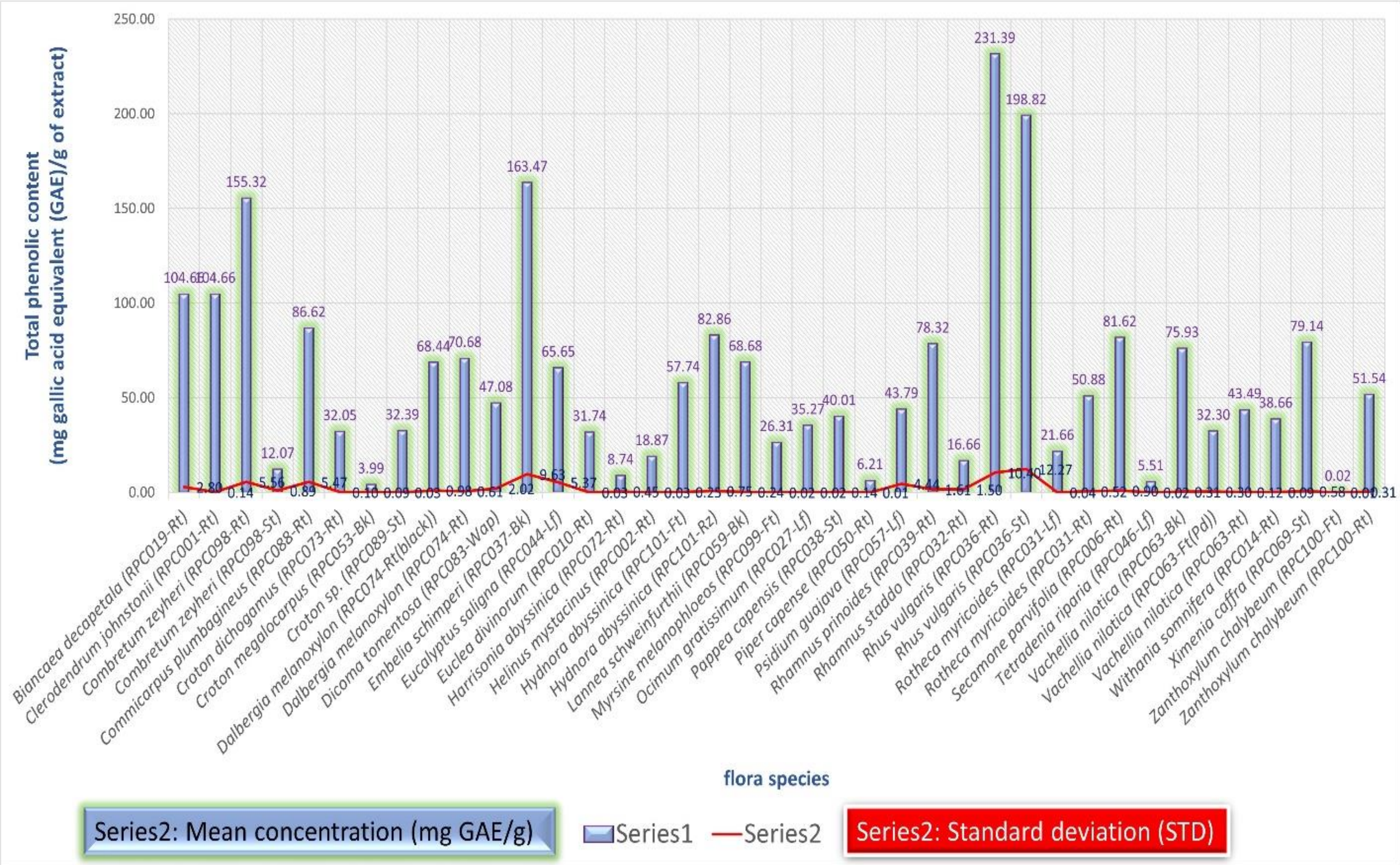


Figure 50: **Total phenolic content (mg GAE/g of extract) of flora used in the TFS and TM**

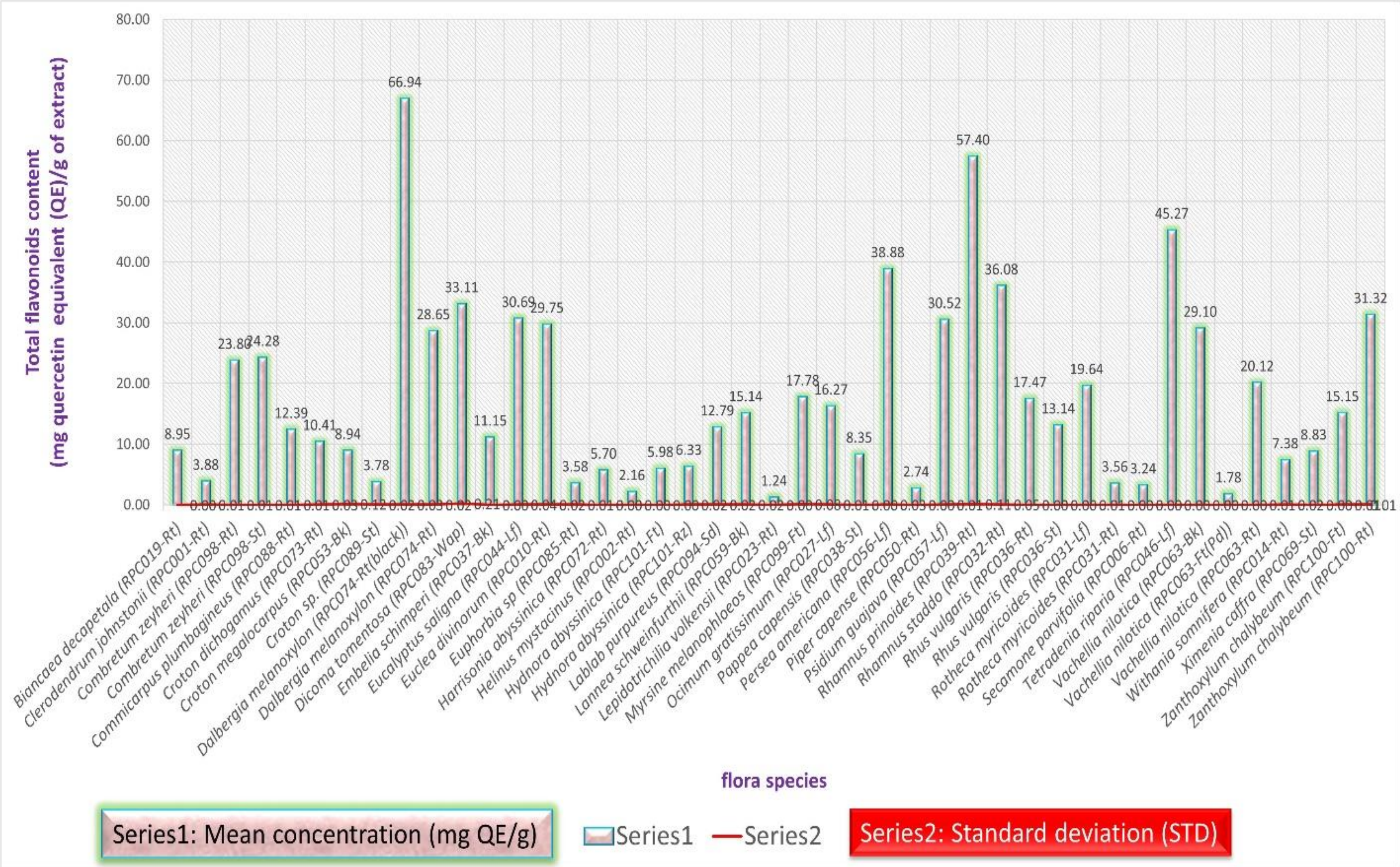


Figure 51: **Total flavonoid content (mg QE/g of extract) of flora used in the TFS and TM**

Among the species used in the Maasai TFS and TM, the *Rhus vulgaris* root had the highest TPC followed by its stem (Fig. 50). The leaf extract of this species is reported to have strong antioxidant activity though at a lower TPC (Table 5; Belew *et al.*, 2021) than the current TPC (Fig. 50): Phenolic content of a species may vary with flora parts and extracting methods or solvents (Fernando *et al.*, 2013). So, the roots and stem extract of this species (Fig. 50) are expected to have a higher antioxidant capacity: The TPC has a significant linear correlation with antioxidant capacity (Belew *et al.*, 2021). Phenolic compounds like 2-Hydroxy-4-methoxy benzaldehyde (**3**) present in this species contribute to its TPC and antioxidant capacity (Amarowicz & Pegg, 2019; Kougan *et al.*, 2013).

Moreover, compound (**3**) (Table 5) has anti-inflammatory and anticancer activity against various tumors including colorectal cancer (Ochwang'i *et al.*, 2014; Thangam *et al.*, 2019). Such biological activities lower the risk of developing gout and GACs like hyperchlorhydria and kidney disorders (Allegrini *et al.*, 2022; Shulkes & Baldwin, 2013; Stockton, 1897). Furthermore, *Rhus vulgaris* has TFC (Fig. 51) comparable to that reported (Table 5) elsewhere (Belew *et al.*, 2021). Flavonoids also have antioxidant and anti-inflammatory activities (Amarowicz & Pegg, 2019; Qi *et al.*, 2023). Still, flavonoids are among the polar compounds with diuretic properties (Aswini *et al.*, 2020). This supports the traditional use of *Rhus vulgaris* as one of the "*Olchani-imotori*" ingredients with kidney-cleansing properties (Appendix 4). So, the antioxidant capacity (TPC and TFC) of *Rhus vulgaris* supports its potential use against gout and GACs.

Table 5: Reported total phenolic and flavonoid content and biological activities of flora commonly used in the TFS and TM

Species	Extract TPC (mg GAE/g)	Extract TFC (mg QE/g)	Antioxidant/Anti-inflammatory/Anti-hyperuricemia activity			Compounds	Biological activity	Reference
			Assay: Standard (S)	C_E, µg/ml (%I)	C_S, µg/ml (%I)			
Rhus vulgaris	Lf-MeOH: (83.15 ± 7.6)	Lf-MeOH: (23.47 ± 4.87)	DPPH: Asc	163.63 (71.6%) 22.86 ± 3.71 mg AAE/g	49.00 (95.1%)	**Rt**: 2-Hydroxy-4-methoxy benzaldehyde (**3**)	anti-inflammatory; anti-tumor for skin, colorectal, & breast cancer	Belew *et al.* (2021), Kougan *et al.* (2013), and Ochwang'i *et al.* (2014)
Dalbergia melanoxylon	Bk-MeOH (42.8)	Bk-MeOH (5.9)	DPPH: Asc NO H_2O_2	10.22 (IC_{50}) 30.46 (IC_{50}) 33.14 (IC_{50})	13.35 (IC_{50}) 19.47 (IC_{50}) 27.74 (IC_{50})	**Rt-H**; Melanoxoin (**5**) isoliquiritigenin (**15**)	anticancer	Chung (2022) and Swetha (2017)
Embelia schimperi		Ft-$CHCl_3$	DPPH: Asc	58.2 (IC_{50})	4.42 (IC_{50})	**St**: 5-(7'Z-pentadecenyl) resorcinol (**4**), **Bk**: epicatechin (**17**), **Ft**: Embelin (**28**)	nematocidal, anticancer	Caruso *et al.* (2020), Guyasa *et al.* (2018), Tane *et al.* (2014), Zebeaman and Gebeyehu (2018)
Combretum Zeyheri	Lf-EtOH	Lf-EtOH	COX-1: Ind COX-2: Ind DPPH: Asc TMAMQ: GA	100 (97%) 100 (42%) 21 (100%) 25 (100%)	100 (0.4%) 100 (0.3%) 54 (100%) 31 (100%)	**Rt**: protocatechuic acid (**7**), procyanidin B3 (**21**)	Antioxidant, anti-inflammatory	Chirisa and Mukanganyama (2016), Fyhrquist *et al.* (2020)
	Lf-70%(aq)-Acetone (380)	Lf-70%(aq)-Acetone (15)	DPPH: Asc	31.25 (80%) 15.63 (IC_{50})	62.5 (90%)			Mathipa *et al.* (2022)
	St-70%(aq)-Acetone (350)	St-70%(aq)-Acetone (5)	DPPH: Asc	250 (80%) 125 (60%) 62.5 (IC_{50})	62.5 (90%)			
Withania somnifera	Rt-EtOH	Rt-EtOH	Xanthine Oxidase: Allopurinol	200 (76%) 100 (69%) 95 (IC_{50})	200 (93%) 100 (86%) 6.1 (IC_{50})	Quercetin (**22**), withaferin A (**29**), *Sitoindosides VII-X* (**30-33**)	anti-rheumatism (gouty arthritis) anxiety, mental disorder, stomach tonic, inflammation	Akram *et al.* (2014)
	Rt-MeOH	Rt-MeOH	DPPH: Asc	800ppm (66.1%)				Azhar *et al.* (2020)

Species	Extract TPC (mg GAE/g)	Extract TFC (mg QE/g)	Antioxidant/Anti-inflammatory/Anti-hyperuricemia activity			Compounds	Biological activity	Reference
			Assay: Standard (S)	C_E, µg/ml (%I)	C_S, µg/ml (%I)			
	(11.60 ± 0.350)	(39.13 ± 0.607)		400 ppm (54.6%) 100ppm (45.3%)				
Rhamnus prinoides	Rtb-MeOH (97.9)	Rtb-MeOH (57.06)	DPPH: Asc	253.0 (IC_{50})		laxative anthraquinones (**12**) apigenin (**26**), kaempferol (**27**)	anti-plasmodial rheumatism, antimalarial, anti-inflammatory	Kimondo *et al.* (2019 and Kimondo (2020)
	Rtb-$H_2$0 (95.3)	Rtb-$H_2$0 (29.34)	DPPH: Asc	377.3 (IC_{50})				
	St-EtOH (228.21 ± 13.34)	St-EtOH (352.25 ± 10.95) Rutin	DPPH: Trolox	510 (IC_{50})	121 (IC_{50})			Chen *et al.* (2020)
			COX-2: Asp	20.61 (IC_{50})				
Pappea capensis	Stb-MeOH (56.7)	Stb-MeOH (35.38)	DPPH: Asc	378.6 (IC_{50})	50.32 (IC_{50})	*p*-coumaric acid (**6**); **17**, quercetin-3-*O*-rhamnoside, (**25**), **26**, **27**, Vitamins: E (**14**) & C (**34**)	anti-inflammatory	Karau *et al.* (2012b) Kimondo *et al.* (2019), Kimondo (2020) and Muruthi *et al.* (2023b)
	Stb-H_2O (124.1)	Stb-H_2O (71.48)	DPPH: Asc	208.8 (IC_{50})				
Hydnora abyssinica	Rz-MeOH (0.31 ± 0.05)	Rz-MeOH (0.02 ± 0.01)				protocatechuic acid (**7**), Catechin (**16**)	Anti-gastric ulcer & anti-cancer	Teopolina (2019)
	Rz-EtOH	Rz-EtOH	DPPH	(77%)				Osman *et al.* (2014)
	Ft-EtOH	Ft-EtOH	DPPH: Asc	500 (80.3%) 100 (79.4%) 50 (74.5%) 10 (60.8%)	500 (97.1%) 100 (96.9%) 50 (96.9%) 10 (87.0%)			Al-Fatimi *et al.* (2016)
Harrisonia abyssinica	Rt-MeOH	Rt-MeOH (0.12 ± 0.02)	DPPH: Asc	493.94 (IC_{50})	10.14 (IC_{50})	Alloptaeroxylin (**13**), harrisonin (**35**)	Antimicrobial	Madivoli *et al.* (2018) and Masila (2014)

Species	Extract TPC (mg GAE/g)	Extract TFC (mg QE/g)	Antioxidant/Anti-inflammatory/Anti-hyperuricemia activity			Compounds	Biological activity	Reference
			Assay: Standard (S)	C_E, µg/ml (%I)	C_S, µg/ml (%I)			
	(0.08 ± 0.01)							
Zanthoxylum chalybeum	Stb-MeOH (4602 ± 32)	Stb-MeOH (6.18 ± 0.00)	DPPH: Trolox	1.57 (IC_{50})	0.05 (IC_{50})	Ailanthoidol (**11**), 6-acetonyldihydrochelerythrine (**12**), skimmianine (**36**), chalybemides: A-C (**37-39**), lupeol (**40**)	anti-diabetic	Masumbu *et al.* (2023) and Ochieng *et al.* (2020)
Lannea schweinfurthii	Rt-MeOH (101.27 ± 0.10)	Rt-MeOH (13.58 ± 0.30)	DPPH: Trolox	15.1 (IC_{50})	0.0096 (IC_{50})	Catechin **(16)**, epicatechin gallate (**20**)	Antioxidant	Adewusi and Steenkamp (2011b), Yaouba *et al.* (2018) and
	Bk-MeOH	Bk-MeOH	DPPH: Asc	5.6 (EC_{50})	5.0 (IC_{50})			Maroyi (2019)
Ximenia caffra	Lf-MeOH 261.87 ± 7.11	Lf-MeOH	ABTS: Trolox	1.46 ± 0.01 mmol Trolox/g		Gallic acid (**10**) catechin (**16**), quercetin (**22**), kaempferol (**27**),	antiproliferative	Zhen *et al.* (2015)
Biancaea decapetala	Wd-MeOH 13.28 ± 0.0057	Wd-MeOH 3.93 ± 0.005	DPPH: Asc	1500 (51.65%)	1500 (91.62%)	Resveratrol (**2**) Gallic acid **(10),** Epicatechin (**17**), quercetin (**22**), apigenin (**26**)	Antioxidant, anti-inflammatory	Patil and Deshmukh (2023) Pawar and Surana (2010)
Vachellia nilotica	Bk-MeOH (237.26 ± 1.83)	Bk-MeOH (118.32)	DPPH: Asc	54.61 (IC_{50})	50.32 (IC_{50})	Quercetin (**22**), Kaempferol (**27**)	anti-inflammatory, anticancer Ali *et al.* (2012)	Al-Nour *et al.* (2019), Eldeen *et al.* (2010) and Kimondo *et al.* (2019) Kimondo, (2020)
	Bk-H_2O (149.66 ± 0.60)	Bk-H_2O (83.75)	DPPH: Asc	102.96 (IC_{50})	50.32 (IC_{50})			
Ocimum gratissimum	Lf-EtOH (242.3)	Lf-EtOH (73.55)	DPPH: BHT	395 (IC_{50})	580 (IC_{50})	quercetin (**22**), apigenin (**26**) ursolic acid (**41**)	Antioxidant, anti-inflammatory, Anticarcinogenic	Ouyang *et al.* (2013)
	Lf-EtOAc fraction (330.21)	Lf-EtOAc fraction (92.58)		750 (83.18%) 148 (IC_{50})	750 (80.54 %) 580 (IC_{50})			

Species	Extract TPC (mg GAE/g)	Extract TFC (mg QE/g)	Antioxidant/Anti-inflammatory/Anti-hyperuricemia activity			Compounds	Biological activity	Reference
			Assay: Standard (S)	C_E, μg/ml (%I)	C_S, μg/ml (%I)			
	Lf-EtOAc (10.34 ± 0.47)	Lf-EtOAc	DPPH: Asc Fe Chelation: 1,10-phenanthroline	1580 (IC_{50}) 5510 (IC_{50})				Ajayi *et al.* (2017) and Ojo *et al.* (2013)

DPPH, 2,2´-diphenyl-1-picrylhydrazyl radical; *Asc*, Ascorbic acid (Vitamin "C"); C_E, extract concentration; C_S, standard concentration; *%I*, percentage inhibition; *XO*, xanthine oxidase; H_2O_2, hydrogen peroxide; *NO*, nitric oxide; IC_{50}, concentration inhibiting 50% substances like XO, DPPH, H_2O_2, and NO; *COX-1/2*, Cyclooxygenase-1/2; *EtOH*, ethanol; *MeOH*, methanol; *EtOAc*, ethyl acetate; *Wd*, wood; *Rtb*, root bark; *Stb*, stem bark; *ABTS*, 2,2′-azinobis(3-ethylbenzothiazoline-6-sulfonic acid; *BHT*, butylated hydroxytoluene; *TMAMQ*, tetramethoxy azobismethylene quinone; *Asp*, aspirin; *Ind*, indomethacin; GA, Gallic acid

Dalbergia melanoxylon root heartwood had the highest TFC (Fig. 51). Also, its TPC was slightly higher than TFC (Fig. 50 & 51). The bark extract of this species has antioxidant properties close to or higher than ascorbic acid (Asc) or vitamin C (Swetha, 2017) though at lower TPC and TFC (Tables 5) than measured in the current study (Fig. 50 & 51). Thus, the root heartwood extract of this species is expected to have higher antioxidant activities than its bark. This can be supported by the finding that wood extractives are more concentrated in the heartwood of some tropical wood including *Dalbergia melanoxylon* (Yin *et al.*, 2018). The phenolic compounds melanoxoin (**5**) and isoliquiritigenin (**15**) (Table 5) present in *Dalbergia melanoxylon* root heartwood contribute to the antioxidant capacity of this species (Amarowicz & Pegg, 2019; Chung, 2022). Compounds **5** and **15** have anticancer activity against various tumors including colorectal cancer (Chung, 2022). Thus, they can lower the risk of developing gout and GACs including hyperchlorhydria and kidney disorders (Allegrini *et al.*, 2022; Shulkes & Baldwin, 2013; Stockton, 1897). Accordingly, the antioxidant capacity and anticancer properties of *Dalbergia melanoxylon* could support the traditional use of this species in preparing "*Olchani-imotori*" (Fig. 28) with preventive and therapeutic effects on diseases including "*Olgila*" (gout) and GACs (Fig. 44 - 47 & Appendix 4). Also, using *Dalbergia melanoxylon* as a pestle in processing Maasai foods (Fig. 20) could introduce such medicinal properties into processed foods, lowering the risk of developing gout and GACs.

Embelia schimperi Vatke was the second species with a relatively high TPC next to *Rhus vulgaris*: its bark had a TPC of 163.47 ± 9.63 mg GAE/g of extract (Fig. 50). Stem and bark of *Embelia schimperi* contain phenolic compounds like 5-(7'Z-pentadecenyl) resorcinol (**4**) and epicatechin (**17**) (Guyasa *et al.*, 2018; Tane *et al.*, 2014); thus, they contribute to TPC and antioxidant property of the species (Amarowicz & Pegg, 2019). Compounds **4** and **17** (Table 5) also have anti-inflammatory and anticancer activities (Qi *et al.*, 2023; Tane *et al.*, 2014).

Moreover, species of sub-family Myrsinodae including *Embelia schimperi* and *Myrsine melanophloeos* (L.) R. Br. ex Sweet contain a non-phenolic compound, embelin (**28**) which has antioxidant, anticancer and nematicidal activities (Caruso *et al.*, 2020; Zebeaman & Gebeyehu, 2018). Thus, the antioxidant capacity (Fig. 50 & 51) and reported biological activities of these species could support their traditional uses against gastrointestinal parasitic infection and gout, "*Olgila*" (Fig. 45 - 47 & Appendix 4): They associate with OS (Allegrini *et al.*, 2022; Celi, 2011). Traditional use of these species could support the low prevalence of such conditions in Maasai communities (Kimondo, 2020; Kuhnlein, 2014). However, *Embelia schimperi* benefits only men and post-menopause women. The compound (s) in *Embelia* *schimperi* that are responsible for the induction of excess menstrual flow and pregnancy abortion are yet to be determined.

Combretum Zeyheri Sond was the third species with a relatively high TPC next to *Embelia schimperi*: Its root had a TPC of 155.32 ± 5.56 mg GAE/g of extract (Fig. 50). The root of this species contains various phenolic compounds including protocatechuic acid (**7**) and procyanidin B3 (**21**) (Fyhrquist *et al.*, 2020); thus, they contribute to its TPC and antioxidant activity (Amarowicz & Pegg, 2019). Procyanidin B3 like other proanthocyanidins have anti-inflammatory activity; they can inhibit cyclooxygenase enzymes (Amarowicz & Pegg, 2019).

Antioxidant and anti-inflammatory activities of this species are elsewhere reported (Chirisa & Mukanganyama, 2016; Mathipa *et al.*, 2022) though with different parts (Table 5) at high TPC and low TFC compared to that of root determined in this study (Fig. 50 & 51). Since the TFC of the roots and stem of *Combretum Zeyheri* is higher (Fig. 51) than previously reported extracts (Table 5), their antioxidant activity through chelation is expected to be higher too than that of the reported extracts. This may explain why *Combretum Zeyheri* is among the species used by Maasai as holding stick ("*orjibet*") for roasting meat instead of metal irons (Fig. 23): Flavonoids like procyanidin present in this species can prevent Fenton reaction through chelating the iron in meat during the roasting process (Amarowicz & Pegg, 2019; García-Montero *et al.*, 2021). This may reduce lipid peroxidation and its secondary products like MDA, which lead to the formation of advanced glycation end products (AGEs) when roasting meat (Zinöcker & Lindseth, 2018).

So, the traditional uses of *Combretum Zeyheri* as in roasting meat may prevent cardiovascular and CKD caused by AGEs (Aschner *et al.*, 2023). Thus, the antioxidant capacity and reported biological activities of *Combretum Zeyheri* support the traditional use of the species against gout, "*Olgila*" (Fig. 47). Also, *Combretum Zeyheri* is among the ingredients used to prepare "*Olchani-imotori*": thus, the traditional use of this preparation against gout, "*Olgila*" by Maasai is evident (Fig. 28, 40 – 47 and Appendix 3 - 4) as reported elsewhere (Clement *et al.*, 2023).

In this study, it was observed that the TPC of the *Combretum Zeyheri* stem was lower (12.07± 0.89 mg GAE/g) than its TFC (24.28 ± 0.01 mg QE/g) (Fig.). This is unusual as TPC is expected to be higher than TFC: Flavonoids are a family of polyphenols (Lawag *et al.*, 2023). This unusual variation could be explained by the presence of non-flavonoids, which are not necessarily phenolic compounds that give a positive reaction with aluminum chloride ($AlCl_3$) used in the colorimetric determination of TFC, or could be due to an insufficient amount of

Folin-Ciocalteu reagent used in determining the TPC (Molole *et al.*, 2022). Though in this study, an insufficient amount of Folin-Ciocalteu reagent was avoided by diluting the sample when maximum absorbance was reached, Section 3.2.3 (b). So, the probable variation could be the non-flavonoids, which give a positive reaction with $AlCl_3$; this could also apply in other species. Despite this variation, the TPC and TFC make *Combretum Zeyheri* a potential antioxidant and anti-hypeuricamia agent against gout and GACs.

Still, *Withania somnifera* and *Rhamnus prinoides* L. Her were among the common species used to prepare "*Olchani-imotori*" (Fig. 28). The TPC of *Withania somnifera* root extract (Fig. 50) was higher than previously reported (Table 5) while its TFC (Fig. 51) was relatively lower than previously reported (Table 5) (Azhar *et al.*, 2020). So, the radical scavenging activity of its root extract is expected to be higher than previously reported (Table 5). *Withania somnifera* root contains quercetin (**22**) with antioxidant and inhibitory activity against XO (Akram *et al.*, 2014). This supports its use against gout, "*Olgila*" (Fig. 47) as reported by Akram *et al.* (2014). Likewise, *Rhamnus prinoides* contain apigenin (**26**) and kaempferol (**27**) (Chen *et al.*, 2020) with inhibitory activity against XO (Ayyappan & Nampoothiri, 2020); supporting its traditional use against gout, "*Olgila*" (Fig. 47).

Besides, *Withania somnifera* and *Rhamnus prinoides* are among the species claimed to manage various conditions including "*Olgila*" through diuresis induction (Appendix 4) which is also the property of "*Olchani-imotori*" (Appendix 3). Flavonoids like compounds **22**, **26** and **27** are among the polar compounds, that induce diuresis by stimulating regional blood volume, initial vasodilation, or inhibiting tubular reabsorption of water and anions to manage conditions associated with fluid retention (Aswini *et al.*, 2020). Thus, the high TFC of *Rhamnus prinoides* (Fig. 51) could support its common use as a diuretic agent in managing such inflammatory conditions (Appendix 4). The diuretic property of *Withania somnifera* could be enhanced by other polar non-phenolic compounds in addition to its TFC (Fig. 51). *Withania somnifera* contains withaferin A (**29**) and sitoindosides *VII-X* (**30**-**33**) (Saleem *et al.*, 2020). Triterpenoids like withaferin A and saponins like sitoindosides *VII-X* are also polar compounds with diuretic activity (Aswini *et al.*, 2020).

Moreover, Withaferin A and sitoindosides *VII-X* have antioxidant, memory-enhancing, neural protective, anti-stress, anticancer, hepatoprotective or anti-lipid peroxidation properties (Gavande *et al.*, 2015; Saleem *et al.*, 2020). Thus, *Withania somnifera* is elsewhere reported to be used against gout and GACs like hypertension, diabetes, cancer, cognitive decline, kidney disorders and infertility or reduced libido (Gavande *et al.*, 2015; Saleem *et al.*, 2020). Therefore, antioxidant capacity and other biological activities against gout and GACs can also be contributed by non-phenolic phytochemicals; though, not ubiquitous in flora like phenolic compounds are (Kougan *et al.*, 2013).

Furthermore, *Pappea capensis* Eckl. & Zeyh had TPC of 40.01 ± 0.14 mg GAE/g of stem extract (Fig. 50). *Pappea capensis* extract has an antioxidant property at TPC (Table 5) comparable to that determined in the current study (Fig. 50). So, the *Pappea capensis* stem extract (Fig. 50) is expected to have an antioxidant capacity close to that of the previously reported extract (Table 5). *Pappea capensis* stem contains phenolic compounds *p*-coumaric acid (**6**), α-tocopherol (vitamin E) (**14**), catechin (**16**), epicatechin (**17**), quercetin (**22**), quercetin-3-O-rhamnoside (**25**), apigenin (**26**), and kaempferol (**27**); thus, they contribute to its TPC and antioxidant capacity (Amarowicz & Pegg, 2019; Muruthi *et al.*, 2023a). Moreover, the flavonoids (**16**, **17**, **22** and **25-27**) contribute to the TFC of *Pappea capensis* (Fig. 51). Compounds **22**, **26** and **27** have inhibitory activity against XO (Ayyappan & Nampoothiri, 2020). In addition, compound **14** prevents lipid peroxidation and arteriosclerosis (Karau *et al.*, 2012a). Also, *Pappea capensis* contains the non-phenolic compound, vitamin C (**34**) with arteriosclerosis and anti-lipid-peroxidation properties. So, the antioxidant capacity and the reported biological activities of the contributing phytochemicals in *Pappea capensis* support the use of this species in cleaning blood vessels and increasing libido. This species can potentially be used against gout and GACs like hypertension and decreased libido.

Still, *Hydnora abyssinica* A. Braun was among the most common species used against blood pressure. Its rhizome had a TPC of 82.86 ± 0.75 mg GAE/g of extract (Fig. 50), higher than the previously reported extract (Table 5). The same trend was observed for TFC (Fig. 51 & Table 5). Thus, the antioxidant capacity of the rhizome extract is expected to be higher than previously reported (Table 5). Also, the rhizome of *Hydnora abyssinica* contains phenolic compounds like protocatechuic acid (**7**) and catechin (**16**) (Al-Fatimi *et al.*, 2016); thus, contributing to the TPC. Likewise, catechin contributes to the TFC (Amarowicz & Pegg, 2019). The compounds have antioxidant and anti-inflammatory activities (Al-Fatimi *et al.*, 2016; Amarowicz & Pegg, 2019). So, the antioxidant capacity of *Hydnora abyssinica* rhizome which is contributed by the compounds with such biological properties, supported the use of this species against hypertension; thus, lowering the risk of developing gout and GACs.

Besides, *Harrisonia abyssinica* was among the most common species used to manage ankle edema, associated with inflammatory conditions including hypertension. *Harrisonia abyssinica* root extract had relatively higher TPC and TFC (Fig. 50 & 51) than previously reported (Table 5); thus, its antioxidant capacity is expected to be higher than previously reported (Table 5). Phenolic compounds like alloptaeroxylin (**13**) contribute to the antioxidant capacity of this species (Masila, 2014). The diuretic properties of the flavonoids like compound **13** and triterpenoids like harrisonin (**35**) present in *Harrisonia abyssinica* root could support its use against ankle edema (Aswini *et al.*, 2020). So, the antioxidant capacity of this species and the biological activities of the compounds support the potential use of this species against gout and GACs like hypertension and edema.

Zanthoxylum chalybeum was the most common species used to manage **R** health conditions: Cough, influenza and pneumonia. It was also used to manage **A** health conditions: Fever and malaria. *Zanthoxylum chalybeum* root extract had relatively higher TPC and TFC than its fruits (Fig. 50 & 51). So, its root is expected to have a higher antioxidant capacity than its fruits. Ailanthoidol (**11**) and 6-acetonyldihydrochelerythrine (**12**) contribute to the TPC and antioxidant capacity of this species (Mguni *et al.*, 2023). The antioxidant capacity of this species can be enhanced by non-phenolic compounds like skimmianine (**36**) with antioxidant activity (Okagu *et al.*, 2021). The alkaloids including compounds **12** and **36** have antimicrobial and antispasmodic properties (Mguni *et al.*, 2023). Thus, the antioxidant capacity of this species has a potential role in managing both OS and respiratory infection or malaria, which leads to ARDS and consequent OS (Taylor *et al.*, 2012). This can lower the risk of developing gout and GACs like ARDS, COPD and malaria (Ozanturk *et al.*, 2016; Taylor *et al.*, 2012). Likewise, the anti-diabetic properties of compounds **12**, **36** and chaylbemides (A-C) (**37**-**39**) further enhance the capacity of *Zanthoxylum chalybeum* to lower the risks of developing gout (Gherghina *et al.*, 2022; Ochieng *et al.*, 2020). Still, the gastroprotective and hepatoprotective properties of skimmianine (**36**) and lupeol (**40**) respectively enhance the capacity of *Zanthoxylum chalybeum* to lower the risk of developing gout (Mguni *et al.*, 2023; Okagu *et al.*, 2021; Stockton, 1897).

Lannea schweinfurthii and *Ximenia caffra* had TPC of 68.68 ± 0.24 mg GAE/g bark extract and 79.14 ± 0.58 mg GAE/g stem extract respectively (Fig. 50). Also, they had a TFC of 15.14 ± 0.02 and 8.83 ± 0.00 mg QE/g of the extract, respectively (Fig. 51). The presence of phenolic compounds like gallic acid (**10**) catechin (**16**), epicatechin gallate (**19**), quercetin (**22**) and kaempferol (**27**) in the species (Adewusi & Steenkamp, 2011a; Maroyi, 2019; Yaouba *et al.*, 2018; Zhen *et al.*, 2015) contribute to their TPC and TFC. Previous studies showed that the same species had antioxidant activity and relatively higher TPC and TFC than in the present study: Though different parts and solvents were used (Adewusi & Steenkamp, 2011a; Zhen *et al.*, 2015) as shown in Table 5. The antioxidant capacity of these species (Fig. 50 & 51) contributed by the phenolic compounds with antioxidant, anti-inflammatory and anti-hyperuricemia properties (Ayyappan & Nampoothiri, 2020) can support the use of these species against gout, "*Olgila*" and GACs including **W** conditions like pregnancy abortion (Fig. 47 & Appendix 4): Antioxidants like phenolic compounds can manage OS associated with pregnancy (Di Fabrizio *et al.*, 2022). Thus, Maasai women who frequently consume the species along with food or medicinal preparations like "*Olchani-imotori*" and "*Shai-ekulee*" (Fig. 28-32 & Appendix 4) may have a lower risk of developing pregnancy-associated complications like gout, preeclampsia and abortion (Horta-baas *et al.*, 2017).

Biancaea decapetala, *Ocimum gratissimum*, and *Vachellia nilotica*, were among the species used to manage **D** conditions as discussed earlier. *Biancaea decapetala* root extract had TPC and TFC (Fig. 50 & 51) higher than the extract of the other part reported elsewhere (Table 5); thus, the antioxidant capacity of the root extract is expected to be higher than that of the other part (Table 5). *Ocimum gratissimum* leaf and *Vachellia nilotica* bark extracts had TPC and TFC (Fig. 50 & 51) relatively less than that of its extracts, which have antioxidant activities as reported elsewhere (Table 5). Despite the relatively low TPC and TFC, the extracts of the latter two species are expected to have antioxidant activities: Though relatively lower than previously reported (Table 5). The phenolic compounds, resveratrol (**2**), gallic acid (**10**), epicatechin (**17**), quercetin (**22**), apigenin (**26**) and kaempferol (**27**) present in *Biancaea decapetala*, *Ocimum gratissimum*, and *Vachellia nilotica* (Ajayi *et al.*, 2017; Al-Nour *et al.*, 2019; Patil & Deshmukh, 2023) contribute to their TPC and TFC (Amarowicz & Pegg, 2019). The antioxidant capacity of *Ocimum gratissimum* can be enhanced by non-phenolic compounds, like ursolic acid (**41**).

Furthermore, the antioxidant capacity of these species (Fig. 50 & 51) contributed by such phytochemicals promoting gut commensal microbiota, keeping gut epithelial barrier integrity and inhibiting XO (Ayyappan & Nampoothiri, 2020; García-Montero *et al.*, 2021) can support the species' use against hyperchlorhydria symptoms and in facilitating digestion (Appendix 4). These species can lower the risks of developing gout and GACs including hyperchlorhydria.

Indeed, the TPC and TFC of extracts of the flora determined in the current study (Fig. 50 & 51) are comparable to the extracts determined previously which had antioxidant activities between 1.57 µg/ml (IC_{50}) at high TPC and 493.94 µg/ml (IC_{50}) at low TPC (Table 5). So, the flora used in the Maasai TFS and TM are also expected to have antioxidant activities comparable to their previous extracts. The flora's antioxidant capacities (TPC and TFC) support their use against ailments including MDs like gout, "*Olgila*" and GACs. Also, the antioxidant capacities indicate the presence of antioxidant agents like polyphenols with anti-inflammatory, and anti-hyperuricemia activities in the flora used against gout, "*Olgila*" and GACs.

However, mineral nutrients in the flora can enhance the antioxidant, anti-inflammatory, and anti-hyperuricemia properties of the phytochemicals and vice versa. For instance, the presence of manganese can enhance the inhibition of xanthine oxidase by luteolin, a phenolic compound (Dong *et al.*, 2017); thus, increasing the antioxidant and anti-hyperuricemia properties of the species containing both manganese and luteolin. Likewise, the antioxidants, polyphenols can prevent oxidation of nitric oxide, NO (Ashworth *et al.*, 2015), a vasodilator increasingly produced by the adequate intake of potassium (Oberleithner *et al.*, 2009); thus, lowering the risk of hypertension and hyperuricemia may be enhanced in flora with both adequate potassium and antioxidants. Therefore, determining the mineral content of flora is important in understanding which flora have significant mineral contributions in managing such MDs: Mineral content may vary with species and environment in which a specie grow (Soetan *et al.*, 2010).

4.4 Mineral Content of the Flora and its Health Benefits in the Maasai TFS and TM

4.4.1 Potassium Content of the Flora and Its Health Benefits

Analysis of 43 floral parts from 35 commonly used species using FP6440 flame photometry showed that the flora had potassium (K) content ranging from 97.68 mg K 100 g -1 (*Rhamnus prinoides* root) to 1392.01 mg K 100 g -1 (*Piper capense* root). Flora with high potassium content and frequent use in the Maasai TFS and TM supported their use against gout and GACs.

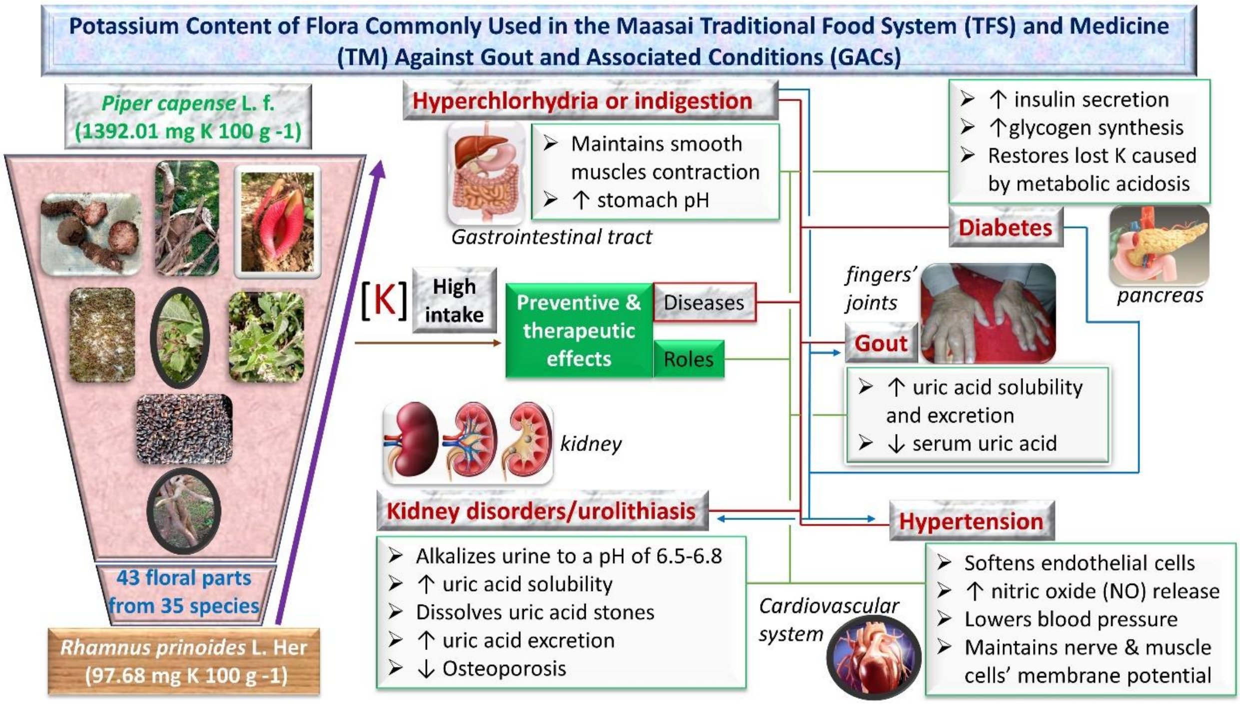


Figure 52: Graphical summary of objective four results, K content

(i) Potassium Content and Health Benefits of Flora

The potassium content (Kc) of 43 floral parts from 35 species frequently used in the Maasai TFS and TM was determined by the FP6440 flame photometer. The floral parts from which the Kc was determined included bark (*Bk*), fruit (*Ft*) or pod (*Pd*), leaf (*Lf*), root (*Rt*), rhizoid (*Rz*), stem (*St*) and whole aerial part (*Wap*). The flame photometer measured potassium concentration against the standard calibration curve (Table 4). The potassium concentration of each sample was measured in mmol/L by the instrument and later converted to mg/100g -dry weight (Fig. 53): It is based on Codex Alimentarius Commission, CAC per 100 g (Forouzesh *et al.*, 2022). Based on CAC per 100 g, Kc of the floral parts of the species used in the Maasai TFS and TM ranged between 97.68 mg K 100 g $^{-1}$ (*Rhamnus Prinoides* root) and 1392.01 mg K 100 g $^{-1}$ (*Piper capense* root) (Fig. 53).

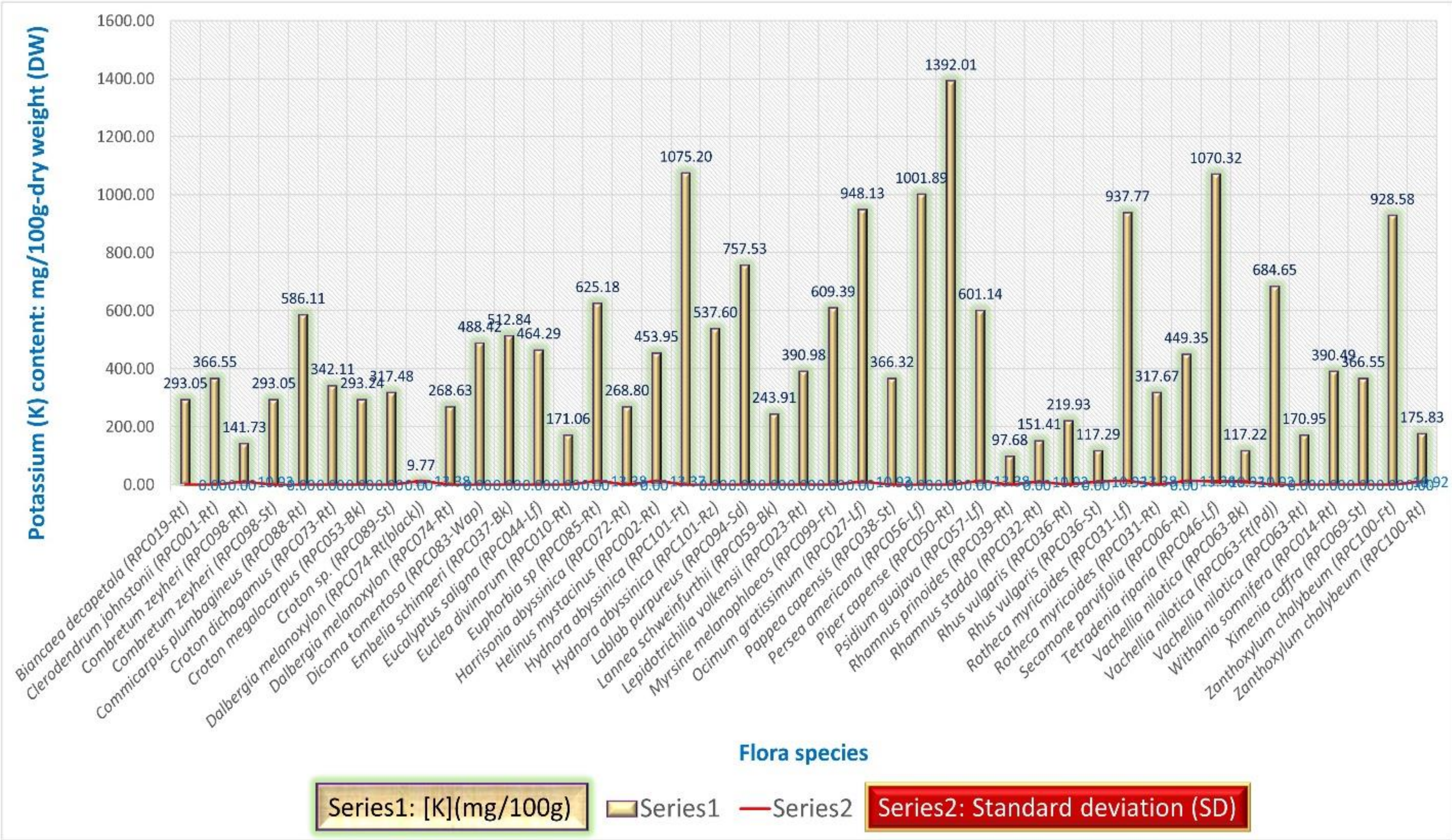


Figure 53: Potassium concentration in milligrams (mg) per 100-gram DW of a used plant part

Flora especially fruits and vegetables are among the important sources of potassium (McLean & Wang, 2021). High intake of fruits and vegetables, especially as traditional diets, helps to meet the recommended daily potassium intake (RDI), which ranges between 3500 mg and 4700 mg of potassium per day (Khan *et al.,* 2012). The RDI of potassium within the ranges is known to prevent and manage various MDs including gout and its comorbid conditions (Khan *et al.,* 2012). Indeed, high potassium intake helps to sustain serum potassium at its normal concentration range, 3.5-5.5 mmol/L (Khan *et al.*, 2012; Weiss *et al.*, 2017). High serum potassium within its normal physiological range reduces the risks for acquiring MDs such as arrhythmias, hypertension, stroke, gout, insulin resistance and some disorders of the kidney and digestive organs that may occur as a consequence of hypokalemia, serum potassium concentration below its normal range (Barbera *et al.*, 2016; MacGregor & He, 2001; McLean & Wang, 2021; Weiss *et al.*, 2017).

Floral parts of the species used in the Maasai TFS and TM had potassium concentrations ranging from 97.68 mg K 100 g $^{-1}$ (*Rhamnus Prinoides* root) and 1392.01 mg K 100 g $^{-1}$ (*Piper capense* root) (Fig. 53). These species are traditionally used to prevent and treat various diseases (Appendix 4): Some are MDs that may occur due to hypokalemia (McLean & Wang, 2021).

Piper capense root had the highest potassium concentration compared to other used plant parts (Fig. 53). This species is used as an ingredient in the Maasai herbal meat soup, "*Olchani-imotori*" (Fig. 28), and as medicine against joint pain and inflammation (Fig. 47). Also, it is used to induce diuresis (Appendix 4). Joint pain and inflammation are among gout's symptoms, managed by diuretic agents (Sharma *et al.*, 2019). Consumption of natural food sources or medicine with high Kc usually increases serum potassium level and maintains it to its normal range, 3.5-5.5 mmol/L (Khan *et al.*, 2012; Weiss *et al.*, 2017). High serum potassium within its normal range prevents precipitation of uric acid into uric acid renal stones caused by hyperuricemia and urinary acidic pH of 5.0-5.5 (Barbera *et al.*, 2016). So, high Kc in *Piper capense* root may support its traditional use against "*olgila*" and in cleansing kidneys (Appendix 4). Also, the high Kc and diuretic properties of *Piper capense* may support its use against hypertension. *Piper capense* is traditionally used against hypertension (Kasali *et al.,* 2021).

Consumption of diuretics with high potassium concentration may help to prevent hypokalemia which may occur when diuretics that do not spare potassium are used especially in treating conditions such as hypertension, which is associated with edema (Weiss *et al.*, 2017). Hypokalemia may result in arrhythmias due to its electrophysiological effects: Resting membrane hyperpolarization, Na^+-K^+ ATPase inhibition, and suppression of K^+ channel conductance (Weiss *et al.*, 2017). So, high potassium intake from such plant sources is vital for preventing and managing gout and GACs like hypertension and arrhythmias.

Still, the use of *Piper capense* against hypertension can be supported by the beneficial effect of potassium on cardiovascular function (Oberleithner *et al.*, 2009). Increased serum potassium concentration within the normal physiologic range softens vascular endothelium and consequently increases the release of nitric oxides, NO (Oberleithner *et al.*, 2009). The effect of potassium on the vascular endothelium and NO release is enhanced at lower serum sodium and aldosterone concentrations (Oberleithner *et al.*, 2009). NO is a powerful vasodilator; thus, it increases blood flow and reduces blood pressure (Ashworth *et al.*, 2015). Polyphenols protect nitric oxide from oxidation, enhancing its vasodilation activity (Ashworth *et al.*, 2015). So, the effect of potassium in reducing blood pressure may be increased by intake of antioxidants. Accordingly, the use of *Piper capense* against hypertension can be linked to its high concentration of potassium and partly by the presence of antioxidants and nitrates, which generate the NO (Ashworth *et al.*, 2015; Kasali *et al.*, 2021; Sokamte *et al.*, 2019).

Besides, this study recorded *Hydnora abyssinica* as the second leading species with the relatively highest potassium concentration at 1075.20 mg K 100 g^{-1} of its fruit (Fig. 53). But its rhizome had a concentration of 537.60 mg K 100 g^{-1}. Its fruit is a food source (Fig. 14) while rhizome is used for medicinal purposes against various ailments including diabetes and pressure (Appendix 4) as it is reported elsewhere (Hafeez *et al.*, 2016; Osman & Badwi, 2010). The use of this species against diabetes could be supported by the role of potassium on glucose intolerance (MacGregor & He, 2001). Intake of potassium restores the lost potassium due to metabolic acidosis (McLean & Wang, 2021). Also, potassium is among the elements responsible for secreting insulin from the beta cells of the pancreas (Khan *et al.*, 2012). Increased potassium intake usually improves glucose intolerance by lowering blood glucose through the increased secretion of insulin and glycogen synthesis (Khan *et al.*, 2012; MacGregor & He, 2001). Although fruit of *Hydnora abyssinica* is reported to be used as a food source, its higher potassium concentration than in the species rhizome suggests that the consumption of fruit can potentially be more effective against diabetes than the rhizome.

Furthermore, this study recorded *Tetradenia riparia* as the third species with a relatively high potassium concentration at 1070.32 mg K 100 g $^{-1}$ of its leaves. This was followed by the leaves of *Persea americana* with concentration of 1001.89 mg K 100 g $^{-1}$. *Persea americana* was followed by *Ocimum gratissimum*, *Rhotheca myricoides*, *Zanthoxylum chalybeum*, *Lablab purpureu* and *Vachellia nilotica* with concentrations of 948.13, 937.77, 928.58, 757.53 and 684.65 mg K 100 g $^{-1}$ of its used part, respectively (Fig. 53).

Tetradenia riparia, *Ocimum gratissimum* and *Vachellia nilotica* are traditionally used against gastrointestinal disorders: indigestion, stomach bloating and constipation (Appendix 4). The disorders are among the symptoms of hyperchlorhydria which is the marked condition in gout patients (Stockton, 1897). Potassium in alkaline salt form is one of the important remedies against hyperchlorhydria and subsequent gout (Chambers, 1901; Stockton, 1897). Furthermore, potassium plays an important role in muscle contraction, thereby its increased intake improves conditions like constipation (Daly & Farrington, 2013). So, potassium in the species can support their traditional use against such gastrointestinal disorders, and these species can potentially be used against gout associated with hyperchlorhydria.

Ocimum gratissimum is traditionally used against renal stones: it has anti-urolithiasis properties (Khan *et al.*, 2017). Consumption of potassium particularly its alkaline salts like citrate and bicarbonate salts can alkalize urine to a pH value between 6.5 and 6.8, dissolving the renal stones and preventing the precipitation of uric acid into renal stones (Barbera *et al.*, 2016). This may prevent kidney damage and the rising of the serum uric acid thereby reducing the complication of gout and vascular stiffness associated with hyperuricemia (Barbera *et al.*, 2016; Ramirez-Sandoval *et al.*, 2017). So, *Ocimum gratissimum* may contain anions that form alkaline salts of its potassium thereby supporting the use of the species against urolithiasis. It can potentially be used against hypertension, associated with vascular stiffness (Ramirez-Sandoval *et al.*, 2017). Moreover, *Ocimum gratissimum* is reported elsewhere to have strong xanthine oxidase inhibitory activity thereby being a potential therapy against gout (Ajayi *et al.*, 2017). The therapeutic effect of *Ocimum gratissimum* against gout is related to the free radical scavenging activity of its phenolic compounds, though (Ajayi *et al.*, 2017). While Ajayi *et al.* (2017) link the anti-gout property of Ocimum gratissimum to its anti-oxidants, the phenolic compounds this study links the anti-gout property of the species to its potassium which can manage uric acid renal stone (gout). Indeed, a high intake of potassium through the consumption of such vegetables is known to offer therapeutic effects and protection from kidney diseases (Lanham-New *et al.*, 2012; McLean & Wang, 2021). Low intake of potassium at late chronic kidney disease or renal failure is recommended, though (McLean & Wang, 2021).

Although the species containing potassium are expected to play a role in the management of gout and its comorbid conditions, they may have varying contributions to the management of the conditions depending on their potassium concentration and frequency of use (McLean & Wang, 2021). For instance, in the Maasai community of Monduli some of the species were frequently used as food sources (Fig. 14) or ingredients in the Maasai foods (Fig. 11 and Appendix 3) while others were used without being integrated into the foods to treat ailments only when it was required (Appendix 4).

Exceptional to the plant parts of *Rhotheca myricoides*, *Dicoma tomentosa*, *Eucalyptus saligna*, *Euphorbia* sp, *Persea americana*, *Psidium guajava* and *Tetradenia riparia*; the parts of the remaining 28 species (Fig. 53) were integrated into various Maasai foods particularly "*Olchani-imotori*" (a mixture of herbal decoction and meat broth or stock), milk, tallow, clarified butter and animal blood (Fig. 28 & Appendix 4). The species parts integrated into the Maasai foods have various roles: improving the quality of the foods and treating and preventing ailments (Appendix 3).

For instance, the plant parts of *Ocimum gratissimum*, *Zanthoxylum chalybeum*, *Vachellia nilotica*, *Myrsine melanophloeos*, *Ximenia caffra* and *Croton sp*. (Fig. 53) are traditionally used to improve aroma, taste, color, of the Maasai herbal milk tea, "*Shai-ekulee*" (Fig. 32). They also prevent and treat conditions like constipation, stomach bloating, indigestion, diabetes, joint pain and inflammation (Appendix 4).

Moreover, *Piper capense* and *Vachellia nilotica* improve the aroma, color and taste of the "*Olchani-imotori*", usually consumed with other foods like roast or cooked meat (Fig. 23). The following species are more frequently used to prepare the "*Olchani-imotori*": *Withania somnifera*, *Rhamnus staddo*, *Harrisonia abyssinica*, *Pappea capensis* and *Rhamnus Prinoides* (Fig. 28). However, their used parts have a lower potassium concentration (below 684.65 mg K 100 g^{-1}) than *Piper capense* root and *Vachellia nilotica* pods (Fig. 53). Despite the relatively low concentration of potassium in the most frequently used flora in the Maasai diets, the contribution of these species to the dietary intake of potassium may be high due to their high frequency of use as diets or a diet ingredient (McLean & Wang, 2021). The species integrated into the "*Olchani-imotori*" have therapeutic and preventive roles against various conditions including joint pain and inflammation, indigestion, constipation, and kidney disorders (Appendix 4).

Besides, seeds of *Lablab purpureus* are used as a food source (Fig. 14). The seeds have a potassium concentration of 757.53 mg K 100 g $^{-1}$ (Fig. 53). *Lablab purpureus* has a wide range of pharmacological activities including antidiabetic and antilithiatic properties (Al-Snafi, 2017).

So, species with relatively high concentrations of potassium and high frequency of use particularly as diet or ingredient of a diet are important dietary sources of potassium (McLean & Wang, 2021); thus, they may play a significant role in managing gout and GACs.

On the other hand, some species were less frequently used; their parts were used as an independent medicine or mixed with the Maasai food products to treat ailment(s) only when required (Appendix 4). Parts of *Tetradenia riparia*, *Persea americana* and *Rhotheca myricoides*, *Euphorbia sp*, *Psidium guajava*, *Dicoma tomentosa*, and *Eucalyptus saligna* (Fig. 53) were used as medicine without being mixed with a food product (Appendix 4). They had potassium concentrations ranging between 1070.32 – 464.29 mg K 100 g $^{-1}$ in decreasing order (Fig. 53). Also, they used against indigestion, hypertension, gout, diabetes and nephrolithiasis (Appendix 4) as elsewhere reported (Erdem *et al.*, 2016; Kasali *et al.*, 2021; Ogundeko *et al.*, 2022). Furthermore, parts of *Secamone parvifolia*, *Croton megalocarpus*, *Lannea schweinfurthii* and *Euclea divinorum* were mixed with food sources like milk, clarified butter and or tallow, particularly to treat an ailment(s) when the need arises (Appendix 4); they had potassium concentration ranged between 449.35 – 171.06 in a decreasing order (Fig. 53). Also, they were used against ailments including constipation, stomachache and edema (Appendix 4). Although these species are less frequently used than those integral to the daily consumed Maasai diets, their potassium contribution in managing the MDs cannot be ignored.

Indeed, the diverse of species documented in this study are the source of potassium to the Maasai community at concentrations ranging between 97.68 – 1392.01 mg K 100 g $^{-1}$. But the globally known important food sources of potassium by weight are potatoes and bananas with concentrations of 475 and 396 mg K 100 g $^{-1}$ respectively (Lanham-New *et al.*, 2012; McLean & Wang, 2021; Money, 1964). Tomatoes and strawberries have concentrations of 273 and 164 mg K 100 g $^{-1}$ respectively; they are important sources, by energy, though (McLean & Wang, 2021; Money, 1964). So, the species investigated in this study that have higher concentrations of potassium than the globally known important sources, and with high frequency of use in the Maasai diets, could be the best and alternative source of dietary potassium. The traditional use of such species could support the claim that the prevalence of MDs such as gouts and GACs is lower in communities like Maasai which practices TFS and TM (Kimondo, 2020).

Apart from potassium, there are other minerals like calcium, iron, magnesium, manganese and zinc with beneficial biological activities against gout and GACs (Cormick & Belizán, 2019; García-Montero *et al.*, 2021; Gherghina *et al.*, 2022; Kass & Sullivan, 2016; Rubio *et al.*, 2009). Determining the content of such minerals in flora particularly the most commonly used ones in the Maasai TFS and TM is also important in managing gout and GACs.

4.5 Content of Ca, Fe, Mg, Mn, and Zn in the Flora and their Health Benefits

Analysis of 43 floral parts from 35 species commonly used TFS and TM using atomic absorption spectrophotometry (AAS) showed that the minerals, Ca, Fe, Mg, Mn and Zn in the flora had their highest content varying between 263.85 and 9117.00 µg/g dry weight (DW) (Appendix 6). Flora with high mineral content and frequent use in the Maasai TFS and TM support their use against gout and GACs (Fig. 54).

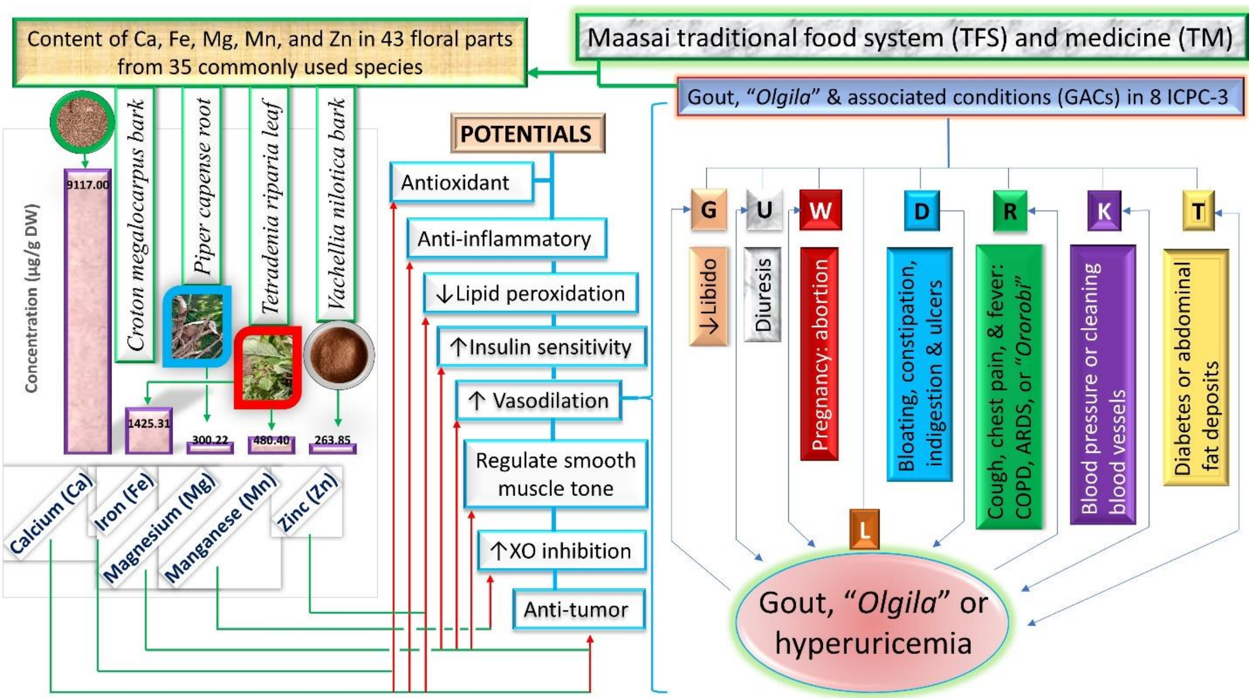


Figure 54: Graphical summary of objective four results, Ca, Fe, Mg, Mn, and Zn content

4.5.1 Zinc Content in the Flora and Potential Health Benefits

The zinc (Zn) content of the flora most commonly used in the Maasai TFS and TM is shown in Fig. 55. *Vachellia nilotica* bark had the highest zinc (Zn) content, 263.85 ± 1.10 µg/g DW, followed by *Piper capense* root, *Eucalyptus saligna* leaves and *Pappea capensis* stem (Fig. 55). The frequent use of these species in food or medicinal preparations like "*Olchani-imotori*" has a significant contribution to the recommended daily intake (RDI) of Zn: 8-11 mg/day (García-Montero *et al.*, 2021). Based on the highest content of Zn, at least 42 g dry weight (DW) of the used species' part can meet the RDI. The antioxidant and anti-inflammatory activities of zinc (Lee, 2018; Prasad, 2014) can support the use of these species against gout, "*Olgila*", reduced libido or infertility, cleaning blood vessels and preventing heart tightness (hypertension). Zinc can prevent OS, lipid peroxidation and the generation of inflammatory cytokines associated with the conditions (Gherghina *et al.*, 2022; Lee, 2018). So, the flora (Fig. 55) particularly those with high Zn content have potential use against gout and GACs.

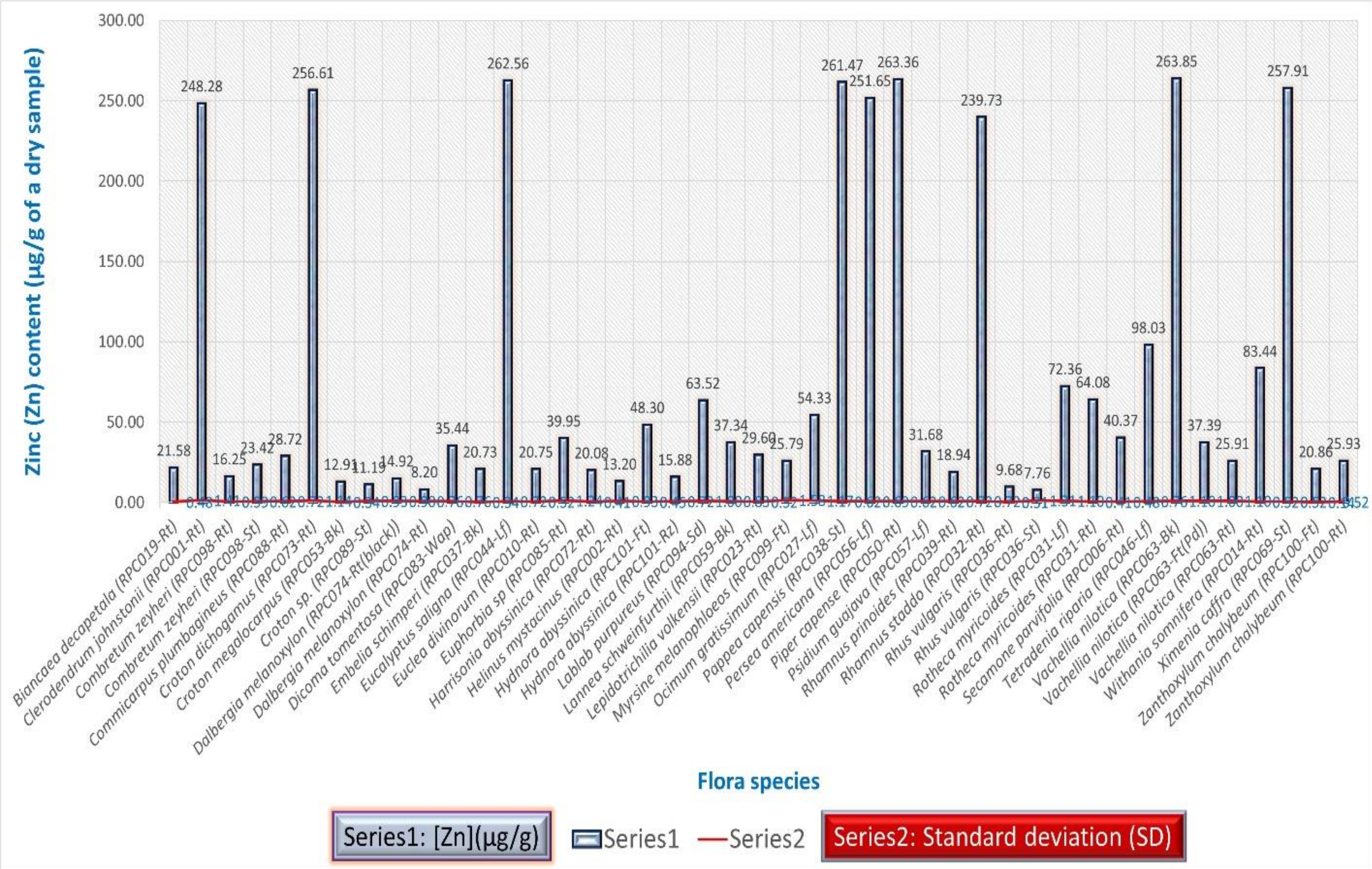


Figure 55: **Zinc (Zn) content in flora commonly used in the Maasai TFS and TM**

4.5.2 Manganese Content in the Flora and Potential Health Benefits

The most commonly used flora in the Maasai TFS and TM had manganese (Mn) content as shown in Fig. 56. *Tetradenia riparia* leaf had the highest Mn content, 480.40 ± 2.28 µg/g DW, followed by *Croton dichogamus* root, *Myrsine melanophloeos* fruit and *Piper capense* root (Fig. 56). Likewise, based on the highest content of Mn, at least 10.41 g DW of the used species' part is needed to meet the RDI of Mn: The 2-5 mg/day (Rubio *et al.*, 2009). The capacity of Mn to prevent lipid peroxidation and enhance the inhibition of XO by flavonoids like luteolin can support the potential use of these species against gout, and GACs like diabetes and cancer (Luanda & Ripanda, 2023). For instance, *Tetradenia riparia* has luteolin in addition to Mn; thus, supporting its use against rheumatism, diabetes and cancer (Luanda & Ripanda, 2023). Still, the biological activities of Mn agree with the traditional use of these species against "*Olgila*", gastrointestinal, and respiratory disorders (Fig. 47 & Appendix 4): they are associated with OS (Gherghina *et al.*, 2022; Stockton, 1897; Taylor *et al.*, 2012).

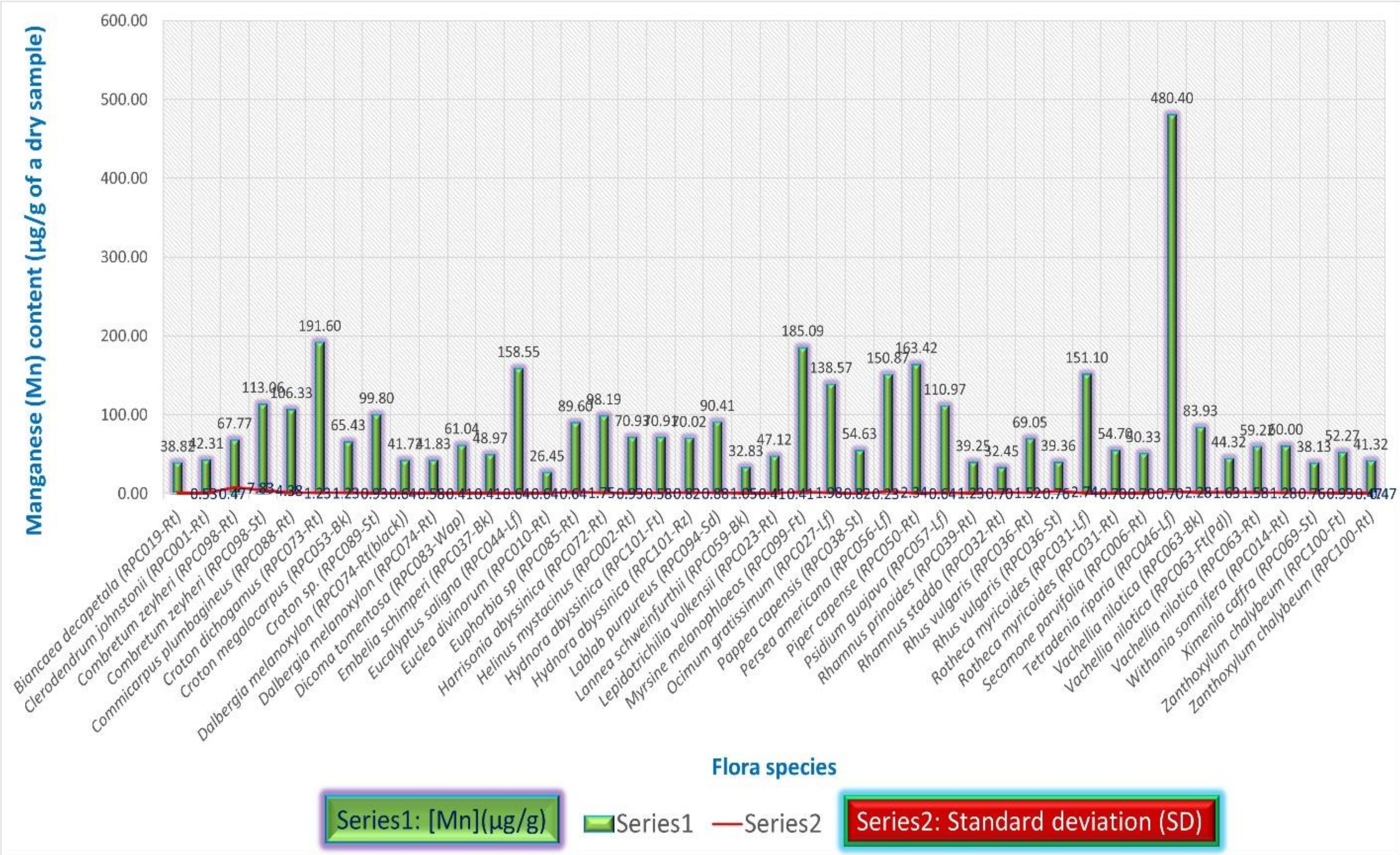


Figure 56: Manganese (Mn) content in flora commonly used in the Maasai TFS and TM

4.5.3 Iron Content in the Flora and Potential Health Benefits

The most commonly used flora in Maasai TFS and TM had iron (Fe) content as seen in Fig. 57. *Tetradenia riparia* leaf had the highest Fe content, 1425.31 ± 4.51 µg/g DW, followed by *Piper capense* root, *Harrisonia abyssinica* root, and *Commicarpus plumbagineus* root (Fig. 57). The RDI of Fe is 12-18 mg/day (García-Montero *et al.*, 2021; Rubio *et al.*, 2009); thus, at least 12.63 g DW of the species with the highest Fe content can meet the RDI. The antioxidant activity of iron (Rapa *et al.*, 2019) can support the use of these species against "*Olgila*", gastrointestinal, and respiratory disorders (Fig. 47 & Appendix 4). The prooxidative effect of iron can be prevented by flavonoids like luteolin and resveratrol present in *Tetradenia riparia* and *Biancaea decapetala*, respectively through chelation (Amarowicz & Pegg, 2019; Luanda & Ripanda, 2023).

Also, resveratrol promotes the growth of commensal Bifidobacterium which can bind excess iron in the gut, preventing the prooxidative effect of iron (García-Montero *et al.*, 2021). Likewise, vitamin C in *Pappea capensis* can increase the absorption of soluble non-heme iron in the body while maintaining its reduced form (Karau *et al.*, 2012a): It prevents anemia and OS associated with iron (Amarowicz & Pegg, 2019; Karau *et al.*, 2012a). Thus, the common use of such species with high iron content in preparing foods or medicines like "*Olchani-imotori*", is not only important in preventing or managing inflammatory conditions like gout, "*Olgila*"; but, also anemia which may cause hypoxia leading to such inflammatory conditions (Bortolotti *et al.*, 2021; Rapa *et al.*, 2019). This could agree with the use of *Vachellia nilotica* bark (Fig. 57) in both, increasing blood (Table 3) and against "*Olgila*" (Fig. 47).

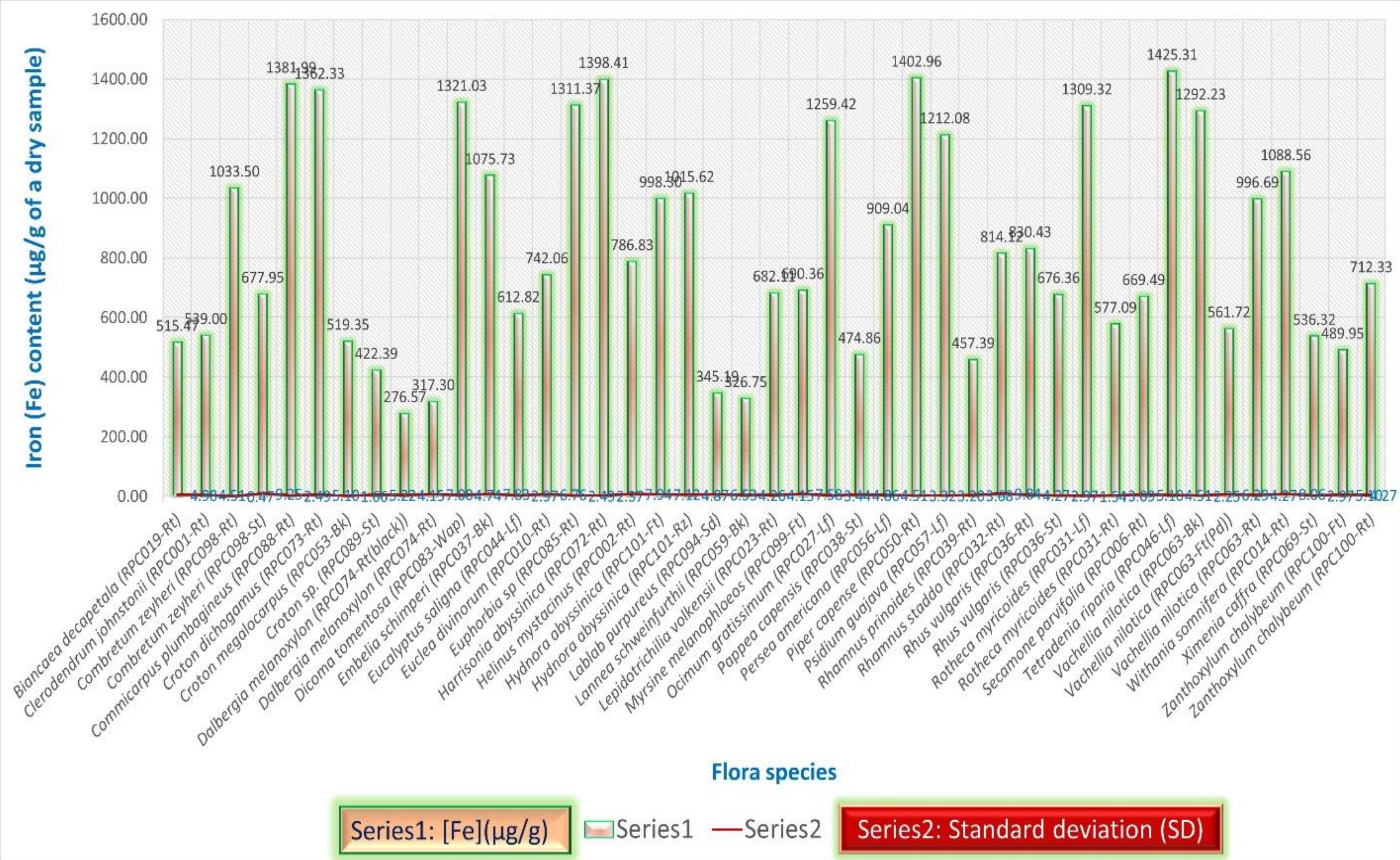


Figure 57: **Iron (Fe) content in flora commonly used in the Maasai TFS and TM**

4.5.4 Magnesium Content in the Flora and Potential Health Benefits

The most commonly used flora in the Maassai TFS and TM had magnesium (Mg) content, as shown in Fig. 58. *Piper capense* root had the highest Mg content, 300.22 ± 1.72 µg/g DW, followed by *Tetradenia riparia* leaves, *Helinus mystacinus* root and *Ocimum gratissimum* leaves (Fig. 58). The RDI (Kass & Sullivan, 2016) mg/day (Kass & Sullivan, 2016); hence, at least 1398.97 g DW of the species with the highest content can meet the RDI. The anti-inflammatory activity and regulatory role on smooth muscle tone by magnesium (Blaszczyk & Duda-Chodak, 2013; Moraes & Surani, 2019; Rapa *et al.*, 2019) can support the use of these species against "*Olgila*", cough, constipation, stomach bloating and indigestion (Fig. 47 & Appendix 4): The GACs (Gherghina *et al.*, 2022; Shulkes & Baldwin, 2013; Stockton, 1897). So, frequent use of these species in food or medicinal preparations like "*Olchani-imotori*" and "*Shai-ekulee*" (Fig. 28 & 32) could contribute to the low prevalence of gout and GACs in the Maasai community. Indeed adequate dietary magnesium intake reduces the risk of developing gout and GACs including diabetes, metabolic syndrome, CKD, hypertension, and poor respiratory ventilation (Kass & Sullivan, 2016; Moraes & Surani, 2019; Rapa *et al.*, 2019).

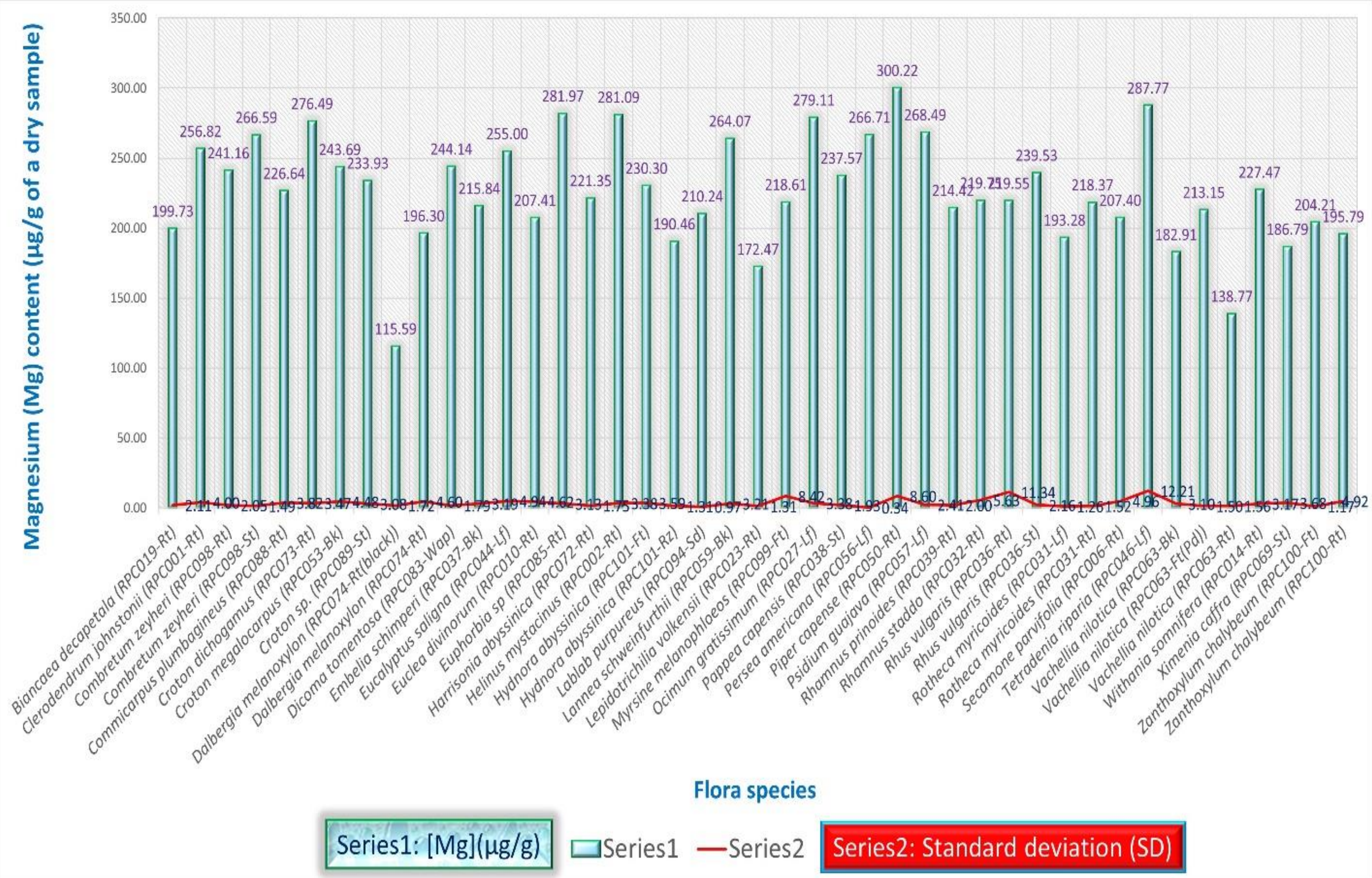


Figure 58: Magnesium (Mg) content in flora commonly used in the Maasai TFS and TM

4.5.5 Calcium Content in the Flora and Potential Health Benefits

The most commonly used flora in the Maassai TFS and TM had calcium (Ca) content, as shown in Fig. 59. *Croton megalocarpus* bark had the highest Ca content, 9117.0 ± 305.8 µg/g DW, followed by *Rhus vulgaris* root, *Vachellia nilotica* bark, *Rhus vulgaris* stem and *Croton dichogamus* root (Fig. 59). The RDI of calcium is 1000-1300 mg/day (Cormick & Belizán, 2019); thus, at least 142.6 g DW of the species with the highest content can meet the RDI. Antioxidant and anti-inflammatory properties (Cheng, 2016; Szlacheta *et al.*, 2020; Zhong & Darmani, 2018) of calcium can support the use of these species against gastrointestinal disorders and "*Olgila*" conditions (Fig. 47 and Appendix 4): The GACs (Gherghina *et al.*, 2022; Stockton, 1897). Thus, the species with high Ca content and frequent use especially in "*Olchani-imotori*" and "*Shai-ekulee*" (Fig. 28) may lower the risks of developing gout and GACs.

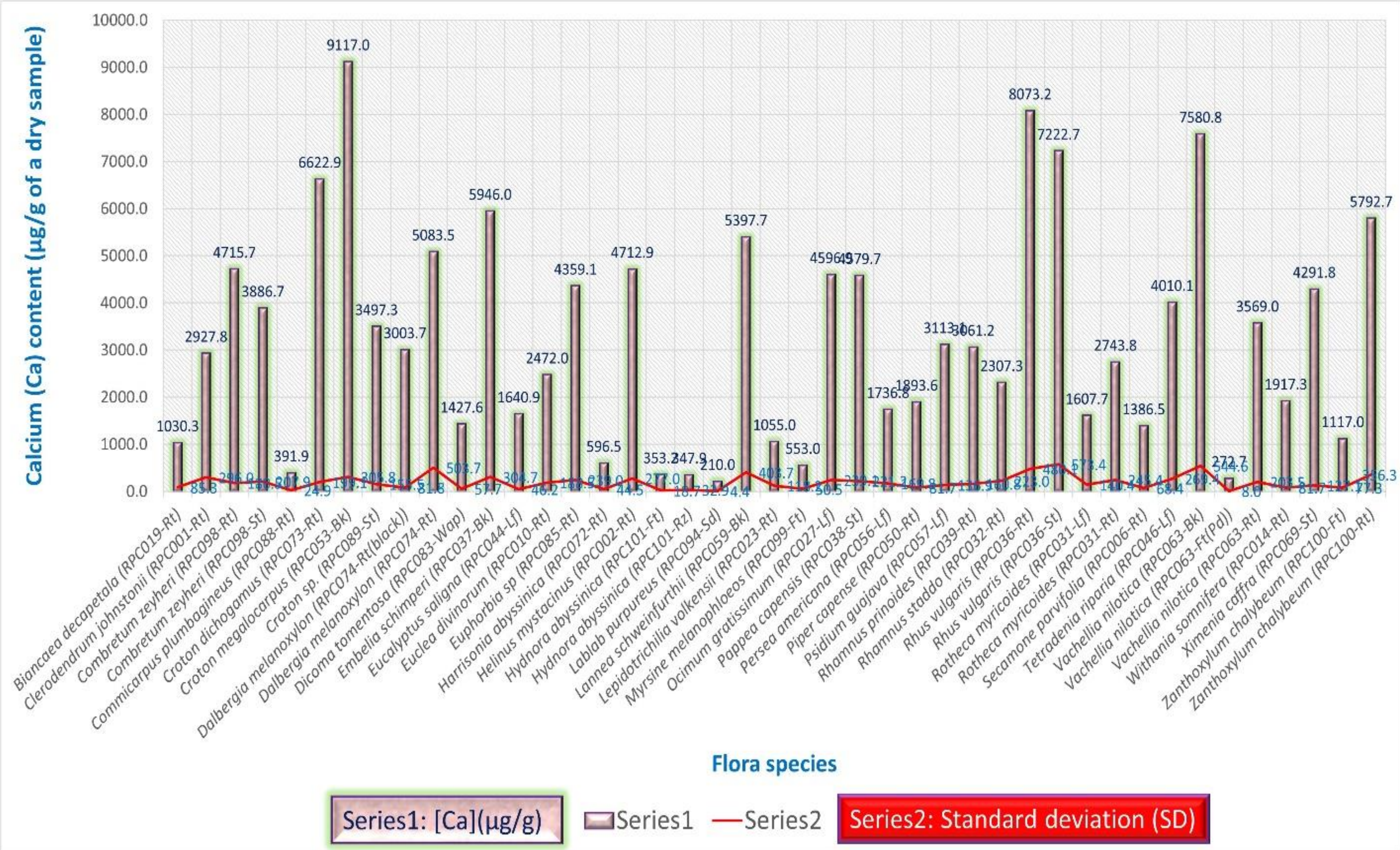


Figure 59: **Calcium (Ca) content in flora commonly used in the Maasai TFS and TM**

Indeed, the integration of flora especially with a high content of minerals and phytochemicals (Appendix 6) that have biological activities against gout, "*olgila*" and GACs in Maasai TFS represents a food matrix that can offer preventive and therapeutic effects against the MDs: An adequate or complete food matrix constitutes different compounds or substances that interact in a coordinated way in the human body to give positive effects against an ailment and vice versa is true (García-Montero *et al.*, 2021). Also, using the FPT involving flora with such minerals and phytochemicals may enhance the nutraceutical roles of the Maasai foods (dishes). The health benefits derived from the qualities of the Maasai TFS agree that processing techniques and the food matrix, rather than the nutrients, provide the benefits or dangers resulting from food consumption (García-Montero *et al.*, 2021). Thus, consuming Maasai foods (dishes), or flora with such health benefits, or formulations developed based on the qualities of the Maasai TFS is expected to keep a low prevalence of MDs as opposed to GFS.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The present study gathered knowledge on Maasai TFS and TM used by MTPs. Monduli and adjacent Arusha rural areas had a diversity of 101 flora species distributed in 42 families and 84 genera. The flora had enormous benefits in the Maasai TFS and TM. The Maasai TFS qualities, a diversity of species culturally accepted as foods, FPTs, and CPR, are ethnobiologically linked to the health benefits the MTPs obtain. Most flora (78 species) were used as direct food sources, food ingredients, and for food processing in the TFS. Animal-based products, cereals, pulses, fruits, roots, and vegetables were the most common food items integrated into the TFS. Various 19 foods (dishes) were prepared from flora and non-flora ingredients. The FPTs, nixtamalization was linked to prevention of hyperchlorydria, which is a marked condition in gout, while the meat roasting process, which integrates flora and avoids the use of salt and metal materials, was linked to disease prevention, including “Olgila”.

The CPR for food selection ensured individual health needs are attained based on age, gender, pregnancy and child care, health conditions, social positions, menopause status, as well as reinforce the Maasai socio-structure and cohesion. Most flora species (79%) were used as MPs to manage 69 health conditions, including gout, “Olgila”, and GACs: some disorders of the genital, urinary, digestive, respiratory, circulatory, and endocrine systems, as well as some pregnancy disorders. The risk factors for developing gout, “Olgila” and GACs, were potentially reduced through the high use of MPs along with food sources in making preparations with both nutritional and medicinal roles, like “Olchani-imotori”, which was usually consumed along with other foods, particularly meat. The formulations or flora commonly used in TFS and TM with high antioxidant capacity (TPC and TFC) and mineral content are potential antioxidants and AHAs against diseases, including gout, “Olgila” and GACs.

Some conservation strategies, particularly the preservation or cultivation of some flora species (6%), were evident in the study area; they might have contributed to most species present in the IUCN Red List being in the LC category. However, most of the flora were native species (93%) and sourced from wild habitats, predominantly forests, followed by savannas, with the most common habit and part being tree and root, respectively. Also, a least percentage of the species (2%) were nearly threatened and vulnerable, while some were sold in the open markets.

Thus, to ensure the sustainable conservation and use of the flora in Maasai TFS and TM, the indigenous stewardship of the natural resources should be supported by integrative government and nongovernmental conservation programs in line with SDGs 10, 13, and 15.

The findings of this study provided the basis for adopting or developing a sustainable food system with diverse food dishes and native flora species, which have adequate antioxidants and minerals against diseases, including gout and GACs. Also, it provides a basis for adopting or developing FPTs that ensure an adequate supply of minerals and bioactive compounds for promoting health and lowering the risk of developing diseases, including gout and GACs. Likewise, the knowledge gathered in this work could guide education and policy formulation on the conservation and sustainable use of the valuable flora identified in this study.

Although the diverse foods (dishes) and flora species, as well as higher flora antioxidant capacity and mineral content, support the claimed health benefits, the Maasai obtained from their TFS and TM, the TPC values determined by Folin-ceocateu menthod can be overestimated in the presence of other valuable non-phenolic compounds, like ascorbic acid (vitamin C) in the sample (Lawag et al., 2023). Also, the TFC can be unusually higher than TPC in the presence of non-phenolic compounds, which are also non-flavonoid in the sample, but contribute to TFC values (Lawag et al., 2023).

5.2 Recommendations

This study did not establish the nature, bioactivity, or validate the safety of phytochemicals, nutrients, or minerals in flora or dishes used against gout, “Olgila”, GACs, and disease risk factors by MTPs in their TFS and TM. However, for some species, such information is established elsewhere. Also, the biological activities and safety of the formulations, “Osugila-14P” and “Osugila-14E,” were not validated. However, the process is underway. Likewise, the claimed low prevalence of diseases, including MDs, was not validated. Therefore, this study recommends an in-depth investigation of the phytochemical and nutritional profile, particularly of the most frequently used species and dishes against gout, “Olgila,” and GACs, and establish their effect on disease biomarkers, like uric acid or cytokines, to validate the lower prevalence of diseases. Also, the substances or factors responsible for the medicinal roles of FPT need to be determined. Likewise, validation of biological activities and safety of “Osugila-14P” and “Osugila-14E” may be necessary before patent.

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APPENDICES

Appendix 1: Questionnaire for Ethnobiological and Ethnobotanical Surveys on Maasai TFS and TM

General Information

Village: …………………. Questionnaire Number: …………………

Informants' consent for the participation in the study:

I.. (name of informant) hereby give my full consent and consciousness to participate in this study and declare that to the best of my knowledge, the information that I have provided is true, accurate, and complete.

Date..(Signature/Thumb impression of Informant)

SECTION A: Informants' Details

Gender	:………………………………
Age:	:………………………………
Marital status	:………………………………
Tribe:	:………………………………
Education Level	:………………………………
Occupation / Professional	:………………………………
Years of Experience in the occupation / professional	:………………………………
Place of Residence /Location	:………………………………

SECTION B: Information on Maasai Traditional Food System (TFS)

1. What are staple foods you have been eating in your life?

2. How is such food (s) prepared?

3. Is there any substance added in the food prepared for eating?

4. What is the name of the substance added in the food if any?

5. In which form (fresh or dry) the substance is added in the food?

6. What is the role of the substance added in the food?

7. What is the proportion of food and the additive eaten per meal?

8. What is the frequency (e.g twice/day) for eating such food?

9. At what condition (s) if any, is convenient for eating such food? Why at that specific conditions if any?

10. Can anyone eat such food or there are restrictions? Why such restrictions if any?

11. What are the advantages of eating such food?

12. Is the food identified taken as a medicine? If yes state the disease it treats.

13. For how long is the medicinal food should be used for treating such disease if any?

SECTION C: Information on the Flora Used as Food or Food Ingredients

1. What are plants or plant products you have been using as food or food ingredients, if any?

2. What part of the plant do you use?

3. How is it used? (dried or fresh)

4. How do you prepare it for use?

5. If the herb is used as a food ingredient, in which food is added?

6. How is the ingredient prepared with the food?

7. At what conditions if any, is convenient for using the herb as food or food ingredient? Why at that specific conditions if any?

8. What is the proportion of the herb consumed per meal?

9. What is the consumption frequency (e.g., once per day) of the herbs?

10. What is the role of the herbs as food or food ingredient?

11. What is the medicinal purpose of the herbs if any? State the disease(s) it treats if any.

12. For how long the herbs should be taken for treatment of such disease if any?

13. Is there any side effect of the herbs?

14. What antidotes can be taken in case of overdose of the herbs?

SECTION D: Information on Gout, Risks Factors and Its Management

1. Do you have an inflammation or experience of having it on any joint (such as big toe/insteps/ankles/heels/knees/wrists/fingers/elbow e.t.c)? If yes specify the joints.

2. Do you have an experience of sudden severe pains on the identified joints? What can be done to alleviate the inflammation and pain?

3. Do you have an experience of stiffness/tenderness/redness/warmth/swelling on the identified joints? What can be done to control the conditions?

4. What kind of disease is represented with such symptoms?

5. Do you have an experience of slow healing sores or cuts/Hunger/fatigue/frequent peeing or thirst/dry mouth and itchy skin/Blurred vision/unplanned weight loss/areas of darkened skin (e.g., armpits and neck)/frequent infections? What do the symptoms represents and what can be done to control the disease symptoms?

6. Do you have an experience of severe headache/fatigue/confusion/vision problems/chest pain/difficult breathing/irregular heart beat/blood in urine/pounding in your chest, neck or ears? What do the symptoms represent and what can be done to control the symptoms?

7. Do you have an experience of decreased urine output/fluid retention/swelling in legs, ankle or feet/fatigue/confusion/nausea/weakness/irregular heart beat? What do the symptoms represent and what can be done to control the symptoms?

8. What kind of physical activities you often do?

9. What is the intense of the physical activity?

10. What is the frequency of such physical activity?

11. What is the role of such physical activity?

12. What health impact do such physical activities have?

13. What kind of symptoms represent gout?
14. What is the name of gout in your local language?
15. What are the causes of gout?
16. How do you prevent or deal with gout?
17. Does any family member or relative or a friend has ever suffered from gout and how he or she or they manage to address it?
18. What plants or plant products if any, are used for gout management?
19. What part of the plant do you use?
20. How is it used? (dried or fresh)
21. How do you prepare it for gout management?
22. What other plants if any are mixed with the plant?
23. What is the proportion/dose of the plant(s) used?
24. For how long the dose can be used to effectively manage gout?
25. What is the route of delivery of the dose to manage the disease?
26. What is the role/function of the plant(s) in management of gout?
27. Is there any side effect of the plant(s) used?
28. What antidotes can be taken in case of overdose of the plant(s)

Appendix 2: Approval Letter from Tanzania Forest Service (TFS) to Conduct Research

Jamhuri ya Muungano wa Tanzania
WIZARA YA MALIASILI NA UTALII
WAKALA WA HUDUMA ZA MISITU
TANZANIA

Anwani: 'TFS'
Fax Na: Fax Na. 027 - 2509521
Barua Pepe: tfsmonduli@gmail.com
Simu: 07562657566/0712830152
Kumb.Na.TFS. MON/168/401/01

TFS MONDULI
S. L. P. 1
MONDULI

15Th June 2020

Mwenyekiti wa Kijiji cha Engalaoni/Imbibia/Losimingori/Mlimani/
Emairete/Enguiki/Iloirinito/Iltakwara na Makuyuni.
S. L. P. 1,
Monduli.

YAH: KUWATAMBULISHA NDUGU RICHARD PAUL CLEMENT PAMOJA NA GABRIEL LAIZER.

Tafadhali husika na somo tajwa hapo juu,

Richard paul clementi ni mwanafunzi katika Chuo Kikuu cha Sayansi cha NELSON MANDELA-TENGERU na Gabriel Laizer ni Mtaalamu wa Mimea (Botanist). Wamekuja kufanya Tafiti kuhusiana na mimea tiba kwenye vijiji kama nilivyoviorodhesha hapo juu ndani ya Wilaya yetu.

Hivyo basi kama OFISI YA MALIASILI –MONDULI chini ya Wakala ya Huduma Za Misitu Tanzania, tunaomba wapewe ushirikiano katika kukamilisha kazi hii kwa kipindi chote watakachokuwa kwenye eneo lako.

Wako katika Utumishi Wa Umma.

GODLISTEN E. KOKA
MHIFADHI MISITU (W) MONDULI

Appendix 3: Maasai Traditional Food System (TFS)

Food		Ingredients					Food				
Name (local name)	**FC**	**Name (local names)**	**FC**	**Part / source / form used**	**Amount/rate**	**Role(s)**	**Amount/rate**	**Frequency**	**Condition of use**	**Restriction**	**Roles**
"*Emberere*"	1	whole maize grains	1	Sd (fresh / dry)	3 Kg	nutrition, energy	1L per person	twice-thrice per day	any	none	nutrition, energy
		water	1	liquid	6-8 L	medium					
		bean	1	Sd (fresh / dry)	1 Kg	nutrition, energy					
		banana	1	Ft (fresh)	1-bunch ("chana")	nutrition, energy					
		Soda ("magadi")	1	crystals	0.5-table spoon	taste, soften grains					
		milk ("*kulee*")	1	fresh / yogurt	1 L	nutrition, energy					
		Olea europaea subsp. *africana* (Mill.) P.S.Green ("*oloirien*")	1	St (smoke and ashes)	10-14 cm	preservation, aroma, and taste					

Food		Ingredients					Food				
Name (local name)	**FC**	**Name (local names)**	**FC**	**Part / source / form used**	**Amount/rate**	**Role(s)**	**Amount/rate**	**Frequency**	**Condition of use**	**Restriction**	**Roles**
"*Engideri*"	1	banana ("ndizi ng'ombe")	1	Ft (fresh)	1-buch ("chana")	Nutrition, energy	1L per person	twice-thrice per day	Sick, lactation, or thirst	none	Nutrition, energy, stops diarrhea, increases lactation milk, and body fluid
		milk ("*kulee*")	1	fresh/ yogurt	1L	Nutrition, energy					
		water	1	liquid	3 L	Nutrition, energy					
		Olea europaea subsp. *africana* (Mill.) P.S.Green ('*oloirien*')	1	St (smoke and ashes)	10-14cm	preservation, aroma and taste					
"*Engitalolo*"	8	whole maize grains	8	Sd (fresh/dry)	2-3 Kg	nutrition, energy	1L per person	twice-thrice per day	pregnancy/ lactation	Male (circumcised)	Nutrition, energy, increases lactation milk, improve eye sight, increases appetite, increases body fluid, quench thirst, and prevent diseases
		Solanum villosum ("mnavu"/ "*engirola*")	8	Lf (fresh)	10-20L	Increases blood, improve sight, and prevent diseases					
		water	8	liquid	5L	medium					
		soda ("magadi")	8	crystals	1-table/tea spoon	soften maize grains					
		beans	1	Sd (fresh/dry)	2Kg	nutrition, energy					
		green banana ("ndizi ng'ombe")	1	Ft (fresh)	1-bunch ("chana")	nutrition, energy					
		milk ("*kulee*")	4	fresh / yogurt	0.5-2L	nutrition, energy					
		cooked porridge	3	Sd-maize flour	any	nutrition, energy					
		Olea europaea subsp. *africana* (Mill.) P.S.Green ("*oloirien*")	6	St (smoke and ashes)	10-15cm	preservation, taste, aroma					

Food		Ingredients					Food				
Name (local name)	FC	Name (local names)	FC	Part / source / form used	Amount/rate	Role(s)	Amount/rate	Frequency	Condition of use	Restriction	Roles
"*Eng'orno*" (milk butter or "siagi")	3	*Olea europaea* subsp. *africana* (Mill.) P.S.Green ("*oloirien*")	3	St (smoke and ashes)	10-15cm/1.5L	preservation, taste, and aroma	1-2 table spoon per person	once per day	any	none	nutrition, energy
"*Eujandapa*"	1	*Eleusine coracana* / finger millet ("ulezi")	1	Sd (flour)	0.25Kg	nutrition, energy	1L per person	twice-thrice per day	any	none	nutrition, energy
		milk ("*kulee*")	1	fresh / yogurt	0.25 L	nutrition, energy					
		fat (ghee/tallow)	1	cow / goat /sheep	3-table spoon	taste					
		sugar	1	crystals	2-table spoon	taste					
		water	1	liquid	3L	medium					
"*Euji*" (porridge)	7	whole maize grains	7	Sd (flour)	0.25-1.5 Kg	nutrition, energy	0.25-2 L per person	once-twice per day	cold weather or meal starter	none	nutrition, energy, quench thirst, therapy for excessive drunker of alcohol, "*enemasher*"
		water	7	liquid	4-10 L	medium					
		milk ("*kulee*")	6	fresh / yogurt	any	nutrition, energy					
		fat (ghee/tallow)	3	cow / goat /sheep	any	taste					
		salt	2	crystals	1-tea spoon	taste					
		Olea europaea subsp. *africana* (Mill.) P.S.Green ("*oloirien*")	6	St (smoke and ashes)	10-15cm	preservation, taste, and aroma					

Food		Ingredients					Food				
Name (local name)	**FC**	**Name (local names)**	**FC**	**Part / source / form used**	**Amount/rate**	**Role(s)**	**Amount/rate**	**Frequency**	**Condition of use**	**Restriction**	**Roles**
"*Ilmariko*"	2	banana ("mshale"/ "Uganda")	2	Ft (fresh)	2-bunch ("chana")	nutrition, energy	2 L per person	once per day	any	none	nutrition, energy
		Irish potatoes	2	Tb (fresh)	2L	nutrition, energy					
		meat ("*ingiring*")	2	cow / goat /sheep	2Kg	nutrition, energy					
		onion	2	bulb (Bb)	3-bulb	nutrition, energy					
		tomatoes	2	Ft	2-3 fruits	nutrition, energy					
		fat (ghee/tallow)	2	cow / goat /sheep	2-table spoon	nutrition, energy					
		salt	2	crystals	2-table spoon	nutrition, energy					
"*Imotori*" (soup)	1	meat from cow / goat / lamb	1	back-tail	any (required)	nutrition, energy	0.50-2.0 L per person	once-twice per day	any	male (due to back-tail and large intestine meat)	nutrition, energy
			1	gastro-intestine ("utumbo")	any (required)	nutrition, energy					
		grinded maize grains	1	Sd (dry)	0.5 Kg	nutrition, energy					
		banana	1	Ft (fresh)	1-bunch ("chana")	nutrition, energy					
		water	1	liquid	any (required)	medium					

Food		Ingredients					Food				
Name (local name)	**FC**	**Name (local names)**	**FC**	**Part / source / form used**	**Amount/rate**	**Role(s)**	**Amount/rate**	**Frequency**	**Condition of use**	**Restrictio n**	**Roles**
"*Ingiring-lombenek*" (meat-vegetable roast)	1	meat ("*ingiring*")	1	Cow / goat / sheep	any (required)	nutrition, energy	0.25-0.50 L per person	Once per day	lactation	none	nutrition, energy, and increases lactation milk
		banana	1	Ft (fresh)	1-bunch ("chana")	nutrition, energy					
		tomatoes	1	Ft (fresh)	2-5 fruits	nutrition, energy					
		fat (ghee/tallow)	1	cow / goat /sheep	any (required)	nutrition, energy					
		salt	1	crystals	small amount	taste					
		water	1	liquid	any (required)	medium					

Food		Ingredients					Food				
Name (local name)	**FC**	**Name (local names)**	**FC**	**Part / source / form used**	**Amount/rate**	**Role(s)**	**Amount/rate**	**Frequency**	**Condition of use**	**Restriction**	**Roles**
"*Ingiring-naapejo*" (roast meat)	20	goat and sheep meat	20	brisket ("*oloikulu*")		nutrition, energy	0.25-10 Kg per person	Once per day or several times per day	Sick, ceremony, far from home ("*ronjo*"/ "boma"), and post-delivery	none	nutrition, energy
			20	liver ("*emonywa*")		nutrition, energy					
			20	rear legs ("*emuro*")		nutrition, energy					
			20	ribs ("*Ilarasi*")		nutrition, energy					
		cow meat	20	below armpit steak ("*orng'abosho*")		nutrition, energy					
			20	brisket ("*enagilkitan*")		nutrition, energy					
			20	chest ("*embutwai*")		nutrition, energy					
			20	fore legs ("*engejorongai*")		nutrition, energy					
			20	heart ("*ortau*")		nutrition, energy					
			20	liver("*emonywa*")		nutrition, energy					
			20	neck ("*embosi*" / "*orkotete*" / "*ermutu*")		nutrition, energy					
			20	rear legs ("*ormuwo*")		nutrition, energy					
			20	ribs ("*engelemian*")		nutrition, energy					
			20	ribs steak ("*engaina*")		nutrition, energy					
			20	stomach ("*endanu*")		nutrition, energy					

Food		Ingredients					Food				
Name (local name)	**FC**	**Name (local names)**	**FC**	**Part / source / form used**	**Amount/rate**	**Role(s)**	**Amount/rate**	**Frequency**	**Condition of use**	**Restriction**	**Roles**
"*Irmakuku*" ('*ngaramumu*') Or " *ngararumu-ombenek*"	19	whole maize grains	19	Sd (fresh / dry)	2-5Kg or 4L ("sado") per 8-14 people	nutrition, energy	1L per person or 1-2 Kg per person	once-twice per day or twice per week	any or along with other food (tea)	male (in case of leafy vegetable), young babies and older people (food is hard to digest)	nutrition, energy, and longer satiation
		water	19	liquid	4-6 L	medium					
		Soda ("magadi")	17	crystals	0.5-1.0 tea spoon	soften grains (maize/bean), remove stomach gas					
		beans	15	Sd (fresh / dry)	0.5-2Kg	nutrition, energy					
		Lablab purpureus, "*ngwara*" (*appendix 4*)	1	Sd (fresh / dry)	1Kg	nutrition, energy					
		salt	16	crystals	0.5 tea spoon / 2-3 table spoon	taste					
		fat (ghee / tallow)	1	cow / goat / sheep	2-table spoon	taste					
		banana ("*irmakosho*"), except that of "mshale"	3	Ft (dried)	few pieces	taste, nutrition, energy					
		Solanum villosum ("mnavu"/ "*engirola*")	1	Lf (fresh)	any	Increases blood, improve sight, and prevent diseases					
		tomatoes	5	Ft (fresh)	any	nutrition, energy					
		onion	5	Ft (fresh)	any	nutrition, energy					

Food		Ingredients					Food				
Name (local name)	**FC**	**Name (local names)**	**FC**	**Part / source / form used**	**Amount/rate**	**Role(s)**	**Amount/rate**	**Frequency**	**Condition of use**	**Restriction**	**Roles**
"*Kulee*" (milk)	15	*Olea europaea* subsp. *africana* (Mill.) P.S.Green ("*oloirien*")	9	St (smoke and ashes)	10-15 cm per 1.5 L milk	preservation, taste and aroma	0.25-1.0 L per person or 2-table spoon to 0.25 L per a sick person	twice-thrice per day or once per treatment	any/sick	pregnancy (*Albizia anthelmintica* induces abortion)	nutrition, energy, and medicine (*appendix 4*)
		Albizia anthelmintica Brongn ("*emukutan*")	3	Bk/Rt (dry)	1/8 L-powder per 10 L milk	medicine, increase body heat					
"Olaroi" / "*enailang'a*" (blood-based food)	4	blood	4	liquid	0.5-1 L	nutrition, energy	0.5 L per person	once-twice per day	far from home ("*ronjo*"/ "boma"), pregnancy, post-delivery, along with other food (soup/green tea /porridge), and hunger	none	nutrition, energy, increase blood/iron and alternative food in hunger
		milk ("*kulee*")	3	liquid	2-3 L	nutrition, energy					
		meat ("*ingiring*")	3	with soft fat	1 Kg	nutrition, energy					
		fat (ghee / tallow)	1	cow / goat/ sheep	2-table spoon	nutrition, energy					

Food		Ingredients					Food				
Name (local name)	**FC**	**Name (local names)**	**FC**	**Part / source / form used**	**Amount/rate**	**Role(s)**	**Amount /rate**	**Frequency**	**Condition of use**	**Restriction**	**Roles**
"*Olchani-imotori*" (meat-herbal soup)	20	goat and sheep meat ("*ingiring*")	19	brisket ("*oloikulu*")	2- 5 Kg or any required amount	nutrition, energy	0.25-5 L per person	once-fourth per day	cold weather, sick, lactation, ceremony, far from home ("*ronjo*" / 'boma'), post-delivery, along with other foods ("ndafu" / "*ugali"*/ "*irmakuku*")	female (in case of "*olchan-oyokie*" / "*emukutan*") or male (in case of leafy vegetable)	nutrition, energy, disease treatment & prevention, increases body heat, and cleanse kidney: diuretic (*appendix 4*)
			19	fore legs ("*engejorongai*")		nutrition, energy					
			19	large intestine ("*erangi*")		nutrition, energy					
			19	Lungs, "*irkipio/washiwashi*"		nutrition, energy					
			19	neck ("*embosi*" / "*orkotete*"/ "*ermutu*")		nutrition, energy					
			19	rear legs ("*emuro*")		nutrition, energy					
			19	ribs ("*Ilarasi*")		nutrition, energy					
			19	small intestine ("*eminyor*")		nutrition, energy					
		cow meat ("*ingiring*")	19	below armpit steak ("*orng'abosho*")		nutrition, energy					
			19	brisket ("*enagilkitan*")		nutrition, energy					
			19	chest ("*embutwai*")		nutrition, energy					
			19	fore legs ("*engejorongai*")		nutrition, energy					
			19	heart ("*ortau*")		nutrition, energy					
			19	neck ("*embosi*"/ "*orkotete*" / / "*ermutu*")		nutrition, energy					
			19	rear legs ("*ormuwo*")		nutrition, energy					
			19	ribs ("*engelemian*")		nutrition, energy					
			19	stomach ("*endanu*")		nutrition, energy					
		water	19	Liquid	3-20 L	medium					
		cow, goat, and sheep fat	6	hard fat ("*engurinyi*" / "*engulaa*")	Closed hand finger volume	nutrition, energy					
		medicinal flora ("*Olchani*")	18	Herbs, 44 plants species (*appendix 4*)	2-5 pieces of 10-20 cm long for each of the species parts	medicine (*appendix 4*), food color, taste, aroma, viscosity, and appetite					

Food		Ingredients					Food				
Name (local name)	**FC**	**Name (local names)**	**FC**	**Part / source / form used**	**Amount/rate**	**Role(s)**	**Amount/rate**	**Frequency**	**Condition of use**	**Restriction**	**Roles**
"*Olgali*" / "*Olgali-lombeneki*"	13	whole maize grains	13	Sd (flour)	1-3 Kg per 4-5 people	nutrition, energy	1L per person or 0.25-1.0 Kg per person	once-twice per day	along with other foods (milk, vegetables/ beans)	none	nutrition, energy, increases blood, improve sight, and prevent diseases
		water	13	liquid	3-7 L	medium					
		salt	3	crystals	0.5-1 table spoon	taste					
		fat (ghee / tallow)	3	cow/goat/sheep	2-5 table spoon	taste & soften ugali					
		beans	6	Sd (fresh/dry)	1 Kg	nutrition, energy					
		onion	2	Bulb (Bb) (fresh)	2-bulb	nutrition, energy					
		Solanum villosum ("mnavu"/ "*engirola*")	3	Lf (fresh)	any	Increases blood, improve sight, and prevent diseases					
		tomatoes	2	Ft (fresh)	3-fruits	nutrition, energy					
		carrot	2	Tb (fresh)	2-root tubers	nutrition, energy					

Food		Ingredients					Food				
Name (local name)	**FC**	**Name (local names)**	**FC**	**Part / source / form used**	**Amount/rate**	**Role(s)**	**Amount/rate**	**Frequency**	**Condition of use**	**Restriction**	**Roles**
"*Olmushele*" (rice food)	2	rice	2	Sd (dry)	2-10 Kg	nutrition, energy	2 kg rice per 10 people	once-twice per day	ceremony	none	nutrition, energy
		water	2	liquid	4-20 L	medium					
		salt	2	crystals	1-table spoon	taste					
		fat (ghee / tallow)	2	cow/goat/sheep	2-table spoon	nutrition, energy					
		Solanum villosum ("mnavu" / "*engirola*")	2	Lf (fresh)	any	Increases blood, improve sight, and prevent diseases					
		tomatoes	2	Lf (fresh)	2-3 fruits	nutrition, energy					
		onion	2	Bulb (Bb)	3-bulb	nutrition, energy					
		Irish potatoes	2	Tb (fresh)	2 L	nutrition, energy					
		meat ("*ingiring*")	2	cow/goat/sheep	2 Kg	nutrition, energy					
		carrot	2	Rt (fresh)	2-root tubers	nutrition, energy					

Food		Ingredients					Food				
Name (local name)	**FC**	**Name (local names)**	**FC**	**Part / source / form used**	**Amount/rate**	**Role(s)**	**Amount/rate**	**Frequency**	**Condition of use**	**Restriction**	**Roles**
"*Oloshoro*" / "*Irpaek-lekule*"	21	grinded maize grains	21	Sd	1-5 Kg	nutrition, energy	0.25-2 L per person	once-thrice/ many times per day	day time / sick / cold weather	none	nutrition, energy, quenches thirst
		water	21	liquid	5-12 L	medium					
		banana ("ndizi ng'ombe")	4	Ft (fresh)	1-bunch ("chana")	nutrition, energy					
		cooked porridge ("*euji*")	11	Sd-maize flour	0.25 L or 1 Kg per 6-10 L of porridge	nutrition, energy					
		milk ("*Kulee*")	21	fresh/yogurt	1-10 L	nutrition, energy					
		Olea europaea subsp. *africana* (Mill.) P.S.Green ("*oloirien*")	17	St (smoke and ashes)	15-40 cm	preservation, taste, aroma					
		Grewia bicolor Juss. ("*Ositeti*")	2	St (smoke and ashes)	15-40 cm	preservation, taste, aroma					
		Lippia javanica (Burm f.) Spreng. ("*osinoni*")	2	St (smoke and ashes)	15-40 cm	preservation, taste, aroma					
		Cordia monoica Roxb ("*oseki*")	1	St (smoke and ashes)	15-40 cm	preservation, taste, aroma					
		Cordia monoica Roxb. ("*ordoko*")	1	St (smoke and ashes)	15-40 cm	preservation, taste, aroma					

Food		Ingredients					Food				
Name (local name)	**FC**	**Name (local names)**	**FC**	**Part / source / form used**	**Amount/rate**	**Role(s)**	**Amount/rate**	**Frequency**	**Condition of use**	**Restriction**	**Roles**
"*Orikitao*"	11	grinded maize grains	11	Sd (dry)	2-4 Kg	nutrition, energy		once-thrice per day	farming or along with other food (tea)	none	nutrition, energy
		water	11	liquid	4-6 L	medium					
		beans	11	Sd (fresh / dry)	0.5-3 Kg	nutrition, energy					
		Lablab purpureus "*ngwara*"	1	Sd (fresh / dry)	0.5-1 Kg	nutrition, energy					
		soda ("magadi")	4	crystals	0.5-table spoon / 1-tea spoon	soften grains (beans) & reduces stomach gas (bloating)					
		salt	9	crystals	2-3 table spoon	taste					
		meat ("*ingiring*")	3	cow /goat /sheep	any required	nutrition, energy					
		carrot	3	Tb (fresh)	any required	nutrition, energy					
		potatoes	3	Tb (fresh)	any required	nutrition, energy					
		onion	3	Bb (fresh]	any required	nutrition, energy					
		tomatoes	3	Ft (fresh)	any required	nutrition, energy					
		fat / oil	3	(butter / groundnut /goat / "korie" / "kasuku")	any required	nutrition, energy					

Food		Ingredients					Food				
Name (local name)	**FC**	**Name (local names)**	**FC**	**Part / source / form used**	**Amount/rate**	**Role(s)**	**Amount/rate**	**Frequency**	**Condition of use**	**Restriction**	**Roles**
"*Shai-ekulee*" (milk tea)	3	Water	1	liquid	1 L	medium	0.25 L (a cup) per person	once-twice per day	any / sick/ pregnancy	male (when *Sphaeranthus bullatus* or herbs for female are used)	nutrition, energy, medicine (*appendix 4*)
		milk	3	liquid	0.5-2.0 L	nutrition, energy					
		tea leave	1	powder	0.5-table spoon	taste					
		sugar	1	crystals	any sweetness	taste					
		spice (ginger/cardamom)	1	Rt / Ft (powder)	any	taste, aroma					
		Rapanea melanophloeos (L.) Mez. ("*iloodwa*")	1	Ft (powder)	0.5-table spoon	taste, aroma, raises body temperature, medicine (*appendix 4*)					
		Sphaeranthus bullatus Mattf. ("*Orkipire lekima*")	1	Lf & Rz or Wp (fresh)	1.0-palm	taste, aroma, increases labor pain					
		Croton sp. ("*enjanie-emburkel*")	1	St (powder)	2-table spoon / 1-palm	taste, aroma, appetite, medicine (*appendix 4*)					
		Zanthoxylum chalybeum (Engl.) Kokwaro ("*oloisuki*")	1	Rt /Ft / Bk (powder)	2-table spoon	taste, aroma, medicine (*appendix 4*)					
		Acacia nilotica (L.) Wild ex Delile ("*Orkiloriti*")	1	Bk (powder)	1-2 table spoon	taste, aroma, medicine (*appendix 4*)					
		Ximenia caffra Sond ("*eng'gamai*" / "*Ilama*")	1	Rt (powder)	1-2 table spoon	taste, aroma, medicine (*appendix 4*)					
		Ocimum gratissimum ("*Ormanyinyikwai*")	1	Lf (powder)	1-2 table spoon / 1-palm	taste, aroma, medicine (*appendix 4*)					

Maasai terminologies are written in small letters, italic, within double inverted commas while Swahili terminologies are written in small letters, within double inverted commas throughout the document.

Abbreviations: *FC* frequency of citation habitat; *PU* part used (*Bk* bark, *Ft* fruit, *Lf* leaves, *Rt* root, *Rz* rhizome, *Sd* seed, *Tb* tuber, *Wp* whole aerial part); Standard units (*L* liter, *Kg* kilograms, *cm* centimeters)

Appendix 4: Flora used in Maasai TFS and TM

Family	Scientific name	Vernacular name (Maasai)	O/E	RL	Habitat	Habit	PU	RA	UV	RFC	Preparation and application	Ailment(s) treated / role(s) performed	Collection N0.
Amaranthaceae	*Cyathula orthacantha* (Hochst. ex Asch.) Schinz.	Olaisai	N	Ab	Sa	H	Rt	Or	0.05	5	Fresh or dry roots is boiled, and the decoction is drunk	Joints' (knee's) pain	RPC086
Anacardiaceae	*Lannea schweinfurthii* (Engl.) Engl.	Orupande	N	Ab	Sa	T	Bk	Or	0.29	10	Bark powder is decocted and mixed with milk & animal tallow (fats)/clarified butter, and then drunk Milk and animal tallow/clarified butter mixture is infused with the bark powder, and then drunk	Clean uterus, reliefs uterus pain, stops excess menstrual flow, stop bleeding & abortion in young pregnancy	RPC059
	Ozoroa insignis subsp. *reticulata* (Baker f.) J.B.Gillett	Olokinonoi	N	LC	Sa	T	St		0.10	10	Stem is crafted or curved into a stirrer ("*orkipire*")	Stirring liquid food	RPC096
	Rhus vulgaris Meikle	Olmusigiyoi	N	Ab	Sa	Sb	Ft, Bk, & Rt	Or	0.67	43	Fruit is chewed and swallowed Bark or roots' decoction is mixed with a meat's broth/stock, and then drunk. Tea or fresh milk is infused with roots' powder and drunk	Source of food Joins a broken bone and cleanse kidney (diuretic)	RPC036
	Sclerocarya birrea subsp. *multifoliolata* (Engl.) Kokwaro	Ormang'uai	N	Ab	Sa	T	Ft, St, & Bk	Or	0.76	43	Fruit is chewed, and its soft part is swallowed, or the seed is broken and oily nut is eaten Stem is crafted /curved into a mortar ("*engiuri*") Dry or fresh bark is boiled in water, and its decoction is drunk to the baby cow	Source of food and produces alcohol. Excess fruits cause alcoholism, diarrhea, dizziness, vomiting, or weaken joints Grinds food staffs or herbal medicines Sickness in baby cow	RPC070
Apocynaceae	*Carissa spinarum* L	Olamuriaki	N	LC	Fo	Sb	Ft & Rt	Or	0.86	29	Fruit is chewed and swallowed Roots' decoction is mixed with meat's broth/stock, and then drunk	Source of food Diuretic/cleanse kidney Gonorrhea, bone pain, raises body temperature & immunity	RPC052
	Tabernaemontana pachysiphon Stapf	Ormurasha / Ormuraha	N	LC	Fo	T	Rt	Or	0.19	5	Roots' decoction is mixed with meat's broth/stock, and then drunk	Joints' pain, boil/swelling Diuretic/cleanse kidney, increases body energy	RPC051

Family	Scientific name	Vernacular name (Maasai)	O/E	RL	Habitat	Habit	PU	RA	UV	RFC	Preparation and application	Ailment(s) treated / role(s) performed	Collection N0.
Asclepiadaceae	*Secamone parvifolia* (Oliv.) Bull.	osinandei	N	Ab	Fo	Cl	Rt	Or	0.10	5	Fresh or dry root is boiled in water, and the formed decoction is mixed with fresh milk & tallow/clarified butter, and then drunk	Clean uterus, reliefs womb/uterus pain	RPC006
Asparagaceae	*Asparagus setaceus* (Kunth) Jessop	Embere papa	N	Ab	Fo	H	Rt	Or	0.19	14	Fresh (preferred) or dry root is chewed, or its decoction is mixed with meat's broth/stock, and then drunk	Facilitates erection / increases libido	RPC004
											Roots' decoction is mixed with honey and the decoction of *Hydnora abyssinica* rhizomes & *Tragia ukambensis* roots	Blood pressure and diabetes	
Asteraceae	*Dicoma tomentosa* Cass.	Olchani lolasurai	N	Ab	Bu	H	Wp	De/ Or	0.05	5	Dry aerial part is roasted on a hot sheet pan, then grinded into a powder which is applied on a small bleeding cut made on either side of snake bite area along the blood flow direction.	Detoxify snake poison in human and animal (e.g. cow)	RPC083
											The formed powder is also mixed with water, and then drunk		
	Sphaeranthus bullatus Mattf.	Orkipire lekima	N	Ab	We	H	Lf, Rz, & Wp	Or	0.05	5	Fresh leaves and rhizome, or whole aerial part is boiled in water, and its decoction is mixed with a fresh milk, and then drunk	Increases Labor pain / facilitates delivery process	RPC047
	Gymnanthemum auriculiferum (Hiern) Isawumi **Syn**: *Vernonia auriculifera* (Hiern)	Ormaduduu	N	LC	Fo	Sb	Rt	Or	0.38	10	Fresh or dry root is boiled in water, and its decoction is drunk	Diuretic/cleanse kidney Gonorrhea, pain of waist, legs or joints	RPC008
Boraginaceae	*Cordia africana* Lam.	Ormuringiringa	N	LC	Fo	T	St & Bk	De/ Or	0.33	14	Bark decoction is mixed with the decoction of *Lippia kituiensis* root & *Chenopodium schraderianum* leaves, and then drunk, steamed on the body, or mixed with chicken's broth / blood, and then drunk	Measles and "*OSUPETAI*"	RPC042
											Stem is crafted or curved into a mortar ("*engiuri*")	Grinds food staffs or herbal medicines	

Family	Scientific name	Vernacular name (Maasai)	O/E	RL	Habitat	Habit	PU	RA	UV	RFC	Preparation and application	Ailment(s) treated / role(s) performed	Collection N0.
Boraginaceae	*Cordia monoica* Roxb	Oseki	N	LC	Sa	T	Lf, Ft, St, Bk, & Rt	Na/Or	0.67	38	Fresh leaves are crafted or made into a mat ("*enaraa*"), or they squeeze coagulated blood	Hold meat / animal in a slaughtering process, or dissolve coagulated blood	RPC048
											Fruits are chewed and swallowed, or they are made into a juice, and then drunk	Source of food	
											A dry stem piece is burn into a smoke/ash which is spread into the storage container (calabash)	Food preservation, taste/flavor	
											Stem is crafted or curved into sharp end stick ("*orjibet*"), pierced into meat pieces, and then erect beside a fire	Hold meat in the roasting process	
											Water is infused with bark powder, or roots decoction is mixed with fresh milk & tallow/clarified butter, and then drunk	Cleans uterus and reliefs menstruation pain	
	Cordia monoica Roxb.	Oldorko	N	LC	Sa	Sb	Ft & St	Na/Or	0.29	19	Fruit is chewed and soft part is swallowed	Source of food	RPC065
											Stem is crafted or curved into sharp end stick ("*orjibet*"), pierced into meat pieces, and then erected beside a fire	Hold meat in the roasting process	
											Dry stem pieces burn into a smoke/ash which is spread into the storage container (calabash)	Food preservation, taste/flavor	
	Cordia sinensis Lam	Ingululu	N	**LC**	Sh	T	Ft	Or	0.05	5	Fruit is chewed and soft part swallowed	Source of food	RPC091
	Cordia sp.	Olebalelon	N		Sa	Sb	St & Rt	Or	0.71	24	Stem's/roots' decoction is mixed with meat's broth/stock, and then drunk	Pneumonia/chest pain and clean uterus	RPC082
												Diuretic/cleanse kidney	
												"*OSUPETAI*" / "*OLGILA*"	
												Provide taste, smell & viscosity to the meat broth/stock, increases blood, increases lactating mothers' milk, reliefs tiredness	
Burseraceae	*Commiphora africana* A. Rich	Esilalei	N	LC	Sa	T	St		0.19	19	Stem is curved into a stirrer ("*orkipire*") or mortar ("*engiuri*")	Stirring liquid food, grinding food staffs or herbal medicines	RPC097

Family	Scientific name	Vernacular name (Maasai)	O/E	RL	Habitat	Habit	PU	RA	UV	RFC	Preparation and application	Ailment(s) treated / role(s) performed	Collection N0.
Fabaceae (Caesalpiniaceae)	*Biancaea decapetala* (Roth) O.Deg. **Syn:** *Caesalpinia decapetala* (Roth) Alston	Ormashinga	A	LC	Fo	Cl	Lf, Ft, St, & Rt	Or	0.71	14	Fresh Leaves are chewed, and its juice is swallowed	Stomachache	RPC019
											Fruit is squeeze into a juice which is applied on a material joint	Glue	
											Stem decoction is mixed with meat's broth/stock, and then drunk	Hernia, Joints' pain & swelling	
											Roots' decoction is mixed with meat's broth/stock, and then drunk	Hernia, Joints' pain & swelling, back pain	
											Banana and *Lablab purpureus* seeds mixture is cooked while infused with root, and then eaten	Induces diarrhea, treats constipation, "*OSUPETAI*" and clean pelvis	
	Senna didymobotrya (Fresen.) H.S.Irwin & Barneby	Ormapinu	N	LC	Fo	Sb	Lf	Or	0.14	5	Kitchen warm dried leaves is boiled in water, and its decoction is mixed with castral oil, and then drunk	Induces diarrhea, clean infected chest mucus, treat "*OSUPETAI*"	RPC015
Capparaceae	*Capparis fascicularis* DC.	Ormakirutu / Olaiturudia	N	**LC**	Sh	Sb	Rt	Na/Or	0.10	10	White roots' decoction is mixed with *Cyathula orthocantha* roots' decoction, and then drunk	Joints' (knee's) pain	RPC092
											Dry red root is burn on fire, and its smoke is inhaled through nostrils	headache	
Celastraceae	*Mystroxylon aethiopicum* (Thunb.) Loes **Syn:** *Cassine aethiopica* Thunb.	Olodong'anayo	N	LC	Fo	T	St		0.29	14	Stem is curved into pestle ("*emushi*")	Grinds food staffs or herbal medicines	RPC029
Amaranthaceae (Chenopodiaceae)	*Dysphania schraderiana* (Schult.) Mosyakin & Clemants **Syn:** *Chenopodium schraderianum* Schult.	Olekukunu	N & Sy	Ab	Gr	H	Lf	De/Or	0.67	19	Fresh leaves decoction is mixed with *Solanum aculeastrum* roots' decoction, and then drunk	Diuretic/cleanse kidney	RPC026
											Fresh leaves decoction is mixed with chicken broth/blood, or with a decoction of *Cordia africana* barks & *Lippia kituiensis* roots, and then drunk	Boil/swelling, joints' pain, tiredness, measles and "*OSUPETAI*"	

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Combretaceae	*Combretum zeyheri* Sond	Ormararoi-oibor	N	LC	Sa	T	St, Bk, & Rt	Or	0.95	24	Barks'/roots'/stem's decoction is mixed with meat's broth/stock, and then drunk, or milk tea is infused with barks' powder, and then drunk	Diuretic/ cleanse kidney Pain of muscles, joints (knee & instep), back, waist, and chest. "*OSUPETAI*" or '*OLGILA*', clean uterus	RPC098
											Stem is curved into a sharp end stick ("*orjibet*"), pierced through meat pieces, and erected beside fire	Hold meat in the roasting process	
	Terminalia brownii Fresen	Orbukoi	N	LC	Sa	T	Bk	Or	0.19	5	Bark is boiled in water, and its decoction is drunk by human or to a cow	Induces vomiting, antidote for a swallowed poison and treat blood in urine / bilharzia in either human or cow	RPC058
Cucurbitaceae	*Lagenaria siceraria* (Molina) Standl	Oltulet /engotii	N & Ct	Ab	Sa	Cl	Ft		2.48	100	Dry fruit is crafted or curved into a container	Stores liquid foods: milk, "*oloshoro*", "*engitalolo*", "*euji*" or "*emberere*"	RPC093
Ebenaceae	*Euclea divinorum* Hiern	Osojo	N	LC	Sa, Fo	T	Rt	Or	0.14	5	Roots are boiled in water, and its decoction is mixed with fresh milk and tallow/clarified butter, and then drunk	Induces diarrhea, treats "*OSUPETAI*" and swelling from legs to the eyes	RPC010
Peraceae (Euphorbiaceae)	*Clutia abyssinica* Jaub. & Spach	Enginyamasambi	N	LC	Fo	Sb	Rt	Or	0.38	10	Root is boiled in water, and its decoction is drunk	Diuretic/cleanse kidney Gonorrhea, pain of waist, legs or joints	RPC007
Euphorbiaceae	*Croton dichogamus* Pax.	Oloibor benek	N	LC	Bu	Sb	Rt	Or	0.24	5	Roots' decoction is mixed with meat's broth/stock, and then drunk	Pain of joints, back, and waist, reliefs tiredness, provides food's (broth/stock) taste	RPC073
	Croton macrostachyus Hochst. ex Delile	Oloiyapiyap	N	LC	Fo	T	Lf, Bk, & Rt	Or	0.38	14	Roots' decoction is mixed with honey, *Aloe sp* root and decoction of other herbs and the formed mixture ("*opururua*") is drunk, or bark decoction is mixed with meat's broth/stock, and then drunk	Induces diarrhea and treats intestinal parasites (worms)	RPC005
											Fresh leaves are cooked, and then eaten	Vegetable food, treats intestinal worms	

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Euphorbiaceae	*Croton megalocarpus* Hutch	Ormarbait	N	LC	Fo	T	Bk	Or	0.86	19	Fresh milk is infused with bark's powder, and then drunk	Induces diarrhea, treats "*OSUPETAI*", intestinal parasites (worms), pain of joints, back, and waist, and clean or detoxify the body	RPC053
	Croton sp.	Enjanie-emburkel	N		Sh	Sb	St & Bk	Or	0.57	14	Meat's broth /stock or cold water is infused with stem powder, and then drunk	Reliefs stomachache, facilitates food digestion, increases appetite, cleanse kidney (diuretic), increases body heat	RPC089
											Milk tea **/** meat's broth or stock **/** cold water is infused with bark's powder, and then drunk	Boil/swelling, gonorrhea, "*ENARPOSESENI*" (hernia), worms, malaria, and facilitates food digestion, increases appetite**,** induces abortion	
	Euphorbia sp	Emukutie	N		Bu	H	Rt	Or	0.19	10	Fresh root is chewed, and its juice is swallowed	Cough, tonsillitis, restore lost voice due to excessive singing	RPC085
	Ricinus communis L.	Oldule	N & Sy	Ab	Fo	Sb	Ft & Rt	Or	0.29	14	Seeds are squeezed, and its oil is mixed with *Senna didymobotrya* leaves' decoction, and then drunk	Induces diarrhea and remove infected chest mucus	RPC049
											Roots' decoction is mixed with honey, *Aloe sp* roots, and the decoction of other herbs, and the formed mixture ("*opururua*") is drunk	Diuretic/cleanse kidney and build the body	
	Tragia ukambensis Pax var.ukambensis	Engipwapwa	N	**LC**	Gr	H	Rt	Or	0.10	5	Roots' decoction is mixed with honey and the decoction of *Hydnora abyssinica* rhizomes and *Asparagus setaceus* roots, and then drunk	Blood pressure and diabetes.	RPC080
Fabaceae	*Vachellia nilotica* (L.) P.J.H.Hurter & Mabb. **Syn:** *Acacia nilotica* (L.) Wild ex Delile	Orkiloriti	N	**LC**	Sa	T	Ft, Bk, & Rt	Or	1.05	33	Decoction of dry fruits or bark is mixed with meat's broth/stock, or a tea is infused with bark's powder, and then drunk	Pain of muscles and joints**,** gonorrhea, relief tiredness, dissolves animal fats and facilitate food digestion, provides viscosity and good taste of meat's broth/stock, builds the body**,** cleanse kidney (diuretic)**,** increases "*MORI*"/ "*EMBOSHONA*" (confidence or angriness)	RPC063
											Root is boiled in water, and its decoction is drunk, or the roots' decoction is mixed with meat's broth/stock, and then drunk	Reliefs joints' pain & body weakness, induces diarrhea & muscles dislocation	

Family	Scientific name	Vernacular name (Maasai)	O/E	RL	Habitat	Habit	PU	RA	UV	RFC	Preparation and application	Ailment(s) treated / role(s) performed	Collection N0.
Fabaceae	*Albizia anthelmintica* (A.Rich.) Brongn.	Emukutan	N	LC	Sa	T	Bk & Rt	Or	1.48	52	Fresh milk is infused with bark's powder, and then left for about 4 days before drunk, or bark's decoction is mixed with meat's broth/stock, and then drunk	Intestinal parasites (worms), increases body heat	RPC062
											Decoction of roots' powder is mixed with *Embelia schimperi* decoction and lamb tallow (fats), and then drunk or	Intestinal parasites (worms), an antidote for a swallowed poison**,** treats "*OSUPETAI*", fever, boil or swelling, and gonorrhea	
											Roots' decoction is mixed with fresh milk and meat's broth/stock, or with milk/meat's broth alone, or with cow blood, and then drunk	Increases body heat, induces bile juice vomiting (treats-malaria)**,** induces diarrhea **Note:** A. *anthelmintica & E. schimperi* induce abortion	
	Albizia harveyi E. Fourn.	Orperelong'o	N	LC	Sa	T	Bk	Or	0.10	5	Bark's decoction is mixed with meat's broth/stock, and then drunk	Provides a good taste of meat's broth/stock and build the body	RPC078
	Dalbergia melanoxylon Guill. & Perr.	Oltiasika	N	NT	Sa	T	Rt	Or	0.14	14	Roots' decoction is mixed with meat's broth/stock, or its roots' decoction and that of *Withania somnifera* roots are mixed with meat's broth/stock, then drunk	Joins fast a broken bone and treats an internal wound	RPC074
	Lablab purpureus (L.) sweet subsp. uncinatus Verdc.	Ngwara	N & Ct	Ab	Gr	H	Sd	Or	0.19	10	Seeds are cooked in water, and its formed soup is drunk or eaten	Joins a broken bone and is a food source	RPC094
											Seeds are cooked with banana, then infused with *Caesalpinia decapetala* root, and then eaten as medicine	Medium for the herbal medicine	
	Philenoptera eriocalyx (Harms) Schrire **Syn:** *Lonchocarpus eriocalyx* Harms	Embararwai	N	Ab	Sa	T	Lf		0.10	10	Fresh leaves are crafted into a mat ("*enaraa*")	Holds animal or meat in a slaughtering process, and it prevents contamination	RPC061
	Tamarindus indica L.	Orperelong'o /Ormasamburai	N	LC	Sa	T	Ft	Or	0.19	19	Fruit is chewed, and its soft part is swallowed, or the fruit is processed into a juice, and then drunk	Source of food	RPC060
	Vigna parkeri Baker subsp. *acutifolia* Verdc	Orkalei	N	LC	Gr	Cl	Tb	Or	0.10	5	Tuber is chewed, and its resulting juice is swallowed	Source of food and stop thirst	RPC087

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Salicaceae (Flacourtiaceae)	*Dovyalis abyssinica* (A.Rich.) Warb.	Emaduai	N	LC	Fo	T	Ft, St, & Rt	Or	0.67	52	Fruit is chewed and swallowed	Source of food	RPC017
											The stem is curved into a mortar ("*engiuri*")	Grinds food staffs or herbal medicines	
											Roots' decoction is mixed with meat's broth/stock, and then drunk	Appetizer in meat's broth/stock	
	Oncoba routledgei Sprague	Emoroo	N	Ab	Fo	Sb	Ft	Or	0.10	10	Fruit is chewed, and its soft part is swallowed	Source of food	RPC024
Aristolochiaceae (Hydnoraceae)	*Hydnora abyssinica* A. Braun	Erukunyi	N	Ab	Sa	Srp	Ft & Rz	Or	0.24	19	Fresh fruit is chewed or warmed on fire like a potato, and then eaten.	Food source	RPC101
											Dry rhizome is grinded into powder, and its decoction is mixed with honey and roots' decoction of *Tragia ukambensis* & *Asparagus setaceus,* and then drunk	Blood pressure and diabetes	
											Fresh rhizome or its powder is boiled in water, and its formed decoction is drunk	Stomachache or diarrhea	
Lamiaceae	*Leucas sp*	Enjaniengusero	N		Bu	H	Lf & Wp	Or	0.10	5	Leaves or whole aerial part is boiled in water, and its formed decoction is drunk	Stomachache and pneumonia	RPC084
	Ocimum gratissimum L.	Ormanyinyikwai	N	Ab	Sh	H	Lf & Rt	Or	0.48	19	Milk tea / tea is infused with leaves, and then drunk, or fresh leaves is chewed, and its formed juice is swallowed	Influenza, releases stomach gas, provides good taste/flavor	RPC027
											Leaves' decoction is mixed with the decoction of *Eucalyptus saligna* leaves, and then drunk	Joints' (finger's & knee's) pain, cleanse kidney (diuretic)	
											Roots' decoction is mixed with meat's broth/stock, or roots' decoction is mixed with the decoction of *Solanum incanum* and *Lippia kituiensis* roots, and then drunk	Fever, joints' pain	
	Tetradenia riparia (Hochst.) Codd.	Ormakingi	N & Ct	LC	Fo	H	Lf & Wp	Or Oc	0.24	14	Leaves are squeezed, and its formed juice is swallowed, or put into a cavity of an infected teeth or an infected eye	Stomachache, tooth pain, and eye infection	RPC046
								De Na			Decoction of leaves/whole aerial part is mixed with that of *artemisia annua* leaves, and then steamed on the body	Treats dry cough and influenza	

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Lauraceae	*Persea americana* Mill.	Orparachichi	A & Ct	**LC**	Fo	T	Lf & Ft	Or	0.29	14	Fresh leaves' decoction is mixed with the decoction of *Z. deremense* root and *Psidium guajava* leaves, then drunk	Fever/malaria	RPC056
											Fruit is chewed and swallowed	Source of food	
Malvaceae	*Abutilon longicuspe* Hochst. ex A.Rich.	Oldadai	N	Ab	Fo	Sb	St & Bk		0.19	10	Stem is curved into a sharp end stick ("*orjibet*"), pierced into meat pieces, and then erected beside a fire	Holds meat in the roasting process	RPC020
											Bark is streamed into a rope	Tie food staffs/herbs or other materials	
	Thespesia garckeana F. Hoffm.	Emotoo	N	LC	Sa	T	Lf, Ft, & St	Or	0.24	14	Fresh leaves are crafted into a mat ("*enaraa*")	Hold animal/meat and prevent contamination in a slaughtering process	RPC095
											Fruit is chewed, and its soft part is swallowed	Source of food	
											Stem is curved into a sharp end stick ("*orjibet*"), pierced through meat pieces, and then erected beside a fire	Holds meat in the roasting process	
Meliaceae	*Ekebergia capensis* Sparrm	Ormukuna	N	LC	Fo	T	St		0.14	14	Stem is curved into a mortar ("*engiuri*")	Grinds food staffs or herbal medicines	RPC022
	Lepidotrichilia volkensii (Gürke) J.-F.Leroy	Engilelekuru	N	LC	Fo	T	Rt	Or	0.33	19	Roots' decoction is mixed with meat's broth/stock, or with fresh goat's feces juice, and then drunk	Diuretic/cleanse kidney, treats joints' pain, boil/swelling on breast, legs, or other parts, excess causes vomiting	RPC023
											Roots' decoction is drunk along with fresh goat's skin wrapped on a neck	Tonsillitis	
Francoaceae (Melianthaceae)	*Bersama abyssinica* Fresen	Eng'arangupe	N	LC	Fo	T	Rt	Or	0.10	10	Roots' decoction is mixed with meat's broth/stock, and then drunk	Diuretic/cleanse kidney	RPC003
Mimosaceae	*Acacia sp*	Orimbai	N		Fo	T	Bk	Or	0.19	10	Bark is boiled in water, and its formed decoction is drunk	Stomachache and "*OSUPETAI*"	RPC041
	Acacia sp.	Osiyamalei	N		Sa	T	Bk	Or	0.14	5	Bark decoction is mixed with meat's broth/stock, and then drunk	Treats joints' pain and inflammation, increases "*MORI*"/ "*EMBOSHONA*"	RPC068
Moraceae	*Ficus sycomorus* L.	Orng'aboli	N	LC	Fo, We	T	Ft	Or	0.05	5	Fruit is chewed and swallowed	Source of food	RPC090

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Moraceae	*Ficus thonningii* Blume	Oreteti	N	LC	Fo	T	Bk & Rt	Or	1.10	52	Bark/root is boiled into water, and its formed decoction is drunk, or its powder is swallowed	Stop diarrhea	RPC028
											Fresh roots' bark is peeled and the inner part is chewed like gum	Stop thirst	
											Roots' woody is crafted into a brush ("*esosian*")	Spreads and cleans herbal ashes/smoke in a calabash for food preservation	
											People surround the whole aerial part	Ritual purpose	
Primulaceae (Myrsinaceae)	*Embelia schimperi* Vatke	Olchani-onyokie	N	LC	Fo	Sb	Lf, Bk, & Rt	Or	1.43	48	Leaves are chewed and swallowed	Source of food	RPC037
											Hot/cold water is infused with bark powder and then drunk	Pain in joints, back, muscles, and ribs It also treats Anaplasmosis in cattle	
											The decoction of bark powder is mixed with "iloodwa"/ "ngesi" powder's decoction and fresh milk or lamb tallow (fats), and then drunk.	"*OSUPETAI*" or "*OLGILA*", boil, gonorrhea	
											The bark is warmed and chewed along with honey	Influenza, cough, fever, stomachache, and throat wounds	
											Decoction of bark's/root's powder is mixed with *Albizia anthelmintica* roots' decoction and lamb tallow (fats), or decoction of bark's powder is mixed with tallow (fats), and then drunk	Induces diarrhea, treats joints' (finger/knee's) inflammation, boil, "*OSUPETAI*", gonorrhea **Note:** *Embelia schimperi* induces excess menstrual flow and abortion	
	Myrsine melanophloeos (L.) R.Br. ex Sweet	Iloodwa / Engodwai	N	Ab	Fo	T	Ft	Or	1.33	29	Dry fruits are ground into powder, and swallowed along with Coca-Cola soda or salt water solution, or mixed with a hot lamb tallow (fat), and swallowed.	Diuretic/cleanse kidney, treats gonorrhea, internal wounds, intestinal parasites and "*OSUPETAI*"	RPC099
	Syn: *Rapanea melanophloeos* (L.) Mez.										The decoction of fruit powder is mixed with the decoction of *Embelia schimperi* bark powder & and fresh milk or lamb fats, and then drunk.	Induces diarrhea, treats joint pain, Intestinal parasites (worms), and "*OSUPETAI*"	
Myrtaceae	*Eucalyptus saligna* Smith	Orkelebu	A & Ct	LC	Fo	T	Lf & St	Or	0.19	10	Leaves are boiled with *Ocimum gratissimum* leaves in water, and the formed decoction is drunk	Diuretic/cleanse kidney, treats joints' (finger's & knee's) pain	RPC044
											The stem is curved into a sharp end stick ("*orjibet*"), pierced through meat pieces, and erected beside fire	Holds meat in a roasting process	
											Stem is crafted into a pestle ("*emushi*")	Grinds food staffs or herbal medicines	

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Myrtaceae	*Psidium guajava* L.	Ormaperai	A & Ct	**LC**	Fo	T	Lf & Ft	Or	0.29	14	Leaves are boiled with *Zanthoxylum deremense or chalybeum* roots and *Persea americana* leaves in water, and the formed decoction is drunk	Fever/malaria	RPC057
											Fruit is chewed and swallowed	Source of food	
Nyctaginaceae (Plumbaginaceae)	*Commicarpus plumbagineus* (Cav.) standl; **SCF:** *Plumbago zeylanica* L	Orng'eriandus	N	Ab	Bu	H-Cl	Rt	Or	0.76	14	Root is boiled in water, and its formed decoction is drunk, or mixed with meat's broth/stock, or mixed with fresh milk, and then drunk	Diuretic/cleanse kidney; treats inflammation of a joint (knee/ankle); gonorrhea; "*OSUPETAI*"; stomachache; the pain of joints (knee & ankle), back, waist, and bones	RPC088
Ximeniaceae (Olacaceae)	*Ximenia caffra* Sond	Eng'gamai / Ilama	N	LC	Sa	Sb	Ft, St, Bk, & Rt	Or	1.43	52	Fruit is chewed, and its soft part is swallowed	Source of food for human/cow/goat	RPC069
											Stem/bark/root is boiled in water, and the formed decoction is drunk, or mixed with meat's broth/stock, and then drunk, or roots' decoction is mixed with fresh milk and tallow/clarified butter, and then drunk	Dissolves animal fats, provides color, taste, odor & viscosity to the meat's broth/stock, and add blood (red in color)	
												Diuretic/cleanse kidney	
												Joint pain, stomach ulcers, clean uterus, reliefs uterus pain, stops excess menstrual flow or bleeding and abortion in young pregnancy, relaxes the body	
Olacaceae	*Olea europaea* subsp. *cuspidata* (Wall. & G.Don) Cif.	Oloirien	N	Ab	Fo	T	St	Na/Or	1.95	100	Stem is chopped into piece(s) which is burnt into smoke and ash, then spread by brush ("*esosian"*) into the storage container (calabash)	Preserve, and provide good odor, and taste to the liquid foods: milk, "*oloshoro*", "*engitalolo*", "*euji*" and "*emberere*"	RPC035
	Syn: *Olea europaea* subsp. *africana* (Mill.) P.S.Green										Stem's smoke is sniffed through nostrils	headache	
											The curved sharp end stick ("*orjibet*") is pierced through meat's pieces and set beside a fire	Holds meat in the roasting process	
Papaveraceae	*Argemone mexicana* L	Olemokolo	A & Sy	Ab	Gr	H	St	De	0.05	5	Fresh stem is cut, and the juice that oozes out is applied on the wounded skin	Treat wounds	RPC077
Piperaceae	*Piper capense* L. f.	Olerubat	N	LC	Fo	T	Rt	Or	0.48	24	Roots' decoction is mixed with meat's broth/stock, and then drunk	Provides good taste and odor to the meat's broth/stock Diuretic/cleanse kidney and blood, treats pain of joints, boil/swelling and stomachache	RPC050

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Polygonaceae	*Rumex usambarensis* (Engl.) Dammer	Engaisiijoi	N	Ab	Fo	H	Tb	Or	0.38	24	Tuber is pounded into a paste which is then boiled into water, and its formed decoction is drunk	Induces vomiting to an intoxicated patient and detoxify a swallowed poison	RPC043
											Tubers' decoction is mixed with fresh milk, or meat's broth/stock, and then drunk	"*OSUPETAI*", stomach ulcers, clean uterus and infertility in women	
Rhamnaceae	*Helinus mystacinus* (Aiton) E.Mey. ex Steud.	Olesupeni	N	Ab	Fo	Cl	Lf & Rt	Or	0.90	33	Water is infused with the pounded fresh leaves, and then used as a soap	Used as a washing soap	RPC002
											Root is boiled in water, and its formed decoction is drunk, or mixed with meat's broth/stock, or mixed with honey and the *Aloe sp* roots, and then drunk	Diuretic/cleanse kidney, treats "*OSUPETAI*", gonorrhea, the pain of the back, waist, and joints, and increases libido	
											Fresh milk or tea is infused with roots' powder, and then drunk		
	Rhamnus Prinoides L. Her	Orkonyil	N	LC	Fo	Sb	Rt	Or	0.95	38	Root is boiled in water, and its formed decoction is drunk, or mixed with meat's broth/stock, and then drunk	Diuretic/cleanse kidney, treats joints' pain, boil/swelling, gonorrhea, reliefs tiredness or body weakness and causes sweating	RPC039
	Rhamnus staddo A. Rich	Engokola	N	LC	Fo	T	Rt	Or	0.90	43	Roots' decoction is mixed with meat's broth/stock, or with honey, *Aloe sp* roots and decoction of other herbs, and then drunk	Diuretic/cleanse kidney, treats stomachache, "*OSUPETAI*", inflammation of joints (finger/knee/ankle), the pain of joints, back, and waist, causes sweating	RPC032
	Scutia myrtina (Burm. f.) Kurz	Osikardei	N	LC	Fo	Cl-T	Ft, St, Bk, & Rt	Or	0.43	29	Fruit is chewed, and its soft part is swallowed	Source of food	RPC009
											Stem's/barks' decoction is mixed with meat's broth/stock, and then drunk	Diuretic/cleanse Kidney	
											Root is boiled in water, and its formed decoction is drunk, or mixed with honey, *Aloe sp* roots and decoction of other herbs to form "*opururua*", and then drunk	Induces diarrhea, diuretic/cleanse kidney, and treats "*OSUPETAI*"	
	Ziziphus mucronata Willd. Subsp.mucronata	Oloilalei	N	LC	Sa	T	Ft, St, Bk, & Rt	Or	0.62	24	Fruit is chewed, and its soft part is swallowed	Source of food	RPC064
											Stem's/bark's/roots' decoction is mixed with meat's broth/stock or tallow/clarified butter, and then drunk Milk or tea is infused with roots' powder	Increases appetite, dissolves animal fats, facilitates digestion, provide viscosity and taste to the meat's broth/stock, treats pain of the back and stop excess menstrual flow	

Family	Scientific name	Vernacular name (Maasai)	O/E	RL	Habitat	Habit	PU	RA	UV	RFC	Preparation and application	Ailment(s) treated / role(s) performed	Collection N0.
Rubiaceae	*Vangueria infausta* Burch	Emardanyi / egumi	N	LC	Fo	T	Ft	Or	0.81	81	Fruit is chewed, and its soft part is swallowed	Source of food	RPC030
Rutaceae	*Clausena anisata* (Willd.) Hook. F. Ex Benth	Ematasia	N	LC	Fo	Sb	Ft & St	Or	0.81	48	Fruit is chewed, and its soft part is swallowed	Source of food	RPC034
											Stem is crafted into a toothbrush, or curved into a sharp end stick ("*orjibet*"), pierced into meat pieces, and then set beside a fire	Cleans teeth, or holds meat in a roasting process	
	Zanthoxylum asiaticum (L.) Appelhans, Groppo & J.Wen **Syn:** *Toddalia asiatica* (L.) Lam	Olaiseremai	N	Ab	Fo	T-Sb	Lf & Rt	Or	0.19	19	Leaves are chewed, and its formed juice is swallowed	Stops milk in a lactating mother	RPC012
											Roots' decoction is mixed with meat's broth/stock, and then drunk	Diuretic /cleanse kidney	
	Toddalia simplicifolia Engl. **Syn:** *Vepris simplicifolia* (Engl.) Mziray	Olgilai	N	LC	Fo	T	St & Rt	Or	0.86	38	Stem is curved into an axe handle / a canning stick	Holds axes for cutting materials, or it's used to provide a punishment	PRC011
											Roots' decoction is mixed with meat's broth/stock, or mixed with honey/sugar and decoction of other herbs to form "*opururua*" / alcohol, and then drunk	Diuretic /cleanse kidney (white urine), treats fever, gonorrhea, intestinal parasite (worms), "*OSUPETAI*"	
	Zanthoxylum deremense (Engl.) Kokwaro	Oloisuki	N	VU	Fo	T	Ft, St, Bk, & Rt	Na /Or	0.95	33	Milk tea/porridge / water/ meat's broth or stock is infused with powder of fruit / stem / bark / root, and then drunk	Cough, influenza, fever/ malaria, and pneumonia: "*OROROBI*", boil/swelling, and "*OSUPETAI*"	RPC054
											Stem/bark/root is boiled in water, and its formed decoction is drunk or mixed with meat's broth/stock, and then drunk		
											Roots' decoction is mixed with that of *Persea americana* leaves and *Psidium guajava* leaves, and then drunk		
											Root is burnt on a fire, and its smoke is sniffed through nostrils	Headache	
	Zanthoxylum chalybeum Engl.	Oloisuki	N	LC	Fo	T	Ft, St, Bk, & Rt	Na /Or	0.95	33	Same as *Zanthoxylum deremense*	Same as *Zanthoxylum deremense*	RPC100

Family	Scientific name	Vernacular name (Maasai)	O/E	RL	Habitat	Habit	PU	RA	UV	RFC	Preparation and application	Ailment(s) treated / role(s) performed	Collection N0.
Sapindaceae	*Deinbollia borbonica* Scheff	Oloibor kulalet	N	LC	Fo	T	Ft	Or	0.24	24	Fruit is chewed, and its soft part is swallowed	Source of food	RPC013
	Pappea capensis Eckl. & Zeyh.	Endimigomi	N	LC	Sa	T	St, Bk, & Rt	Or	0.81	38	Stem's decoction is mixed with meat's broth/stock or tallow/clarified butter, and then is drunk, or stem's decoction is drunk along with male cow blood	Stomachache, increases libido, strength, and energy, and cleans blood vessels and bones	RPC038
											Tea or meat broth/ stock is infused with bark powder or roots' decoction is mixed with meat broth/stock then drunk	Increases body heat, refreshes and builds the body, treats pain of joints (knee & waist, Gonorrhea, fever, and increases libido	
Rutaceae (Simaroubaceae)	*Harrisonia abyssinica* Oliv.	Endundulu	N	LC	Sa	Sb	Rt	Or	1.14	38	Roots' decoction is mixed with meat's broth/stock, or tea is infuse with roots' powder, and then drunk	Pain of back, bones, muscles, joints, and waist gonorrhea, syphilis, "*OSUPETAI*", swelling on the prostate, painless swelling on ankles/finger joints (when pressed not restored easily), increases "*MORI*"/ "*EMBOSHONA*"	RPC072
Solanaceae	*Datura stramonium* L	Oldule/ Ormunanaa	A & Sy	Ab	Gr	H	Sd	Or	0.05	5	Seeds are grinded into powder, mixed with fats or margarine ("Kasuku"/"Kimbo"/Cow boy), and then roasted in a pot connected with a funnel thereby the smoke is directed to the infected teeth	Pain of bored or infected teeth (with red headed worms)	RPC079
	Physalis peruviana L.	Tamtam	A & Sy	Ab	Fo	H	Lf & Ft	Or	0.43	14	Leaves are chewed, and its formed juice is swallowed	Stomachache, releases stomach gas	RPC055
											Fruit is chewed and swallowed	Source of food	
	Solanum aculeastrum Dunal	Olturunga	N	LC	Fo	Sb	Rt	Or	0.38	10	Roots' decoction is mixed with meat's broth/stock, or roots' decoction is mixed with that of *Chenopodium schraderianum* leaves, and then drunk	Diuretic/ cleanse kidney treats boil/swelling, joint pains, and reliefs tiredness	RPC025
	Solanum sp.	Endemelwa	N		Fo	H	Rt	Or	0.38	10	Roots' decoction is mixed with meat's broth/stock, and then drunk	Diuretic/cleanse kidney, treats "*OSUPETAI*", boil/swelling and reliefs tiredness	RPC021

Family	Scientific name	Vernacular name (Maasai)	O/E	RL	Hab itat	Hab it	PU	RA	UV	RFC	Preparation and application	Ailment(s) treated / role(s) performed	Collection N0.
Solanaceae	*Solanum incanum* L.	Endulelei	N	LC	Fo & Gr	H	Ft & Rt	Or	0.57	10	Fruit is squeezed, and its resulting juice is mixed with soda ash which dissolved in water, and then mixed with a clotted blood	Dissolves clotted blood	RPC016
											Root is boiled in water, and its formed decoction is drunk, or mixed with meat's broth/ stock, and then drunk, or root is chewed and swallowed	Hernia, influenza, fever, pneumonia, and joint pain	
	Withania somnifera (L.) Dunal	Olesayet	N	Ab	Fo & Sa	H	Lf, St, & Rt	De/ Or	2.67	48	Leaves are squeezed into a juice, or the leaves / stem / root is burnt into ashes, and put on a wound	Treats wound	RPC014
											Roots' decoction is mixed with meat's broth/stock, or with fresh milk and honey, or milk tea is infused with roots' powder, and then drunk	Diuretic/ cleanse kidney, treats pain of joints, back and waist, joints' swelling, boil, ulcers gonorrhea, and "*OSUPETAI*"	
Malvaceae (Sterculiaceae)	*Dombeya kirkii* Mast	Orporokwai	N	Ab	Sa	T	St, Bk, & Rt	Or	0.38	19	Stem is curved into a sharp end stick, pierced into meat's pieces and erected beside a fire	Hold meat in the roasting process	RPC066
											Bark's or roots' decoction is mixed with meat's broth/stock, and then drunk	Provides taste and viscosity to the meat's broth/stock, dissolves and stop deposit of fats in a stomach, dissolves animal fats and stop its deposit in a stomach, diuretic/cleanse kidney, treats pain of urinary tract	
Malvaceae (Tiliaceae)	*Grewia bicolor* Juss.	Ositeti	N	Ab	Sa	Sb	Lf, Ft, St, & Rt	Na/ Or	1.62	57	Fresh leaves are crafted or made into a mat, or used to squeeze coagulated blood	Hold animal/meat and prevent its contamination in the slaughtering process or dissolves coagulated blood	RPC071
											Fruit is chewed, and its soft part is swallowed	Source of food	
											Stem is crafted into a stirrer handle, or sharp end sticks which is pierced through meat and erected beside a fire	Stirring liquid food, or hold meat in a roasting process	
											Stem is burnt into a smoke and ashes which are then spread and fumigated into a calabash, or roots' decoction is mixed with meat's broth/stock	Provides, taste, odor/flavor and preserves food	

Family	Scientific name	Vernacular name (Maasai)	O/E	RL	Habitat	Habit	PU	RA	UV	RFC	Preparation and application	Ailment(s) treated / role(s) performed	Collection N0.
Malvaceae (Tiliaceae)	*Grewia villosa* Willd	Irmangula	N	LC	Sa	Sb	Ft & Rt	Or	0.76	38	Fruit is chewed, and its soft part is swallowed, or fruit is mixed with water to form a juice, and then drunk	Source of food, excess fruits' seed makes stool stiff and obstructs defecation	RPC081
											Roots' decoction is mixed with fresh milk & tallow/clarified butter, and then drunk	Clean uterus, reliefs uterus pain and stop bleeding/abortion in young pregnancy	
Urticaceae	*Urtica massaica* Mildbr.	Olmatejo	N	Ab	Fo	H	Lf & Rt	De/ Or	0.29	10	Fresh leaves are beaten on a swollen part	Reduces swelling	RPC018
											Roots' decoction is mixed with honey, *Aloe sp* roots, and other herbal decoction, and the formed "*opururua*" is drunk	Diuretic/ cleanse kidney and build the body	
Lamiaceae (Verbenaceae)	*Clerodendrum johnstonii* Oliv.	Olosholo	N	LC	Fo	Cl	Rt	Or	0.24	19	Root is boiled in water, and its formed decoction is drunk, or mixed with meat broth/stock, and then drunk	Diuretic/cleanse kidney, treats pain of back and waist	RPC001
	Rotheca myricoides (Hochst.) Steane & Mabb.	Orkibasirkon	N	LC	Fo	Sb	Lf & Rt	Or	0.24	14	Leaves are chewed, and its formed juice is swallowed, or the leaves are boiled in water, and its formed decoction is drunk	Cough and fever	RPC031
	Syn: *Clerodendrum myricoides* (Hochst.) R.Br. ex Vatke										Roots' decoction is drunk or mixed with honey and *Aloe sp* root, and then drunk.	Fever	
Verbenaceae	*Lippia javanica* (Burm f.) Spreng.	Osinoni	N	Ab	Fo	Sb	Lf		1.71	57	Leaves are crafted into a mat ("*enaraa*"), or they are wrapped on a slice of meat as a gift paper	Hold animal/meat, prevent contamination and provide taste or flavor to the meat in a slaughtering process and packing meat's gift	RPC033
	Lippia kituiensis Vatke	Osinoni oriri	N	Ab	Fo	Sb	Rt	Or	0.38	19	Roots' decoction is mixed with that of *Solanum incanum* roots & *Ocimum gratissimum* roots, or with meat's broth/ stock, or with chicken's broth/blood, and then drunk, or	The pain in joints, fever, and "*OSUPETAI*"	RPC040
											With decoction of *Cordia africana* bark & *Chenopodium schraderianum* leaves, and then drunk and steamed on the body	Measles	
	Verbena officinalis L	Engoombai	N & Sy	Ab	Bu	H	Wp	Or	0.10	5	Fresh aerial part is boiled in water, and its formed decoction is mixed with fresh milk, and then drunk	Induces vomiting and detoxify a swallowed poison	RPC045

Family	Scientific name	Vernacular name (Maasai)	O/E	RL	Habitat	Habit	PU	RA	UV	RFC	Preparation and application	Ailment(s) treated / role(s) performed	Collection N0.
Vitaceae	*Cyphostemma subciliatum* (Baker) Desc. ex Wild & R.B.Drumm.	Olorondo	N	Ab	Sa	Cl	Tb	Or	0.29	10	Tuber is boiled in water, and its formed decoction is drunk, or mixed with meat's broth/stock, and then drunk	Diuretic/ cleanse kidney; provides taste to the meat's broth/stock; treats joints (knee/legs) pain, boil/swelling, "*OSUPETAI*", releases the umbilical cord	RPC076
Xanthorrhoeaceae	*Aloe sp*. Mast	Osukuroi	N		Sa	H	Rt	Or	0.48	29	Root is mixed with honey, decoction of other herbs and left for about four days to form "*opururua*", and then drunk; rarely sugar is used in place of honey	Diuretic / cleanse kidney, induces diarrhea, broad-spectrum treatment for diseases or "*OSUPETAI*"	RPC067
Zygophyllaceae	*Balanites aegyptiaca* (L.) Delile	Eng'oswa	N	LC	Sa	T	Ft, St, Bk, & Rt	Or	0.62	33	Fruit is chewed, and its soft part is swallowed	Source of food	RPC075
											The stem is curved into a pestle ("*emushi*") or stirrer handle	Grinds food staffs/ herbal medicines or stirring liquid foods	
											Bark or root is boiled in water, and its formed decoction is drunk	Induces nausea and vomiting, discharges bile juice, and treats malaria	

Maasai names of ailment(s) or health conditions are written in caps and italics, within double inverted commas while other Maasai terminologies except vernacular names are written in small letters and italics, within double inverted commas throughout the document.

Abbreviations: *O* origin / *E* Ecology (*N* native species, *A* alien/introduced species, *Sy* synanthropes, *Ct* cultivated); *RL* IUCN Red List Category (*LC* least concern, *NT* near threatened, *VU* vulnerable, *Ab* absences in IUCN Red List); habitat (*Bu* bushland, *Fo* forest, *Gr* grassland, *Sa* savanna, *Sh* shrubland, *We* wetland); habit (*Cl* climber, *H* herb, *Sb* shrub, *Srp* Subterranean root holoparasite, *T* tree); *PU* part used (*Bk* bark, *Ft* fruit, *Lf* leaves, *Rt* root, *Rz* rhizome, *Sd* seed, *Tb* tuber, *Wp* whole aerial part); *RA* route of application (*De* dermal, *Na* nasal, *Oc* ocular, *Or* oral); *UV* use value; *RFC* relative frequency of citation; *SCF* similar characteristics and function.

Appendix 5: Flora from Maasai TFS and TM, Available in the Open-markets: Ngaramtoni, Makuyuni, Meserani, and Monduli

Scientific name (vernacular name)	Part used	Role(s) performed / Market value (s)
Acacia nilotica (Orkiloriti)	Bark (Bk)	Clean blood, increases "Mori" and strength
Albizia anthelmintica (Emukutan)	Bark (Bk)	Treats intestinal parasites (worms), "*Osupetai*", fever, boil or swelling, and gonorrhea; anti-dote for a swallowed poison; increases body heat. **Note**: The MP induces vomiting and diarrhea
Clerodendrum myricoides (Orkibasirkon)	Root (Rt)	Treats cough and fever
Embelia schimperi (Olchani onyokie)	Bark (Bk)	Treats pain of joints, back, muscles, and ribs; and "*Osupetai*", gout ("*Olgila*"), boil, gonorrhea, joints' inflammation, stomachache, influenza, cough, and fever **Note**: The MP induces diarrhea and abortion or excess menstrual flow (not suitable for women at reproductive age)
Engong'otutisho	Root (Rt)	Relief muscles, "*oseseni*" pain, the pain of the back, waist, and joints, body weakness, treats gonorrhea, and syphilis, induces diuresis and diarrhea
Hydnora abyssinica (Erukunyi)	Rhizome (Rz)	Stomachache or ulcers
Lannea schweinfurthii (Orupandei)	Bark (Bk)	Clean uterus, stop excess menstrual flow/pregnancy bleeding and pain, relieve its pain
Lepidotrichilia volkensii (Engilelekuru)	Root (Rt)	Treats Joints' pain, "*Osupetai*"
Leucas sp (Enjaniengusero)	Leaves (Lf)	Stomachache
Ndukushi	Tuber (Tb)	Induces vomiting of bile juice and treats malaria

Scientific name (vernacular name)	**Part used**	**Role(s) performed / Market value(s)**
Oltang'oruwa	Root (Rt)	Increases "*Mori*" or confidence, makes meat soup viscous, causes sweating, raises body temperature, immunity, and energy
Oremiti	Stem (St)	Toothbrush
Orkitalaswa	Bark (Bk)	Increases "*Mori*", clean stomach, treats cough, "*Osupetai*" (caused by roast food), inflammation or edema on the knee, fingers, and toes
Ortarakwai	Stem (St)	Stem smoke treats headache
Osokonoi	Bark (Bk)	Treats cough, pneumonia, asthma, fever/malaria
Rapanea melanophloeos (Iloodwa/ngesi)	Fruit (Ft)	Treats gonorrhea, internal wounds, intestinal parasites (worms), "*Osupetai*", joint pain, and induce diuresis. **Note**: The MP can induce diarrhea
Rhamnus Prinoides (Orkonyil)	Root (Rt)	Treats pain of joints, boil/swelling, gonorrhea, reliefs tiredness or body weakness and increases body heat, induces diuresis
Rhamnus staddo (Engokola)	Root (Rt)	Treats "*Osupetai*" and broken bones
Secamone parvifolia (Osinandei)	Root (Rt)	Clean the uterus and relieve womb/uterus pain
Vepris simplicifolia (Olgilai)	Root (Rt)	Treats fever, gonorrhea, intestinal parasite (worms), and "*Osupetai*"
Zanthoxylum chalybeum (Oloisuki)	Root (Rt) / Bark (Bk)	Treats fever, cough, and influenza
Zanthoxylum deremense (Oloisuki)	Root (Rt) / Bark (Bk)	Treats fever, cough, and influenza

Appendix 6: Total phenolics, flavonoids, and minerals content for the commonly used flora in Maasai TFS and TM

Species (Collection N0-part used)	TPC (mg GAE/g) n = 4 Mean ± SD	TFC (mg QE/g) n = 4 Mean ± SD	[K] (mg/100g) n = 4 Mean ± SD	[Ca] (μg/g) n = 4 Mean ± SD	[Fe] (μg/g) n = 4 Mean ± SD	[Mg] (μg/g) n = 4 Mean ± SD	[Mn] (μg/g) n = 4 Mean ± SD	[Zn] (μg/g) n = 4 Mean ± SD
Biancaea decapetala (RPC019-Rt)	104.66 ± 2.80	8.95 ± 0.00	293.05 ± 0.00	1030.26 ± 85.29	515.47 ± 4.98	199.73 ± 2.11	38.82 ± 0.53	21.58 ± 0.48
Clerodendrum johnstonii (RPC001-Rt)	104.66 ± 0.14	3.88 ± 0.01	366.55 ± 0.00	2927.78 ± 296.04	539.00 ± 4.51	256.82 ± 4.00	42.31 ± 0.47	248.28 ± 1.41
Combretum zeyheri (RPC098-Rt)	155.32 ± 5.56	23.80 ± 0.01	141.73 ± 10.93	4715.69 ± 180.47	1033.50 ± 0.47	241.16 ± 2.05	67.77 ± 7.83	16.25 ± 0.59
Combretum zeyheri (RPC098-St)	12.07 ± 0.89	24.28 ± 0.01	293.05 ± 0.00	3886.72 ± 207.90	677.95 ± 9.25	266.59 ± 1.49	113.06 ± 4.38	23.42 ± 0.62
Commicarpus plumbagineus (RPC088-Rt)	86.62 ± 5.47	12.39 ± 0.01	586.11 ± 0.00	391.93 ± 24.88	1381.99 ± 2.49	226.64 ± 3.82	106.33 ± 1.23	28.72 ± 0.72
Croton dichogamus (RPC073-Rt)	32.05 ± 0.10	10.41 ± 0.03	342.11 ± 0.00	6622.87 ± 199.14	1362.33 ± 5.10	276.49 ± 3.47	191.60 ± 1.23	256.61 ± 1.14
Croton megalocarpus (RPC053-Bk)	3.99 ± 0.09	8.94 ± 0.12	293.24 ± 0.00	9116.97 ± 305.82	519.35 ± 1.66	243.69 ± 4.48	65.43 ± 0.93	12.91 ± 0.34
Croton sp. (RPC089-St)	32.39 ± 0.03	3.78 ± 0.02	317.48 ± 0.00	3497.26 ± 155.48	422.39 ± 5.22	233.93 ± 3.08	99.80 ± 0.64	11.19 ± 0.93
Dalbergia melanoxylon (RPC074-Rt(black))	68.44 ± 0.98	66.94 ± 0.03	9.77 ± 13.38	3003.65 ± 81.79	276.57 ± 4.15	115.59 ± 1.72	41.72 ± 0.58	14.92 ± 0.90
Dalbergia melanoxylon (RPC074-Rt)	70.68 ± 0.61	28.65 ± 0.02	268.63 ± 0.00	5083.46 ± 503.75	317.30 ± 7.00	196.30 ± 4.60	41.83 ± 0.41	8.20 ± 0.76
Dicoma tomentosa (RPC083-Wap)	47.08 ± 2.02	33.11 ± 0.21	488.42 ± 0.00	1427.60 ± 57.75	1321.03 ± 4.74	244.14 ± 1.79	61.04 ± 0.41	35.44 ± 0.76
Embelia schimperi (RPC037-Bk)	163.47 ± 9.63	11.15 ± 0.00	512.84 ± 0.00	5945.97 ± 304.74	1075.73 ± 7.83	215.84 ± 3.19	48.97 ± 0.64	20.73 ± 0.34
Eucalyptus saligna (RPC044-Lf)	65.65 ± 5.37	30.69 ± 0.04	464.29 ± 0.00	1640.94 ± 46.23	612.82 ± 2.97	255.00 ± 4.94	158.55 ± 0.64	262.56 ± 0.72
Euclea divinorum (RPC010-Rt)	31.74 ± 0.03	29.75 ± 0.02	171.06 ± 0.00	2472.01 ± 188.47	742.06 ± 6.76	207.41 ± 4.62	26.45 ± 0.64	20.75 ± 0.52
Euphorbia sp (RPC085-Rt)		3.58 ± 0.01	625.18 ± 13.38	4359.07 ± 238.99	1311.37 ± 2.49	281.97 ± 3.13	89.60 ± 1.75	39.95 ± 1.24
Harrisonia abyssinica (RPC072-Rt)	8.74 ± 0.45	5.70 ± 0.00	268.80 ± 0.00	596.45 ± 44.45	1398.41 ± 2.37	221.35 ± 1.75	98.19 ± 0.93	20.08 ± 0.41
Helinus mystacinus (RPC002-Rt)	18.87 ± 0.03	2.16 ± 0.00	453.95 ± 13.37	4712.86 ± 277.02	786.83 ± 7.94	281.09 ± 3.38	70.93 ± 0.58	13.20 ± 0.93
Hydnora abyssinica (RPC101-Ft)	57.74 ± 0.25	5.98 ± 0.00	1075.20 ± 0.00	353.19 ± 18.67	998.30 ± 7.12	230.30 ± 3.59	70.91 ± 0.82	48.30 ± 0.45
Hydnora abyssinica (RPC101-Rz)	82.86 ± 0.75	6.33 ± 0.02	537.60 ± 0.00	347.88 ± 32.89	1015.62 ± 4.87	190.46 ± 1.31	70.02 ± 0.88	15.88 ± 0.72
Lablab purpureus (RPC094-Sd)		12.79 ± 0.02	757.53 ± 0.00	209.96 ± 4.45	345.19 ± 6.53	210.24 ± 0.97	90.41 ± 1.05	63.52 ± 1.00
Lannea schweinfurthii (RPC059-Bk)	68.68 ± 0.24	15.14 ± 0.02	243.91 ± 0.00	5397.70 ± 403.74	326.75 ± 4.26	264.07 ± 3.21	32.83 ± 0.41	37.34 ± 0.83
Lepidotrichilia volkensii (RPC023-Rt)		1.24 ± 0.00	390.98 ± 0.00	1055.00 ± 118.24	682.11 ± 4.15	172.47 ± 1.31	47.12 ± 0.41	29.60 ± 0.52
Myrsine melanophloeos (RPC099-Ft)	26.31 ± 0.02	17.78 ± 0.08	609.39 ± 0.00	553.02 ± 50.55	690.36 ± 7.58	218.61 ± 8.42	185.09 ± 1.98	25.79 ± 1.58
Ocimum gratissimum (RPC027-Lf)	35.27 ± 0.02	16.27 ± 0.01	948.13 ± 10.93	4596.87 ± 239.14	1259.42 ± 3.44	279.11 ± 3.38	138.57 ± 0.82	54.33 ± 1.17
Pappea capensis (RPC038-St)	40.01 ± 0.14	8.35 ± 0.00	366.32 ± 0.00	4579.69 ± 221.22	474.86 ± 4.86	237.57 ± 1.93	54.63 ± 0.23	261.47 ± 0.62

Species (Collection N0-part used)	TPC (mg GAE/g) n = 4 Mean ± SD	TFC (mg QE/g) n = 4 Mean ± SD	[K] (mg/100g) n = 4 Mean ± SD	[Ca] (µg/g) n = 4 Mean ± SD	[Fe] (µg/g) n = 4 Mean ± SD	[Mg] (µg/g) n = 4 Mean ± SD	[Mn] (µg/g) n = 4 Mean ± SD	[Zn] (µg/g) n = 4 Mean ± SD
Persea americana (RPC056-Lf)		38.88 ± 0.03	1001.89 ± 0.00	1736.82 ± 169.80	909.04 ± 4.51	266.71 ± 0.34	150.87 ± 2.34	251.65 ± 0.69
Piper capense (RPC050-Rt)	6.21 ± 0.01	2.74 ± 0.00	1392.01 ± 0.00	1893.62 ± 81.74	1402.96 ± 3.32	300.22 ± 8.60	163.42 ± 0.64	263.36 ± 0.62
Psidium guajava (RPC057-Lf)	43.79 ± 4.44	30.52 ± 0.01	601.14 ± 13.38	3113.08 ± 136.91	1212.08 ± 3.20	268.49 ± 2.41	110.97 ± 1.23	31.68 ± 0.62
Rhamnus prinoides (RPC039-Rt)	78.32 ± 1.61	57.40 ± 0.11	97.68 ± 0.00	3061.24 ± 160.81	457.39 ± 3.68	214.42 ± 2.00	39.25 ± 0.70	18.94 ± 0.72
Rhamnus staddo (RPC032-Rt)	16.66 ± 1.50	36.08 ± 0.05	151.41 ± 10.92	2307.33 ± 223.00	814.12 ± 9.84	219.75 ± 5.63	32.45 ± 1.52	239.73 ± 0.72
Rhus vulgaris (RPC036-Rt)	231.39 ± 10.40	17.47 ± 0.00	219.93 ± 0.00	8073.17 ± 480.06	830.43 ± 4.27	219.55 ± 11.34	69.05 ± 0.76	9.68 ± 0.31
Rhus vulgaris (RPC036-St)	198.82 ± 12.27	13.14 ± 0.00	117.29 ± 10.93	7222.67 ± 573.41	676.36 ± 2.97	239.53 ± 2.16	39.36 ± 2.74	7.76 ± 1.31
Rotheca myricoides (RPC031-Lf)	21.66 ± 0.04	19.64 ± 0.01	937.77 ± 13.38	1607.73 ± 140.37	1309.32 ± 1.54	193.28 ± 1.26	151.10 ± 0.70	72.36 ± 1.10
Rotheca myricoides (RPC031-Rt)	50.88 ± 0.52	3.56 ± 0.00	317.67 ± 0.00	2743.80 ± 245.36	577.09 ± 3.09	218.37 ± 1.52	54.70 ± 0.70	64.08 ± 0.41
Secamone parvifolia (RPC006-Rt)	81.62 ± 0.90	3.24 ± 0.00	449.35 ± 13.38	1386.53 ± 68.41	669.49 ± 5.10	207.40 ± 4.96	50.33 ± 0.70	40.37 ± 0.48
Tetradenia riparia (RPC046-Lf)	5.51 ± 0.02	45.27 ± 0.00	1070.32 ± 10.93	4010.08 ± 269.37	1425.31 ± 4.51	287.77 ± 12.21	480.40 ± 2.28	98.03 ± 0.76
Vachellia nilotica (RPC063-Bk)	75.93 ± 0.31	29.10 ± 0.00	117.22 ± 10.92	7580.85 ± 544.62	1292.23 ± 2.25	182.91 ± 3.10	83.93 ± 1.63	263.85 ± 1.10
Vachellia nilotica (RPC063-Ft(Pd))	32.30 ± 0.30	1.78 ± 0.00	684.65 ± 0.00	272.66 ± 8.01	561.72 ± 6.29	213.15 ± 1.50	44.32 ± 1.58	37.39 ± 1.00
Vachellia nilotica (RPC063-Rt)	43.49 ± 0.12	20.12 ± 0.01	170.95 ± 0.00	3568.99 ± 203.45	996.69 ± 4.27	138.77 ± 1.56	59.22 ± 1.28	25.91 ± 1.10
Withania somnifera (RPC014-Rt)	38.66 ± 0.09	7.38 ± 0.02	390.49 ± 0.00	1917.26 ± 81.69	1088.56 ± 8.06	227.47 ± 3.17	60.00 ± 0.76	83.44 ± 0.52
Ximenia caffra (RPC069-St)	79.14 ± 0.58	8.83 ± 0.00	366.55 ± 0.00	4291.81 ± 127.13	536.32 ± 2.97	186.79 ± 3.68	38.13 ± 0.93	257.91 ± 0.52
Zanthoxylum chalybeum (RPC100-Ft)	0.02 ± 0.01	15.15 ± 0.01	928.58 ± 0.00	1116.97 ± 77.34	489.95 ± 5.10	204.21 ± 1.17	52.27 ± 0.47	20.86 ± 0.14
Zanthoxylum chalybeum (RPC100-Rt)	51.54 ± 0.31	31.32 ± 0.01	175.83 ± 10.92	5792.66 ± 356.27	712.33 ± 4.27	195.79 ± 4.92	41.32 ± 0.47	25.93 ± 0.52

RESEARCH OUTPUTS

(i) Publications

Clement, R. P., Runyogote, J., Raymond, J., & Chacha, M. N. (2023). Ethnobiological survey to determine the link between health benefits and qualities of Maasai traditional food system in Monduli, Arusha, Tanzania. *Agroecology and Sustainable Food Systems*, 47(8), 1077-1124.

Clement, R. P., Runyogote, J., Raymond, J., & Chacha, M. N. (2024). Ethnobotanical survey of plants used in the Maasai food system and traditional medicine against gout and associated conditions in Monduli-Tanzania. *Journal of Herbs, Spices & Medicinal Plants*, 30(4), 386-412.

(ii) Patentable products

Based on the findings of this study, products coded "*Osugila-14P*" and "*Osugila-14E*" were formulated, which had mineral and phenolic contents as shown in Figs. 60 and 61, respectively. The products are expected to provide nutrition, antioxidant, anti-inflammatory, and anti-hyperuricemia effects against gout, "*Olgila*" and GACs; their biological activities and safety may require validation before patent.

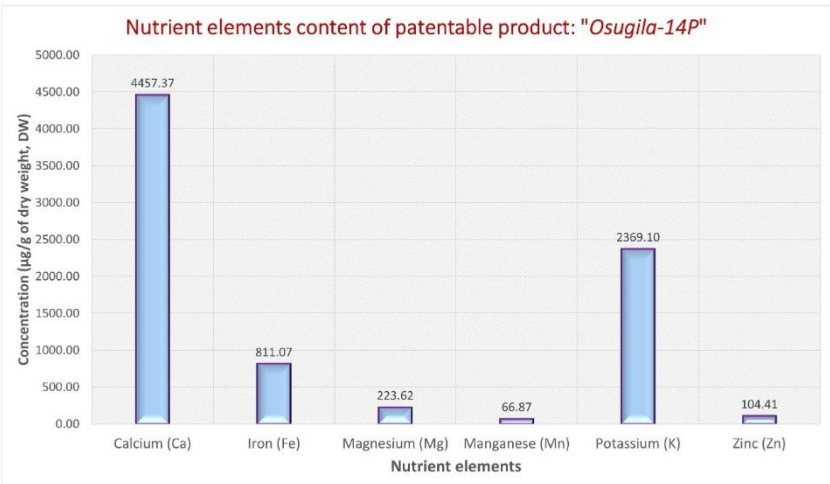

Figure 60: Mineral contents of patentable product: "*Osugila-14P*"

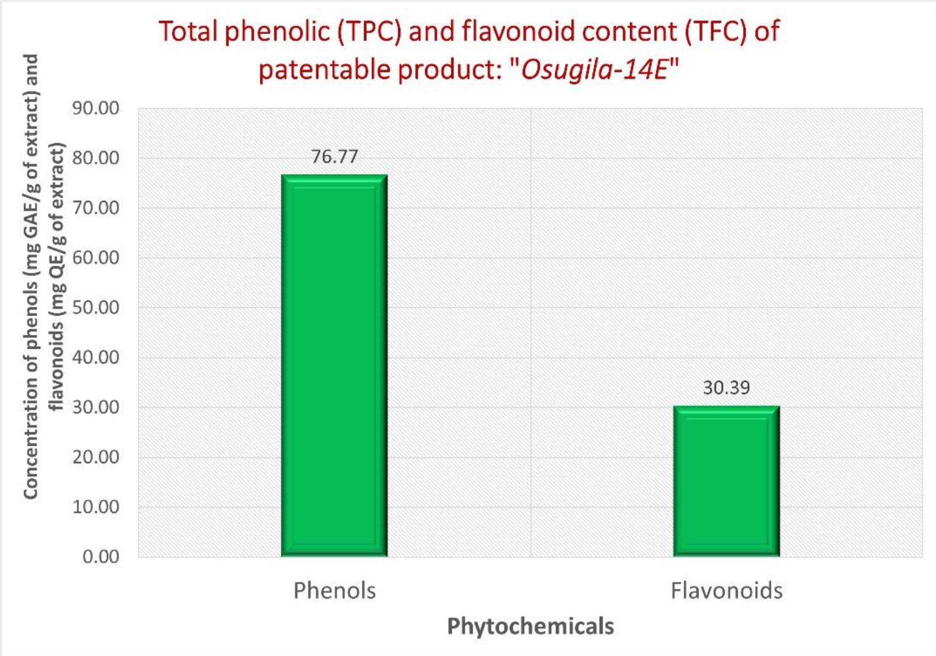

Figure 61: Phenolic and flavonoid content of patentable product: "*Osugila-14E*"

(iii) Poster presentation