Addressing different forms of malnutrition among rural women and children in East Africa: the contribution of processed fruits and vegetables

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Table of Contents

List of abbreviations

BMI	: Body mass index
CAJ	: Cashew apple juice
CLP	: Cassava leaves powder
cm	: Centimeters
CoD	: Cost of diet
DAN	: Dried African nightshade
DCL	: Dried cowpea leaves
DDS-W	: Dietary diversity score for women
FAO	: Food and Agriculture Organization
FGD	: Focus group discussion
FruVaSe	: Fruits and vegetables for all seasons
FVs	: Fruits and vegetables
g	: Grams
GCB	: Guava-cashew nut bar
JCB	: Jackfruit-cashew nut bar
KAPs	: Knowledge, attitude and practices
kg	: Kilograms
m	: meters
ml	: Milliliter
NCD	: Non-communicable diseases
OLS	: Ordinary least square
PCA	: Principal component analysis
RFI	: Recommended food intake

SDG : Sustainable development goals

SMEs : Small and medium enterprises

SSA : sub-Saharan Africa

TZS : Tanzania shillings

USD : United States dollars

VIF : Variance inflation factor

WHO : World Health Organization

Chapter 1. General introduction

1.1. Background of the study

1.1.1. Malnutrition and its implications for women and children

Malnutrition in all forms – undernutrition, micronutrient deficiencies and overweight and obesity – poses challenges for individuals, societies, and countries at large (Swinburn et al., 2019; Committee on World Food Security, 2021). Globally, malnutrition figures continue to rise, especially in Africa, with women and children most affected due to their vulnerability in societies (FAO et al., 2021; Committee on World Food Security, 2021). In the 2020 and 2021 Global Nutrition Reports (Global Nutrition Report, 2020, 2021), 820 million people were undernourished, with 149.2 million and 45.4 million children under five years of age being stunted and wasted, respectively. Anemia affects 571 million women of reproductive age worldwide. As recently as 2019, almost one-fifth of the population in Africa was chronically undernourished (FAO et al., 2021). The East Africa region is also severely affected by different forms of malnutrition. For instance, 34.5% of African-stunted children are in East Africa. Again, more than a quarter of the wasted children and 3.7% of overweight children in Africa live in East Africa; 69% of children in East Africa suffer from micronutrient deficiencies (FAO et al., 2021). For women, anemia is on the rise: for example, 45% of women of reproductive age in Tanzania suffer from anemia (United Republic of Tanzania, 2016b). Overweight and obesity rates are rising as well among women, notably in countries like Kenya, Tanzania, and Uganda (Ajayi et al., 2016; Kenya Ministry of Health, 2016). Despite these staggering figures, there are some progress that have been made on some of the nutrition indicators: for example, Kenya, Tanzania and Uganda are on course for meeting the target for childhood wasting (Global Nutrition Report, 2021). However, the region is far from far from realizing the Sustainable Development Goal (SDG) 2 targets, primarily targets 2.1 (end hunger and ensure access to nutritious foods) and 2.2 (end all forms malnutrition)

Malnutrition unleashes very dire health and economic consequences. Every year, about 4 million deaths are recorded due to overweight and obesity (Afshin et al., 2017). Malnourished children experience physical growth impairment and delayed cognitive development in addition to becoming easily susceptible to infectious diseases, which result in increased morbidity and mortality. For women, the risk of maternal and neonatal mortality increases, and the associated health effects have long-lasting repercussions throughout their lifetime and for future generations

(FAO et al., 2021; Committee on World Food Security, 2021). Economically, lost productivity and increased health costs create huge financial consequences for countries (Shekar and Popkin, 2020).

Poor diets are a key contributing factor to the rising malnutrition (FAO et al., 2021) while healthy diets – in both quantity and quality – support optimal development and wellbeing of women and children and guard against all forms of malnutrition (Committee on World Food Security, 2021). However, consumption of healthy diets is a huge challenge in Africa. For instance, in East Africa, three-quarters of the people cannot access healthy diets (FAO et al., 2021). Diets consumed are typically low-quality, consisting of energy-dense foods, and are poor in micronutrients (Global Nutrition Report, 2020; FAO et al., 2021; Global Nutrition Report, 2021; International Food Policy Research Institute, 2021). Over the years, there has been a continuous shift toward the consumption of such diets (Popkin et al., 2012; Shekar and Popkin, 2020). Nutritious foods like fruits and vegetables (FVs) are low in diets, which some studies have attributed to the fact that they are seasonally available and, if available, they are expensive for the poor and the vulnerable to afford (Hirvonen et al., 2020; FAO et al., 2021). Nonetheless, FVs are highly recommended in diets to help tackle all forms of malnutrition (FAO et al., 2021; Committee on World Food Security, 2021).

1.1.2. Fruit and vegetable consumption in addressing malnutrition

Consumption of FVs is highly recommended because of their excellent sources of micronutrients and fiber. Documented micronutrients found in FVs include vitamins A, C, E, iron, zinc, calcium, potassium, phosphorous, and magnesium (Slavin and Lloyd, 2012; James and Zikankuba, 2017; FAO, 2020). Hence, consumption of FVs can be an effective intervention to address malnutrition in all its forms. Indeed, several studies have reported an inverse relationship between FV consumption and malnutrition. Data from He et al. (2004) showed that increased consumption of FV was associated with up to 28% lower risk of a woman becoming obese – an assertion reiterated by FAO (2020). Again, among women, adequate intake of FV was associated with lower odds of being anemic (Ghose and Yaya, 2018). For children, intake of FVs resulted in a lower prevalence of stunting and anemia than those who did not consume FVs (Augusto et al., 2015). Diseases such as cardiovascular diseases, cancers, and diabetes are also reduced through the consumption of FVs (WHO, 2004; Slavin and Lloyd, 2012; FAO, 2020).

However, consumption of FV has been inadequate. Consumption figures from East Africa (figure 1.1) are low and below the WHO recommended intake amount of 200g/day for either fruit or vegetable and 400g/day for both. In 2004, inadequate consumption of FV was ranked number six out of 20 risk factors enabling global mortality (WHO, 2004). Now, out of 10 risk factors causing global deaths, low fruit intake is number three (Global Burden of Disease Study, 2020). Meanwhile, with adequate consumption, an estimated 2.7 million lives can be saved yearly (WHO, 2004). Varied factors contribute to the low consumption of FVs, including their inadequate production and supply to meet demand (Mason-D'Croz et al., 2019), seasonal nature, high perishability levels and high prices (Rickman et al., 2007; FAO, 2020). For instance, around 50% of FVs are lost after harvesting (Rickman et al., 2007) and higher seasonal price differences for FVs: for example, 61% seasonal price gap for tomatoes compared to 33% for maize (FAO et al., 2021). Therefore, addressing such bottlenecks is necessary to ensure increased consumption of FVs to combat malnutrition.

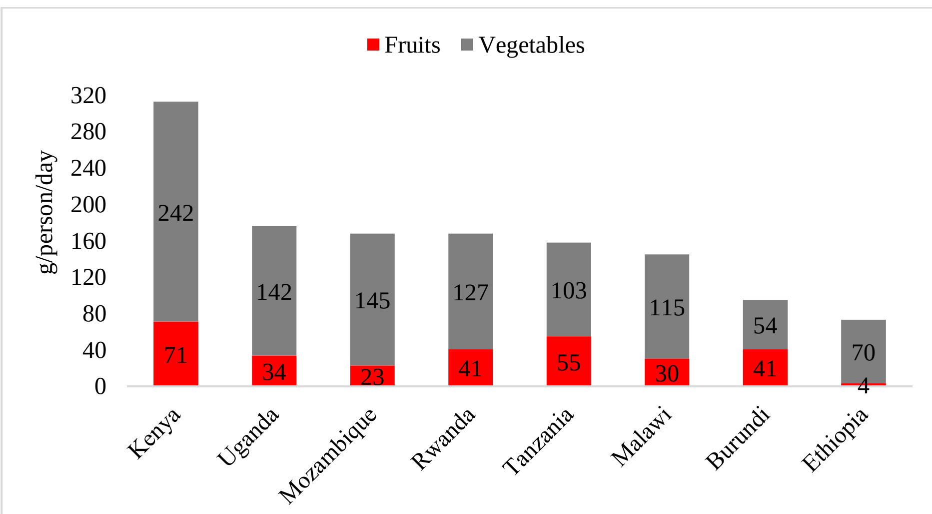

Figure 1.1. Consumption of fruits and vegetables across countries in East Africa. Calculation and plotting based on data from Ruel et al. (2005)

1.1.3. Importance of fruit and vegetable processing in curbing malnutrition

Food processing provides a feasible approach to address the high perishability levels of FVs and make them available for consumption throughout the year, as well as help lower seasonal price gaps. Therefore, a range of processing techniques, including drying, freezing, heating, and canning, have been employed in that regard (Rickman et al., 2007; Floros et al., 2010; Safefood, 2013; James and Zikankuba, 2017). Although there can be nutrient losses through processing, it can also be an effective vehicle to improve the nutritional value of foods, including FVs (Jaenicke and Virchow, 2013). Also, through processing, FVs can be transformed into products that have a longer shelf-life, are safe, nutritious, convenient, and easily transportable to consumers (Garratt et al., 2002; Rickman et al., 2007; Floros et al., 2010; Jaenicke and Virchow, 2013). For instance, in Tanzania, cassava leaves can be processed into products that address consumers' concerns about fresh cassava leaves being inconvenient and having some health-related risks (Pato Dickson Innocensia, 2013). But, most importantly, through processed FVs, women and children can be buffered during periods of food insecurity (Keding et al., 2013b). Nonetheless, in general, there have been negative perceptions associated with processed foods as unhealthy (Keding et al., 2013b; Weaver et al., 2014). Various studies have linked the consumption of certain processed foods to negative health outcomes, including obesity (Monteiro et al., 2011; Popkin et al., 2012; Holmes et al., 2018). At the same time, some studies have documented the importance of processed foods in providing the calorie and micronutrient needs for many vulnerable people, who otherwise would suffer from hunger and micronutrient deficiencies due to high food perishability and food scarcity (Floros et al., 2010; Khonje et al., 2020). Without the processing of FVs, vulnerable people like women and children could be denied certain nutrients at certain times of the year, which could help combat malnutrition year-round.

1.2. The fruit and vegetables for all seasons project

This study was integrated into a larger project named "Fruits and vegetables for all seasons" (FruVaSe). The project aimed to improve nutrition and economically empower women in East Africa through improved resource-efficient processing techniques and new market solutions for highly nutritious surplus FVs and their by-products in a life-cycle approach. The project was spearheaded by the University of Goettingen in Germany in collaboration with Erfurt University of Applied Sciences in Germany, Makerere University in Uganda, Universities of Nairobi and Eldoret in Kenya, and the Nelson Mandela African Institution of Science and Technology in Tanzania. The following work packages (WP) were created under the project:

- WP 1: Processing and preservation of fruits and their by-products, nutrient retention, and shelf-life period.

- WP 2: Processing and preservation of green leafy vegetables, nutrient retention, and shelf-life period.
- WP 3: Food patterns and knowledge, attitudes, and practices of consumption of selected FV.
- WP 4: Resource-efficient, energy-autonomous FV processing.
- WP 5: Marketing of FV products, including packaging, marketing channels, and consumer acceptance.

This study was under WP 3. The project countries were Kenya, Tanzania, and Uganda. In each country, highly nutritious FVs were selected for study. Guava fruit (*Psidium guajava*) and cowpea leaves (*Vigna unguiculata*) were selected in Kenya. In Tanzania, cashew apple (*Anacardium occidentale)* and African nightshade (*Solanum* spp.) were studied, while jackfruit (*Artocarpus heterophyllus)*, cowpea leaves (*Vigna unguiculata*), and cassava leaves (*Manihot esculenta*) were chosen in Uganda. The three countries and the selected FVs except cassava leaves were selected for this study.

1.3. Research gaps

As indicated above (see study background), malnutrition highly affects women and children. The existence of different malnutrition forms inhibits the optimal growth of women and children and makes them easily susceptible to diseases (Committee on World Food Security, 2021), which therefore requires sustainable mechanisms to address every form of malnutrition.

Over 70% of the world's overweight and obese adults reside in low and middle-income countries, posing significant risks for these countries (Shekar and Popkin, 2020). Various studies, including Becquey et al. (2010), Keding et al. (2011), Frank et al. (2014), Pisa et al. (2015), and Holmes et al. (2018), have gauged possible linkages between food intake and health outcomes including overweight and obesity through dietary pattern (referred to in this study as "pattern") analyses. However, most of these studies and others have been urban-centered to the neglect of rural areas. Two studies: Keding et al. (2011) and Pisa et al. (2015), have been identified to be rural-focused in sub-Saharan Africa (SSA), in terms of principal component analysis (PCA)-driven pattern evaluation. Meanwhile, overweight and obesity in rural areas are rapidly rising (Afshin et al., 2017; Shekar and Popkin, 2020). Therefore, more studies need to focus on rural areas to establish pathways to curb overweight and obesity. Additionally, pattern analyses to determine the linkage between diets and overweight and obesity have broadly been attributed to the consumption of processed foods (Becquey et al., 2010; Holmes et al., 2018). This notwithstanding, food processing largely provides an avenue for a safe, diverse, adequate, and easy supply of foods (Floros et al., 2010), especially for FVs. Moreover, not all processed foods are linked to overweight and obesity (Khonje et al., 2020). Hence, during pattern assessment, distinguishing between different processed foods and relating them to overweight and obesity could be a helpful approach. However, studies on the characterization of processed foods in pattern assessment and health outcomes are limited, especially in SSA – with none for rural settings. Thus far in the literature, there are several classifications for processed foods. A notable classification is the NOVA classification which groups processed foods based on the extent and purpose of their industrial processing (Monteiro et al., 2019). This classification method has been applied chiefly to processed foods in high and middle-income countries to establish an association with varied health outcomes (Elizabeth et al., 2020). On the other hand, applying this classification method for countries in SSA and especially for rural areas could be challenging as most foods are locally prepared by small and medium-scale enterprises (SMEs). As such, many foods may not fit the NOVA classification. Additionally, the NOVA system does not provide an accurate means to define foods. It categorizes food products based on the quantity of ingredients in the food and not necessarily by the level of processing. Furthermore, the notion of the NOVA system to assume that commercially produced foods are low in nutritional value and are associated with chronic diseases is erroneous as it ignores the benefits of diets with the accurate mix of foods from all processing stages. The classification system again overlooks essential components such as food decisions and choices that connect with certain health factors (Petrus et al., 2021). Reardon et al. (2021) developed a new classification for SSA that has thus far not been applied in pattern analysis in SSA. Furthermore, studies analyzing the impact FVs – in any processed form – on overweight and obesity in pattern assessment are limited. As a result, more studies are needed in this direction.

Micronutrient deficiencies are also prominent among women and children. FVs contain essential micronutrients that could help address micronutrient deficiencies, but their seasonality and high perishability levels pose a considerable challenge to the availability of FVs year-round (Rickman et al., 2007; FAO, 2020). Processed FVs could provide a feasible option to address this challenge. However, there are negative perceptions associated with processed foods as unhealthy. Among others, it is because the benefits of processed foods, especially nutritious ones like FVs, have not been communicated clearly and consistently to consumers to overcome the negative messaging (Keding et al., 2013b; Weaver et al., 2014). Based on the processing method, some processed foods can provide critical micronutrients otherwise unavailable in diets or even beyond those provided by fresh ones (Floros et al., 2010; Dwyer et al., 2012), of which processed FVs could have such potential. Yet data on processed foods, particularly FVs, in their contribution to quality diets are limited. Within SSA and rural areas, studies on them are non-existent. The limited data on the contribution of nutritious processed foods to diets could fuel the increasing miscommunication about processed foods and could serve as a disadvantage for the poor and vulnerable, who may need to rely on them to meet their nutritional needs. Additionally, studies to evaluate their contribution to ensuring inexpensive but nutritious diets, which could aid in the fight against micronutrient malnutrition, are sparse.

To be able to process FVs for better nutrition, more processing techniques including innovations are needed (Global Panel, 2018). It can be even more vital and may help to place these processing techniques and innovations at the heart of food production areas, mostly in rural communities, to ensure adequate consumption of FVs for better nutrition, especially in East Africa, where a high diversity of nutrient-rich FVs are produced, yet high malnutrition exists (Akombi et al., 2017). However, before introducing processing techniques and innovations for FV, it is imperative to assess the knowledge and perceptions of communities towards the processing of FVs and their consumption which could inform their acceptance or otherwise, as well as processed FVs. Thus far, such assessments are limited in the literature. Furthermore, existing data on actual FV consumption in SSA are quite old – data provided by Ruel et al. (2005). This also limits data-driven policy-related interventions. Therefore, there is the need for more studies to gauge the perceptions of communities of FV production towards FV processing and consumption and consequently also provide adequate and actual data on FV consumption.

This study, therefore, contributes new knowledge to the literature to address these research gaps with three studies. The first study examines patterns and processed foods and overweight and obesity. The second study analyzes processed FVs and diet cost and nutrient adequacy, while the last study provides the knowledge and perceptions regarding FV processing and consumption.

1.4. Objectives and research questions

The aim of this study is to characterize patterns by processed foods, including FVs and how they affect overweight and obesity, assess processed FVs impact on diet cost and nutrients and investigate the knowledge, attitude, and practices toward FV processing and consumption. This study recruited: young children between 6-23 months due to the importance of FVs as part of their complementary feeding, from rural Tanzania; and school-aged children between 6-13 years because they mostly pick fruits in the wild for consumption, and are often overlooked in food consumption studies, from rural Tanzania; and women of reproductive age (15-49 years) due to their important role in shaping household nutrition and their physiological demand for nutrients, from rural Kenya, Tanzania, and Uganda. Data of children 6-23 months and children 6-13 years were also collected in Kenya and Uganda, however, it was not utilized for this study, yet, by MSc students from Kenya and Uganda, respectively. The following specific objectives and research questions were developed to achieve the overall aim.

- **Objective 1:** To describe dietary behavior characterized by different processed foods – including FVs – categories and establish the relationship with overweight and obesity **(Study 1 under Chapter 2)**.

  Research questions 1:

  - What are the rates of overweight ad obesity among rural women in East Africa?
  - What dietary patterns exist in rural East Africa as explained by the different food processing categories?
  - How do the dietary patterns characterized by the different food processing categories – and FVs – relate to overweight and obesity?

- **Objective 2:** To explore the impact of processed FVs in reducing diet cost and ensuring nutritional adequacy in diets **(Study 2 under Chapter 3)**.

  Research questions 2:

  - What are the costs and nutrient gaps (if any) in standard diets from local food sources for women and children in rural Tanzania year-round?
  - Are processed FVs able to reduce the standard diet costs and fill nutrient gaps (if any)?

○ **Objective 3:** To assess the knowledge, attitude, and practices (KAPs) towards FV processing and consumption **(Study 3 under Chapter 4)**.

Research questions 3:

- What are the consumption estimates of FVs for women in rural East Africa?
- What are the KAPs towards FV processing and consumption?
- Is there a relationship between the women's knowledge and attitude towards FV processing and consumption and their actual FV consumption?

1.5. Thesis structure

The results of the three studies are outlined in this dissertation in the following chapters:

○ **Study 1 (under Chapter 2): "Dietary patterns as characterized by food processing levels and their association with the health outcomes of rural women in East Africa"** was published in *Nutrients* but has been adapted in this dissertation. This study revealed the patterns, including those consisting of FVs, that exist in rural East Africa using data from women in Kenya, Tanzania, and Uganda. Patterns were also characterized in this study according to three processed food categories and were associated with overweight and obesity.

○ **Study 2 (under Chapter 3):** "**Are processed fruits and vegetables able to reduce diet costs and address micronutrient deficiencies? Evidence from rural Tanzania"** has been published in *Public Health Nutrition*. Using rural Tanzania as a case study, study 2 first examined the cost of standard diets for women and children through modeling. The modeled standard diets were then assessed to ascertain any gaps in nutrients. Some selected processed FVs from the FruVaSe project were added to the diets, after which their impact in terms of cost reduction and filling nutrients gaps were evaluated.

○ **Study 3 (under Chapter 4):** "**Fruit and vegetable processing and consumption: knowledge, attitude, and practices among rural women in East Africa"** is currently under peer review in *Food Security*. This study adopted data from rural Kenya, Tanzania, and Uganda and recruited only women to gauge their knowledge, attitude, and practices towards FV processing and consumption. First, FV consumption estimates were determined. Then the women's knowledge, attitude, and practices were assessed, including constructing knowledge and attitude indices for

FV processing and consumption. A relationship between the indices and the FV consumption estimates was investigated through correlation analysis.

The ensuing chapter, Chapter 5, highlights some key findings of the studies and discusses the findings. In the same chapter, policy implications from the results are stipulated as well as areas for future research. The conclusions derived from the studies are presented in Chapter 6.

Chapter 2. Dietary patterns as characterized by food processing levels and their association with the health outcomes of rural women in East Africa

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Author contribution

Jacob Sarfo	: conceptualized the study, collected and analyzed the data and developed the manuscript.
Elke Pawelzik	: reviewed the manuscript and made inputs
Gudrun B. Keding	: reviewed the manuscript and made inputs

Abstract

Overweight and obesity are rapidly rising in Sub-Saharan Africa including in rural areas. However, most studies focus on urban centers, and have attributed this epidemic to the consumption of processed foods without their clear characterization. This study investigated food intake patterns defined by food processing levels and their association with overweight/obesity in rural areas. Four 24-hour dietary recalls, anthropometric measurements, and socio-demographic characteristics were collected from 1152 women in Kenya, Tanzania, and Uganda. The PCA method was used to extract patterns characterized by food processing levels. The association between patterns and overweight/obesity was ascertained with regression models. The overweight/obesity rate was 47%, 42%, 26%, and 38% in Kenya, Tanzania, Uganda, and East Africa (as pooled data), respectively. Several patterns were identified, yet a “plant-based pattern” largely characterized by unprocessed and minimally processed foods and a “purchase pattern” mainly distinguished by highly processed foods were dominant. The “plant-based pattern” was inversely or not associated with overweight/obesity, while the “purchase pattern” had a positive association or no association. A clear distinction on processed foods as healthy and unhealthy should be made based on their nutrient provision to avoid their mischaracterization as unhealthy. Policies to reverse consumption of unhealthy processed foods while promoting healthy ones like fruits and vegetables should be pursued.

Keywords: Africa; dietary patterns; overweight and obesity; rural areas; processed foods; women

2.1. Introduction

Malnutrition, in all its forms, presents a key global challenge to good health outcomes among individuals and populations (Swinburn et al., 2019). Of crucial concern among global nutrition challenges is rising overweight and obesity levels. In 2016, the number of obese adults was estimated to be around 678 million (Global Nutrition Report, 2020). Shekar and Popkin (2020) intimated that more than 70% of the world's overweight and obese adults reside in low- and middle-income countries, and a global yearly death rate of 4 million is attributed to overweight and obesity (Afshin et al., 2017). Overweight and obesity – which are a resultant effect of too little energy expenditure to compensate for excessive energy intake – are largely driven by a shift in food intake from nutrient-dense foods to energy-dense foods that are highly concentrated in sugars, fats, salt, and multiple other ingredients. The shift in food intake is what is largely known as the "nutrition transition" (Popkin et al., 2012; Shekar and Popkin, 2020). Overweight and obesity do not only spur the risks of non-communicable diseases (NCDs) such as type 2 diabetes, cardiovascular diseases, and certain cancers (WHO, 2011; Steyn and McHiza, 2014), but they also unleash dire economic consequences for countries through lost productivity and increased health costs (Shekar and Popkin, 2020).

As a result, over the years, many studies have gauged the possible linkages between a shift in food intake and several health outcomes including overweight and obesity levels. Initial analyses of these linkages relied on using single food items or nutrients, yet the complexity of the human diet requires understanding the interactive effects of both food and nutrients, and not either in isolation (Hu, 2002; Frank et al., 2014). Hence, a dietary pattern – referred to in this study as pattern – analysis provides a more useful tool to combine both food and nutrients to describe an entire diet and associate it with health outcomes. Several statistical methods have been used to characterize the patterns of populations, as patterns are directly unmeasurable (Hu, 2002). Some statistical methods used so far include principal component analysis (PCA), cluster analysis, index analysis, and the reduced rank regression. The PCA and cluster analyses use an *a posteriori* approach to explore data to classify foods/food groups that are correlated to better explain diets or cluster people together based on dietary intake, respectively. The index analysis is based on an *a priori* method where individuals are scored based on predefined diet indexes; such indexes are normally constructed based on knowledge from previous studies (Togo et al., 2001; Schulze and

Hoffmann, 2006). The reduced rank regression approach uses both *a posteriori* and *a priori* methods to assess the linear function of foods/food groups that provide significant variation in a set of predetermined response outcomes, usually diet-related diseases (Hoffmann et al., 2004; Weikert and Schulze, 2016). Thus far, PCA has been a well-established statistical tool for approximating patterns to describe the diet behavior of a population. In Sub-Saharan Africa (SSA), for example, studies on patterns and their linkage to different health outcomes have been mostly PCA-driven studies (Becquey et al., 2010; Keding et al., 2011; Frank et al., 2014; Pisa et al., 2015; Holmes et al., 2018; Auma et al., 2019).

However, these studies and others have been centered around urban areas to the neglect of rural communities. To the best of our knowledge, only two studies have been performed in SSA focusing on rural women in Tanzania and rural adolescents in South Africa, conducted by Keding et al. (2011) and Pisa et al. (2015), respectively. Meanwhile, overweight and obesity levels in rural areas are rapidly growing as part of the overall rising levels of this health epidemic in low- and middle-income countries (Afshin et al., 2017; Shekar and Popkin, 2020). Furthermore, most of these studies that use data reduction methods such as PCA to determine patterns in SSA broadly attribute processed foods to rising overweight and obesity and other NCDs. This notwithstanding, food processing largely provides an avenue for a safe, diverse, adequate, and easily accessible supply of food (Floros et al., 2010). Thus far in the literature, processed foods have been classified by their degree of processing, and notable among them is the NOVA classification. The NOVA classification mainly classifies foods based on the extent and purpose of their industrial processing (Monteiro et al., 2019). Indeed, several studies – mostly in high- and middle-income settings – have adopted the NOVA classification to distinguish processed foods to establish their relationship with varied health outcomes (Elizabeth et al., 2020). However, in SSA, studies on the characterization of processed foods in pattern assessment are limited – including the assessment of nutritious foods like fruits and vegetables (FVs) on overweight and obesity – with none for rural settings to the best of our knowledge.

Through this study, we contribute to addressing these literature gaps by employing longitudinal food intake data and the usage of a recent food processing classification by Reardon et al. (2021) for SSA. The latter is better suited for our data as compared to the NOVA classification system to describe dietary behavior characterized by different food processing levels in rural Kenya, Tanzania, and Uganda. Specifically, this study aims to: (a) ascertain the level of overweight and obesity among rural women in East Africa (Kenya, Tanzania, and Uganda); (b) approximate patterns in rural East Africa as explained by different food processing levels; and (c) analyze the relationship between the patterns (including FVs) characterized by the different food processing levels, with overweight and obesity as health outcomes. In all three countries, only women were recruited because women play an important role in shaping household nutrition – by way of caregiving – especially in rural areas, and especially for children. Hence, studying their dietary behavior is imperative to be able to design appropriate interventions that could shape the entire household nutrition (Kurz and Johnson-Welch, 2001).

This study is integrated in an overall project named “Fruits and Vegetables for all seasons” (FruVaSe). The project seeks to promote improved resource-efficient processing techniques and new market solutions for surplus fruits and vegetables for rural development in Kenya, Tanzania, and Uganda.

2.2. Materials and Methods

2.2.1. Study areas and design

Under the FruVase project, seven study sites were chosen to study six specific nutritious fruits and vegetables. Kenya consisted of the Taita-Taveta and Kitui counties to study guava fruit (*Psidium guajava*) and cowpea leaves (*Vigna unguiculata*), respectively. In Tanzania, cashew apple (*Anacardium occidentale)* was studied in Mtwara, while African nightshade (*Solanum* spp.) was researched on in Morogoro. The Kayunga, Jinja, and Kasese districts were selected to study jackfruit (*Artocarpus heterophyllus)*, cowpea leaves (*Vigna unguiculata*), and cassava leaves (*Manihot esculenta*), respectively. In these selected areas, various forms of malnutrition exist (Table 2.1) despite the excellent nutrient sources of the FVs indicated above. All the study sites were selected for this study except for Kasese in Uganda, due to an Ebola outbreak during the data collection.

Two sampling designs were employed: purposive and simple random. Sub-regions, districts, or counties in the study areas that frequently cultivate the selected FVs, which were, hence, available for consumption, were purposively chosen. In Tanzania, two sub-regions were selected per area, one sub-district per district was chosen in Uganda, and three sub-counties were selected in Kenya: two in Taita-Taveta and one in Kitui. A list of communities/villages for the sub-areas was obtained from the regional, district, and county offices. Per study area (six areas), 10 communities/villages were randomly selected. A comprehensive list of households in the randomly selected communities/villages was compiled with the help from community health workers/nutritionists and community leaders. Inclusion criteria were households with a woman of reproductive age (15–49 years) excluding pregnant women, and a child between 6 and 23 months, and/or a school-aged child between 6 and 13 years. Thirty households were randomly chosen per community/village except for those in Morogoro in Tanzania and Kayunga in Uganda. In these two areas, between 21 and 47 and 20 and 49 households were selected per community/village, respectively, proportional to the number of households (see Figure S2.1). During the survey, neighboring households that met the inclusion criteria were selected in instances where a sampled household did not meet the criteria, or the woman could not be reached. Overall, 1800 households were sampled across the three countries – 600 households per country. Since the focus of the present study is on women, we only used and discussed the data applicable to the women

Table 2.1 Survey timelines, data collected, and malnutrition indicators across the six rural study sites in Kenya, Tanzania, and Uganda.

Country	Study area	FruVaSe target crop	Plenty season		Lean season		Malnutrition indicators	References for malnutrition indicators
			Survey date	Data collected	Survey date	Data collected		
Kenya	Kitui	Cowpea leaves	December 2019	24-hour recall	June 2019	24-hour recall; anthropometrics; socio-economic and demographics	Stunting (35%) for young children	(McMullin and Wekesa, 2017)
	Taita-Taveta	Guava	April/May 2019	24-hour recall; anthropometrics; socio-economic and demographics	October 2019	24-hour recall	48% food insecure; Stunting (35%) for young children.	(Taita Taveta County Government, 2013; MoALF, 2016)
Tanzania	Morogoro	African nightshade	June/July 2019	24-hour recall; anthropometrics; socio-economic and demographics	January 2020	24-hour recall	Iron deficiency for young children (66%) and women (47%).	(United Republic of Tanzania, 2016a, 2016b)
	Mtwara	Cashew apple	October/November 2019	24-hour recall	April/May 2019	24-hour recall; anthropometrics; socio-economic and demographics	Iron deficiency for young children (59%)	(Martin et al., 1997; United Republic of Tanzania, 2016b)
Uganda	Jinja	Cowpea leaves	February 2020	24-hour recall	August 2019	24-hour recall; anthropometrics; socio-economic and demographics	Stunting (31%); wasted (2%); underweight (12%) for young children	(Republic of Uganda, 2015)

	Kayunga	Jackfruit	Triple burden of malnutrition among women	(Uganda Bureau of Statistics, 2017)

Ten villages were chosen per study area. Total number of households: 300 per study area, 600 per country, and 1800 for the overall study

2.2.2. Data Collection

A combination of cross-sectional and longitudinal household surveys was conducted with the women via face-to-face interviews. Socio-economic and demographic data were collected through cross-sectional surveys. These data consisted of age, education (years spent schooling and level), household headship, occupation, nutrition education, marital status, household size, and wealth status using seven household variables including the type of building materials for house floor, wall, and roof, the availability of potable water, toilet facility, ownership of agricultural land, and livestock.

Again, the cross-sectional data included anthropometric measurements as indicated in table 2.1. Weights and heights were measured following the measurement guidelines on anthropometry (Cogill, 2003). Measurements were taken twice and recorded for each woman to ensure accuracy. Final weights and heights measurements were obtained by averaging the recorded values. Electronic Seca scales calibrated to a minimum weight of 0.1kg were used to determine weights. Women stood on the scale wearing light clothing and were barefoot. For height measurement, women stood on height boards, except in Kenya where stadiometers were used, and were barefoot and without any headgear. Measurements were recorded to the nearest 0.1cm. During analysis, implausible measurements were screened for and excluded.

Dietary assessment (24-hour dietary recall) was conducted using the longitudinal approach (Table 2.1). Data were collected across the plenty and lean seasons of the FruVaSe targeted fruits and vegetables. During the survey, all food and drinks consumed during the previous 24 hours of the day of visit were collected using the 24-hour dietary recall tool. Per season, two non-consecutive dietary recalls were conducted. Local plates/bowls and cups, as well as different sizes of typical local fruits and snacks, served as measurement units. For example, women were asked to identify how many plates/bowls of “ugali” (in Kenya or Tanzania) or “posho” (in Uganda), a stiff porridge, they consumed, and how many plates/ bowls of a side dish or other accompanying foods. Additionally, if they consumed any fruit or snack, they were asked to identify the size and the number. For drinks, local cups were used to assess the quantity of consumption.

Standard recipes were prepared per country to ascertain the actual portion size of food and drinks collected during the survey. First, the quantity of each ingredient was weighed before cooking. Meal/dishes were then fitted in the local plates/bowls and cups, used as measurement units during the survey, and weighed (as a portion size, which was done twice, and the average was calculated). Conversion rates were calculated by dividing the entire quantity of prepared meal/dish by the portion size that fit into the local plates/bowls or cups. The quantity of ingredients of a meal/dish was calculated by dividing the ingredients (weighed before cooking) by the respective conversion rate. The actual portion size of intake for a meal/dish for a woman was calculated by multiplying the portion size (fitted into the local plates/bowls or cups) by the unit of measurement collected during the survey. Additionally, ingredient quantities for the actual portion size were computed by multiplying the ingredients of the fitted meal/dish by the respective unit of measurement collected during the survey. For instance, if a woman consumed two plates of "ugali" or "posho", we multiplied two by the fitted portion size of "ugali" or "posho". We also determined the quantity of ingredients (example, maize flour and water) by multiplying the ingredients (maize flour and water) of the fitted portion size of "ugali" or "posho" by two. Likewise, if a woman took five medium-sized sweet bananas, we multiplied five by the portion size of a medium-sized banana, as measured. These calculations are demonstrated mathematically below:

$$PSS_k = (\text{local portion size 1} + \text{local portion size 2})/2 \quad (1)$$

$$CR_k = WM_k/PSS_k \quad (2)$$

$$IPSS_k = WI_k/CR_k \quad (3)$$

$$APS_{kj} = PSS_k \times MU_{kj} \quad (4)$$

$$IAPS_{kj} = IPSS_k \times MU_{kj} \quad (5)$$

where portion size for a meal/dish (fitted into a local plate/bowl or cup) = PSS_k; conversion rate for a meal/dish = CR_k; total weight/quantity of meal/dish cooked (in one pot) = WM_k; ingredients for fitted portion size of meal/dish = $IPSS_k$; weighed ingredients for a meal/dish before cooking = WI_k; actual portion size of a meal/dish for a particular woman = APS_{kj}; measurement unit collected during survey for a meal/dish or food item for a particular woman = MU_{kj}; ingredients for actual portion size of a meal/dish for a particular woman = $IAPS_{kj}$.

The standard recipes prepared were complemented by the Kenya food recipes (FAO/Government of Kenya, 2018) and the Tanzania food composition tables (Lukmanji et al., 2008). For statistical analysis, the ingredients/food items and their respective quantities of intake were largely used.

2.2.3. Extraction of patterns and food processing levels

Patterns were approximated by means of PCA. Although other methods exist, PCA has been largely used for many studies linking patterns to health outcomes (see the introduction section). Hence, its adoption for this study provided an avenue for the comparability of results. PCA is a statistical tool that reduces a large number of, in this case, foods consumed in grams per day into a smaller group of factors that shows the combinations of different food groups consumed and can be used to explain dietary behavior of study subjects or a population (McCann et al., 2001; Togo et al., 2001). This tool was therefore applied to convert food items from Kenya (63), Tanzania (68), Uganda (81), and East Africa (103) – as pooled data of the three countries – into different factors to characterize the dietary behavior of rural women.

First, food intake quantities for all four dietary recalls (two per season) were screened for outliers, and implausible quantities were removed. The quantities for the four recalls were aggregated. Food items – excluding condiments and spices – were then classified into food groups based on intake distribution, nutrient similarities, and their levels of processing. Overall, three food processing levels were defined: unprocessed, minimally processed, and highly processed. Unprocessed foods were foods that required simple cleaning or washing and had not been subjected to any form of processing; minimally processed foods had undergone some form of modifications such as drying, fermentation, milling, freezing, pasteurization etc.; and highly processed foods (including ultra-processed and ultra-processed prepared foods away from home) were defined as foods with potentially high amount of salt, sugar, oil, and/or multiple ingredients that are manufactured by small and medium enterprises (SMEs) and industrial firms to extend their shelf-lives and make them attractive and palatable (Reardon et al., 2021). Food items were classified according to these three definitions under agriculture interpretation – where foods existed in their raw forms before being converted for consumption, and nutrition interpretation – where foods were converted through some preparation methods for final consumption. The nutrition interpretation was adopted for the final analysis. Tables S2.1, S2.2, S2.3 and S2.4 indicate how the food items identified were classified based on the food processing definitions, and under the agriculture and nutrition interpretations for Kenya, Tanzania, Uganda, and East Africa, respectively. The food and drinks were initially classified into 20 food groups, then were re-classified into 14, 12, and 11 food groups for analysis and comparison. For each food group under the four classifications, the amount of intake (in grams) was obtained by summing up the intake amount of all food items identified under that food group. Intake quantity (in grams) per food group was then standardized – mean = 0 and standard deviation = 1 – to account for large variances that may exist across the food groups (Auma et al., 2019).

The standardized values were fed into the PCA tool as primary data to extract patterns. Varimax with Kaiser Normalization was used as a rotation method to extract patterns that are not correlated to each other, but rather correlations between food groups that describe patterns (Pisa et al., 2015; Holmes et al., 2018; Auma et al., 2019). After comparison, the 11-food grouping was chosen for Tanzania, Uganda, and East Africa, while the 12-food grouping was selected for Kenya. Rice was constructed as an additional food group in the Kenya food grouping. These groupings provided for the most detailed and coherent interpretation of patterns as well as the highest total percentage of variance explained in the patterns.

Following other studies (Frank et al., 2014; Holmes et al., 2018; Auma et al., 2019), patterns with eigenvalues >1 and explained by a high percentage of variance were retained. In all, four patterns were retained, except for Uganda, where five were retained. Patterns were interpreted and labelled with food groups with rotated factor loadings ≥ ±0.45. Factor loadings showcase the correlation between the food groups and the patterns; high positive loadings indicating positive correlations and high negative loadings representing an inverse relationship. Factor scores were computed for each pattern by aggregating the intake amount of the standardized food groups weighted by their respective factor loadings. Finally, each woman obtained a factor score for each pattern: a high positive score indicating a woman's close association with such pattern and a negative score indicating otherwise (Keding et al., 2011; Holmes et al., 2018).

2.2.4. Data analysis

Descriptive statistics by way of means were calculated for age, education (years spent in school), household head (yes = 1, no = 0), nutrition education (yes = 1, no = 0), household size, and body mass index (BMI). Significant differences across the countries were tested for using the Kruskal – Wallis and Dunnett tests. Percentage distributions were calculated for the variables: marital status, occupation, education level, and wealth status. BMI was calculated as weight (kg) divided by height (m) squared and classified as the following: underweight = <18.5 kg/m^2; normal = 18.5−24.9 kg/m^2; overweight = 25.0−29.9 kg/m^2; and obesity = ≥30.0 kg/m^2, according to the WHO report on obesity (WHO, 2000). The association between socio-economic and demographic variables and patterns was determined using the Spearman and point-biserial correlation methods. The Spearman correlation (ρ) was applied to two non-normally distributed continuous variables, while the point-biserial (r_{pb}) correlation was applied to one dummy variable and one continuous variable (Keding et al., 2017).

Factor scores of each pattern were divided into three terciles. The first tercile represents women within the lowest segment of a pattern, while those in the third tercile represent the highest segment of a pattern. Logit regression models were constructed to ascertain the association between overweight and obesity and patterns. In these models, overweight and obesity (yes = 1, no = 0) was the dependent variable and the pattern (in terciles) was the main explanatory variable. Subsequently, these models were adjusted for possible confounders using the socio-economic and demographic variables. Since coefficients of logit models are difficult to interpret, odds ratios (OR) and the 90% confidence interval (CI) were calculated for logical interpretation. With OR, the odds of women within the highest tercile of a pattern being overweight and obese relative to those in the lowest tercile of the same pattern were calculated. A linear trend across the terciles was tested using the continuous values of the patterns to denote significance (Holmes et al., 2018), as shown in terciles 3.

To understand the relationship between patterns and BMI, the ordinary least square (OLS) model was employed. BMI values were used as dependent variable, while the factor scores of the pattern served as the independent variable in the OLS models. However, the residuals of the models were not normally distributed—violating a key assumption of an OLS model. The socio-economic and demographic variables were included in the models to obtain normally distributed residuals. These variables also acted as covariates. Possible multi-collinearity was tested using variance inflation factor (VIF), and robust standard errors were used to account for heteroscedasticity. Location as a dummy variable was included in both the logit and OLS models for East Africa to account for unobserved differences, such as culture and other socio-economic factors, across the three countries. Statistical significance was pegged at 10%, 5%, 1%, and 0.1%. Analyses were conducted for adult women ≥19 years, [32], and separately for Kenya (N= 445);

Tanzania (N = 292); Uganda (N = 415); and East Africa (N = 1152) as pooled data, using the R statistical tool 4.0.0.

2.3. Results

2.3.1. Socio-economic and demographic characteristics

The average age of the women in Kenya, Tanzania, and Uganda was 33.8, 32.2, and 31.3 years, respectively. There were significant differences between the average age in Kenya and the other two countries. Between Tanzania and Uganda, there was no significant difference. The mean age in East Africa was estimated at 32.5 years. The highest level of education for more than half of the women was primary school across the board. In East Africa, this culminated to an average of 7.5 years in school for a rural woman; however, there were significant differences across countries (Table 2.2). Overall, more than 70% were married, which reinforced the fact that most of them are not household heads. Low nutrition education (for the previous 6 months to the day of the survey) was recorded across countries. A relatively large proportion of the women lived in households classified as having high wealth. Further details are illustrated in table 2.2.

Table 2.2 Socio-economic and demographic statistics of women of reproductive age in Kenya, Tanzania, Uganda, and East Africa.

Variables	Kenya	Tanzania	Uganda	East Africa (Pooled Data)
Age of participants (years)	33.88 *^{KT} (8.28)	32.24 (8.55)	31.25 ***^{KU} (8.46)	32.52 (8.46)
Household size	5.25 ***^{KT} (2.14)	4.62 ***^{TU} (1.94)	6.44 ***^{KU} (2.79)	5.52 (2.46)
Household head (yes = 1, no =0)	0.24 (0.43)	0.19 (0.39)	0.16 *^{KU} (0.37)	0.20 (0.40)
Body mass index (kg/m^2)	25.35 (5.14)	24.87 ***^{TU} (4.80)	23.44 ***^{KU} (3.83)	24.54 (4.69)
Nutrition education received during the past 6 months (yes = 1, no = 0)	0.14 *^{KT} (0.35)	0.09 (0.28)	0.10 $^{+KU}$ (0.29)	0.11 (0.32)
Years spent in school	8.44 ***^{KT} (3.21)	6.54 **^{TU} (2.49)	7.21 ***^{KU} (3.65)	7.52 (3.31)
Educational level (%)				
None	3.82	8.90	8.89	6.94

Primary	67.42	79.79	54.33	65.83
Secondary	22.25	10.62	34.13	23.59
Tertiary	6.51	0.68	2.64	3.65
Marital status (%)				
Married	74.38	76.71	77.16	75.98
Widowed or divorced or single	25.62	23.29	22.84	24.02
Main occupation (%)				
None	15.06	7.88	17.79	14.22
Farmer	62.92	75.00	62.26	65.74
Trader	12.58	10.27	10.34	11.19
Other (vocational skills, civil servant, teacher)	9.44	6.85	9.61	8.84
Wealth status (%)				
Low	22.02	17.47	28.60	26.91
Medium	37.53	32.19	34.38	32.38
High	40.45	50.34	37.02	40.71
N	445	292	415	1152

Standard deviations are in parentheses. +, *, **,*** represent statistical significance of $p < 0.1$, $p < 0.05$, $p < 0.01$, $p < 0.001$ according to the Kruskal–Wallis and Dunnett tests for significant differences across countries. ^{KT}: significant difference between Kenya and Tanzania; ^{KU}: significant difference between Kenya and Uganda; ^{TU}: significant difference between Tanzania and Uganda.

2.3.2. Body mass index as a proxy for health outcomes

The BMI in East Africa among rural women was 24.5 kg/m^2 – almost at the threshold of overweight. In Kenya, the average BMI was within the overweight classification. Country comparison showed significant differences between Kenya and Uganda, and Tanzania and Uganda (Table 2.2). In Kenya and Tanzania, the rates of overweight and obesity were almost twice as much as Uganda. Overall, around 25% and 13% of the rural women were overweight and obese, respectively, in East Africa (Figure 2.1).

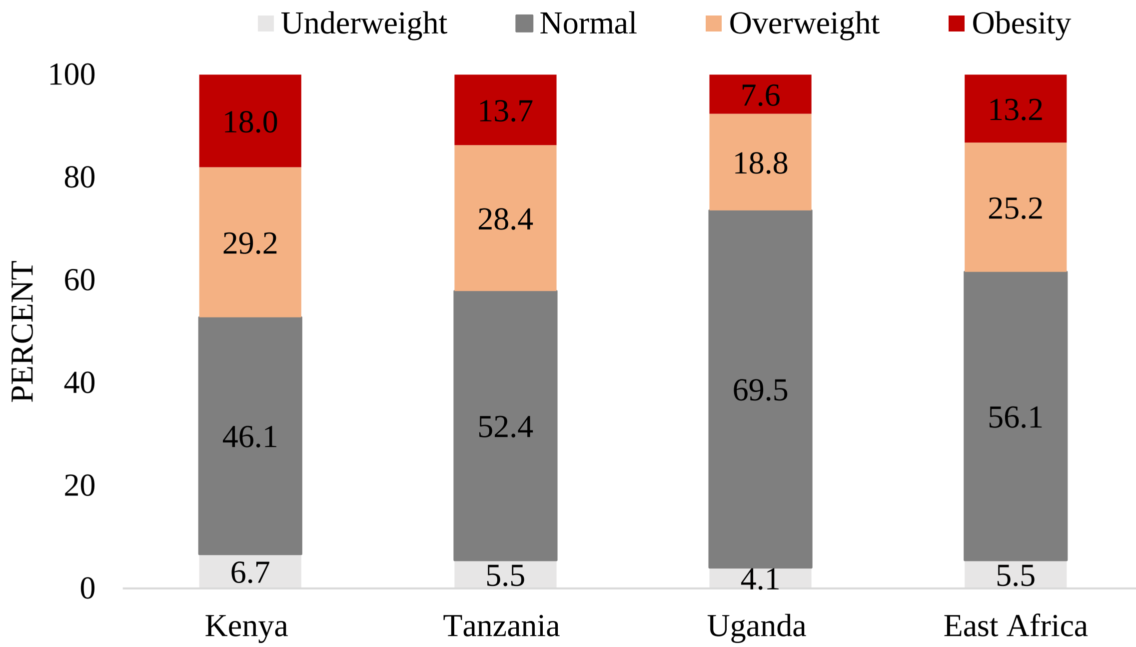

Figure 2.1 The rate of underweight, normal weight, overweight, and obesity among rural women of reproductive age in Kenya (N = 445), Tanzania (N = 292), Uganda (N = 415), and East Africa (N = 1152).

2.3.3. Patterns as characterized by food processing levels

Four components were retained to characterize diet behavior in Kenya and were labeled as plant-based, purchase I, plant- and animal-based, and purchase II patterns, respectively. The four patterns explained 59% of the variation in diets. The plant-based pattern was characterized by the intake of starchy plants such as cereals, roots, and tubers, as well as of pulses and nuts, and oils and fats – a mixture of minimally and highly processed foods. Components two and four were classified as purchase patterns because the foods under them were mostly purchased in supermarkets, small shops, and from street food vendors. They consisted of both minimally and highly processed foods (Table 2.3). The plant- and animal-based pattern was made up of plant food sources including vegetables and animal food sources. Patterns identified in Kenya were also found in Tanzania. The difference, however, was that only one purchase pattern, described by highly processed foods, was identified in Tanzania. Additionally, a distinct pattern (starchy plants) made up of minimally processed cereals, roots, and tubers was found. The four patterns explained 60% of the variance in diets among rural women (Table 2.4).

In Uganda, three out of the five patterns – the purchase pattern, plant-based pattern I, and plant-based pattern II – retained can be related to the patterns found in Kenya and Tanzania. Just like in Tanzania, the purchase pattern in Uganda consisted wholly of highly processed foods. The two plant-based patterns reflected the plant-based and starchy plants patterns extracted in Kenya and Tanzania. The two additional patterns extracted were animal-based and vegetables. The animal-based pattern was made up of poultry, fish, meat, and milk, while the vegetable pattern consisted of vegetables (Table 2.5). Again, in table 2.5, oils and fats correlated positively with these patterns, indicating that most of the animal food sources and vegetables were fried or at least consumed in combination with oils and fats in rural Uganda. For East Africa as a whole, four patterns, namely mixed, plant-based, purchase, and vegetable, were identified. They cumulatively explained 53% of the variance, as shown in table 2.6. Except for the mixed pattern, all the patterns were identical with the patterns from the three countries. However, some differences existed in the food sources. While the purchase pattern consisted of highly processed foods – tea with bread and snacks, the plant-based and vegetable patterns were wholly made up of pulses and nuts and vegetables, respectively. The mixed pattern was a mixture of four food groups including fruits, and was characterized by unprocessed, minimally, and highly processed foods (Table 2.6).

Table 2.3 Patterns extracted for women of reproductive age in **Kenya** based on 12 food groups and characterized by three food processing categories.

Rotated component	Extracted pattern	Food group with food items	Loading coefficient	Food processing level explaining pattern (in nutrition)	Proportion variance explained (%)	Cumulative variance explained (%)
1	Plant-based pattern	**Cereals, roots, and tubers:** Irish potato, sweet potato, maize, sorghum, millet, taro, plantain	0.78	Minimally and highly processed	17	17
		Pulses and nuts: Beans, cowpea, green grams, peas	0.87			
		Milled cereals, roots, pulses, and nuts: Millet flour, maize flour, sorghum flour, wheat flour	−0.59			

		Oils and fats: Sunflower cooking oil, margarine, hydrogenated fat	0.48			
2	Purchase pattern I	**Tea:** tea	0.87	Minimally and highly processed	16	33
		Sugar and sugary drinks: Sugar, soda, sugary drinks (mango sweetened)	0.64			
		Milk: Pasteurized milk, fermented milk	0.68			
3	Plant and animal-based pattern	**Vegetables:** Amaranth leaves, African nightshade, cowpea leaves, cabbage, carrot, eggplant, kales, onion, spinach, tomato, bitter lettuce, pumpkin leaves	0.86	Minimally and highly processed	14	47
		Meat, poultry, and fish: Beef, poultry, goat meat, offals, small dried fish, fish, egg, pork	0.46			
		Oils and fats: Sunflower cooking oil, margarine, hydrogenated fat	0.72			
4	Purchase pattern II	**Bread and snacks:** Bread, chips, noodles, *mandazi*, *halfcake* (wheat dough fried in oil), *chapati* (wheat flatbread)	0.61	Minimally and highly processed	11	59
		Rice: rice	0.78			

Factor loadings ≥ ±0.45 are shown in the loading coefficient column to characterize the correlation between the food group and pattern.

Table 2.4 Patterns extracted for women of reproductive age in **Tanzania** based on 11 food groups and characterized by three food processing categories.

Rotated component	Extracted pattern	Food group with food items	Loading coefficient	Food processing level explaining pattern (in nutrition)	Proportion variance explained (%)	Cumulative variance explained (%)
1	Plant and animal-based pattern	**Vegetables:** Amaranth leaves, African nightshade, cabbage, carrot, cassava leaves, Chinese cabbage, cowpea leaves, cucumber, eggplant, green pepper, jute mallow leaves, kales, okra, onion, potato leaves, pumpkin, pumpkin leaves, spinach, sweet potato leaves, tomato	0.85	Minimally and highly processed	19	19
		Meat, poultry, and fish: Beef, poultry, fish, goat meat, small dried fish	0.70			
		Oils and fats: Cashew nut milk, coconut milk, sunflower cooking oil	0.84			
2	Purchase pattern	**Tea:** tea	0.90	Highly processed	18	37
		Sugar and sugary drinks: Sugar, soda, sugary drinks (lemon, mango sweetened)	0.89			
		Bread and snacks: Bread, noodles, *mandazi*, *vitumbua* (dough from rice or maize or wheat flour fried in oil), buns, *chapati* (wheat flatbread), *samosa* (fried pastry with vegetables and/or meat filling)	0.52			
3	Plant-based pattern	**Fruits:** Cashew apple, jackfruit, lemon/orange, mango, passion fruit, papaya, watermelon, pineapple, sweet banana	0.63	Unprocessed and minimally processed	11	49

		Milled cereals, roots, pulses, and nuts: Cassava flour, groundnut flour/paste, maize flour, millet flour, rice flour	0.51			
		Pulses and nuts: Bambara groundnut, beans, cowpeas, groundnut	0.60			
4	Starchy plants	**Cereals, roots, and tubers:** Cassava, Irish potatoes, maize, plantain, rice, sweet potatoes, taro, millet	0.87	Minimally processed	11	60
		Bread and snacks: Bread, noodles, *mandazi*, *vitumbua* (dough from rice or maize or wheat flour fried in oil), buns, *chapati* (wheat flatbread), *samosa* (fried pastry with vegetables and/or meat filling)	−0.59			

Factor loadings ≥ ±0.45 are shown in the loading coefficient column to characterize the correlation between the food group and pattern.

Table 2.5 Patterns extracted for women of reproductive age in **Uganda** based on 11 food groups and characterized by three food processing categories.

Rotated component	**Extracted pattern**	**Food group with food items**	**Loading coefficient**	**Food processing level explaining pattern (in nutrition)**	**Proportion variance explained (%)**	**Cumulative variance explained (%)**
1	Purchase pattern	**Tea:** coffee, tea	0.45	Highly processed	14	14
		Sugar and sugary drinks: Sugar, soda, sugary drinks (orange, passion, pineapple, tamarind sweetened)	0.74			
		Bread and snacks: Bread, buns, *mandazi*, *halfcake* (dough fried in oil), *chapati* (wheat flatbread), *bagiya* (cassava and soybean flour fried in oil), cake, chips,	0.72			

		cornflakes, *hardcorn*, noodles, pancake, popcorn, *samosa* (fried pastry with vegetables and/or meat filling)				
2	Plant-based pattern I	**Milled cereals, roots, pulses, and nuts:** Beans flour, groundnut flour/paste, maize flour, millet flour, sesame paste, sorghum flour, soybean flour/paste	0.80	Minimally processed	13	27
		Pulses and nuts: Beans, groundnut, soybean	0.81			
3	Animal based pattern	**Milk:** Pasteurized milk	0.45	Minimally and highly processed	12	39
		Meat, poultry, and fish: Beef, poultry, smoked fish, egg, fish, goat meat, offals, small dried fish	0.80			
		Oils and fats: Sunflower cooking oil, ghee, palm oil	0.59			
4	Plant-based pattern II	**Cereals, roots, and tubers:** Taro, cassava, cassava flour, cocoyam, Irish potatoes, maize, millet, plantain, rice, sorghum, sweet potatoes	0.73	Unprocessed and minimally processed	11	51
		Fruits: Apple, avocado, guava, jackfruit, lemon/orange, mango, passion fruit, papaya, pineapple, sweet banana, watermelon	0.77			
5	Vegetable pattern	**Vegetables:** African nightshade, amaranth leaves, bitter berries, bitter tomatoes, cowpea leaves, cucumber, cabbage, carrot, mushroom, eggplant, garden eggs, green pepper, kales, onion, pumpkin, pumpkin leaves, spinach, tomato	0.76	Minimally and highly processed	10	61

		Oils and fats: Sunflower cooking oil, ghee, palm oil	0.53			

Factor loadings ≥ ±0.45 are shown in the loading coefficient column to characterize the correlation between the food group and pattern.

Table 2.6 Patterns extracted for women of reproductive age in **East Africa** based on 11 food groups and characterized by three food processing categories.

Rotated component	**Extracted pattern**	**Food group with food items**	**Loading coefficient**	**Food processing level explaining pattern (in nutrition)**	**Proportion variance explained (%)**	**Cumulative variance explained (%)**
1	Mixed pattern	**Cereals, roots, and tubers:** Cassava, cocoyam, maize, millet, plantain, Irish potatoes, rice, sorghum, sweet potatoes, taro	0.75	Unprocessed, minimally, and highly processed	17	17
		Fruits: Apple, avocado, cashew apple, guava, jackfruit, lemon/orange, mango, passion fruit, papaya, pineapple, sweet banana, tamarind, watermelon	0.48			
		Milk: Pasteurized milk, fermented milk	0.47			
		Sugar and sugary drinks: Sugar, soda, sugary drinks (lemon, mango, orange, passion, pineapple, tamarind sweetened)	0.76			
2	Plant-based pattern	**Pulses and nuts:** Bambara groundnut, beans, cowpeas, green grams, groundnut, peas, soybean	0.73	Minimally processed	13	30
		Milled cereals, roots, pulses, and nuts: Beans flour, cassava flour, groundnut flour/paste, maize flour, millet flour, rice flour, sesame paste, sorghum flour,	−0.49			

		soybean flour/paste, wheat flour				
		Meat, poultry, and fish: Smoked fish, egg, fish, goat meat, offals, beef, poultry, pork, small-dried fish	−0.54			
3	Purchase pattern	**Tea:** tea, coffee	0.64	Highly processed	13	44
		Bread and snacks: Bread, buns, *mandazi*, *halfcake*, *vitumbua* (dough from rice or maize or wheat flour fried in oil), *chapati* (unleavened flatbread), *bagiya* (cassava and soybean flour fried in oil), chips, cornflakes, *hardcorn*, noodles, pancake, popcorn, *samosa* (fried pastry with vegetables and/or meat filling)	0.68			
4	Vegetable pattern	**Vegetables:** African nightshade, amaranth leaves, bitter berries, bitter lettuce, bitter tomatoes, cabbage, carrot, cassava leaves, Chinese cabbage, cowpea leaves, cucumber, eggplant, garden eggs, green pepper, jute mallow leaves, kales, mushroom, onion, okra, sweet potato leaves, pumpkin, pumpkin leaves, spinach, tomato	0.81	Minimally processed	10	53

Factor loadings ≥ ±0.45 are shown in the loading coefficient column to characterize the correlation between the food group and pattern.

2.3.4. Correlation between patterns and socio-economic and demographics indicators

The plant-based pattern identified in Kenya showed a mild significant positive correlation with household size ($\rho = 0.12$) and being married ($r_{pb} = 0.10$) but was negatively correlated with the wealth index ($\rho = -0.31$), education ($\rho = -0.25$), and nutrition education ($r_{pb} = -0.22$). Purchase pattern II was positively correlated with the wealth index ($\rho = 0.12$) and education ($\rho = 0.13$), and, at the same time, was slightly negatively associated with household size ($\rho = -0.15$) and being married (r_{pb} = −0.09). Other correlation results for Kenya are detailed in table S2.5. For Tanzania, the plant-based pattern was positively correlated with being married (r_{pb} = 0.11) and was negatively associated with the wealth index (ρ = −0.16). Just as it was observed in Kenya, the purchase pattern was positively correlated with the wealth index (ρ = 0.10) and education (ρ = 0.17), in addition to age (ρ = 0.12). Being a household head in Tanzania was positively associated with women following the plant- and animal-based pattern (r_{pb} = 0.13). In table S2.6, starchy plants pattern correlated positively with age only (ρ = 0.19).

For the correlation between the patterns obtained in Uganda and the socio-economic and demographic factors, the purchase pattern was positively correlated with the wealth index (ρ = 0.09) and education (ρ = 0.26), as observed in Kenya and Tanzania, while it was inversely associated with age (ρ = −0.15), being a household head (r_{pb} = −0.09), and household size (ρ = −0.10). Plant-based patterns I and II showed different associations: plant-based pattern I was positively correlated with education (ρ = 0.12) and nutrition education (r_{pb} = 0.19) and had a mild negative association with household size (ρ = −0.09); and plant-based pattern II was only positively correlated with age (ρ = 0.10) and was negatively correlated with the wealth index (ρ = −0.17). Further correlation results are shown in table S2.7. In East Africa, the correlation results showed that purchase pattern (highly processed food-based diet) was positively correlated with the wealth index (ρ = 0.17) and education (ρ = 0.31) and had a weak relationship with nutrition education (r_{pb} = 0.07). This means as wealth, education, and nutrition education increase, more women follow the purchase pattern. Yet, there was a negative relationship with household size (ρ = −0.08). The plant-based pattern – characterized by pulses and nuts – correlated positively with age (ρ = 0.10), household size (ρ = 0.10), and education (ρ = 0.16). Thus, as age, household size, and education increase, women are more likely to follow the plant-based pattern (Table S2.8).

2.3.5. Association between patterns and overweight and obesity

Table 2.7 highlights the association between the patterns and overweight and obesity. In Kenya, there was a significant positive association between women in tercile 3 of purchase pattern II (bread and snacks and rice) and overweight and obesity (OR 1.52; CI 0.99, 2.32) relative to those in tercile 1. More than half (54%) of the overweight and obese women were within the highest segment (tercile 3) of purchase pattern II (Figure 2.2). There was no significant association between the other patterns including those with vegetables and overweight and obesity (Table 2.7). The same table shows that none of the patterns were significantly associated with overweight and obesity except for the plant-based pattern, which contained fruits, in Tanzania. Women within the highest tercile, following the plant-based pattern, compared to those at the lowest tercile of this pattern, were about 41% less probable of being overweight and obese (OR 0.59; CI 0.35, 0.98). Hence, the percentage of overweight and obese women within the highest tercile of this pattern was lower, as shown in figure 2.2. None of the patterns were significantly associated with overweight and obesity in Uganda. For East Africa as a whole, only two patterns – the plant-based and purchase patterns – were significantly associated with overweight and obesity. The plant-based pattern was negatively associated with overweight and obesity (OR 0.59; CI 0.41, 0.85). On the other hand, the purchase pattern, characterized by highly processed foods – tea with bread and snacks – was positively associated with overweight and obesity. Women in the highest tercile were 22% more probable of being overweight and obese than women in the lowest tercile (OR 1.22; CI 0.89, 1.66). Overall, about almost half (46%) of the overweight and obese women were found in the highest tercile of the purchase pattern (Figure 2.2). The patterns with fruits or vegetables had no association with overweight and obesity.

Table 2.7 Association between patterns extracted (in terciles) and overweight and obesity among rural women of reproductive age in Kenya, Tanzania, Uganda, and East Africa.

Patterns	**Kenya**		**Tanzania**		**Uganda**		**East Africa**	
	N	**OR (90% CI)**	**N**	**OR (90% CI)**	**N**	**OR (90% CI)**	**N**	**OR (90% CI)**
Plant-based pattern [a]								
Tercile 1	149	1.00 (Ref.)	98	1.00 (Ref.)	139	1.00 (Ref.)	384	1.00 (Ref.)
Tercile 2	148	1.02 (0.66, 1.57)	97	0.79 (0.47, 1.31)	138	1.34 (0.84, 2.13)	384	0.71 (0.51, 0.99)
Tercile 3	148	0.72 (0.46, 1.12)	97	0.59 * (0.35, 0.98)	138	0.91 (0.56, 1.49)	384	0.59 ** (0.41, 0.85)
Purchase pattern [b]								
Tercile 1	149	1.00 (Ref.)	98	1.00 (Ref.)	139	1.00 (Ref.)	384	1.00 (Ref.)
Tercile 2	148	1.13 (0.74, 1.72)	97	0.73 (0.44, 1.23)	138	0.78 (0.48, 1.26)	384	0.99 (0.74, 1.31)
Tercile 3	148	1.52^{+} (0.99, 2.32)	97	0.85 (0.51, 1.43)	138	0.95 (0.58, 1.53)	384	1.22 * (0.89, 1.66)
Plant and animal-based pattern								
Tercile 1	149	1.00 (Ref.)	98	1.00 (Ref.)	--	--	--	--
Tercile 2	148	0.96 (0.63, 1.44)	97	0.88 (0.54, 1.47)	--	--	--	--
Tercile 3	148	1.05 (0.68, 1.60)	97	0.87 (0.52, 1.47)	--	--	--	--
Purchase pattern I								
Tercile 1	149	1.00 (Ref.)	--	--	--	--	--	--
Tercile 2	148	0.88 (0.58, 1.34)	--	--	--	--	--	--
Tercile 3	148	0.98 (0.64, 1.49)	--	--	--	--	--	--
Starchy plants								

Tercile 1	--	--	98	1.00 (Ref.)	--	--	--	--
Tercile 2	--	--	97	1.23 (0.74, 2.05)	--	--	--	--
Tercile 3	--	--	97	0.76 (0.44, 1.28)	--	--	--	--
Vegetable pattern								
Tercile 1	--	--	--	--	139	1.00 (Ref.)	384	1.00 (Ref.)
Tercile 2	--	--	--	--	138	0.96 (0.60, 1.54)	384	0.86 (0.66, 1.12)
Tercile 3	--	--	--	--	138	1.04 (0.64, 1.67)	384	0.76 (0.58, 1.00)
Plant-based pattern I								
Tercile 1	--	--	--	--	139	1.00 (Ref.)	--	--
Tercile 2	--	--	--	--	138	1.24 (0.77, 2.00)	--	--
Tercile 3	--	--	--	--	138	0.91 (0.56, 1.47)	--	--
Animal-based pattern								
Tercile 1	--	--	--	--	139	1.00 (Ref.)	--	--
Tercile 2	--	--	--	--	138	1.31 (0.82, 2.09)	--	--
Tercile 3	--	--	--	--	138	0.81 (0.50, 1.32)	--	--
Mixed pattern								
Tercile 1	--	--	--	--	--	--	384	1.00 (Ref.)
Tercile 2	--	--	--	--	--	--	384	0.69 (0.53, 0.90)
Tercile 3	--	--	--	--	--	--	384	0.96 (0.60, 1.57)

[a] Plant-based pattern II for Uganda; [b] Purchase pattern II for Kenya; Tercile 1 = women within the lowest segment the pattern; Tercile 3 = women within the highest segment following the pattern. Models were estimated using logit regression modeling and odds ratio (OR) and confidence intervals at 90% were calculated. Overweight and obesity (binary) as outcome variable and pattern (in three terciles) as explanatory variable with socio-economic and demographic factors as covariates in the models. +, *, **, represent the statistical significance of $p < 0.1$, $p < 0.05$, $p < 0.01$, respectively, for the trend test across the terciles.

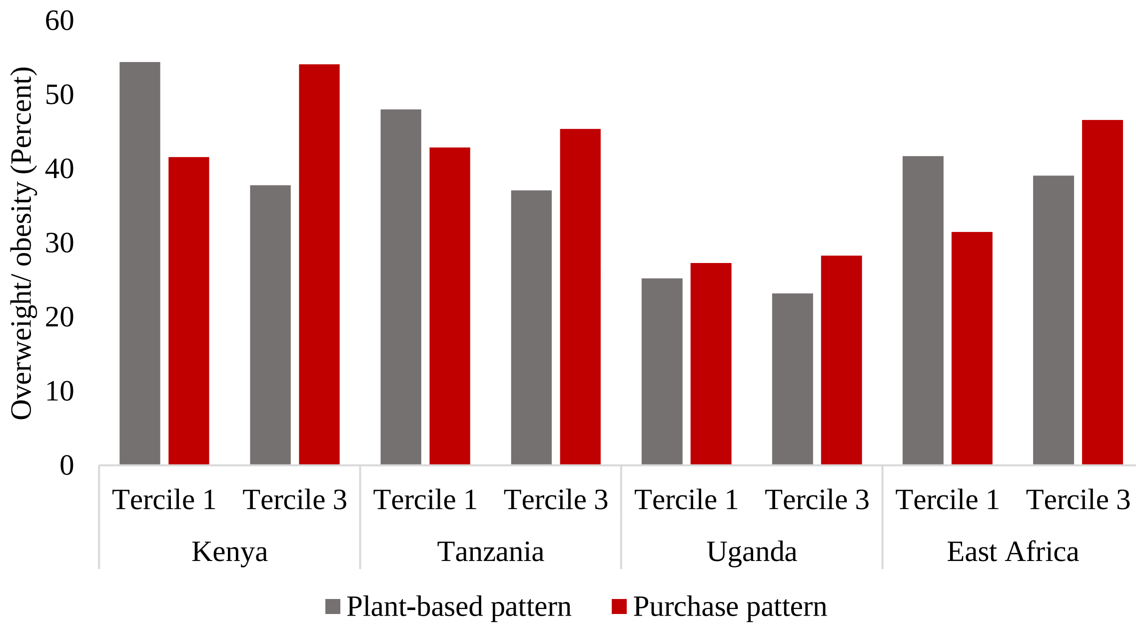

Figure 2.2 Percentage of overweight and obese rural women in the lowest (tercile 1) and highest (tercile 3) segments of the patterns (only plant-based and purchase patterns are shown here) in Kenya (N = 210), Tanzania (N = 123), Uganda (N = 110), and East Africa (N = 443). For Uganda, figures of plant-based pattern II are shown, while purchase pattern II is shown for Kenya.

2.3.6. Relationship between patterns and body mass index (in continuous values)

Table 2.8 showcases the relationship between the patterns and BMI across countries and East Africa. The two purchase patterns in Kenya were significant and positively associated with high BMI values . The plant-based pattern had an inverse relationship with BMI. Again, in Tanzania, the plant-based pattern with fruits was negatively associated with BMI, as shown in table 2.8. No significant relationship was found between the patterns and BMI in Uganda . In East Africa, the purchase pattern, defined by highly processed foods, increased BMI , indicating a significant positive relationship between the two variables. In contrast, the plant-based pattern — characterized by pulses and nuts – reduced BMI, signaling a negative relationship between the two variables. Mixed and vegetable patterns with fruits or vegetables showed no significant relationship with BMI . Full models are shown in tables S2.9, S2.10, S2.11 and S2.12 for Kenya, Tanzania, Uganda, and East Africa, respectively.

Table 2.8 Relationship between extracted patterns and body mass index of women of reproductive age in rural Kenya, Tanzania, Uganda, and East Africa.

Independent Variables	**Body Mass Index**			
	Kenya	**Tanzania**	**Uganda**	**East Africa**
Plant-based pattern [a]	−0.568 * (0.258)	−0.693 ** (0.257)	0.169 (0.166)	−0.696 *** (0.160)
Purchase pattern [b]	0.422 [+] (0.256)	−0.243 (0.283)	−0.090 (0.180)	0.454 *** (0.137)
Plant- and animal-based pattern	−0.062 (0.282)	−0.131 (0.267)	--	--
Purchase pattern I	0.480 * (0.228)	--	--	--
Starchy plants	--	−0.200 (0.281)	--	--
Vegetable pattern	--	--	−0.193 (0.118)	−0.117 (0.084)
Plant-based pattern I	--	--	−0.184 (0.157)	--
Animal-based pattern	--	--	−0.072 (0.153)	--
Mixed pattern	--	--	--	−0.180 (0.167)
Control Variables	Yes	Yes	Yes	Yes
N	445	292	415	1152

[a] Plant-based pattern II for Uganda; [b] Purchase pattern II for Kenya. Models were estimated using ordinary least square regression modeling. Estimated coefficients and robust standard errors in parentheses are shown. Body mass index as an outcome variable and patterns as explanatory variables with socio-economic and demographic factors as control variables are shown. +, *, **, ***, represent statistical significance of $p < 0.1$, $p < 0.05$, $p < 0.01$, $p < 0.001$, respectively.

2.4. Discussion

2.4.1. Overweight and obesity in sub-Saharan Africa

The present study demonstrated the current rates of overweight and obesity, patterns characterized by food processing levels, and how they are associated with overweight and obesity among rural women in East Africa. This study showed that the overweight and obesity rate is high in rural Kenya and Tanzania compared to Uganda. Regionally, the rate (overweight and obesity combined) was 38.4%. According to Shekar and Popkin (2020) and Reardon et al. (2021), overweight and obesity are rapidly rising in SSA particularly among individuals within the highest socio-economic strata, and hence, the high rates identified in the present study are not entirely surprising. Indeed, this is backed by other studies in SSA that have documented high rates of overweight and obesity. Ajayi et al. (2016) in their study of four SSA countries, reported high rates of overweight and obesity in both urban and rural areas. For instance, the overweight and obesity rate was 46% in rural Uganda and 75% in urban Tanzania. In a study by Keding et al. (2013a), among women in rural Tanzania**,** 22% of the women were overweight and obese. Additionally, the Kenya Ministry of health (2016) in its mid-term review report of the health sector strategic plan in 2016 reported between 35% and 44% overweight and obesity rates for individuals residing in Taita-Taveta and Kitui counties (the same counties sampled for this study). The report also expressed concern of a continuous increase in overweight and obesity and the danger as a national health issue. The figure of overweight and obesity depicted in this study for Kenya (47%) was in line with that of the Kenya Ministry of health (2016); for Tanzania (42%), it was almost twice the findings by (Keding et al., 2013a); yet, the data for the latter study were collected more than 10 years ago, which could explain the increase; and in rural Uganda, our result (26%) was almost half the rate indicated by Ajayi et al. (2016), suggesting that the rates differ highly between different rural areas.

Over the years, overweight and obesity rates have risen among women globally. A global trend analysis between 1980 and 2013 showed an increased rate of 8% (Ng et al., 2014). In SSA, for instance, being a woman is a significant predictor for being overweight and obese (Ajayi et al., 2016). In a study by Holmes et al. (2018), data pooled from four countries showed that overweight and obesity rates for women were more than twice as much as men. Similar statistics were reported in Burkina Faso (Becquey et al., 2010) and Kenya (Kenya Ministry of Health, 2016). Despite these findings being largely urban centered, Popkin et al. (2012) intimated that rural women are also increasingly catching up with their compatriots in urban areas. The present study reaffirms this assertion made by Popkin et al. (2012) of growing overweight and obesity among rural women. This unfolding trend is particularly worrying because women play a critical role in shaping the overall household nutrition especially in rural areas (Kurz and Johnson-Welch, 2001). Moreover, bad health outcomes such as overweight and obesity for women are a huge public health concern that consequently poses adverse effects for the proper cognitive and healthy development of young children, and in general, for building a strong human capital base for a society.

2.4.2. Patterns and the nutrition transition

Patterns identified across the countries and at the regional level are not different and are not entirely different from patterns obtained in other studies by Keding et al. (2011) and Auma et al. (2019). In rural Tanzania, Keding et al. (2011) identified five patterns; the same number of patterns was extracted for Uganda and the four patterns extracted for Kenya, Tanzania, and East Africa equaled the number reported in the study of Auma et al. (2019). A purchase pattern, also identified by Keding et al. (2011), was found in the three countries and at the regional level. Again, the purchase pattern reflected that of the transitioning, processed pattern reported in Uganda by Auma et al. (2019). Indeed, in these two studies and the present study, this pattern was made up of bread and snacks, sugar, tea (with milk, sugar, or both), rice, and pasta, which are sometimes considered micronutrient poor (Monteiro et al., 2011). Identification of the purchase pattern across the study areas confirms the full force of the nutrition transition in rural areas. Additional patterns extracted, such as the plant-based, plant- and animal-based, and animal-based patterns, can be equated to the traditional inland and/or pulses, traditional coast, and animal product patterns in Keding et al. (2011), respectively. To a large extent, the plant-based, traditional (high fat), and animal-based patterns described in Auma et al. (2019) can also be reflected in the additional extracted patterns listed above. Aside from these similarities in patterns, a vegetable pattern was uniquely identified in our study, but only in Uganda and East Africa. Although other patterns were identified, the trend across the countries shows a nutrition transition from stage 3 (“Industrialization/ Receding Famine”) to stage 4 (“Non-communicable Disease”) as defined by Popkin (Popkin, 2006).

2.4.3. Processed foods, wealth, and overweight and obesity

The purchase pattern largely characterized by highly processed foods had a significant positive association with overweight and obesity and BMI in Kenya and East Africa, yet there was a non-significant negative association in Tanzania and Uganda. These mixed findings were also expressed by Togo et al. (2001) in their review study when they identified heterogeneous (positive and negative) associations between patterns equivalent to the purchase pattern and obesity and BMI. Although the data are mixed, in the present study, there is a trend towards increased BMI values by following the purchase pattern. Generally, in SSA, there has been a rapid shift in dietary intake that prominently features the increased consumption of highly processed foods, which increases the risk of obesity and other nutrition-related diseases (Reardon et al., 2021).

Unfortunately, their increased consumption also has adverse effects on the environment, social, and cultural dimensions: as the intensity of food processing increases, the energy required for processing and other activities such as packaging and transportation increases, and, additionally, traditional food cultures gradually diminish (Seferidi et al., 2020).

The increased consumption of highly processed foods has been attributed to varied factors including their easy accessibility even in small/local shops, high visibility through advertisement and campaigns, convenience, palatability, lower prices relative to fresh or minimally processed foods, and long shelf-life (Floros et al., 2010; Monteiro et al., 2011; Boysen et al., 2019). High income or wealth also has been identified as a trigger of increased intake of highly processed foods (Monteiro et al., 2011). The authors (Monteiro et al., 2011) further espoused that as disposable income increases, the consumption of highly processed foods increases, while the consumption of fresh or minimally processed foods decreases. Keding et al. (2011) and the Kenya Ministry of health (2016) supported this notion in their studies, which determined that wealth has a direct relationship with the consumption of micronutrient-poor diets that are correlated with obesity and high BMI in Tanzania and Kenya, respectively. This trend is in accordance with the findings of our study, as the wealth index was significantly positively correlated with the purchase pattern – largely characterized by highly processed foods – and negatively correlated with patterns mainly characterized by unprocessed and minimally processed foods across the three countries and in East Africa. According to Reardon et al. (2021)**,** most rural folks who work constantly purchase food outside the home to reduce the opportunity cost of cooking at home. This could be applicable to our study areas, as most of the women were farmers and possibly spend more time working on the farm, and hence, constantly purchase food. In SSA, SMEs are responsible for 80% of minimally and highly processed and packaged foods that are manufactured domestically—such as mandazi and bread, also identified in this study. Hence, this can explain the apparent proliferation of highly processed foods on retail markets (Reardon et al., 2021). In Windhoek, Namibia, street food stands, small stores, mobile food vendors, and shops in open markets retail highly processed foods like snacks, oily foods, and sweetened beverages (Nickanor et al., 2019). In rural Tanzania, small shops are active vehicles for selling highly processed foods like cookies (Reardon et al., 2021). It can be concluded that same street food vendors and small/local shops in our study areas could play an active role in the high consumption of highly processed foods, and consequently, the increased risk of overweight and obesity. Therefore, the so-called built food environment including both informal and formal markets (Downs et al., 2020) needs to be analyzed more carefully in relationship to health outcomes.

The prevalence of obesity has raised negative publicity for processed foods, in general. Meanwhile, food processing can provide significant interventions for the continued flow of nutritious foods, and thus, not all processed and even highly processed foods are unhealthy (Floros et al., 2010; Khonje et al., 2020). Indeed, the findings of the present study suggest this also: the pattern characterized by largely minimally processed foods and with FVs had a negative or no association with overweight and obesity and BMI, and the pattern mainly characterized by highly processed foods had a heterogenous association – positive or no association – with overweight and obesity and BMI. Both minimally and highly processed foods can provide the calorie and micronutrient needs for many poor households, who otherwise would suffer from hunger and micronutrient deficiencies due to high perishability and scarcity of foods (Khonje et al., 2020) like FVs. Previous studies have highlighted the importance of processed foods including FVs in diets: for example, frozen, dried, or canned fruits and vegetables contributed 35% of dietary fiber, 62% of vitamin E, 51% of vitamin C, 40% of folate, and 25% of vitamin A to diets in the USA (Dwyer et al., 2012). Additionally, processed cereals fortified with iron, folate, and thiamine, and milk fortified with vitamin A and D, were used to reduce significantly the number of individuals with an inadequate intake of the above micronutrients (Weaver et al., 2014). Again, minimally processed FVs, from the FruVaSe project, in the form of vegetable soup mix, dried vegetables, vegetable powder, and fruit and nut bars not only helped address micronutrients gaps of iron, zinc, and vitamin A and C in diets, but also substantially reduced diet cost by up to 53% (Sarfo et al., unpublished results). In the present study, the underweight women (although small percentage) could rely on both minimally and highly processed foods to meet their nutrients needs. Additionally, women with high likelihood of being underweight during periods of food scarcity could depend on these foods to avert such a phenomenon. It must, however, be noted that highly processed foods enriched and fortified with nutrients could still have a low-calorie quality due to the loss of the food matrix during processing, and thus may not prevent the occurrence of chronic diseases (Fardet and Rock, 2019).

2.4.4. Country comparison

It was no surprise that none of the patterns was significantly associated with overweight and obesity and BMI in Uganda. First, Uganda recorded the lowest rate of overweight and obesity, almost half the rate as in Kenya or Tanzania, which might be a contributing factor. Additionally, food variety was highest in Uganda (81 food items), which could translate into high dietary diversity compared to the other countries. Rutayisire et al. (2018) found no linkage between patterns and overweight and obesity among 8900 Chinese children, attributing overweight and obesity to possible triggers of genes, screening time, and unobserved environmental factors. These triggers could also account for the overweight and obesity recorded in Uganda, as well as in Tanzania for the non-significant association with the purchase pattern. Again, the non-significant association between the purchase pattern and overweight and obesity and BMI in Tanzania and Uganda relative to Kenya could also be attributed to differences in nutrients and the amount of salt, sugar, fat, and other additives in the foods, emphasizing that not all highly processed foods might be unhealthy, particularly in rural areas where industrially processed foods could be few. By analyzing the built food environments in the study areas, Kenya possessed more formal food markets than informal in the form of supermarkets, hypermarkets, and mobile vendors as compared to Tanzania and Uganda, where street food vendors, kiosks/small shops, and mobile food vendors were predominant relative to formal food markets. This could also be a significant contributing factor for the differences, as formal food markets like supermarkets have been shown to contribute to increasing overweight and obesity in adults (Khonje et al., 2020).

2.4.5. Study strengths and limitations

One major strength of this study was the design and usage of a single methodological approach that was adapted to the local contexts of the three countries and provided a strong basis to compare the results. Additionally, the usage of longitudinal food intake data from all three countries is one strength that deserves mention; most studies thus far have used cross-sectional food intake data. We performed individual country and regional analyses with an adequate sample size. Additionally, we determined patterns with a clear distinction of food processing levels and how they affect overweight and obesity and BMI in rural areas– to our knowledge, this is the first study to do so for a rural setting in SSA.

A key limitation was the exclusion of physical activity as a confounder in our models, especially when previous studies (Slagter et al., 2018; Bedrick et al., 2020) show that physical activity reduces the probability of obesity. Energy intake was also not adjusted for; however, energy adjustment does not reveal any significant results (Northstone et al., 2008). The usage of the 24-hour recall to collect food intake data depends heavily on the knowledge and skills of the interviewer and is associated with recall bias (Auma et al., 2019). Yet, this was mitigated by recruiting and training university students/graduates as enumerators from the food and nutrition fields as well as pre-testing and validating the 24-hour recall tool together with other questionnaires. Furthermore, the four non-consecutive dietary recalls may have helped offset any intra-individual food intake variability. Although anthropometric measurements were cross-sectionally taken at different time periods within and across countries, no significant differences in BMI across seasons were envisaged, as only slight differences in BMI across seasons in rural areas exist (Keding et al., 2013a). This study was also limited by the sampling technique. Sampling was restricted to districts/counties/regions that produced selected FVs that were focused on in the FruVaSe project, in which framework this study took place. Hence, the results may only be applicable to the selected sites, calling into question the external validity of the results. The PCA method has been criticized for its inability to generate patterns that act as risk factors to diseases (Hoffmann et al., 2004). Additionally, the subjective nature of its analytical procedure has been questioned, including food groupings, retained patterns, the factor loading coefficient, and pattern interpretation (Auma et al., 2019). Notwithstanding these gaps, the PCA is a well-established method for dietary patterns research in SSA, and, as such, was useful for this study.

2.4.6. Policy implications and further work

First, the seeming shift of dietary intake towards unhealthy processed foods in rural areas must be reversed. Reardon et al. (2021) observed that increased risk of overweight and obesity was also because of no or low consumption of FVs, legumes, and pulses. Therefore, a food environment where these nutritious foods are constantly advertised, available, and accessible must be pursued. The challenge with these highly nutritious foods is often seasonal availability (e.g., in terms of FVs), where healthy processed options could bridge the gap. We propose investment in processing innovations and technologies, including research to preserve fresh and raw foods for a longer time, which would make foods available and at the same time affordable, especially for the poor.

Furthermore, food-based dietary guidelines that would help shift consumption from unhealthy processed foods to healthy ones are needed for each country and should be adapted to the local situation. At present, in East Africa, only Kenya has food-based dietary guidelines (FAO, 2021).

Second, food manufacturers, street food vendors, and small shops retailing processed foods must be fully engaged at the national or sub-national levels when designing policies/interventions to curb unhealthy foods, and consequently, overweight and obesity levels. This is particularly important because portion size/calorie, as well as additive and ingredient control mechanisms can be pursued at that level to reduce the excessive consumption of unhealthy foods. While the definition of “unhealthy foods” must be clear on a local level, international benchmarks on the portion of intake of unhealthy processed foods should be enacted.

Taxes on highly processed foods help control obesity; however, caution is needed as these foods also provide the calorie needs of the poor (Boysen et al., 2019). We therefore propose that local taxes at the district/county/regional level can be increased for unhealthy processed foods, and the income be invested, used as subsidies, or as incentives for promoting and/or rewarding the production and processing of nutritious foods such as FVs. Such a policy intervention could also spur employment through production and processing in rural areas.

One major challenge for processed foods is differentiating between nutritious/ healthy and rather unhealthy choices, such as pure fruit juice *versus* fruit drinks with flavor and sugar or carefully solar-dried fruits or vegetables *versus* open sun-dried ones. The current food processing levels—of which there seems to be no consensus—that classify foods into healthy or unhealthy are problematic. Rather, the classification of processed foods regarding which are healthy or unhealthy must be based on the nutrients retained and inclusive of the quality of their calories, i.e., represented by a preserved food matrix effect, and the amount of added salts, sugar, fats, and other additives. As such, a comprehensive work on processed foods clearly defined as healthy or unhealthy based on some internationally or nationally agreed benchmarks on nutrients and the amount of salt, sugar, fat, and other additives must be done, which certainly requires an interdisciplinary approach of nutritionists, food scientists and technologists, food economists, and professionals from other food disciplines. In addition, an international consensus on food processing classifications with their standard criteria for inclusion of foods is needed – and most likely need to be reviewed every few years as new processing technologies and processed products evolve. Further work is needed to understand the attitude and behaviors of rural populations towards processed foods and overweight and obesity as well as their perception of different processed foods being healthy or unhealthy or both. Additionally, the consumption of heathy and unhealthy processed foods and their repercussions for the environment and economic activities in rural areas must be established in the literature. Panel data studies are needed to understand the trend of dietary intake and how that affects overweight and obesity across varied time periods.

2.5. Conclusion

This study showed rising overweight and obesity rates among rural women in East Africa. Several patterns characterized by three food processing levels were identified, yet two patterns – plant-based and purchase patterns – were dominant across Kenya, Tanzania, Uganda, and East Africa (as pooled data). The plant-based pattern, largely characterized by unprocessed and minimally processed foods, had an inverse or no association with overweight and obesity and BMI. On the other the hand, a purchase pattern mainly identified by highly processed foods had a positive or no association with overweight and obesity and BMI. Also, patterns with fruits and vegetables were characterized by unprocessed and minimally fruits and vegetables and were negatively or not associated with overweight and obesity. These heterogenous findings indicate the need to draw clear distinctions on processed foods as healthy and unhealthy based on their nutrient provision, inclusive of the quality of calories, i.e., represented by a preserved food matrix effect, as well as the amount of added salt, sugar, fats, and other additives, to avoid their general mischaracterization as unhealthy. Nonetheless, policy interventions (see policy implications) must be instituted to shift the course of increased consumption of unhealthy processed foods towards nutritious fresh and/or processed foods such as fruits and vegetables, which consequently help curb overweight and obesity.

Supplementary materials

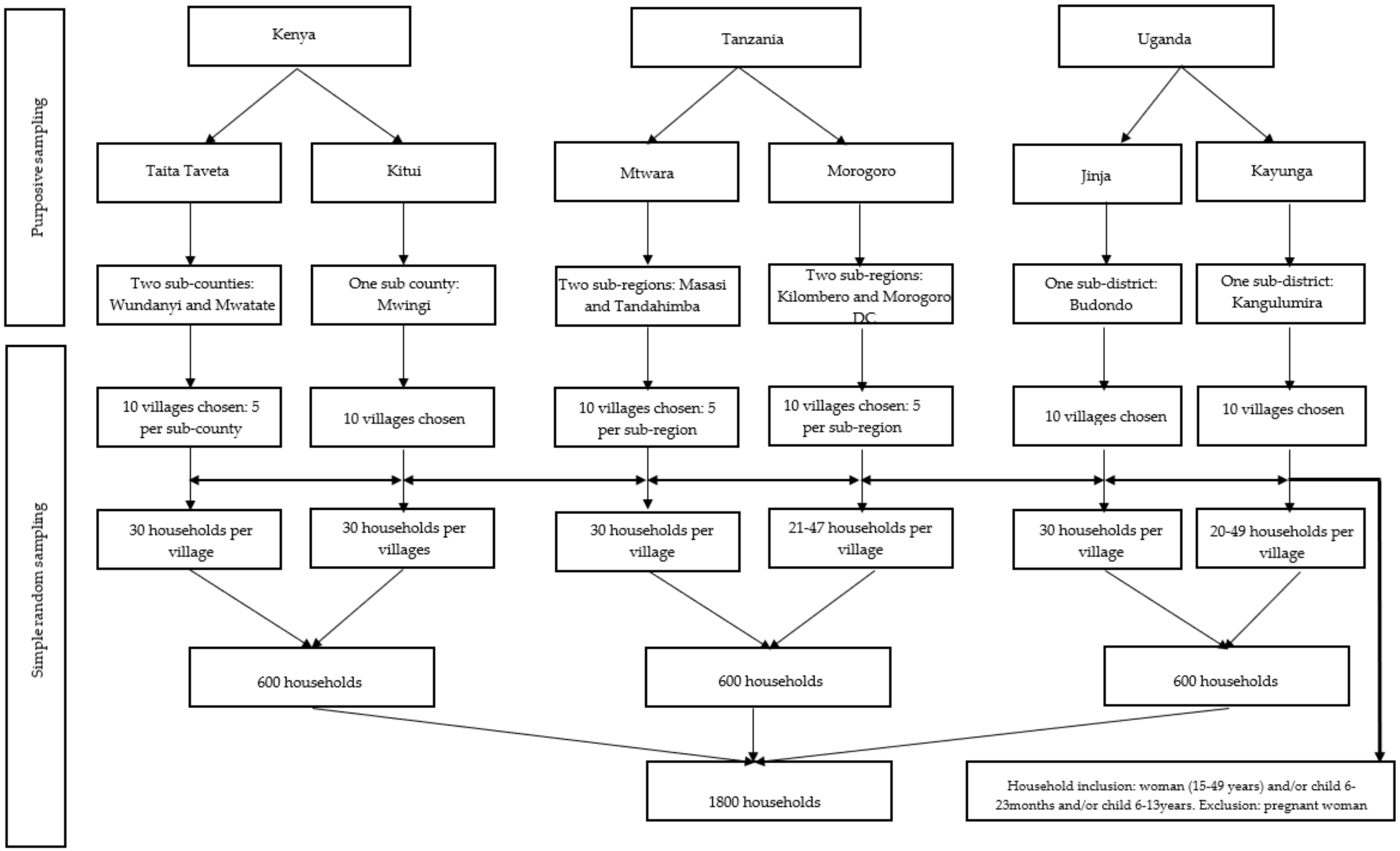

Figure S2.1 Sampling techniques used in selecting households for survey in Kenya, Tanzania and Uganda

Table S2.1 Classification of food items identified in rural **Kenya** into food groups and processing levels.

Food group	Food items	Level of processing (in agriculture/form before consumption)	Level of processing (in nutrition/final form for consumption)[a]
Cereals, roots, and tubers	Irish potato, sweet potato, maize, sorghum, millet, taro, plantain	Unprocessed	Minimally processed
Vegetables	Amaranth leaves, African nightshade, cowpea leaves, cabbage, carrot, eggplant, kales, onion, spinach, tomato, bitter lettuce, pumpkin leaves	Unprocessed	Minimally processed
Fruits	Avocado, guava, mango, orange, passion fruit, papaya, pineapple, sweet banana, tamarind, watermelon	Unprocessed	Unprocessed
Pulses and nuts	Beans, cowpea, green grams, peas	Unprocessed	Minimally processed
Milled cereals, roots, pulses, and nuts	Millet flour, maize flour, sorghum flour, wheat flour	Minimally processed	Minimally processed
Rice	Rice	Minimally processed	Minimally processed
Meat, poultry, and fish	Beef, poultry, goat meat, offals, small-dried fish, fish, egg, pork	Minimally processed	Minimally processed
Milk	Pasteurized milk, fermented milk	Minimally processed	Minimally processed
Oils and fats	Sunflower cooking oil, margarine, hydrogenated fat	Highly processed	Highly processed
Sugar and sugary drinks	Sugar, soda , sugary drink(mango sweetened)	Highly processed	Highly processed
Bread and snacks	Bread, chips, noodles, *mandazi*, *halfcake* (dough fried in oil), *chapati* (wheat flatbread)	Highly processed	Highly processed

Tea	Tea	Highly processed	Highly processed

[a] Food items are converted for final consumption mainly through preparation methods such as boiling, frying, steaming, baking.

Table S2.2 Classification of food items identified in rural **Tanzania** into food groups and processing levels.

Food group	Food items	Level of processing (in agriculture/form before consumption)	Level of processing (in nutrition/final form for consumption)[a]
Cereals, roots, and tubers	Cassava, Irish potatoes, maize, plantain, rice, sweet potatoes, taro, millet	Unprocessed	Minimally processed
Vegetables	Amaranth leaves, African nightshade, cabbage, carrot, cassava leaves, Chinese cabbage, cowpea leaves, cucumber, eggplant, green pepper, jute mallow leaves, kales, okra, onion, potato leaves, pumpkin, pumpkin leaves, spinach, sweet potato leaves, tomato	Unprocessed	Minimally processed
Fruits	Cashew apple, jackfruit, lemon/orange, mango, passion fruit, papaya, watermelon, pineapple, sweet banana	Unprocessed	Unprocessed
Pulses and nuts	Bambara groundnut, beans, cowpeas, groundnut	Unprocessed	Minimally processed
Milled cereals, roots, pulses, and nuts	Cassava flour, groundnut flour/paste, maize flour, millet flour, rice flour	Minimally processed	Minimally processed
Milk	Pasteurized milk	Minimally processed	Minimally processed
Meat, poultry, and fish	Beef, poultry, fish, goat meat, small-dried fish	Minimally processed	Minimally processed
Oils and fats	Cashew nut milk, coconut milk, sunflower cooking oil	Highly processed	Highly processed
Sugar and sugary drinks	Sugar, soda , sugary drinks(lemon, mango sweetened)	Highly processed	Highly processed

Bread and snacks	Bread, noodles, *mandazi*, *vitumbua* (dough from rice or maize or wheat flour fried in oil), buns, *chapati* (wheat flatbread), *samosa* (fried pastry with vegetables and/or meat filling)	Highly processed	Highly processed
Tea	Tea	Highly processed	Highly processed

[a] Food items are converted for final consumption mainly through preparation methods such as boiling, frying, steaming, baking.

Table S2.3 Classification of food items identified in rural **Uganda** into food groups and processing levels.

Food group	Food items	Level of processing (in agriculture/form before consumption)	Level of processing (in nutrition/final form for consumption)[a]
Cereals, roots, and tubers	Taro, cassava, cassava flour, cocoyam, Irish potatoes, maize, millet, plantain, rice, sorghum, sweet potatoes	Unprocessed	Minimally processed
Vegetables	African nightshade, amaranth leaves, bitter berries, bitter tomatoes, cowpea leaves, cucumber, cabbage, carrot, mushroom, eggplant, garden eggs, green pepper, kales, onion, pumpkin, pumpkin leaves, spinach, tomato	Unprocessed	Minimally processed
Fruits	Apple, avocado, guava, jackfruit, lemon/orange, mango, passion fruit, papaya, pineapple, sweet banana, watermelon	Unprocessed	Unprocessed
Pulses and nuts	Beans, groundnut, soybean	Unprocessed	Minimally processed
Milled cereals, roots, pulses, and nuts	Beans flour, groundnut flour/paste, maize flour, millet flour, sesame paste, sorghum flour, soybean flour/paste	Minimally processed	Minimally processed
Milk	Pasteurized milk	Minimally processed	Minimally processed

Meat, poultry, and fish	Beef, poultry, smoked fish, egg, fish, goat meat, offals, small-dried fish	Minimally processed	Minimally processed
Oils and fats	Sunflower cooking oil, ghee, palm oil	Highly processed	Highly processed
Sugar and sugary drinks	Sugar, soda , sugary drinks (orange, passion, pineapple, tamarind sweetened)	Highly processed	Highly processed
Bread and snacks	Bread, buns, *mandazi*, *halfcake* (dough fried in oil), *chapati* (wheat flatbread), *bagiya* (cassava and soybean flour fried in oil), cake, chips, cornflakes, *hardcorn*, noodles, pancake, popcorn, *samosa* (fried pastry with vegetables and/or meat filling)	Highly processed	Highly processed
Tea	Tea, coffee	Highly processed	Highly processed

[a] Food items are converted for final consumption mainly through preparation methods such as boiling, frying, steaming, baking.

Table S2.4 Classification of food items identified in rural **East Africa** into food groups and processing levels.

Food group	Food items	Level of processing (in agriculture/form before consumption)	Level of processing (in nutrition/final form for consumption)[a]
Cereals, roots, and tubers	Cassava, cocoyam, maize, millet, plantain, Irish potatoes, rice, sorghum, sweet potatoes, taro	Unprocessed	Minimally processed
Vegetables	African nightshade, amaranth leaves, bitter berries, bitter lettuce, bitter tomatoes, cabbage, carrot, cassava leaves, Chinese cabbage, cowpea leaves, cucumber, eggplant, garden eggs, green pepper, jute mallow leaves, kales, mushroom, onion, okra, sweet potato leaves, pumpkin, pumpkin leaves, spinach, tomato	Unprocessed	Minimally processed
Fruits	Apple, avocado, cashew apple, guava, jackfruit, lemon/orange, mango, passion fruit, papaya, pineapple, sweet banana, tamarind, watermelon	Unprocessed	Unprocessed

Pulses and nuts	Bambara groundnut, beans, cowpeas, green grams, groundnut, peas, soybean	Unprocessed	Minimally processed
Milled cereals, roots, pulses, and nuts	Beans flour, cassava flour, groundnut flour/paste, maize flour, millet flour, rice flour, sesame paste, sorghum flour, soybean flour/paste, wheat flour	Minimally processed	Minimally processed
Milk	Pasteurized milk, fermented milk	Minimally processed	Minimally processed
Meat, poultry, and fish	Smoked fish, egg, fish, goat meat, offals, beef, poultry, pork, small-dried fish	Minimally processed	Minimally processed
Oils and fats	Cashew nut milk, coconut milk, sunflower cooking oil, hydrogenated fat, ghee, margarine, palm oil	Highly processed	Highly processed
Sugar and sugary drinks	Sugar, soda , sugary drinks (lemon, mango, orange, passion, pineapple, tamarind sweetened)	Highly processed	Highly processed
Bread and snacks	Bread, buns, *mandazi*, *halfcake, vitumbua* (dough from rice or maize or wheat flour fried in oil), *chapati* (wheat flatbread), *bagiya* (cassava and soybean flour fried in oil), chips, cornflakes, hardcorn, noodles, pancake, popcorn, *samosa* (fried pastry with vegetables and/or meat filling), vitumbua	Highly processed	Highly processed
Tea	Tea, coffee	Highly processed	Highly processed

[a] Food items are converted for final consumption mainly through preparation methods such as boiling, frying, steaming, baking.

Table S2.5 Correlation between dietary patterns extracted and socio-demographic indicators among rural women in **Kenya.**

Socio-demographic variables	Plant-based pattern	Purchase pattern I	Plant and animal-based pattern	Purchase pattern II
Age	-0.00	0.01	0.02	-0.00
Wealth index	-0.31^{***}	0.04	0.06	0.12^{**}
Household head (1=yes, 0=no)	-0.07	-0.14^{**}	-0.08^{+}	0.02
Household size	0.12^{*}	0.06	-0.09^{+}	-0.15^{**}
Education (in years)	-0.25^{***}	0.07	0.11^{*}	0.13^{**}
Marital status (1=married, 0= single or divorced or widowed)	0.10^{*}	0.06	-0.08^{+}	-0.09^{+}
Nutrition education (1=yes, 0=no)	-0.22^{***}	-0.04	0.16^{***}	0.02
N	445	445	445	445

Spearman correlation method was used for age, wealth index, household size and years in school and the dietary patterns. Point-biserial method was used for household head, marital status, and nutrition education and the dietary patterns. +,*,**,***, represent statistical significance of $p < 0.1$, $p < 0.05$, $p < 0.01$, $p < 0.001$, respectively.

Table S2.6 Correlation between dietary patterns extracted and socio-demographic indicators among rural women in **Tanzania.**

Socio-demographic variables	Plant and animal-based pattern	Purchase pattern	Plant-based pattern	Starchy plants
Age	-0.04	0.12^{*}	0.08	0.19^{**}
Wealth index	0.09	0.10^{+}	-0.16^{**}	-0.05
Household head (1=yes, 0=no)	-0.13^{*}	0.08	-0.00	0.09
Household size	0.03	-0.08	-0.03	0.07
Education (in years)	-0.06	0.17^{**}	-0.04	0.09
Marital status (1=married, 0= single or divorced or widowed)	-0.08	0.01	0.11^{+}	-0.01
Nutrition education (1=yes, 0=no)	0.06	0.05	0.02	0.07
N	292	292	292	292

Spearman correlation method was used for age, wealth index, household size and years in school and the dietary patterns. Point-biserial method was used for household head, marital status, and nutrition education and the dietary patterns. +,*,**, represent statistical significance of $p < 0.1$, $p < 0.05$, $p < 0.01$, respectively.

Table S2.7 Correlation between dietary patterns extracted and socio-demographic indicators among rural women in **Uganda.**

Socio-demographic variables	Purchase pattern	Plant-based pattern I	Animal based pattern	Plant-based pattern II	Vegetable pattern
Age	-0.15**	-0.06	-0.09+	0.10*	-0.09+
Wealth index	0.09+	-0.00	0.03	-0.17***	-0.01
Household head (1=yes, 0=no)	-0.09+	0.06	-0.02	0.01	-0.07
Household size	-0.10*	-0.09+	0.11*	0.08	0.09+
Education (in years)	0.26***	0.12*	0.13**	-0.06	0.02
Marital status (1=married, 0= single or divorced or widowed)	-0.01	-0.00	-0.02	0.02	0.00
Nutrition education (1=yes, 0=no)	0.03	0.19***	0.12*	-0.03	0.13**
N	415	415	415	415	415

Spearman correlation method was used for age, wealth index, household size and years in school and the dietary patterns. Point-biserial method was used for household head, marital status, and nutrition education and the dietary patterns. +,*,**,***, represent statistical significance of $p < 0.1$, $p < 0.05$, $p < 0.01$, $p < 0.001$, respectively.

Table S2.8 Correlation between dietary patterns extracted and socio-demographic indicators among rural women in **East Africa.**

Socio-demographic variables	Mixed pattern	Plant-based pattern	Purchase pattern	Vegetable pattern
Age	-0.07*	0.10***	0.01	0.02
Wealth index	-0.09**	-0.01	0.17***	-0.00
Household head (1=yes, 0=no)	-0.07*	0.03	-0.04	-0.05+
Household size	0.24***	0.10***	-0.08**	0.00
Education (in years)	-0.00	0.16***	0.31***	0.04
Marital status (1=married, 0= single or divorced or widowed)	0.05+	0.03	-0.04	-0.03
Nutrition education (1=yes, 0=no)	-0.01	-0.00	0.07*	0.05
N	1152	1152	1152	1152

Spearman correlation method was used for age, wealth index, household size and years in school and the dietary patterns. Point-biserial method was used for household head, marital status, and nutrition education and the dietary patterns. +,*,**,***, represent statistical significance of $p < 0.1$, $p < 0.05$, $p < 0.01$, $p < 0.001$, respectively.

Table S2.9 Relationship between extracted patterns and body mass index (BMI) of women of reproductive age in rural **Kenya**.

	Body mass index			
Independent variables	(1)	(2)	(3)	(4)
Plant-based pattern	-0.568*	--	--	--
	(0.258)			
Purchased pattern I	--	0.480*	--	--
		(0.228)		
Plant and animal-based pattern	--	--	-0.062	--
			(0.282)	
Purchased pattern II	--	--	--	0.422+
				(0.256)
Age	0.170***	0.177***	0.179***	0.173***
	(0.031)	(0.032)	(0.032)	(0.032)
Wealth index	2.197***	2.415***	2.491***	2.436***
	(0.582)	(0.554)	(0.559)	(0.554)
Household head (1=yes, 0=no)	-1.095	-0.862	-1.059	-1.005
	(0.694)	(0.693)	(0.702)	(0.695)
Household size	0.011	-0.006	-0.002	0.025
	(0.115)	(0.115)	(0.116)	(0.116)
Education (in years)	0.007	0.024	0.020	0.013
	(0.079)	(0.077)	(0.079)	(0.077)
Marital status (1=married, 0= single or divorced or widowed)	0.134	0.120	0.065	0.144
	(0.677)	(0.681)	(0.696)	(0.691)
Occupation:				
None	0.761	1.168	1.071	0.767
	(0.813)	(0.815)	(0.807)	(0.786)
Trader	1.287+	1.264	1.287	1.268
	(0.778)	(0.771)	(0.784)	(0.777)
Other	0.092	-0.171	0.109	0.088
	(0.763)	(0.754)	(0.784)	(0.774)
Nutrition education (1=yes, 0=no)	0.977	1.236	1.238	1.272+
	(0.776)	(0.750)	(0.779)	(0.767)
Model intercept	19.206***	18.808***	18.824***	18.940***
	(1.440)	(1.444)	(1.446)	(1.435)
F-statistic	8.854***	8.388***	8.100***	8.224***
Adjusted R^2	0.15	0.14	0.14	0.14
N	445	445	445	445

Models were estimated using ordinary least square regression modeling. Estimated coefficients and robust standard errors in parentheses are shown. Body mass index as outcome variable and

dietary pattern as explanatory variable with socio-economic factors as possible confounding factors. +, *, ***, represent statistical significance of $p < 0.1$, $p < 0.05$, $p < 0.001$, respectively.

Table S2.10 Relationship between extracted patterns and body mass index (BMI) of women of reproductive age in rural **Tanzania**

	Body mass index			
Independent variables	(1)	(2)	(3)	(4)
Plant and animal-based pattern	-0.131 (0.267)	--	--	--
Purchase pattern	--	-0.243 (0.283)	--	--
Plant-based pattern	--	--	-0.693** (0.257)	--
Starchy pattern	--	--	--	-0.200 (0.281)
Age	0.145*** (0.034)	0.149*** (0.035)	0.152*** (0.034)	0.149*** (0.035)
Wealth index	0.817 (0.671)	0.851 (0.675)	0.518 (0.668)	0.751 (0.678)
Household head (1=yes, 0=no)	-0.776 (0.828)	-0.686 (0.811)	-0.686 (0.798)	-0.680 (0.820)
Household size	-0.097 (0.140)	-0.110 (0.143)	-0.121 (0.141)	-0.091 (0.142)
Education (in years)	0.021 (0.154)	0.040 (0.156)	0.023 (0.156)	0.031 (0.156)
Marital status (1=married, 0= single or divorced or widowed)	0.301 (0.801)	0.363 (0.789)	0.512 (0.792)	0.366 (0.793)
Occupation:				
None	-1.493 (1.043)	-1.487 (1.043)	-1.444 (1.049)	-1.460 (1.058)
Trader	1.108 (0.826)	1.147 (0.819)	1.020 (0.812)	1.220 (0.827)
Other	-0.608 (1.425)	-0.677 (1.397)	-0.399 (1.430)	-0.596 (1.425)
Nutrition education (1=yes, 0=no)	-0.087 (1.057)	-0.083 (1.046)	-0.047 (1.043)	-0.087 (1.042)
Model intercept	20.492*** (1.523)	20.260*** (1.543)	20.194*** (1.526)	20.206*** (1.615)
F-statistic	4.832***	4.878***	5.533***	4.916***
Adjusted R^2	0.08	0.08	0.10	0.08
N	292	292	292	292

Models were estimated using ordinary least square regression modeling. Estimated coefficients and robust standard errors in parentheses are shown. Body mass index as outcome variable and

dietary pattern as explanatory variable with socio-economic factors as possible confounding factors. **,*** represent statistical significance of $p < 0.01$, $p < 0.001$, respectively.

Table S2.11 Relationship between extracted patterns and body mass index (BMI) of women of reproductive age in rural **Uganda**.

	Body mass index				
Independent variables	(1)	(2)	(3)	(4)	(5)
Purchase pattern	-0.090	--	--	--	--
	(0.180)				
Plant-based pattern I	--	-0.184	--	--	--
		(0.157)			
Animal-based pattern	--	--	-0.072	--	--
			(0.153)		
Plant-based pattern II	--	--	--	0.169	--
				(0.166)	
Vegetable pattern	--	--	--	--	-0.193
					(0.118)
Age	0.083***	0.084***	0.083***	0.082***	0.083***
	(0.024)	(0.024)	(0.024)	(0.024)	(0.024)
Wealth index	1.367**	1.349**	1.352**	1.400**	1.369**
	(0.446)	(0.441)	(0.441)	(0.443)	(0.441)
Household head (1=yes, 0=no)	-0.313	-0.249	-0.296	-0.289	-0.314
	(0.616)	(0.622)	(0.619)	(0.618)	(0.618)
Household size	0.107	0.103	0.111	0.104	0.109
	(0.077)	(0.078)	(0.079)	(0.079)	(0.078)
Education (in years)	0.045	0.047	0.043	0.039	0.043
	(0.060)	(0.059)	(0.058)	(0.058)	(0.058)
Marital status (1=married, 0= single or	1.155*	1.171*	1.150*	1.152*	1.157*
divorced or widowed)	(0.462)	(0.467)	(0.462)	(0.464)	(0.462)
Occupation:					
None	0.543	0.539	0.506	0.537	0.593
	(0.484)	(0.483)	(0.489)	(0.485)	(0.483)
Trader	1.250+	1.204+	1.186+	1.182+	1.201+
	(0.637)	(0.616)	(0.618)	(0.617)	(0.619)
Other	-0.011	0.013	-0.034	0.028	-0.041
	(-0.012)	(0.638)	(0.635)	(0.639)	(0.632)
Nutrition education (1=yes, 0=no)	-0.209	-0.102	-0.178	-0.195	-0.133
	(0.670)	(0.686)	(0.679)	(0.674)	(0.674)
Model intercept	18.816***	18.783***	18.835***	18.908***	18.814***
	(1.053)	(1.059)	(1.048)	(1.060)	(1.048)
F-statistic	3.182***	3.186***	3.184***	3.369***	3.426***
Adjusted R^2	0.07	0.07	0.07	0.07	0.08
N	415	415	415	415	415

Models were estimated using ordinary least square regression modeling. Estimated coefficients and robust standard errors in parentheses are shown. Body mass index as outcome variable and

dietary pattern as explanatory variable with socio-economic factors as possible confounding factors. +,*,**,***, represent statistical significance of $p < 0.1$, $p < 0.05$, $p < 0.01$, $p < 0.001$, respectively.

Table S2.12 Relationship between extracted patterns and body mass index (BMI) of women of reproductive age in three countries rural **East Africa**

	Body mass index			
Independent variables	(1)	(2)	(3)	(4)
Mixed pattern	-0.180	--	--	--
	(0.167)			
Plant-based pattern	--	-0.696***	--	--
		(0.160)		
Purchase pattern	--	--	0.454***	--
			(0.137)	
Vegetable pattern	--	--	--	-0.117
				(0.084)
Age	0.138***	0.138***	0.138***	0.138***
	(0.017)	(0.017)	(0.017)	(0.017)
Wealth index	1.314***	1.279***	1.240***	1.333***
	(0.294)	(0.292)	(0.292)	(0.294)
Household head (1=yes, 0=no)	-0.622	-0.617	-0.539	-0.649
	(0.409)	(0.408)	(0.413)	(0.409)
Household size	0.024	0.023	0.026	0.020
	(0.058)	(0.058)	(0.057)	(0.058)
Education (in years)	0.056	0.048	0.041	0.052
	(0.046)	(0.045)	(0.045)	(0.045)
Marital status (1=married, 0= single or divorced or widowed)	0.663+	0.688+	0.682+	0.627+
	(0.367)	(0.367)	(0.369)	(0.366)
Occupation:				
None	0.634	0.516	0.555	0.658
	(0.424)	(0.416)	(0.418)	(0.424)
Trader	1.411***	1.358**	1.299**	1.371**
	(0.427)	(0.420)	(0.422)	(0.425)
Other	0.007	-0.062	-0.102	-0.020
	(0.498)	(0.495)	(0.494)	(0.498)
Nutrition education (1=yes, 0=no)	0.606	0.515	0.587	0.617
	(0.475)	(0.469)	(0.468)	(0.475)
Location:				
Tanzania	-0.133	-1.294**	0.254	-0.117
	(0.369)	(0.472)	(0.374)	(0.370)
Uganda	-1.174**	-1.936***	-1.030***	-1.457***
	(0.416)	(0.329)	(0.310)	(0.300)
Model intercept	19.279***	19.948***	19.256***	19.469***
	(0.839)	(0.799)	(0.798)	(0.797)
F-statistic	13.97***	15.02***	14.67***	14.21***
Adjusted R^2	0.13	0.14	0.13	0.13

N	1152	1152	1152	1152

Models were estimated using ordinary least square regression modeling. Estimated coefficients and robust standard errors in parentheses are shown. Body mass index as outcome variable and dietary pattern as explanatory variable with socio-economic factors as possible confounding factors. +,**,***, represent statistical significance of $p < 0.1$, $p < 0.01$, $p < 0.001$, respectively

Chapter 3. Are processed fruits and vegetables able to reduce diet costs and address micronutrient deficiencies? Evidence from rural Tanzania

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Author contribution

Jacob Sarfo : conceptualized the study, collected and analyzed the data and developed the manuscript.

Elke Pawelzik : reviewed the manuscript and made inputs

Gudrun B. Keding : reviewed the manuscript and made inputs

Abstract

Objective: To assess the impact of integrating processed fruits and vegetables (FVs) into diets in terms of diet cost reduction and ensuring nutritional adequacy year-round.

Design: Market surveys were conducted to record foods. Focus group discussions (FGDs) and 24-hour dietary assessments – from children and women – were carried out to determine culturally accepted dietary habits. Six processed FVs were considered for addition to diets. Using the Cost of Diet linear programming tool, standards diets were first modeled, and subsequently, the processed FVs were included to analyze their impact.

Setting: Rural Tanzania: Mtwara and Morogoro

Participants: Market survey: 50 traders; FGDs: 40 women; 24-hour recalls: 36 infants 6-23 months, 52 children 6-13 years and 292 women.

Results: The standard diet costs between TZS 232 – 2,368 (USD 0.3 – 3) daily for infants. For children 6-13 years, it costs between TZS 1,711 – 7,199 (USD 2.2 – 9.1) daily, and the cost for the women was between TZS 2,793 – 10,449 (USD 3.5 – 13.2). Addition of the processed FVs reduced diet costs by up to 61%, 48%, and 49% for children 12-23 months, 6-13 years, and women, respectively. However, for infants 6-11 months, costs rose by up to 127%. The processed FVs addressed all micronutrient gaps in the diets except for infants 6-11 months, where some micronutrient intakes were unfulfilled.

Conclusions: Processed FVs could provide a feasible option to ensure availability of nutritious but cheap diets year-round. Hence, interventions to process FVs into nutritious and affordable products should extensively be pursued.

Keywords: Africa; Diet costs; Fruits and vegetables; Micronutrients; Processed foods; Children and women

3.1. Introduction

Globally, the number of undernourished people is estimated at 820 million, a figure which has been rising since 2015, particularly in Africa, Latin America, and West Asia (Global Nutrition Report, 2020). Currently, 149.2 million children under five years of age are stunted, and 45.4 million are wasted, while 571 million reproductive-aged women suffer from anemia (Global Nutrition Report, 2021). In Tanzania, three in five children under five years and 45% of women of reproductive age suffer from anemia (United Republic of Tanzania, 2016b). About 14% of school-aged children are anemic (Mrimi et al., 2022). Additionally, 34%, 5%, and 14% of the young children are stunted, wasted, and underweight, respectively (United Republic of Tanzania, 2016b). One of the leading drivers for such high and continuously rising malnutrition numbers resulting in mortalities and morbidities is the consumption of poor and unbalanced diets. Most people, particularly the poor, cannot afford healthy diets due to issues of availability and accessibility: availability in the sense that most nutritious foods like fruits and vegetables (FVs) are seasonal, in addition to their high perishability rate leading to inadequate supply for consumption year-round (Global Nutrition Report, 2020, 2021; International Food Policy Research Institute, 2021). Also, FVs are high in price, making them expensive for poor people to buy, which brings in the accessibility factor (Hirvonen et al., 2020). This phenomenon greatly contributes to food insecurity, where food-insecure households could be trapped in a cycle of poverty (Keding et al., 2013b). Current consumption estimates of FVs in Tanzania are below recommended levels: fruit consumption for children between 6-23 months and 6-13 years is 24g/day and 74g/day, while vegetable consumption is 33g/day and 88g/day, respectively (Alves, 2021). For women of reproductive age, fruit consumption is 56g/day, and vegetable intake is 120g/day according to Sarfo et al. (unpublished results).

One feasible solution for making FVs available and accessible year-round for consumption is the processing of FVs. FVs can be transformed into products with a longer shelf-life, durable, nutritious, convenient, and easily transportable for consumers to have easy accessibility (Garratt et al., 2002; Floros et al., 2010). Through processing – of FVs – households can be buffered during food insecurity periods (Keding et al., 2013b) and could contribute substantially to providing quality diets. For instance, consumers cited inconvenience and health-related risks in Tanzania for not consuming regularly fresh cassava leaves despite their nutritional benefits (Pato Dickson

Innocensia, 2013), thereby the need for processing. Also, processed FVs contribute to increased FV consumption; in the US, consumers of frozen FVs increased their consumption for FV significantly when compared with non-consumers of frozen FVs. Nutrient intakes were also higher (Storey and Anderson, 2018). Notwithstanding these positives, there are negative perceptions associated with processed foods as unhealthy. This, among others, is because the benefits of processed foods, especially the nutritious ones, have not been communicated clearly and consistently to consumers to overcome the negative messaging (Keding et al., 2013b; Weaver et al., 2014). Indeed, not all processed foods contribute to adverse health outcomes, including overweight and obesity (Sarfo et al., 2021), and as such, a distinction on them should be unambiguous. Dwyer et al. (2012) espoused that processed foods can provide critical micronutrients otherwise unavailable in diets. Moreover, some processed foods can provide valuable nutrients beyond those provided by fresh ones depending on the processing method involved, which could retain and even enhance many nutrients (Floros et al., 2010).

Yet data or studies on processed foods – particularly FVs – in their contribution to quality diets have been limited. Within sub-Saharan Africa and rural areas, studies on them are almost non-existent. The limited data on the contribution of processed foods to diets could contribute to the increasing miscommunication about processed foods and serve as a disadvantage to households, especially for poor households, who may need to rely on them to meet their nutritional needs. Additionally, studies to evaluate their contribution to ensuring inexpensive but nutritious diets are sparse.

Therefore, this study aims to contribute to these gaps in the literature by exploring the impact of processed FVs in ensuring nutritional adequacy in diets and reducing nutritious diet costs. In doing so, the present study focused on infants (6-23 months), school-aged children (6-13 years), and women of reproductive age (15-49 years), excluding pregnant women, in rural Tanzania. Specifically, the study sought to answer these two questions: a) What are the costs and nutrient gaps (if any) in standard diets from local food sources for children and women in rural Tanzania year-round? b) Are processed FVs able to reduce the standard diet costs and fill nutrient gaps (if any)?

This study is integrated into a larger project named "Fruits and Vegetables for all seasons" (FruVaSe). The project seeks to promote improved resource-efficient processing techniques and new market solutions for surplus fruits and vegetables for rural development in Kenya, Tanzania, and Uganda.

3.2. Materials and Methods

3.2.1. Study areas and design

This study was conducted in Tanzania, one of the three study countries under the FruVaSe project. In Tanzania, two regions, namely Mtwara and Morogoro, were selected. Mtwara is in the southern part of Tanzania, with rainfall patterns between 840mm-1250mm. The region is predominantly rural, with 80% of the population engaged in farming (United Republic of Tanzania, 2016b). Mtwara is also one of Tanzania's largest cashew production areas (Dimoso et al., 2021). Morogoro is situated in the eastern part of Tanzania and is the third-largest region in terms of land size. Annual rainfall is projected between 600mm-1200mm. Just as Mtwara, the region is predominantly rural. In both regions, agriculture constitutes the main economic activity for most of the population (United Republic of Tanzania, 2016b).

First, the two regions – Mtwara and Morogoro – were purposively selected under the FruVaSe project to study cashew apple and African nightshade, respectively. These FVs were selected because they are considered nutritious yet under-utilized. Again, through purposive sampling, two districts within each study region were chosen because of their cultivation and subsequent availability of the two crops in the selected sites. In Mtwara, Tandahimba and Masasi districts were selected, while Kilombero and Morogoro DC districts were chosen in Morogoro. Communities within these districts were compiled, and five communities were randomly selected per district. A list of households from the selected communities was collected with the help of community health and nutrition workers and community leaders. From the list, 30 households were randomly selected per community in Mtwara. While in Morogoro, the randomly selected households were between 20-47 households per community, which was proportional to the number of households. Overall, 300 households were sampled per study area. A detailed description of the design for Tanzania, including the inclusion and exclusion criteria for compiling household lists, has been published elsewhere (Sarfo et al., 2021).

3.2.2. Data collection

Data were collected across the plenty and lean seasons of cashew apple and African nightshade in Mtwara and Morogoro, respectively. In Mtwara, data collection was conducted in October/November 2019 for the plenty season and April/May 2019 for the lean season. Surveys for plenty and lean seasons in Morogoro were performed in June/July 2019 and January 2020, respectively.

Market surveys across the two seasons were carried out in the ten communities selected per study region. Four traders selling assorted food items were sampled in each community, totaling 40 traders each for Mtwara and Morogoro. However, not all traders were met during both seasons. Some traders had either closed their shops or had moved or could not be identified despite our confirmation with them for a second survey during the initial survey. In Mtwara, 33 traders were surveyed during both seasons, while it was 17 traders in Morogoro. During the survey, all food prices and their corresponding weights were collected at which they were sold. Three different samples of all foods were weighed that corresponded to the same price to ensure accuracy, except for packaged foods with weights printed on them.

Next, all foods recorded from the market survey were compiled for a focus group discussion (FGD) to determine culturally accepted dietary habits. The FGD was one of two tools used to construct dietary behavior. In doing so, women were recruited using the following criteria: first: they were part of the sampled households; second: they prepared and served meals and acted as caregivers for children; third: they were willing to participate and provide sufficient information. In each study region, two FGDs were conducted, consisting of ten women each, two from each selected community. The FGD in Mtwara was conducted during the plenty season, while Morogoro was conducted during the lean season; however, the discussion was not related to the current season. During the FGD, the women answered questions about the frequencies of food intake by selecting one of these options for each food compiled: usually (5+ days/week), often (1-4 days/week), rarely (once a month or year) and never. They were further asked to identify foods considered taboo or are not eaten in the communities.

The second dietary behavior tool employed was the 24-hour dietary assessment. Four non-consecutive dietary assessments – two per season – were conducted across the sampled households for the women. Two non-consecutive assessments were carried out for the children – one per season. In each recall survey, the women identified all foods and drinks consumed during the previous 24 hours of the survey day for themselves and their infant children. The school-aged children identified for themselves the foods and drinks consumed. Each individual's frequency of foods and drinks consumption was constructed into scores (see data analysis) to represent dietary behavior from the 24-hour dietary assessment.

3.2.3. Processed fruits and vegetables

The processed FVs used in this study could be classified as minimally processed because the mode of processing includes processes such as drying and freezing that do not drastically alter the nutrients of the FVs. In all, three processed fruits and three processed vegetables were used, namely cashew apple juice (CAJ), guava-cashew nut bar (GCB), jackfruit-cashew nut bar (JCB), as well as dried African nightshade (DAN), cassava leaves powder (CLP), and dried cowpea leaves (DCL). All six products were developed within the FruVaSe project. However, nutrient content data were already available for only two products – the guava and jackfruit cashew nut bars. The nutrient contents of the remaining products were compiled from literature through google scholar search. In table 3.1, the nutrient profiles of the processed FVs have been compiled on a fresh weight basis per 100g edible portion. Bioavailability rates of 5% and 48% were used to convert iron and calcium into absorbed quantities (Sarfo et al., 2020). Additionally, β-carotene amounts were converted into retinol equivalent using the ratio 12:1 (Termote et al., 2014; Sarfo et al., 2020). All six FV products are described in the following:

Cashew apple juice: the cashew apple was first macerated, and the juice was extracted from it. The juice was refrigerated and frozen at -20^{o}C for nutrient analyses (Lowor and Agyente-Ba, 2009), as presented in table 3.1. Guava-cashew nut bar and jackfruit-cashew nut bar: the guava bar consisted of guava with some mango, cashew nuts, desiccated coconut, and lemon juice, while the jackfruit bar consisted of the same ingredients as the guava bar except that the main ingredient, guava, was replaced with jackfruit. In processing both fruit bars, simple cooking and drying methods were used, which could be suitable and straightforward methods for households and small food processing groups. The fruit nut bars contain high iron, zinc, calcium (Table 3.1), and low sugar. Sensory evaluation showed an acceptability trend for the products (Xing et al., 2021).

Dried African nightshade: average nutrient contents of three dried African nightshades from three studies were used. All three vegetables were processed through solar drying between temperatures of 37 – 63°C (Wafula, 2017; Cheptoo et al., 2019; Managa et al., 2020). Cassava leaves powder: the cassava leaves were pressed to remove excess water and then heat-treated in a hot dry pot, after which they were pounded and cooked in water. The leaves were then dried at 60 °C, milled, and stored in airtight ziplock bags (Achidi et al., 2008). Dried cowpea leaves: cowpea leaves were harvested and solar-dried until the leaves became brittle when felt in hand. The leaves were then sealed and stored in airtight polythene (Kirakou et al., 2017); nutrient contents are depicted in table 3.1.

In costing the price of the processed FVs, prices of similar products from elsewhere were adopted. Average market prices for snacks and fruit juice in the study regions, which equaled TZS 364 (USD 0.5)/100g and TZS 163 (USD 0.2)/100ml, were chosen for the fruit bars and cashew apple juice, respectively. For the processed vegetables, a price of TZS 552 (USD 0.7)/100g, equivalent to the cost of processed vegetables from a recent study by Tepe et al (unpublished results), was used.

Table 3.1 Nutrient composition and prices (in Tanzania shillings (TZS) and USD ($)) of the processed fruits and vegetables per 100g of edible portion added to the modeled diets for women and children in Mtwara and Morogoro, Tanzania.

Processed fruits and vegetables	Price in TZS	Price in USD ($)	Energy (kcal)	Fat (g)	Protein (g)	Fiber (g)	Vitamin A (µg)[a]	Vitam in C (mg)	Iron (mg)[a]	Zinc (mg)	Calcium (mg)[a]	Thiamine (µg)	Riboflavin (µg)	Sodium (mg)	Phosphorous (mg)	Potassium (mg)	Magnesium (mg)
Cashew apple juice	163	0.2	n.a	n.a	n.a	n.a	n.a	252.4	0.07	0.03	60.9	n.a	n.a	0.3	0.9	86.4	12.8
Guava-cashew nut bar	364	0.5	n.a	n.a	n.a	n.a	n.a	n.a	5.8	6.00	71.9	n.a	n.a	41.3	385.4	1034.1	163.1
Jackfruit-cashew nut bar	364	0.5	n.a	n.a	n.a	n.a	n.a	n.a	4.8	6.2	89.0	n.a	n.a	40.2	347.7	1128.2	164.3
Dried African nightshade	552	0.7	258.4	1.5	26.6	19.2	1926.0	38.7	n.a	n.a	n.a	0.5	1.8	n.a	n.a	n.a	n.a
Dried cassava leaves powder	552	0.7	251.5	5.4	26.5	14.1	229.2	45.2	13.5	9.8	609.7	4.8	n.a	35.4	280.9	1324.6	273.9
Dried cowpea leaves	552	0.7	124.7	n.a	31.2	14.2	1836.8	122.8	0.5	0.1	22.4	n.a	n.a	1426.9	30.0	n.a	n.a

[a]Calcium and Iron were converted into absorbed quantities using the rates 48% and 5%, respectively; Vitamin A is retinol equivalent converted from beta-carotene using the ratio 1:12. *n.a*: not available in literature/not determined.

Sources: (Achidi et al., 2008; Lowor and Agyente-Ba, 2009; Kirakou et al., 2017; Wafula, 2017; Cheptoo et al., 2019; Managa et al., 2020; Xing et al., 2021)

3.2.4. Cost of Diet linear programming tool

The Cost of Diet (CoD) linear programming tool was adopted to model standard diets and assess the impact of the processed FVs in the diets. The CoD tool is a mathematical linear computer programming software that models diets that meet individuals or a family's average energy needs as well as their recommended protein, fat, and micronutrient intakes at the least financial cost (Termote et al., 2014; Deptford et al., 2017; Sarfo et al., 2020). The CoD tool contains nutrient contents of 3,580 food items and supplements extracted from five different food consumption tables. It includes macro- and micronutrient recommendations for different individuals based on the specifications from the WHO and FAO as well as typical portion sizes for different individuals (Deptford et al., 2017; Sarfo et al., 2020).

To model diets, additional data upload was needed, including local foods and their corresponding prices and weights and "food constraints" to factor in local food culture. Food constraints – classified into minimum and maximum – refer to the number of times a week that foods can be consumed. Minimum constraints are the least number of times foods are consumed per week and hence can be included in the models, while maximum constraints indicate the maximum number of times foods are consumed weekly (Termote et al., 2014; Deptford et al., 2017). The present study collected data on local foods and food constraints (see data collection) and used the food tables and portion sizes – minimum and maximum – embedded in the tool for analysis.

3.2.5. Data analysis

First, the food items and their corresponding prices and weights obtained from the market surveys were entered into the CoD tool. Average prices of the foods per 100g of edible portion were calculated. The foods were also classified into eight food groups: cereals, roots and tubers; fruits; vegetables; oils and fats; spices and condiments; sweets and beverages; animal source foods; and pulses and nuts. Then, the FGD data on dietary habits were entered to calculate the minimum and maximum constraints of the foods (tables S3.1 and S3.2). Using average food prices and the FGD food constraints, diets were modeled individually for infants: 6-8 months, 9-11 months, 12-23 months; school-aged children 6-13 years; and reproductive-age women 15-49years: non-lactating and non-pregnant and lactating, for both Mtwara and Morogoro.

Using the data from the 24-hour recalls, food constraints were constructed to validate the constraints from the FGD. Firstly, the frequency of each food consumption across the dietary recalls was weighted. For example, if a woman consumed tea during all recall periods (four times), a score of 2 was given, thrice was scored 1.5 while twice, once, and zero attracted weights of 1, 0.5, and 0, respectively. For both children groups, weights were provided based on the two recalls, and hence, tea consumption for a child during both recalls received a weight of 1, once had a score of 0.5, and no consumption received a score of 0. Each score level per food was multiplied by the respective number of women or children who consumed such food. They were then summed up to obtain the total score per food. Based on the respective overall score, the minimum and maximum constraints (number of times per week a food is consumed) were computed for each food accordingly to set benchmarks described in table S3.3. After excluding some households due to unavailability during all recall periods, final samples used in Mtwara for the 24-hour food constraints were 12 infants, 11 school-aged children and 109 women. For Morogoro, the samples were 24, 41 and 183 infants, school-aged children and women, respectively. The 24-hour food constraints were then entered into the CoD tool to recalibrate the constraints from the FGD and re-model the standard diets. Daily diet costs were calculated for the individuals from the two study sites, in Tanzania Shillings (TZS) and US dollars (USD) using the 2020 purchase power parity for private consumption rate in Tanzania as published by the World Bank (World Bank, 2020).

The processed FVs, including their nutrients and prices, were added to the models under different scenarios. For the first scenario, minimum and maximum food constraints of zero and seven were set for the processed FVs, reflecting the food constraints for most of the FVs identified from the 24-hour recalls. Additionally, these food constraints provided the CoD tool the free hand to include which processed FVs – whether single or by different combinations – impact the diets of children and women in terms of cost and nutrients. Under four other scenarios using food constraints of one and seven (days per week food can be consumed), the CoD tool was forced to select the processed FVs: a) one by one; b) all processed fruits together; c) all processed vegetables together; and d) all processed FVs together. The first scenario – adding all six processed FVs to the models (under zero and seven food constraints) – provided the optimal impact (cost and nutrient) for both children and women in Mtwara and Morogoro. Hence, this scenario was used for further analysis. Finally, the impact of the processed FVs in reducing diet cost and bridging nutrient gaps for one day was assessed and represented in percentages. A flow chart of the modeling steps as described above has been depicted in figure 3.1

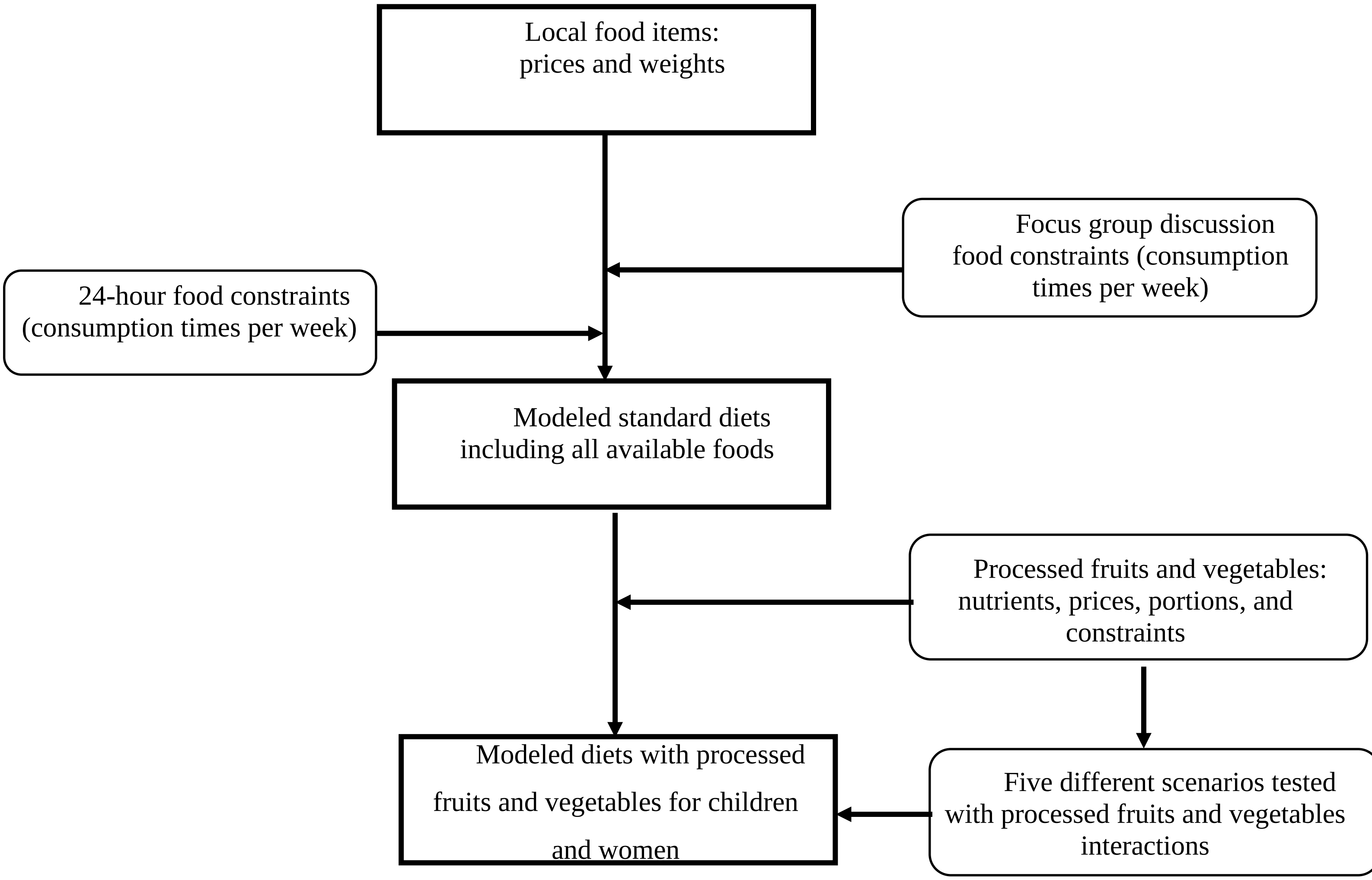


Figure 3.1 Flowchart of how standard diets were modeled with and without the inclusion of processed fruits and vegetables for children and women in Mtwara and Morogoro, Tanzania.

3.3. Results

3.3.1. Standard diet cost

Overall, 62 food items were identified on the market from 33 traders in Mtwara. Most of the foods were from the animal source and sweets and beverages food groups. The animal source food group cost on average – for both seasons – TZS 1,366 (USD 1.7)/100g, while the sweets and beverages cost TZS 545 (USD 0.7). Prices for single food items and average prices for all other food groups are shown in table S4. In Morogoro, 75 foods were surveyed from the 17 traders on the market. Most foods were from the food groups vegetables, fruits, and sweets and beverages as shown in table S3.5, where other food groups are also listed, including their prices.

The cost of a standard daily diet in Mtwara for children between 6-23 months was between TZS 301 – 2,368 (USD 0.4 - 3.0) in the plenty season (August – December) and TZS 232 – 1,515 (USD 0.3 – 1.9) in the lean season (January – July). The diet costs TZS 7,199 (USD 9.1) and TZS 6,207 (USD 7.9) for the school-aged children in the plenty and lean seasons, respectively (Table 3.2). As shown in table 3.2, it would cost between TZS 10,005 – 10,449 (USD 12.7 – 13.2) and TZS 7,448 – 8,457 (USD 9.4 – 10.7) for women to access standard diets in Mtwara during the plenty and lean seasons. The diet cost in Mtwara was mainly driven by the high prices of food sources from the animal source group. On the other hand, diet cost in Morogoro was relatively low. It costs between TZS 346 – 639 (USD 0.4 – 0.8) in the plenty season (June – November) and between TZS 329 – 670 (USD 0.4 – 0.9) in the lean season (December –May) to afford the standard diets for infants. The diet cost for school-aged children in Morogoro was about four times less than the diet cost for the same age group in Mtwara in plenty and lean seasons (Table 3.3). Also, in Morogoro, women would need to pay three times less the price of standard diets for women in Mtwara for both seasons. The modeled diets in Morogoro consisted of more vegetables and animal source foods, and both food groups contributed to a large share of the costs (Table 3.3).

Table 3.2 Cost of standard diet (in Tanzania shillings (TZS) and US dollars (USD)) for one day without processed fruits and vegetables for children and women in Mtwara, Tanzania.

Individual	Plenty season			Lean season		
	Food group and contribution to diet cost	Cost in TZS per day	Cost in USD per day	Food group and contribution to diet cost	Cost in TZS per day	Cost in USD per day
6-8 months	Cereals, roots, and tubers: 22.0% Fruits: 1.7% Vegetables: 25.7% Oils and fats: 4.8% Spices and condiments: 0.5% Sweets and beverages: 2.0% Animal source foods: 43.3% Pulses and nuts: 0%	301	0.4	Cereals, roots, and tubers: 20.9% Fruits: 0% Vegetables: 26.3% Oils and fats: 6.4% Spices and condiments: 0.5% Sweets and beverages: 2.5% Animal source foods: 43.3% Pulses and nuts. 0%	232	0.3
9-11 months	Cereals, roots, and tubers: 11.1% Fruits: 12.7% Vegetables: 29.8% Oils and fats: 2.4% Spices and condiments: 0.2% Sweets and beverages: 1.0% Animal source foods: 42.7% Pulses and nuts: 0%	658	0.8	Cereals, roots, and tubers: 5.0% Fruits: 0% Vegetables: 25.5% Oils and fats: 1.5% Spices and condiments: 0.1% Sweets and beverages: 0.6% Animal source foods: 67.2% Pulses and nuts: 0%	1,098	1.4
12-23 months	Cereals, roots, and tubers: 3.9% Fruits: 3.3% Vegetables: 10.4% Oils and fats: 0.8% Spices and condiments: 0.1% Sweets and beverages: 0.3% Animal source foods: 79.6% Pulses and nuts: 1.5%	2,368	3.0	Cereals, roots, and tubers: 4.4% Fruits: 0% Vegetables: 22.5% Oils and fats: 1.3% Spices and condiments: 0.1% Sweets and beverages: 8.7% Animal source foods: 60.6% Pulses and nuts: 2.3%	1,515	1.9
6-13 years	Cereals, roots, and tubers: 5.0% Fruits: 3.4% Vegetables: 10.9% Oils and fats: 29.1%	7,199	9.1	Cereals, roots, and tubers: 5.6% Fruits: 0% Vegetables: 15.7% Oils and fats: 39.5%	6,207	7.9

	Spices and condiments: 0% Sweets and beverages: 2.9% Animal source foods: 47.7% Pulses and nuts: 1.0%			Spices and condiments: 0% Sweets and beverages: 4.7% Animal source foods: 34.4% Pulses and nuts: 0%		
Women	Cereals, roots, and tubers: 2.6% Fruits: 1.3% Vegetables: 10.9% Oils and fats: 1.3% Spices and condiments: 0.1% Sweets and beverages: 3.4% Animal source foods: 79.4% Pulses and nuts: 1.0%	10,005	12.7	Cereals, roots, and tubers: 2.4% Fruits: 0% Vegetables: 19.3% Oils and fats: 1.7% Spices and condiments: 0.1% Sweets and beverages: 7.6% Animal source foods: 67.8% Pulses and nuts: 1.2%	7,448	9.4
Lactating women	Cereals, roots, and tubers: 2.7% Fruits: 3.3% Vegetables: 12.2% Oils and fats: 1.3% Spices and condiments: 0% Sweets and beverages: 6.4% Animal source foods: 72.9% Pulses and nuts: 1.3%	10,449	13.2	Cereals, roots, and tubers: 3.1% Fruits:1.0% Vegetables: 14.5% Oils and fats: 1.6% Spices and condiments: 0% Sweets and beverages: 9.0% Animal source foods: 69.4% Pulses and nuts: 1.4%	8,457	10.7

$1 = Tsh 790.5 PPP for private consumption

Table 3.3 Cost of standard daily diet (in Tanzania shillings (TZS) and US dollars (USD)) for one day without processed fruits and vegetables for children and women in Morogoro, Tanzania.

Individual	Plenty season			Lean season		
	Food group and contribution to diet cost	Cost in TZS per day	Cost in USD per day	Food group and contribution to diet cost	Cost in TZS per day	Cost in USD per day
6-8 months	Cereals, roots, and tubers: 14.3% Fruits: 0% Vegetables: 68.1% Oils and fats: 4.2% Spices and condiments: 0.3% Sweets and beverages: 3.5%	346	0.4	Cereals, roots, and tubers: 18.5% Fruits: 0% Vegetables: 61.7% Oils and fats: 3.5% Spices and condiments: 0.4% Sweets and beverages: 4.1%	329	0.4

	Animal source foods: 9.6% Pulses and nuts: 0%			Animal source foods: 11.8% Pulses and nuts: 0%		
9-11 months	Cereals, roots, and tubers: 8.3% Fruits: 0% Vegetables: 52.6% Oils and fats: 2.5% Spices and condiments: 0.3% Sweets and beverages: 2.0% Animal source foods: 34.3% Pulses and nuts: 0%	654	0.8	Cereals, roots, and tubers: 11.6% Fruits: 0% Vegetables: 41.6% Oils and fats: 2.2% Spices and condiments: 0.4% Sweets and beverages: 2.6% Animal source foods: 41.7% Pulses and nuts: 0%	582	0.7
12-23 months	Cereals, roots, and tubers: 10.7% Fruits: 0% Vegetables: 35.7% Oils and fats: 3.1% Spices and condiments: 0.3% Sweets and beverages: 2.6% Animal source foods: 35.4% Pulses and nuts: 12.2%	639	0.8	Cereals, roots, and tubers: 12.6% Fruits: 0% Vegetables: 29.1% Oils and fats: 2.4% Spices and condiments: 0.3% Sweets and beverages: 2.8% Animal source foods: 38.5% Pulses and nuts: 14.3%	670	0.9
6-13 years	Cereals, roots, and tubers: 26.7% Fruits: 10.7% Vegetables: 44.6% Oils and fats: 5.9% Spices and condiments: 0.1% Sweets and beverages: 0% Animal source foods: 11.0% Pulses and nuts: 1.0%	1,711	2.2	Cereals, roots, and tubers: 32.5% Fruits: 1.6% Vegetables: 50.4% Oils and fats: 8.5% Spices and condiments: 0.1% Sweets and beverages: 2.8% Animal source foods: 7.0% Pulses and nuts: 0%	1,759	2.2
Women	Cereals, roots, and tubers: 18.7% Fruits: 0% Vegetables: 37.4% Oils and fats: 6.2% Spices and condiments: 0.1% Sweets and beverages: 1.6% Animal source foods: 30.5% Pulses and nuts: 5.6%	2,822	3.6	Cereals, roots, and tubers: 19.4% Fruits: 0% Vegetables: 41.7% Oils and fats: 4.6% Spices and condiments: 0.1% Sweets and beverages: 2.1% Animal source foods: 27.2% Pulses and nuts: 4.9%	3,100	3.9

Lactating women	Cereals, roots, and tubers: 24.8% Fruits: 0% Vegetables: 37.7% Oils and fats: 8.5% Spices and condiments: 0.1% Sweets and beverages: 1.6% Animal source foods: 19.8% Pulses and nuts: 7.5%	2,793	3.5	Cereals, roots, and tubers: 25.6% Fruits: 0% Vegetables: 47.6% Oils and fats: 6.2% Spices and condiments: 0.1% Sweets and beverages: 2.1% Animal source foods: 10.9% Pulses and nuts: 7.5%	3,038	3.8

$1 = Tsh 790.5 PPP for private consumption

3.3.2. Impact of the processed fruits and vegetables on standard diet costs

The addition of the processed FVs to the models showed varying interactions that impacted cost and nutrients across the two study sites and for the individuals. In Mtwara, all three processed fruits – cashew apple juice, guava- and jackfruit-cashew nut bars – and two processed vegetables – cassava leaves powder and dried cowpea leaves – were included in the diets of infants 6-11 months (Figure 3.2). This increased the diet cost on average by 102% and 69% in the lean and plenty seasons (Figure 3.3). With a different combination for infants 12-23 months: guava-cashew nut bar, cassava leaves powder and dried African nightshade in the plenty season, and the two fruits nut bars and all three processed vegetables in the lean, standard diet costs were reduced by 61% and 43%, respectively (Figure 3.3). Furthermore, all six processed FVs added up to the diet of school-aged children in Mtwara except in the lean season where only two were added – guava-cashew nut bar and dried cowpea leaves. This culminated in the diet cost reduction by 48% in the plenty season and slightly going up by 2% in the lean season (Figure 3.3). For the two women groups, diet costs were reduced by an average of 46% and 36% in plenty and lean seasons, respectively (Figure 3.3). This stemmed from combining the three processed vegetables and the two fruit nut bars to their diets, as indicated in figure 3.2.

The processed FVs combinations and their magnitude of impact differed in Morogoro, although the trend is the same as Mtwara. For infants 6-11 months, the three processed fruits plus cassava leaves powder were added to the standard diet, which increased the diet cost, on average, by 48% and 43% in plenty and lean seasons. Only cassava leaves powder added up to the diet of infants 12-23 months (both seasons), the school-aged children, and non-pregnant, non-lactating women (only in the plenty season) – figure 3.2. The corresponding proportions of reduction in the cost of standard diets are depicted in figure 3.3. None of the processed FVs were included in the diet of lactating women, which meant that the standard diet without the processed FVs was adequately cost-optimized and nutritious.

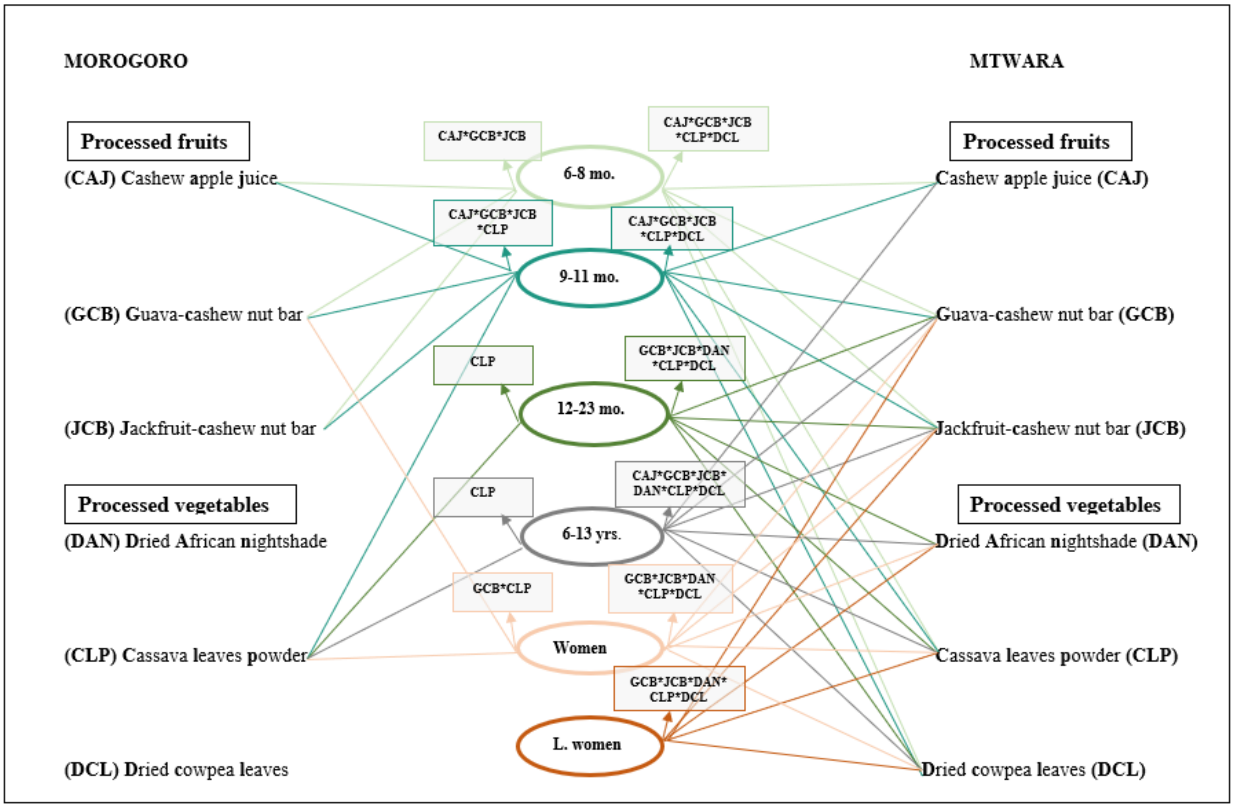
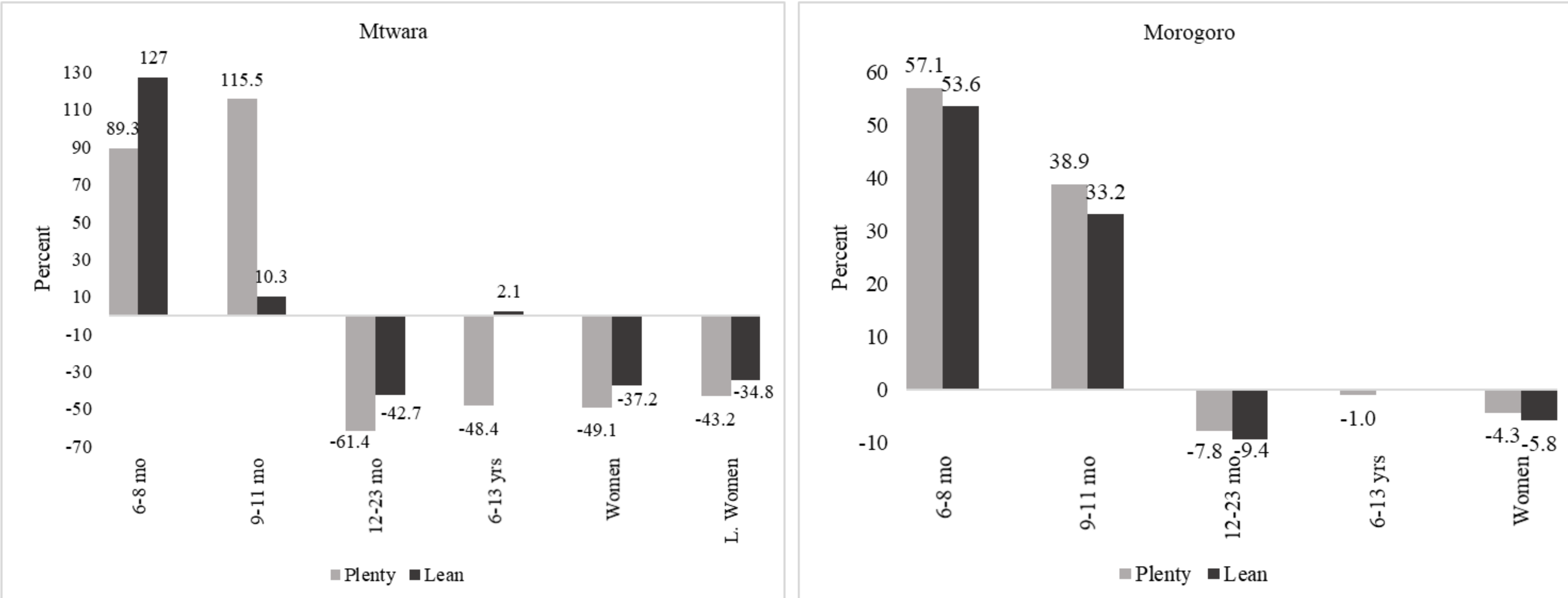


Figure 3.2 The different interactions of the processed fruits and vegetables that impact costs and nutrients of the standard diets for children and women in Mtwara and Morogoro, Tanzania, year-round



6-11mo: CAJ*GCB*JCB*CLP*DCL; **12-23mo:** GCB*JCB*DAN*CLP*DCL; **6-13yrs:** CAJ*GCB*JCB*DAN*CLP*DCL; **Women:** GCB*JCB*DAN*CLP*DCL

6-8mo: CAJ*GCB*JCB; **9-11mo:** CAJ*GCB*JCB*CLP; **12-23mo:** CLP; **6-13yrs:** CLP; **Women:** GCB*CLP

Figure 3.3 Percentage of reduction/increase in the standard diet cost after integrating processed fruits and vegetables into the models for children and women in Mtwara and Morogoro, Tanzania

3.3.3. Micronutrient gaps and the impact of the processed fruits and vegetables

The standard diets showed gaps in micronutrient intakes, particularly for the individuals in Mtwara. While micronutrient deficiencies were found in the diet of only infants 6-11 months in Morogoro, all individuals in Mtwara did not meet recommended levels of certain micronutrients in their diets. Vitamin A and iron were the lacking micronutrients in diets that cut across for all individuals in Mtwara. Additional limited micronutrients included vitamins C, B_2, B_6, and zinc for infants 6-11 months. For infants 12-23 months and school-aged children, vitamin B_2 was inadequate, in addition to the lack of vitamin A and iron (Figure 3.4). The inclusion of the processed FVs at different interactions and combinations – as described above – improved some micronutrient contents. Recommended intakes for vitamins A and C and zinc were met for infants 6-11 months; there was a slight increase in iron content by 18% and slight reductions in vitamins B_2 and B_6 (Figure 3.4). The processed FVs filled up all recommended micronutrient intakes not met in the standard diets for the rest of the individuals except for the school-aged children, where vitamin B_2 decreased by 0.5% in the lean season. In Morogoro, the most pronounced limited micronutrients were vitamin B_2, calcium, iron, and zinc identified in the diets of infants 6-11 months for both seasons. The addition of the processed FVs, given by the different combinations and shown in figure 3.2, fully bridged the micronutrient gaps of calcium and zinc. Iron content increased by 19% on average, while there was a slight reduction in vitamin B_2, as mapped in figure 3.4.

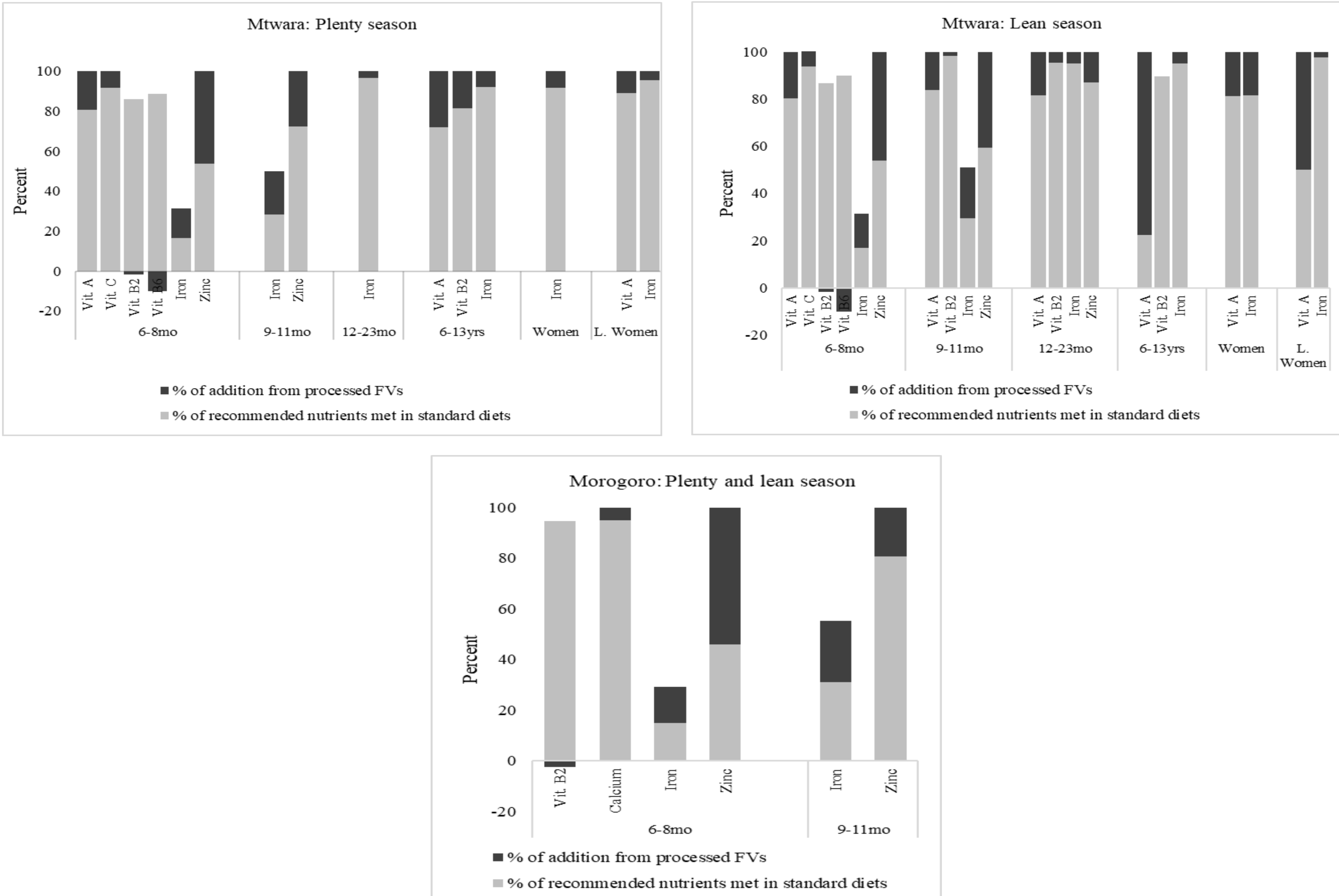


Figure 3.4 Percentage of recommended nutrients met in the standard diets and after adding the processed fruits and vegetables in the models for children and women in Mtwara and Morogoro, Tanzania.

3.4. Discussion

3.4.1. Diets and micronutrient deficiencies

In the present study, standard diets were modeled with processed fruits and vegetables to investigate their impact on diet cost and micronutrient intakes. The costs of the modeled diets were primarily driven by vegetables and animal source foods, which indicates the high prices of these nutritious foods. In an EAT-Lancet report (Hirvonen et al., 2020), where they also modeled diets, they showed that the high cost of FVs and animal source foods is a major contributing factor to expensive nutritious diets and the inability for the poor to afford. Also, in Ethiopia, high price levels for FVs and animal food sources were likely to prevent the poor from accessing these foods and, consequently, nutritious diets (Bachewe et al., 2017). This is a highly likely situation that could exist in rural Tanzania where most people are poor.

Aside from the cost, micronutrient gaps were found in the modeled standard diets. Inadequate micronutrient intakes from diets have been highlighted strongly in earlier studies pertaining to sub-Saharan Africa. In northern Kenya, iron and zinc were the most limiting nutrients in children's and women's diets (Sarfo et al., 2020). Again, in Kenya, diets from Baringo lacked iron, zinc, calcium, and vitamin B_6 (Termote et al., 2014). Additionally, in Mozambique, iron and vitamin B_2 were limiting nutrients in diets (Frega et al., 2012), while iron, calcium, vitamins B_2, B_6, and B_{12} were the micronutrient gaps in diets in Burkina Faso (Arimond et al., 2018). All the micronutrient gaps listed above were also found in the modeled diets in rural Tanzania. Even after integrating the processed FVs, vitamins B_2 and B_6 and iron were still limiting for infants 6-11 months, underscoring the urgent need to address these micronutrient inadequacies for better nutrition and human development. These nutrient gaps persist partly because of the sources of foods that characterize diets, especially in rural areas. Diets largely consist of plant-based foods with low absorption rates for nutrients such as iron and zinc (Zimmermann and Hurrell, 2007; Lopez et al., 2016; Sarfo et al., 2020). Another contributing factor is the insufficient supply and consumption of micronutrient-dense foods such as FVs, meat and dairy foods, largely due to their seasonality and/or high perishability levels. Hence, their inclusion in diets becomes a challenge even if households can afford them. For instance, in this study, the availability of fruits on the market was low, most likely leading to low consumption and limited inclusion in the modeled diets. In addition, low intake of animal source foods, including meat and dairy foods accounts for the reduction in vitamin B_2 for infants across locations and seasons, even after adding the processed FVs, as these animal source foods are rich in vitamin B_2 (Peechakara and Gupta, 2021). Only one animal source food – fish – was included in the diet, emphasizing the need to promote sustainable consumption of animal source foods and/or adding needed micronutrients to foods through fortification.

3.4.2. Nutritional contribution and cost of processed fruits and vegetables

Although most fruits are consumed fresh, compared with vegetables that need to be processed most times before consumption, processing adds the layer of safety and prolonged shelf life. Through processing, anti-nutrients and toxic substances can be inactivated or destroyed to ensure palatability and digestibility. Even though nutrient losses may occur through processing, varied processing techniques can also be used to fortify and/or alter FVs with nutrients that are consistent with nutrition guidelines. (Breene, 1994; Floros et al., 2010; Weaver et al., 2014). This study has shown that processed FVs can promote nutritional adequacy in diets and even reduce diet costs for specific individuals. These findings are also backed by Weaver et al. (2014) who showed in their study that processed foods could contribute to ensuring food and nutrition secured households. In the USA, for instance, processed FVs (frozen, canned, or dried) contributed 35% of dietary fiber, 62% of vitamin E, 51% of vitamin C, 40% of folate, and 25% of vitamin A to diets (Dwyer et al., 2012). This affirms that the possibilities of processed FVs not only lowering postharvest losses but also contribute to improving the nutritional status of individuals who otherwise would have been malnourished. There have been concerns about processed foods, and indeed some processed foods have been widely documented to have direct linkages with adverse health outcomes such as obesity and other non-communicable diseases, including in sub-Saharan Africa (Monteiro et al., 2011; Popkin et al., 2012; Holmes et al., 2018; Sarfo et al., 2021). Therefore, it is vital to make clear distinctions between processed foods such that consumers can make healthy choices. Classification of the healthiness of processed foods by their degree of processing, which is subjective, does not provide a helpful approach for consumers (Weaver et al., 2014). Instead, characterization of healthiness or otherwise based on their nutrient content combined with some agreed benchmarks for salt, fat, sugar, food additives, and calorie quality can be a helpful approach to adopt (Sarfo et al., 2021).

Already most consumers perceive the prices of FVs as expensive. In the USA, low-income households allocated a larger share of their food budget to purchase fresh FVs (Hayden et al., 2016). Yet, the price of canned vegetables was 20% cheaper than fresh-packaged vegetables, with both having similar nutrient content. The price of canned fruits was competitive to fresh fruits with comparable nutrients in some cases. In addition, both processed FVs provided longer shelf-life, presenting an excellent avenue for low-income and poor households to afford FVs to meet their nutritional requirements year-round (Miller and Knudson, 2014). However, the prices of the processed FVs in this study were high relative to the fresh FVs to the extent that their inclusion into diets increased the cost for infants 6-11 months. On the other hand, the increase in diet cost for such children group is not surprising because, during such infant stage, careful and appropriate complementary feeding is critical to ensure healthy growth, as nutrient demands are high (Sawadogo et al., 2006; Daelmans et al., 2009; Imdad et al., 2011). Yet, food choices for these infants are limited in quality and quantity (Imdad et al., 2011) compared to older children and adults. For instance, in Tanzania, current complementary feeding practices are not able to ensure adequate nutrition for infants 6-11months, requiring the need for nutrition interventions to improve nutritional status (Victor et al., 2014). Interventions such as including nutritious processed FVs used in this study into diets could provide adequate nutrition for infants – which, however, would increase diet costs (as evidenced in this study) due to the peculiar nature of infants in ensuring adequate nutrition.

3.4.3. Shelf life and acceptability of processed fruits and vegetables

The objectives of this study did not include determining the shelf life and acceptability of processed FVs; however, it is essential to discuss these themes as they are imperative if processed FVs are to be integrated into diets. According to Miller and Knudson (2014), in selecting foods, especially by low-income households, their shelf life constitutes one of the determining factors. This is because they can rely on such foods for a more extended period to meet their nutritional needs. Equally, through sensory evaluation, consumers can gauge the acceptability or otherwise of foods (Natabirwa et al., 2017). A shelf-life study performed for cashew apple juice showed three months storage capacity with excellent acceptability by consumers (Talasila et al., 2012). Regarding the two fruit nut bars developed within the FruVaSe project, panelists largely accepted both, although the panelists were not the individuals in this study. Shelf-life studies were not done on the fruit nut bars; however, as the water content of the final products was 8% - 10%, perishability processes have been slowed down (Xing et al., 2021). In a study conducted by Pato Dickson Innocensia (2013) in Morogoro, Tanzania, processed cassava leaves were acceptable by consumers compared to fresh cassava leaves. Consumers were also willing to pay for the processed cassava leaves at the prevailing price, indicating that consumers are ready to pay for a premium price on processed vegetables. However, the study was conducted in urban Morogoro, while the present study focused on rural areas. Also, results from sensory studies performed on processed cassava leaves in Rwanda showed overall likeness and acceptability for the product (Umuhozariho et al., 2013). The dried cowpea leaves used in this study had prolonged longevity and were suitable for year-round consumption (Kirakou et al., 2017). In addition, in Uganda, similar solar-dried cowpea leaves were acceptable in taste, flavor, texture and had a stable storage form that could be well marketed for consumption (Natabirwa et al., 2017). According to Tepe et al. (2021), there is a demand and market for processed FVs in East Africa. The trend shows that consumers have general acceptability for processed FVs. They can provide the longevity needed to help bridge seasonality nutrient gaps, especially for vulnerable groups like children and women.

Although affordability of diets was not calculated in this study, it is assumed that in Morogoro, households may be able to afford the modeled diets but may have to commit a large share of their income as a food budget. However, in Mtwara, the affordability of the diets might be a considerable challenge. With the level of development in Morogoro, infrastructure-wise, and easy accessibility to motorable road networks and urban areas, it could provide households the opportunity of ease of access to diverse and inexpensive but nutritious foods on the market. Additionally, in Morogoro, households can easily engage in off-farm income activities to fetch them extra income to theoretically afford healthy diets. In contrast, in Mtwara – specifically the communities surveyed – road networks are bad with public transport to nearby urban areas scheduled at specific times. This could present a situation where food supply and availability could be limited to only those produced in the communities, consequently limiting food diversity and accessibility to other nutritious foods. Again, off-farm income ventures could be restricted as well, limiting income generation to purchase nutritious foods. On the other hand, improved access to markets – measured by off-farm income and short distance to markets – have been shown to be associated with better household nutrition (Sibhatu et al., 2015).

3.4.4. Policy implications and areas for future research

First, investment in science and technology is essential to develop more processing innovations that help process fresh FVs and similarly fresh nutritious yet perishable food such as milk and meat into nutritious products. Also, appropriate channels for transferring these processing innovations to communities where these foods are produced should be developed. This would help farmers/households and small and medium enterprises (SMEs) process their FVs to attract extra income (Sarfo et al., 2021). Second, interventions such as subsidies must be provided to SMEs that engage in FV processing to make processed FVs cheaper for the poor (Sarfo et al., 2021). Third, nutritious processed FVs must be integrated into nutrition guidelines and programs. For instance, the importance of nutritious processed FVs to diets, particularly during off-availability periods of fresh FVs, can be included in nutrition education to women and/or caregivers. Equally, processed FVs should be introduced into children's diets, especially in school feeding and other nutrition programs. They should be educated as well on their importance for healthy development.

Furthermore, similar studies must be performed in different geographical settings to show the contribution of processed FVs to households' diets. Additionally, modeling diets with highly processed FVs or other foods in general – as this study was performed with minimally processed FVs only – should be done to assess their impact on the rural poor in terms of nutrients and costs. Since the modeled diets are hypothetical, studies on their acceptability should be evaluated to determine whether households will accept diets as modeled or require fine-tuning or reject them (Sarfo et al., 2020).

3.4.5. Study limitations

To the best of our knowledge, the present study is the first to model diets by integrating processed FVs to assess their impact in rural communities, where FV production is predominant, especially in Africa. Despite this, the following limitations were identified for this study.

First, there was a high attrition rate for the traders sampled in Morogoro during the second survey. This means data points on availability and prices of some food items might have been missed during the second survey, which could impact the diet cost. Only the foods identified on the market were used for analysis. Foods from households' production that may be consumed but are not available on the market were not considered and thus led to the neglect of some foods in the models. However, the foods identified from the 24-hour recalls but not found on the market were few. Also, the nutrients from all foods used for modeling were based on their raw form; meanwhile, nutrient losses would be expected during food preparation which might further reduce nutrient intake more than reported in the results. The 24-hour constraints were based on qualitative recalls instead of quantitative, neglecting the inter-individual portion sizes of food intake. Usage of the qualitative 24-hour recall is nonetheless consistent with the FGD, which is also qualitative. Furthermore, the sample sizes adopted for the 24-hour constraints were small, especially for the children, which could limit the variability in foods consumed in the study areas to approximate correct dietary habits for modeling. Except for the fruit nut bars, the nutrient contents of the processed FVs are based on food composition tables from elsewhere, which could result in under- or overestimation of the potential of processed FVs in local diets. Again, the actual pricing of the processed FVs was not determined, but rather prices from similar products were used, which can bias the results of the potential of processed FVs in terms of diet cost reduction. The processed FVs were not tested on the specific individuals of the study to understand their acceptability or otherwise for the products. However, as discussed above, there is a general trend for the likeness and acceptability of processed FVs. Lastly, this study did not gauge the acceptability and affordability of the modeled diets with processed FVs, especially when the models are considered hypothetical. Therefore, this creates a challenge as to whether the consumption of these diets could be actualized for the individuals. Moreover, for households to access such nutritious diets, there should be the financial will. As it stands now, this study is unable to assess in actual terms whether households have the financial will to buy such nutritious diets.

3.5. Conclusion

This present study sought to model standard diets for children and women in rural Tanzania and assess the impact of processed fruits and vegetables to reduce diet costs and ensure nutritional adequacy. The addition of processed fruits and vegetables to diets reduced diet costs except for infants 6-11 months, where the cost went up. On nutritional adequacy, the integration of processed fruits and vegetables was able to fill up the micronutrient gaps that persisted in the standard diets for children and women, except in some cases for infants 6-11 months, where some of the micronutrient gaps were not fully bridged. Overall, processed fruits and vegetables could provide a feasible avenue to ensure nutritious but cheap diets for households, especially the poor, year-round. Hence, interventions that would spur the processing of fruits and vegetables into nutritious and affordable products should extensively be pursued at international and national levels. Equally, these nutritious processed fruits and vegetables must be integrated into dietary guidelines and nutrition programs to address the consumption of poor diets. In addition, an unambiguous definition of what "nutritious processed foods" are in general is needed in dietary guidelines to guide consumers to make healthy food choices.

Supplementary materials

Table S3.1 Weekly minimum and maximum constraints of foods (number of times a food is consumed per week) from food group discussion and 24-hour dietary recall for infants 6-23 months, school-aged children 6-13 years and women 15-49 years in Mtwara, Tanzania.

Food	FGD						24-hour recall					
	6-23mo.		6-13years		Women		6-23mo.		6-13years		Women	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
Bread	0	14	0	14	0	14	0	0	0	0	0	7
Maize flour	0	14	0	14	0	14	7	14	0	14	7	14
Millet	0	7	0	7	0	7	0	0	0	0	0	0
Rice	0	14	0	14	0	14	0	14	0	14	0	14
Sorghum	0	7	0	7	0	7	0	0	0	0	0	0
Noodles	0	7	0	7	0	7	0	0	0	0	0	0
Wheat flour	0	7	0	7	0	7	0	0	0	0	0	7
Potato	0	7	0	7	0	7	0	0	0	0	0	0
Sweet potato	0	7	0	7	0	7	0	0	0	0	0	7
Beans	0	7	0	7	0	7	0	7	0	0	0	7
Cowpeas	0	0	0	0	0	0	0	0	0	7	0	0
Groundnut	0	0	0	0	0	0	0	0	0	0	0	7
Beef	0	7	0	7	0	7	0	7	0	0	0	7
Offals	0	7	0	7	0	7	0	0	0	0	0	0
Small-dried fish	0	14	0	14	0	14	0	7	0	7	0	14
Dried fish	0	14	0	14	0	14	0	0	0	0	0	14
Fish	0	14	0	14	0	14	0	14	0	14	0	14
Salted fish	0	14	0	14	0	14	0	0	0	0	0	14
Smoked fish	0	14	0	14	0	14	0	0	0	0	0	14
Octopus	0	0	0	0	0	0	0	0	0	0	0	0
Egg	0	7	0	7	0	7	0	0	0	0	0	7
Powdered milk	0	7	0	7	0	7	0	0	0	0	0	0
Milk	0	7	0	7	0	7	0	0	0	0	0	0
Eggplant	0	14	0	14	0	14	0	0	0	0	0	0
Onion	0	14	0	14	0	14	3	14	0	14	7	14
Peas	0	7	0	7	0	7	0	0	0	0	0	0
Banana	0	14	0	14	0	14	0	0	0	0	0	0
Baobab	0	7	0	7	0	7	0	0	0	0	0	7
Coconut	0	7	0	7	0	7	0	0	0	0	0	0
Coconut milk	0	0	0	0	0	0	0	0	0	7	0	0
Lemon	0	7	0	7	0	7	0	0	0	0	0	0
Lemon juice	0	0	0	0	0	0	0	0	0	0	0	0

Mango juice	0	7	0	7	0	7	0	0	0	0	0	0
Mango	0	0	0	0	0	0	0	7	0	7	0	7
Orange juice	0	7	0	7	0	7	0	0	0	0	0	0
Orange	0	7	0	7	0	7	0	0	0	0	0	0
Passion juice	0	7	0	7	0	7	0	0	0	0	0	0
Peach juice	0	0	0	0	0	0	0	0	0	0	0	0
Pineapple juice	0	7	0	7	0	7	0	0	0	0	0	0
Tomato	0	14	0	14	0	14	0	14	0	14	7	14
Coconut oil	0	0	0	0	0	0	0	0	0	0	0	0
Sunflower cooking oil	0	14	0	14	0	14	0	14	0	14	7	14
Biscuit	0	7	0	7	0	7	0	7	0	0	0	7
Chewing gum	0	7	0	7	0	7	0	0	0	0	0	7
Cookies	0	7	0	7	0	7	0	7	0	0	0	7
Mandazi	0	7	0	7	0	7	0	7	0	7	0	7
Cake	0	7	0	7	0	7	0	7	0	0	0	7
Sugar	0	14	0	14	0	14	3	14	0	14	7	14
Sweets	0	7	0	7	0	7	0	7	0	0	0	7
Salt	7	14	7	14	7	14	3	14	3	14	7	14
Baking powder	0	7	0	7	0	7	0	0	0	0	0	7
Chili sauce	0	7	0	7	0	7	0	0	0	0	0	0
Garlic	0	7	0	7	0	7	0	0	0	0	0	0
Ginger	0	14	0	14	0	14	0	0	0	0	0	0
Tomato paste	0	7	0	7	0	7	0	0	0	0	0	0
Cola (Adam)	0	0	0	0	0	0	0	0	0	0	0	0
Ginger drink	0	7	0	7	0	7	0	0	0	0	0	0
Soda	0	7	0	7	0	7	0	0	0	0	0	0
Coffee	0	0	0	0	0	0	0	0	0	0	0	0
Energy drink	0	7	0	7	0	7	0	0	0	0	0	0
Malt	0	0	0	0	0	0	0	0	0	0	0	0
Tea	0	14	0	14	0	14	0	7	0	14	3	14
N			20 women				12		11		109	

Table S3.2 Weekly minimum and maximum constraints of foods (number of times a food is consumed per week) from food group discussion and 24-hour dietary recall for infants 6-23 months, school-aged children 6-13 years and women 15-49 years in Morogoro, Tanzania.

Food	FGD						24-hour recall					
	6-23mo.		6-13years		Women		6-23mo.		6-13years		Women	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
Bread	0	7	0	7	0	7	0	0	0	0	0	0
Maize flour	7	14	7	14	7	14	7	14	7	14	7	14
Maize	0	14	0	14	0	14	0	0	0	0	0	0
Millet	0	0	0	0	0	0	0	0	0	0	0	0
Rice	0	14	0	14	0	14	0	14	3	14	7	14
Noodles	0	7	0	7	0	7	0	0	0	0	0	0
Wheat flour	0	14	0	14	0	14	0	0	0	0	0	0
Potato	0	7	0	7	0	7	0	0	0	0	0	0
Sweet potato	0	7	0	7	0	7	0	0	0	0	0	0
Bambara groundnut	0	0	0	0	0	0		0	0	0	0	0
Beans	0	14	0	14	0	14	0	7	0	14	0	14
Cowpeas	0	7	0	7	0	7	0	7	0	0	0	7
Groundnut	0	7	0	7	0	7	0	0	0	0	0	0
Peas	0	0	0	0	0	0	0	0	0	0	0	0
Soybean	0	0	0	0	0	0	0	0	0	0	0	0
Liver	0	7	0	7	0	7	0	0	0	0	0	7
Beef	0	14	0	14	0	14	0	7	0	7	0	7
Offals	0	7	0	7	0	7	0	0	0	0	0	7
Small-dried fish	0	14	0	14	0	14	0	7	0	14	0	7
Fish	0	14	0	14	0	14	0	7	0	14	0	14
Salted fish	0	14	0	14	0	14	0	0	0	0	0	14
Shrimp	0	7	0	7	0	7	0	0	0	0	0	0
Egg	0	14	0	14	0	14	0	0	0	0	0	0
Cabbage	0	7	0	7	0	7	0	0	0	0	0	0
Chinese	0	7	0	7	0	7	0	0	0	0	0	0
Carrot	0	14	0	14	0	14	0	0	0	0	0	0
Cucumber	0	14	0	14	0	14	0	0	0	0	0	0
Eggplant	0	14	0	14	0	14	0	0	0	0	0	0
Green pepper	0	14	0	14	0	14	0	0	0	0	0	0
Amaranth	0	14	0	14	0	14	0	0	0	7	0	7
Cassava leaves	0	14	0	14	0	14	0	0	0	7	0	7
Pumpkin leaves	0	14	0	14	0	14	0	7	0	7	0	7
Sweet potato leaves	0	14	0	14	0	14	0	7	0	7	0	7
Okra	0	14	0	14	0	14	0	7	0	0	0	7

Onion	7	14	7	14	7	14	3	14	7	14	7	14
Pumpkin	0	14	0	14	0	14	0	0	0	0	0	0
Radish	0	0	0	0	0	0	0	0	0	0	0	0
Avocado	0	14	0	14	0	14	0	0	0	0	0	0
Banana	0	14	0	14	0	14	0	7	0	7	0	0
Black currant juice	0	7	0	7	0	7	0	0	0	0	0	0
Coconut	0	14	0	14	0	14	0	0	0	7	0	0
Coconut milk	0	0	0	0	0	0	0	7	0	7	0	14
Lemon	0	14	0	14	0	14	0	0	0	7	0	0
Lemon juice	0	0	0	0	0	0	0	0	0	0	0	0
Mango juice	0	7	0	7	0	7	0	0	0	0	0	0
Mango	7	14	7	14	7	14	0	0	0	0	0	0
Orange juice	0	7	0	7	0	7	0	0	0	0	0	0
Orange	0	7	0	7	0	7	0	0	0	7	0	0
Papaya	0	7	0	7	0	7	0	0	0	0	0	0
Passion fruit	0	7	0	7	0	7	0	0	0	0	0	0
Passion juice	0	7	0	7	0	7	0	0	0	0	0	0
Pineapple	0	7	0	7	0	7	0	0	0	0	0	0
Pineapple juice	0	7	0	7	0	7	0	0	0	0	0	0
Tamarind	0	0	0	0	0	0	0	0	0	0	0	0
Tangerine	0	14	0	14	0	14	0	0	0	0	0	0
Tomato	7	14	7	14	7	14	0	14	0	14	3	14
Watermelon	0	7	0	7	0	7	0	0	0	0	0	0
Sunflower cooking oil	0	14	0	14	0	14	3	14	7	14	7	14
Biscuit	0	7	0	7	0	7	0	7	0	7	0	0
Chewing gum	0	0	0	0	0	0	0	0	0	0	0	0
Mandazi	0	7	0	7	0	7	0	7	0	7	0	0
Sugar	0	14	0	14	0	14	7	14	0	14	3	14
Sweets	0	7	0	7	0	7	0	7	0	7	0	0
Baking powder	0	0	0	0	0	0	0	0	0	0	0	0
Chili sauce	0	0	0	0	0	0	0	0	0	0	0	0
Garlic	0	14	0	14	0	14	0	0	0	0	0	0
Ginger	0	14	0	14	0	14	0	0	0	0	0	0
Salt	0	14	0	14	0	14	7	14	7	14	7	14
Pepper	0	7	0	7	0	7	0	0	0	0	0	0
Tomato paste	0	0	0	0	0	0	0	0	0	0	0	0

Cola (Adam)	0	0	0	0	0	0	0	0	0	0	0	0
Strawberry beverage	0	0	0	0	0	0	0	0	0	0	0	0
Energy drink	0	0	0	0	0	0	0	0	0	0	0	0
Malt	0	7	0	7	0	7	0	0	0	0	0	0
Tea	0	7	0	7	0	7	0	0	0	7	3	14
N			20 women				24		41		183	

Table S3.3 Scoring benchmarks for determining the 24-hour constraints (number of times a food is consumed per week) for infants 6-23 months, school-aged children 6-13 years and women 15-49 years in Mtwara and Morogoro, Tanzania.

Mtwara								
6-23 months			6-13 years			Women		
Score	Minimum	Maximum	Score	Minimum	Maximum	Score	Minimum	Maximum
0.0 – 1.0	0	0	0.0 – 1.0	0	0	0.0 – 22.5	0	0
1.5 – 3.0	0	7	1.5 – 3.0	0	7	23.0 – 54.5	0	7
3.5 – 6.0	0	14	3.5 – 6.0	0	14	55.0 – 109	0	14
6.5 – 8.0	3	14	6.5 – 8.0	3	14	109.5 – 163.5	3	14
8.5 – 12.0	7	14	8.5 – 11.0	7	14	164.0 – 218.0	7	14
N	12		N	11		N	109	
Morogoro								
6-23 months			6-13 years			Women		
Score	Minimum	Maximum	Score	Minimum	Maximum	Score	Minimum	Maximum
0.0 – 2.0	0	0	0.0 – 4.5	0	0	0.0 – 25.0	0	0
2.5 – 8.0	0	7	5.0 – 10.5	0	7	26.0 – 91.5	0	7
8.5 – 12.0	0	14	11.0 – 20.5	0	14	92.0 – 183.0	0	14
12.5 – 18.0	3	14	21.0 – 30.5	3	14	184.0 – 274.5	3	14
18.5 – 24.0	7	14	31.0 – 41.0	7	14	275.0 – 366.0	7	14
N	24		N	41		N	183	

Table S3.4 Food items of eight food groups identified on the market from 33 traders and their average prices (in TZS) per 100g edible weight across the plenty and lean seasons in Mtwara, Tanzania.

Food	Plenty (TZS)	Lean (TZS)	Yearly (TZS)
Cereals, roots, and tubers:			
Bread	40	40	40
Maize flour	161.7	118.4	141.6
Millet	--	350	350
Rice	193.9	200.5	197.4
Sorghum	--	266.7	266.7
Noodles	329.6	322.8	325.6
Wheat flour	147.9	160	152.6
Potato	115.4	133.3	119.9
Sweet potato	56.7	56.7	56.7
Average price	***149.3***	***183.2***	***183.4***
Pulses and nuts:			
Beans	217.1	182.8	195.8
Cowpeas	160	--	160
Groundnut	--	200	200
Peas	--	80	80
Average price	***188.6***	***154.3***	***158.9***
Animal source foods			
Beef	600	600	600
Offals	600	600	600
Small- dried fish	1037.5	800	956.4
Dried fish	600	500	533.3
Fish	1569.7	840	1377.7
Salted fish	400	333.3	350
Smoked fish	2090.9	2272.2	2157.72
Octopus	1200	--	1200
Egg	1135.6	1521.2	1283.9
Powdered milk	4250	2000	3500
Milk	3125	1816.7	2470.8
Average price	***1509.9***	***1128.3***	***1366.4***
Vegetables:			
Eggplant	--	100	100
Onion	301.84	91.6	238.8
Tomato	193.1	430.6	253.7
Tomato paste	158.6	809.5	437.6
Average price	***217.9***	***357.9***	***257.5***
Fruits:			
Banana	--	40	40

Baobab	307.8	600	380.9
Coconut	141.1	167.7	159.8
Lemon	--	150.6	150.6
Mango	137.6	--	137.6
Orange	--	48.1	48.1
Average	***195.5***	***201.3***	***152.8***
Sweets and Beverages:			
Biscuit	470	505.0	486.4
Chewing gum	1184.9	366.7	892.7
Cookies	818.9	818.9	818.9
Mandazi	371.7	600	463.0
Cake	285.2	285.2	285.2
Sugar	281.8	280.4	281.0
Sweets	1086.4	680	904.2
Lemon juice	133.3	177.8	160
Mango juice	214.3	197.8	209.3
Orange juice	214.9	192.7	208.1
Pineapple juice	183.2	193.3	186.8
Passion juice	164.6	160.6	163.2
Peach juice	175	--	175
Energy drink	194.3	200	195.4
Malt	233.3	150	191.7
Tea	1687.7	1478.3	1595.8
Cola (Adam)	166.7	166.7	166.7
Ginger drink	170.1	170.1	170.1
Soda	183.3	183.3	183.3
Coffee	1300	4400	3160
Average price	***475.9***	***589.8***	***544.8***
Oils and fats:			
Sunflower cooking oil	412.8	422.1	417.7
Coconut oil	652.2	652.2	652.17
Coconut milk	3333.3	3333.3	3333.3
Average price	***1466.1***	***1469.2***	***1467.7***
Spices and condiments:			
Salt	88	78.3	82.7
Garlic	1539.9	286.0	1181.7
Ginger	471.8	350	410.9
Baking powder	583.3	500	571.4
Chili sauce	179.7	169.2	171.7
Average price	***572.5***	***276.7***	***483.7***

$1 = Tsh 790.5 PPP for private consumption

Table S3.5 Food items of eight food groups identified on the market from 17 traders and their average prices (in TZS) per 100g edible weight across the plenty and lean seasons in Morogoro (n= traders), Tanzania.

Food	Plenty (TZS)	Lean (TZS)	Yearly (TZS)
Cereals, roots, and tubers:			
Bread	329.1	310.6	318.3
Maize flour	120.5	148.6	135.6
Maize	112.9	130.9	127.3
Millet	--	300	300
Rice	149.3	170	161.7
Noodles	294.4	305.2	302.1
Wheat flour	130.6	160	148.2
Potato	118.2	123.4	120.1
Sweet potato	124.5	--	124.5
Average	***172.4***	***206.1***	***193.1***
Pulses and nuts:			
Bambara groundnut	--	350	350
Beans	220.3	278.2	255.7
Cowpeas	200.4	236	230.1
Groundnut	276.4	373.3	324.9
Peas	--	303.0	303.0
Soybean	--	200	200
Average	***232.4***	***290.1***	***277.3***
Animal source foods			
Liver	803.2	800	801.6
Beef	595.2	600	597.6
Offals	398.4	400	399.2
Small- dried fish	651.7	760.9	749.7
Fish	918.4	918.4	918.4
Salted fish	1431.2	1362.5	1379.7
Shrimp	1020.4	838.6	849.9
Egg	678.9	845.7	804
Average	***812.2***	***815.8***	***812.5***
Vegetables:			
Cabbage	151.7	79.4	120.7
Chinese	128.4	--	128.4
Carrot	436.9	349.8	418.2
Cucumber	157.9	134.2	146.1
Eggplant	146.1	119.2	135.8
Green pepper	322.8	306.6	320.2
Amaranth	96.8	60.9	76.6
Cassava leaves	177.2	47.2	121.5
Pumpkin leaves	117.7	75.9	103.8

Sweet potato leaves	119.4	55.3	87.3
Okra	283.2	129.1	217.2
Onion	279.9	380.5	338.75
Pumpkin	--	79.4	79.4
Radish	123.7	--	123.7
Tomato	222.1	268.9	246.9
Tomato paste	--	161.9	161.9
Average	***197.4***	***160.6***	***176.7***
Fruits:			
Avocado	207.1	26.7	146.9
Banana	105.5	93.6	100.4
Coconut	135.2	344.5	252.9
Lemon	129.4	205.3	180
Mango	94.5	77.5	91.7
Orange	85.4	57.1	77.3
Papaya	98.5	98.3	98.4
Passion fruit	303.6	201.9	245.5
Pineapple	80.7	--	80.7
Tamarind	--	200	200
Tangerine	173.6	--	173.6
Watermelon	28	--	28
Average	***131.1***	***144.9***	***139.6***
Sweets and Beverages:			
Biscuit	524.2	426.3	458.9
Chewing gum	1250	--	1250
Mandazi	264.5	--	264.5
Sugar	248.3	264.5	270.2
Sweets	809.9	937.9	901.4
Black currant juice	138.9	--	138.9
Lemon juice	166.7	--	166.7
Mango juice	195	188.9	190.5
Orange juice	126.3	128.5	126.9
Passion juice	132.5	--	132.5
Pineapple juice	131.3	--	131.3
Cola (Adam)	142.9	--	141.9
Strawberry beverage	141.7	--	141.7
Energy drink	139.9	174.2	165.1
Malt	158.3	175	169.5
Tea	1750	3030.3	2578.4
Average price	***395.0***	***665.7***	***451.78***
Oils and fats:			
Sunflower cooking oil	412.6	331.8	362.1
Coconut milk	--	1538.5	1538.5
Average price	***412.6***	***935.2***	***950.3***
Spices and condiments:			
Baking powder	--	853.9	853.9

Chili sauce	--	163.4	163.4
Garlic	949.1	--	949.1
Ginger	492.5	400	488.8
Salt	72.7	80	78.2
Pepper	757.7	628.0	683.6
Average price	***568.0***	***425.1***	***536.2***

$1 = Tsh 790.5 PPP for private consumption

Chapter 4. Fruit and vegetable processing and consumption: knowledge, attitude, and practices among rural women in East Africa

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Author contribution

Jacob Sarfo : conceptualized the study, collected and analyzed the data and developed the manuscript.

Elke Pawelzik : reviewed the manuscript and made inputs

Gudrun B. Keding : reviewed the manuscript and made inputs

Chapter 4 Fruit and vegetable processing and consumption: knowledge, attitude, and practices among rural women in East Africa.

Abstract

High post-harvest losses of fruits and vegetables (FVs) limit their supply and availability for year-round consumption. Hence, processing innovations at their production areas could help address this constraint, which requires the need to assess people's perceptions in these areas. Therefore, this study gauged the knowledge, attitude, and practices towards FV processing and consumption and its relationship with actual FV consumption. Surveys were conducted with women in six study sites – three fruit and three vegetable production areas – in Kenya, Tanzania, and Uganda. Quantitative 24-hour dietary and 7-day FV recalls were collected across two seasons. Open and closed-ended questions were constructed to assess the women's knowledge, attitude, and practices towards FV processing and consumption. The fruit and vegetable sites included 584 and 732 women, respectively. Average fruit consumption was 4-135g/day in the plenty season and 4-106g/day in the lean season. Vegetable consumption was 112-146g/day and 84-180g/day in the plenty and lean season, respectively. There were significant consumption differences across seasons. Most women expressed high knowledge of FV processing and consumption benefits and showed a positive attitude towards FV processing and consumption. Yet, in practice, a small number of women process FVs largely due to limited processing know-how and equipment. The relationship between knowledge and attitude and FV consumption was negative or none. The high knowledge and positive attitude expressed, yet the limited processing know-how and equipment should be a basis for interventions to increase FV processing into nutritious products for better nutrition and to ensure their availability year-round.

Keywords: Africa; Knowledge, attitude and practices; Fruits and vegetables; Food processing; Women; Rural areas

4.1. Introduction

Fruits and vegetables (FVs) are excellent sources of micronutrients as well as fiber. Notable nutrients include vitamins A, C, E, iron, zinc, calcium, potassium, phosphorous, and magnesium (Slavin and Lloyd, 2012; James and Zikankuba, 2017; FAO, 2020). Consumption of FVs has been found to be associated with a reduction in cardiovascular diseases, cancers, diabetes, and obesity (WHO, 2004; Slavin and Lloyd, 2012; FAO, 2020). In 2004, inadequate consumption of FVs was number six out of 20 risk factors enabling global mortality (WHO, 2004). As current as 2019, dietary risks, including low consumption of fruits, are number three out of 10 risk factors causing global deaths (Global Burden of Disease Study, 2020). On the other hand, adequate consumption of FVs could have saved up to 7.8 million premature deaths worldwide (Aune et al., 2017). Despite the nutritional benefits of FVs for good human health, global consumption has been woefully below the WHO's recommended minimum intake of 400g/capita/day or 146 kg/capita/year (Pomerleau et al., 2004; WHO, 2004; Hall et al., 2009). From globally pooled data, 78% of the participants, mainly from low and middle-income countries, consumed below the recommended daily amount (Hall et al., 2009). In sub-Saharan Africa, including countries in East Africa, consumption of FVs is, on average, 169 g/day, which is below the recommended daily intake of 400 g/day (Ruel et al., 2005).

Low consumption of FVs has been attributed to varied reasons, including inadequate production since most of them grow under specific temperatures and humidity and at certain times of the year (Rickman et al., 2007). Compounded by limited production is the perishability of FVs lasting a few days after harvesting. Post-harvest losses in low- and middle-income countries, including Africa, are estimated to be around 50%. When FVs perish, consumption becomes undesirable and unsafe (Rickman et al., 2007; FAO, 2020). Also, nutrients are reduced or completely lost (Global Panel, 2018); for example, spinach can lose up to 27% of its folate in a spate of ten hours when stored at a room temperature of 20°C (Safefood, 2013). These post-harvest losses limit their supply and availability throughout the year for better nutrition (FAO, 2020). For this reason, the Global Panel on Agriculture and Food Systems for Nutrition (Global Panel, 2018) advocated for more innovations to process and preserve nutrient-dense foods such as FVs for better nutrition.

Various processing techniques ranging from temperature to heat treatments, including drying, freezing, boiling, and canning, have been employed to increase the shelf life of FVs (Rickman et al., 2007; Floros et al., 2010; Safefood, 2013; James and Zikankuba, 2017). Through these methods and others, quality deterioration is inhibited. Additionally, FVs can be available all year round, delivering safe and delicious food for home consumption and sale to different consumer groups (Garratt et al., 2002; Rickman et al., 2007; Floros et al., 2010; Jaenicke and Virchow, 2013). As much as there can be nutrient losses during processing, it can also be a vehicle to improve the nutritional value of food products to ensure adequate nutrition and health (Jaenicke and Virchow, 2013). Therefore, it is vital and may help to place processing innovations at the heart of food production areas, mostly in rural communities in sub-Saharan Africa, to ensure good nutrition. Especially in East Africa, where a high diversity of nutrient-rich FVs is produced, yet high malnutrition exists (Akombi et al., 2017).

Before the introduction of processing innovations for FVs, it is highly important to assess the knowledge and perceptions of rural communities towards the processing of FVs and their consumption which could inform the acceptance or otherwise of processing innovations. Thus far, such assessments are limited in the literature, particularly with reference to rural areas. Additionally, consumption data for FV to help provide policy interventions are limited (Pomerleau et al., 2004; Ruel et al., 2005). Therefore, this study seeks to fill these gaps in the literature by assessing current consumption levels of FVs and the knowledge, attitude, and practices towards FV processing and consumption. With a focus on rural women in Kenya, Tanzania, and Uganda, and combined as East Africa, this study aimed at answering the following research questions: a) what are the consumption estimates of FVs in rural East Africa? b) What is the knowledge, attitude, and practices (KAPs) towards FV processing and consumption? and c) Is there a relationship between the women's knowledge and attitude towards FV processing and consumption and their actual FV consumption? Women were selected because of their important role in shaping nutrition in households through caregiving, particularly in rural communities in Africa (Kurz and Johnson-Welch, 2001), and their vast role in the production of FVs (FAO, 2020).

This study is integrated into an overall project named "Fruits and Vegetables for all seasons" (FruVaSe). The project seeks to promote improved resource-efficient processing techniques and new market solutions for surplus fruits and vegetables for rural development in Kenya, Tanzania, and Uganda.

4.2. Materials and Methods

4.2.1. Study areas and design

The study was conducted in Kenya, Tanzania, and Uganda as they represented the countries of study under the FruVaSe project. In each country, the project selected two or three study areas to study six specific nutritious FVs that grow in the selected areas in abundance and some cases, as surplus, which partly even go to waste during their plenty season. In Kenya, Taita-Taveta and Kitui counties were chosen to study guava fruit (*Psidium guajava*) and cowpea leaves (*Vigna unguiculata*), respectively. Mtwara was selected for cashew apple (*Anacardium occidentale*) study, while Morogoro was adopted for African nightshade (*Solanum spp.*) study in Tanzania. Three districts, namely Kayunga, Jinja, and Kasese districts, were selected by the project in Uganda for the research of jackfruit (*Artocarpus heterophyllus*), cowpea leaves (*Vigna unguiculata*), and cassava leaves (*Manihot esculenta*), respectively. These study areas served as the areas for the present study except for Kasese in Uganda because of an Ebola outbreak during data collection. The study areas were grouped as “fruit sites” where the index crop was a fruit and “vegetable sites” where the index crop was a vegetable. The fruits sites consisted of Taita-Taveta, Mtwara, and Kayunga, while the vegetable sites were Kitui, Morogoro, and Jinja, as represented on the map in figure 4.1.

Purposive and simple random sampling designs were adopted to select households for the study. First, sub-areas that cultivate the FruVaSe target FVs, which are available for consumption, were purposively selected. For the fruit sites, two sub-areas were selected in Taita-Taveta and Mtwara and one in Kayunga. One sub-area was chosen in Kitui and Jinja, while two were selected in Morogoro for the vegetable sites. The selected sub-areas are described in detail elsewhere (Sarfo et al., 2021). Second, from a list of communities obtained from the respective local offices in the study areas, ten communities were randomly selected each for the six study areas. Then a comprehensive household list was put together with help from community health and nutrition workers and community leaders. Included in the list were households with a woman of reproductive age (15–49 years), excluding pregnant women, a child between 6 and 23 months, and/or a school-aged child between 6 and 13 years. Except in Morogoro in Tanzania and Kayunga in Uganda, thirty households were randomly selected per community. In Morogoro, between 21 and 47 households were chosen for each community. In Kayunga, between 20 and 49 households were selected per community, proportional to the number of households. There were two survey waves for the same women: during the first survey 300 women were sampled per study area, totaling 900 women each for the fruit and vegetable sites. The samples reduced during the second survey as some women were unavailable or had moved out. Final samples used are shown in table 4.1.

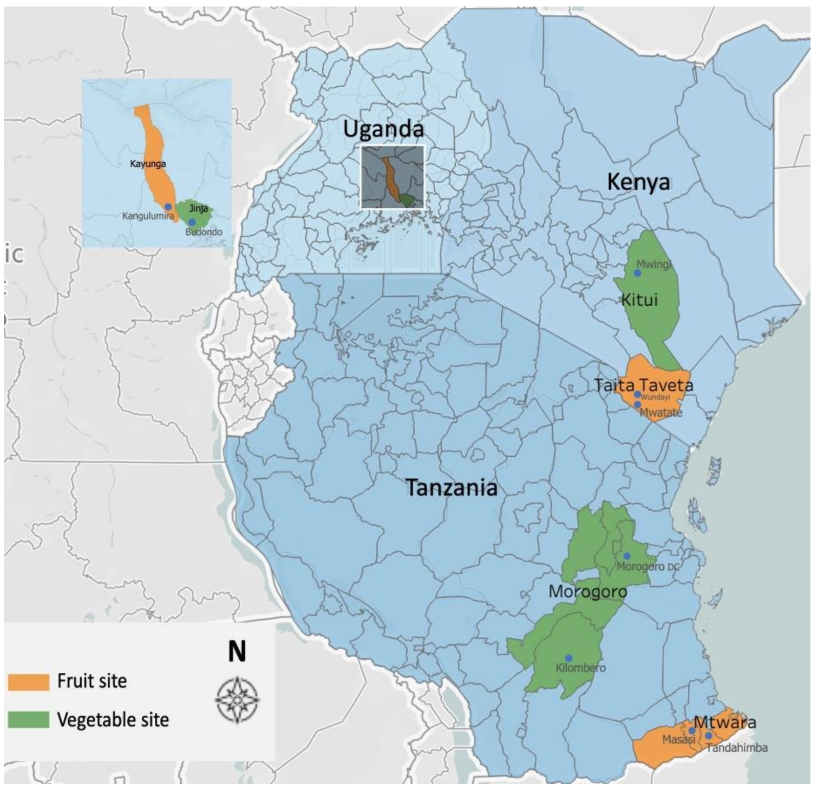

Figure 4.1 Map showing the fruit and vegetable sites selected by the FruVaSe project in Kenya, Tanzania, and Uganda. Source: drawn using DIVA-GIS (www.diva-gis.org)

4.2.2. Data collection

Data were collected across two seasons – plenty and lean seasons – of the FruVaSe target FVs. Combination of cross-sectional and longitudinal household surveys was employed to conduct face-to-face interviews with the women. During the survey, socioeconomic and demographic data including age, education (years spent schooling and level), household headship, occupation, nutrition education received, marital status, household size, FV cultivation, and wealth status (by adopting household variables such as type of building materials for house floor, wall, and roof, the availability of potable water, toilet facility, ownership of agricultural land, and livestock) were collected. However, these data were collected either during the plenty or lean season as cross-sectional surveys (Table 4.1).

Additionally, quantitative 24-hour dietary and 7-day FV recalls were carried out as longitudinal surveys. These recalls were done across the two seasons, as indicated in table 4.1. For the 24-hour dietary recall, the amounts of all foods and drinks consumed for the previous 24 hours of the day of the visit was collected. The 7-day recall assessed either all fruits (at the fruit sites) or all vegetables (at the vegetable sites) consumed, including their estimated amounts, during the past one week of the day of the visit. Standard recipes, complemented by food recipes from Kenya and Tanzania, were prepared to ascertain the food and drink, including the FV consumption quantities collected during the surveys. A comprehensive description of the methodology employed to determine consumption quantities has been published elsewhere (Sarfo et al., 2021).

A set of open and closed-ended questions were constructed to assess the KAPs of the women towards FV processing and consumption, which was carried out as cross-sectional survey. This included questions on "knowledge" centered around fresh and processed FV consumption for better nutrition and benefits associated with FV processing, of which some were Likert-scale type questions. Because either negative or positive responses were required for the Likert-scale type questions, a neutral value for "neither agree nor disagree" was not included. On "attitude," their preferences and perceptions towards fresh and processed FV as well as FV processing were gauged. Regarding "practices," current households' activities on FV processing, if any, were asked for. Some questions were also posed to those who did not engage in FV processing. Questions on fruits were asked in only the fruits sites, and those on vegetables were asked in only the vegetable sites. The questions administered on each theme are detailed in table S4.1. During the administration of the KAPs questionnaire, information on three levels of processed FVs was provided to the women to make sure that all participants understood the three levels in the same way and had the same definition in mind to help them answer some of the questions. The three levels of processed FVs introduced were as follows:

- Unprocessed FVs: FVs that have not been altered or require simple washing, cleaning and/or peeling before they are consumed. Examples given were raw fruits like banana, mango, etc., and vegetables such as tomatoes and onions added to foods for consumption.
- Minimally processed FVs: FVs that have undergone minimal processing and still have a sizeable amount of nutrient retention. Examples used were dried fruits and dried vegetables.
- Highly processed FVs: FVs that have been significantly processed with a high amount of salt, sugar, oil and/or multiple additives and potentially have poor nutrient quality, such as sugar-flavored fruit juices and vegetable sauces with high salt content.

University students/graduates with food and nutrition backgrounds were recruited and adequately trained as enumerators for data collection. For validation, the questionnaires were pre-tested in communities that were not included in the sampling. After the pre-test, the data collection tools were adjusted to ensure reliability.

Table 4.1 Survey dates and data collected in the plenty and lean seasons across the fruit and vegetable sites in East Africa.

Site	Study area	Plenty season		Lean season		N
		Survey date	Data collected	Survey date	Data collected	
Fruit sites	Kenya (Taita-Taveta)	April/May 2019	24-hour recall; 7-day fruit recall; socio-economic and demographics; KAPs	October 2019	24-hour recall; 7-day fruit recall	227
	Tanzania (Mtwara)	October/November 2019	24-hour recall; 7-day fruit recall	April/May 2019	24-hour recall; 7-day fruit recall; socio-economic and demographics; KAPs	138
	Uganda (Kayunga)	February 2020	24-hour recall; 7-day fruit recall	August 2019	24-hour recall; 7-day fruit recall; socio-economic and demographics; KAPs	219
	Kenya (Kitui)	December 2019	24-hour recall; 7-day fruit recall	June 2019	24-hour recall; 7-day vegetable recall; socio-	278

					economic and demographics; KAPs	
Vegetable sites	Tanzania (Morogoro)	June/July 2019	24-hour recall; 7-day vegetable recall; socio-economic and demographics; KAPs	January 2020	24-hour recall; 7-day fruit recall	250
	Uganda (Jinja)	February 2020	24-hour recall; 7-day fruit recall	August 2019	24-hour recall; 7-day vegetable recall; socio-economic and demographics; KAPs	204

4.2.3. Data analysis

Descriptive statistics were calculated in the form of averages for age, household size, household head (yes=1, no=0), nutrition education (yes=1, no=0), education (years spent in school), fruit or vegetable cultivation (yes=1, no=0), and dietary diversity score for women (DDS-W) – calculated following the guidelines published by FAO and FHI 360 (FAO and FHI 360, 2016). Average daily and weekly FV consumptions were computed as well. Weekly consumption amounts were computed to assess the variability in FV consumption by the women. The Kruskal-Wallis and Dunnett tests were used to test for significant differences across the study areas within the fruit and vegetable sites. The Mann-Whitney U test was adopted to test for significant differences between the two seasons for each study area and the pooled data from both sites. Percentage distributions were calculated for education level, marital status, occupation. Wealth status was measured by first scoring the responses from the women for the seven variables adopted (see data collection). The variables and the respective scores were then fed into the principal component analysis (PCA) method to calculate an index. The index scores were divided into three quantiles representing low, medium, and high wealth status, respectively. Percentage distribution was then calculated for the categories of wealth status.

Various studies have used simple score count to ascertain nutritional knowledge and attitude (Dissen et al., 2011; Halloran et al., 2018; Hill et al., 2020; Lomira et al., 2021). However, in this study, indices were constructed and adopted to encompass a set of knowledge and attitude variables. Two knowledge indices were created: one on fresh and processed FV consumption for better nutrition (including eight variables) and the other on FV processing benefits (seven variables) – and one attitude index towards fresh and processed FV consumption for better nutrition (four variables). Each variable used for determining the index was scored based on the responses received from the women. The variables and the scoring system for each index have been depicted in table 4.2. The variables and the respective scores were then fed into the PCA method to calculate the various indices. The scores obtained from the PCA method for each index were then divided into three quantiles – low/negative, fair, and high/positive and from which proportions were computed to assess the relative level of knowledge and attitude towards FV processing and consumption.

Correlation analysis between the socioeconomic and demographic variables and FV consumption was calculated to understand their relationship. Equally, the correlation method was used to gauge the relationship between the knowledge and attitude indices and FV consumption. The 7-day FV consumption was used for the analysis as they showed more variability in FV consumption than the 24-hour recall. Again, only women who consumed FV during the seven days were used. Spearman correlation (ρ) was applied to two continuous variables, the point-biserial (r_{pb}) was used for one dummy variable and one continuous variable and Kendall's rank correlation coefficient (tau) for a continuous variable and an ordinal variable (Keding et al., 2017). Statistical significance was pegged at 10%, 5%, 1% and 0.1%. Analyses were conducted separately for each study area and as pooled data for each site using R statistical tool 4.0.0. Fruit sites: Kenya [Taita-Taveta] (n=227), Tanzania [Mtwara] (n=138); Uganda [Kayunga] (n=219), East Africa [pooled data] (n=584); Vegetable sites: Kenya [Kitui] (n=278), Tanzania [Morogoro] (n=250); Uganda [Jinja] (n=204), East Africa [pooled data] (n=732).

Table 4.2 Variables and scoring system adopted to construct knowledge and attitude indices towards FV processing and consumption.

Variables	Type of questions	Scoring
Knowledge on fresh and processed FV consumption for better nutrition		
One micronutrient derived from FV intake	Open-ended	1 = correctly answered; 0= otherwise
One benefit of FV intake to the body		1 = correctly answered; 0= otherwise
Fresh FVs are good for the body	Likert-scale	1= Agree/strongly agree; 0= disagree/strongly disagree
Fresh FVs are not good for health of children under 2years (6-23 months)		1= disagree/strongly disagree; 0= Agree/strongly agree

Minimally processed FVs are not good for your body		1= disagree/strongly disagree; 0= Agree/strongly agree
Minimally processed FVs are good for children under 2years (6-23 months)		1= Agree/strongly agree; 0= disagree/strongly disagree
Highly processed FVs are not good for your body		1= Agree/strongly agree; 0= disagree/strongly disagree
Highly processed FVs are good for children below 2years (6-23 months)		1= disagree/strongly disagree; 0= Agree/strongly agree
Knowledge on FV processing benefits		
What FV processing technique do you know?	Open-ended	1 = correctly answered; 0= otherwise
Mention any product from FVs that you know		1 = correctly answered; 0= otherwise
One benefit derived from processed FVs		1 = correctly answered; 0= otherwise
Fresh FVs are not perishable	Likert-scale	1= disagree/strongly disagree; 0= Agree/strongly agree
Nutrients are lost and supply is limited when FVs perish		1= Agree/strongly agree; 0= disagree/strongly disagree
Availability of FVs year-round is not assured through processing		1= disagree/strongly disagree; 0= Agree/strongly agree
Reduction in post-harvest losses through processing/preservation		1= Agree/strongly agree; 0= disagree/strongly disagree
Attitude towards fresh and processed FVs consumption for better nutrition		
I like to eat fresh FVs	Closed-ended	1= yes; 0= no
I like to eat minimally processed FVs		1= yes; 0= no; 0.5 = not applicable/don't know
I like to eat highly processed FVs		1= no; 0= yes; 0.5 = not applicable/don't know
I am open to consuming new processed FVs		1= yes; 0= no; 0.5 = don't know/maybe

4.3. Results

4.3.1. Socioeconomic and demographic characteristics

The average age of the women at the fruit and vegetable sites was 32.8 and 32.4, respectively, with no significant difference; however, there were some significant differences across the study areas within the sites. The mean household size in the vegetable sites in East Africa was significantly higher than in the fruit sites, as shown in table 4.3, with significant differences across the study areas. Although nutrition education was low across sites, the number of women who had received nutrition education during the past six months was higher at the fruit site than at the vegetable site. More than 60% of the women were farmers in both sites, with the majority of them engaged in FV production. The highest education level for most is the primary school, which culminates to roughly 7 years in school, but there are significant differences across the study areas and sites. Again, table 4.3 shows that the average DDS-W obtained for all the study areas did not meet the recommended minimum level of five. Overall, a relatively large proportion of the women lived in households classified as having high wealth.

Table 4.3 Socio-economic and demographic statistics of women in the fruit and vegetable sites of Kenya, Tanzania, Uganda, and East Africa.

	Fruit sites				Vegetable sites			
Variables	Kenya (Taita-Taveta)	Tanzania (Mtwara)	Uganda (Kayunga)	East Africa (Pooled data)	Kenya (Kitui)	Tanzania (Morogoro)	Uganda (Jinja)	East Africa (Pooled data)
Age of participants (years)	33.81	33.07	31.69*^{KU}	32.84	34.04*^{KT}	32.10	30.84***^{KU}	32.41
	(8.59)	(9.33)	(8.53)	(8.78)	(7.86)	(8.91)	(8.25)	(8.40)
Household size	4.80**^{KT}	4.13***^{TU}	6.67***^{KU}	5.34	5.59**^{KT}	5.02***^{TU}	6.19*^{KU}	5.64**
	(1.76)	(1.62)	(3.13)	(2.57)	(2.31)	(2.22)	(2.42)	(2.37)
Household head (yes =1, no = 0)	0.22	0.24	0.19	0.22	0.24	0.18	0.14**^{KU}	0.19
	(0.42)	(0.43)	(0.39)	(0.41)	(0.43)	(0.38)	(0.34)	(0.39)
Nutrition education received during the past 6 months (yes = 1, no = 0)	0.26***^{KT}	0.01^{+TU}	0.09***^{KU}	0.14*	0.08	0.11	0.09	0.09
	(0.44)	(0.09)	(0.29)	(0.34)	(0.28)	(0.32)	(0.29)	(0.29)
Fruit/Vegetable cultivation (yes = 1, no= 0)	0.94**^{KT}	0.85	0.91	0.91*	0.98***^{KT}	0.81	0.78***^{KU}	0.87
	(0.23)	(0.36)	(0.28)	(0.29)	(0.13)	(0.39)	(0.41)	(0.34)
Dietary Diversity Score								
Plenty season	4.12***^{KT}	3.36***^{TU}	3.83**^{KU}	3.83	4.07***^{KT}	3.36***^{TU}	3.77***^{KU}	3.77
	(1.06)	(1.07)	(1.23)	(1.16)	(0.81)	(0.94)	(1.14)	(1.01)
Range (Min – Max)	(1 – 7)	(1 – 6)	(1 – 8)	(1 – 8)	(2 – 6)	(1 – 6)	(1 – 8)	(1 – 8)
Lean season	3.81***^{KT}	2.98**^{TU}	3.43***^{KU}	3.47	3.66	3.84*^{TU}	3.67	3.72***
	(1.06)	(1.16)	(1.07)	(1.13)	(0.97)	(0.99)	(1.07)	(1.01)
Range (Min – Max)	(1 – 6)	(1 – 7)	(1 – 7)	(1 – 7)	(1 – 6)	(1 – 7)	(2 – 8)	(1 – 8)
Years spent in school	9.52***^{KT}	6.78	6.95***^{KU}	7.91***	7.53***^{KT}	6.52*^{TU}	7.24^{+KU}	7.15
	(2.67)	(1.75)	(3.73)	(3.22)	(3.18)	(2.87)	(3.68)	(3.30)
Educational level (%)								
None	0.88	5.07	8.22	4.62	6.47	11.76	10.00	9.15
Primary	61.23	90.58	59.82	67.64	74.46	71.57	51.20	65.71
Secondary	29.96	4.35	26.94	22.77	14.39	15.69	36.80	22.40
Tertiary	7.93	0.00	5.02	4.97	4.68	0.98	2.00	2.73

Marital status (%)								
Married	70.48	76.81	67.12	70.72	80.58	73.53	83.60	79.64
Widowed or divorced or single	29.52	23.19	32.88	29.28	19.42	26.47	16.40	20.36
Main occupation (%)								
None	32.16	1.45	13.70	17.98	3.24	11.76	18.40	10.79
Farmer	40.97	95.65	68.95	64.38	78.06	59.80	58.00	66.12
Trader	14.98	2.17	4.57	8.05	9.71	18.63	12.00	12.84
Other (vocational skills, civil servant, teacher)	11.89	0.72	12.79	9.59	8.99	9.80	11.60	10.25
Wealth status (%)								
Low	12.33	23.19	27.40	21.06	37.41	4.41	28.80	32.79
Medium	31.28	32.61	32.88	30.99	34.53	22.06	34.80	30.74
High	56.39	44.20	39.73	47.95	28.06	73.53	36.40	36.48
N	227	138	219	584	278	250	204	732

Standard deviations are in parentheses. Significant differences across the countries within each site were tested using the Kruskal-Wallis and Dunnett tests. [KT]: significant difference between Kenya and Tanzania; [KU]: significant difference between Kenya and Uganda; [TU]: significant difference between Tanzania and Uganda. The Mann-Whitney U test was used to test for significant differences between the pooled data for the two sites. +, *, **,*** represent statistical significance of $p < 0.1$, $p < 0.05$, $p < 0.01$, $p < 0.001$

4.3.2. Fruit and vegetable production

Aside from the FruVaSe FVs which were cultivated in the respective study areas except in Morogoro, where unexpectedly only a small number of women (8%) cultivated African nightshade, other FVs were produced by the women. In the fruit sites, commonly produced fruits were avocado (55%), mango (41%), papaya (38%), passion fruit (24%), and orange (23%). For vegetables, amaranth leaves (50%), sweet potato leaves (33%), pumpkin leaves (33%), eggplant (29%), and leafy kale (28%) were widely cultivated at the vegetable sites (Table S4.2). However, there were slight differences across the study areas, as depicted in table S4.2.

4.3.3. 24-hour fruit and vegetable consumption

Fruit sites

In the plenty season, only 34% of the women consumed fruits during the last day at the fruit sites. During the lean period, the number of women who consumed fruits dropped to 12%. This contrasts with the high percentage (>90%) of women who consumed vegetables across the two seasons (Table S4.3). In table 4.4, which shows the average amount of FV consumption, fruit consumption was between 27-135g/day in the plenty season, while consumption was between 3-45g/day in the lean season. There were significant differences across the study areas in both seasons, with Uganda having the highest consumption amount. Across seasons, there were significant differences with higher consumption quantities in the plenty season. The amount of vegetable consumption was between 112-145g/day and 84-137g/day in the plenty and lean seasons, respectively, with some significant differences across study areas and seasons but not as stark as fruit consumption showed. The percentage of women who consumed FVs according to the recommended food intake (RFI) of 200g/day for either fruit or vegetable (400g/day in total) was low, as depicted in table S4.4. Only 17.8% of the women consumed the recommended amount of fruits and 18.8% the recommended amount of vegetables in the plenty season, with differences across the study areas. For both FV, 13% met the recommended consumption amount of 400g/day. In the lean season, the percentage remained unchanged for vegetable consumption; however, the rate dropped to 4% for recommended fruit consumption and 5% for both FV consumption.

Vegetable sites

For the vegetable sites, vegetable consumption on the previous day was by more than 95% of the women in both seasons. In comparison, only 15% of the women consumed fruits in the plenty season, slightly increasing during the lean season. Average vegetable consumption in the plenty season was estimated between 122-146g/day. The lean season was between 88-180g/day. Consumptions were surprisingly significantly higher in the lean season than in the plenty season in the study areas except Kenya. In both seasons, consumptions in Uganda were the highest. Fruit consumption at the vegetable site was between 4-92g/day in the plenty season and 4-106g/day in the lean season, with significantly higher consumption amounts in Tanzania and Uganda (Table 4.4). More women (21%) – as compared with the fruit sites – consumed the recommended vegetable amount in the plenty season; however, recommended fruit consumption was met by only 8%. Only 9% of the women achieved the recommended 400g/day for FV consumption. No stark differences were observed in the lean season. Detailed study area specifics are presented in table S4.4.

At both sites, almost all the fruits consumed were unprocessed, and the vegetables consumed were minimally processed namely through cooking/boiling for direct consumption.

4.3.4. 7-day fruit and vegetable consumption

Fruit sites

At the fruit sites, where only fruit consumption recall was performed, there were significant differences across seasons and study areas. Average fruit consumption during the 7-day period was higher in the plenty season than in the lean season across study areas. Also, consumption in Kenya was significantly the lowest across seasons (Table 4.4). Additionally, a higher percentage (>60%) of the women consumed fruits 4 – 7 times a week in the plenty season than in the lean season, where only 18% consumed fruits of that frequency. Commonly consumed fruits across the study areas were avocado, banana, mango, orange, pineapple, papaya, and the FruVaSe fruits (Table S4.5). These fruits were also cultivated by most of the women, as already discussed above and shown in table S4.2.

Vegetable sites

Unlike the fruit sites, vegetable consumptions at the vegetable sites were significantly higher in the lean season. There were also significant differences across the study areas, with Tanzania and Uganda obtaining high consumption amounts. There were no vast differences in the percentage of women who consumed vegetables 4 – 7 times a week across the two seasons. The widely consumed vegetables (Table 4.5) included onion, tomato, cabbage, amaranth, eggplant, and cowpea leaves and were largely connected to the kind of vegetables produced. As documented in the 24-hour recall, almost all fruits consumed were unprocessed, and the vegetables consumed were minimally processed, which meant cooking/boiling for direct consumption.

Table 4.4 Consumption of fruits and vegetables during a 24-hour and one-week period for women across two seasons in the fruit and vegetable sites of Kenya, Tanzania, Uganda, and East Africa.

	Fruit sites				Vegetable sites			
Variables	Kenya (Taita-Taveta)	Tanzania (Mtwara)	Uganda (Kayunga)	East Africa (Pooled data)	Kenya (Kitui)	Tanzania (Morogoro)	Uganda (Jinja)	East Africa (Pooled data)
24-hour fruit and vegetable consumption (mean in grams)								
<u>Fruit</u>:								
Plenty season	27.34***^{KT} (83.55)	88.15**^{TU} (155.96)	134.69***^{KU} (193.85)	81.96*** (157.13)	3.55+^{KT} (31.44)	27.85***^{TU} (126.26)	92.91***^{KU} (177.06)	40.84 (130.32)
Lean season	4.91 (26.39)	2.98***^{TU} (28.33)	45.26***^{KU} (101.87)	19.58 (68.81)	3.78***^{KT} (23.76)	106.13***^{TU} (232.56)	33.76***^{KU} (108.06)	42.54* (144.70)
Significance between seasons	***	***	***	***		***	***	
<u>Vegetable</u>:								
Plenty season	145.34***^{KT} (95.35)	112.14 (124.96)	113.30***^{KU} (102.13)	125.48 (106.51)	128.49 (105.33)	121.83+^{TU} (90.68)	145.72+^{KU} (109.93)	132.50+ (103.45)
Lean season	132.72***^{KT} (102.09)	84.43***^{TU} (84.33)	136.94 (123.64)	122.89 (109.04)	88.37***^{KT} (86.94)	160.40 (119.35)	180.10***^{KU} (150.24)	139.8+ (127.24)
Significance between seasons	+	*	+		***	**	+	
<u>Fruit and vegetable</u>:								
Plenty season	172.67 (122.28)	200.29**^{TU} (224.14)	248.00*^{KU} (217.11)	207.40*** (190.60)	132.03 (108.69)	149.70***^{TU} (175.10)	238.62***^{KU} (210.87)	173.40 (174.36)
Lean season	137.63***^{KT} (103.78)	87.41***^{TU} (91.15)	182.20 (160.49)	142.48 (130.69)	92.13***^{KT} (91.47)	266.50 (269.24)	213.89***^{KU} (179.62)	182.30** (199.26)
Significance between seasons	**	***	**	***	***	***		

7-day fruit/vegetable consumption (mean in grams)								
Fruit:								
Plenty season:	879.80***^{KT} (849.15)	2004.00 (1454.35)	1672.60***^{KU} (1355.80)	1443.00 (1296.83)				
Lean season	251.80 (225.72)	287.50***^{TU} (416.85)	547.60***^{KU} (571.19)	371.20 (448.86)				
Significance between seasons	***	***	***	***				
Vegetable:								
Plenty season:					566.50***^{KT} (549.77)	1062.60 (966.64)	853.40***^{KU} (649.86)	802.80 (747.54)
Lean season					1128.20***^{KT} (901.68)	1913.10***^{TU} (1425.39)	1005.90 (899.85)	1305.20 (1137.46)
Significance between seasons					***	***		***
N	227	138	219	584	278	250	204	732

Standard deviations are in parentheses. Significant differences across the countries within each site were tested using the Kruskal-Wallis and Dunnett tests. ^{KT}: significant difference between Kenya and Tanzania; ^{KU}: significant difference between Kenya and Uganda; ^{TU}: significant difference between Tanzania and Uganda. The Mann-Whitney U test was used to test for significant differences between the pooled data for the two sites and between the seasons. +, *, **,*** represent statistical significance of $p < 0.1$, $p < 0.05$, $p < 0.01$, $p < 0.001$.

Table 4.5 Frequency of fruit and vegetable consumption per week for women across two seasons in the fruit and vegetable sites of Kenya, Tanzania, Uganda, and East Africa.

	Fruit sites				Vegetable sites			
Frequency of fruit/vegetable per week	Kenya (Taita-Taveta)	Tanzania (Mtwara)	Uganda (Kayunga)	East Africa (Pooled data)	Kenya (Kitui)	Tanzania (Morogoro)	Uganda (Jinja)	East Africa (Pooled data)
Plenty season (%):								
0 – once	4.4	3.7	6.4	7.7	2.9	7.4	6.4	5.4
2 – 3 times	18.5	21.0	33.8	24.8	15.1	33.4	19.6	21.2
4 – 5 times	9.2	26.8	24.2	19.0	20.1	24.5	21.6	21.8
6 – 7 times	67.9	41.3	35.6	48.5	61.9	36.7	52.4	51.6
Commonly consumed fruit/vegetable in plenty season (in %):	Avocado: 76.2 Guava: 66.5 Banana: 52.0	Mango: 84.8 Cashew apple: 35.5 Papaya: 10.1	Jackfruit: 83.6 Pineapple: 65.3 Avocado:50.7	Avocado: 48.6 Jackfruit: 31.9 Banana: 30.8	Onion: 88.1 Cowpea leaves: 79.5 Tomato:65.1 Cabbage: 21.6 Kales: 15.1	Sweet potato leaves: 78.9 Cassava leaves: 52.9 Pumpkin leaves: 52.9 Tomato: 52.5 Cowpea leaves: 39.7	Amaranth: 77.2 Tomato: 58.8 Onion: 56.4 Eggplant: 50.4 Kales:34.0	Tomato: 59.4 Onion: 57.2 Cowpea leaves: 51.1 Amaranth: 38.8 Eggplant: 25.8
Lean season (%):								
0 – once	46.3	55.8	37.4	45.4	5.4	3.9	10.0	6.5
2 – 3 times	37.5	25.4	44.3	37.0	13.0	27.4	40.8	26.5
4 – 5 times	9.7	7.3	8.2	8.5	15.9	20.1	14.4	16.5
6 – 7 times	6.5	11.5	10.1	9.1	65.7	48.6	34.8	50.5
Commonly consumed fruit/vegetable in lean season (in %):	Banana: 50.7 Avocado: 13.3 Papaya: 12.8	Orange: 39.1 Banana: 21.0 Papaya: 5.8	Jackfruit: 54.8 Papaya: 32.0 Pineapple: 31.5	Banana: 29.6 Jackfruit:20.7 Orange: 19.2	Tomato: 88.1 Onion: 84.5 Cabbage: 66.9 Kales: 42.5 Cowpea leaves: 39.6	Pumpkin leaves: 73.7 Sweet potato leaves: 59.3 Cassava leaves: 58.8 Amaranth: 56.9 Tomato: 52.9	Amaranth: 74.8 Eggplant: 48.4 Kales: 32.8 Tomato: 31.6 Cabbage: 28.8	Tomato: 59.0 Onion: 49.5 Amaranth: 42.4 Cabbage: 37.8 Cowpea leaves: 29.6
N	227	138	219	584	278	250	204	732

4.3.5. Knowledge on fresh and processed fruit and vegetable consumption for better nutrition and fruit and vegetable processing benefits

The responses given by the women – pooled data of the study areas and represented in figure 4.2 – showed a generally high knowledge level on FV consumption, both fresh and processed, for better nutrition at both fruit and vegetable sites. A large proportion of the women agreed/strongly agreed that fresh fruit or vegetable consumption was good for their bodies and equally for their children between 6-23 months old. They also identified that minimally processed fruits or vegetables are good for better nutrition while highly processed fruits or vegetables have adverse effects on the body. More than 65% of the women disagreed/strongly disagreed that minimally processed fruits or vegetables are not good for the body, while more than 55% agreed/strongly agreed that highly processed fruits or vegetables are not good for the body (Figure 4.2). The knowledge index on FV consumption showed that indeed a high proportion of the women exhibited high knowledge in that regard relative to other households within this study – 56% and 44% for the fruit and vegetable sites, respectively (Figure 4.3).

Regarding the responses on benefits of FV processing, the women also demonstrated high knowledge. For instance, as shown in figure 4.2, more than 85% of the women agreed/strongly agreed that post-harvest losses for fruits or vegetables can be reduced through processing. Other responses are detailed in figure 4.2. The proportion of the women who showed a fair to high knowledge on FV processing benefits compared to other study households was estimated at 50% for the fruit sites and 52% for the vegetable sites (Figure 4.3).

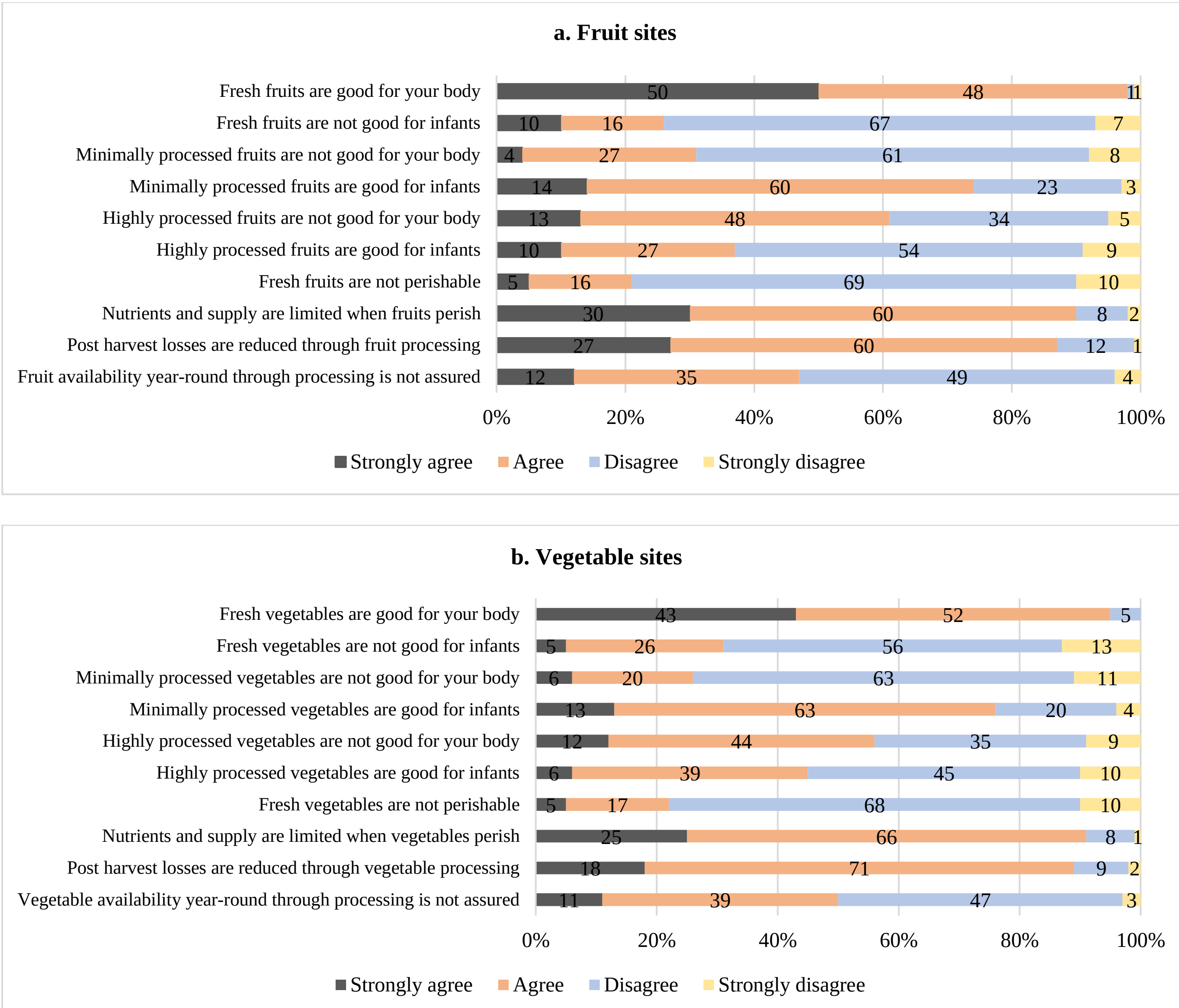

Figure 4.2 Knowledge of the women on the benefits of fruit and vegetable processing and consumption for better nutrition at the (a) fruit (n= 584) and (b) vegetable sites (n=732) in East Africa

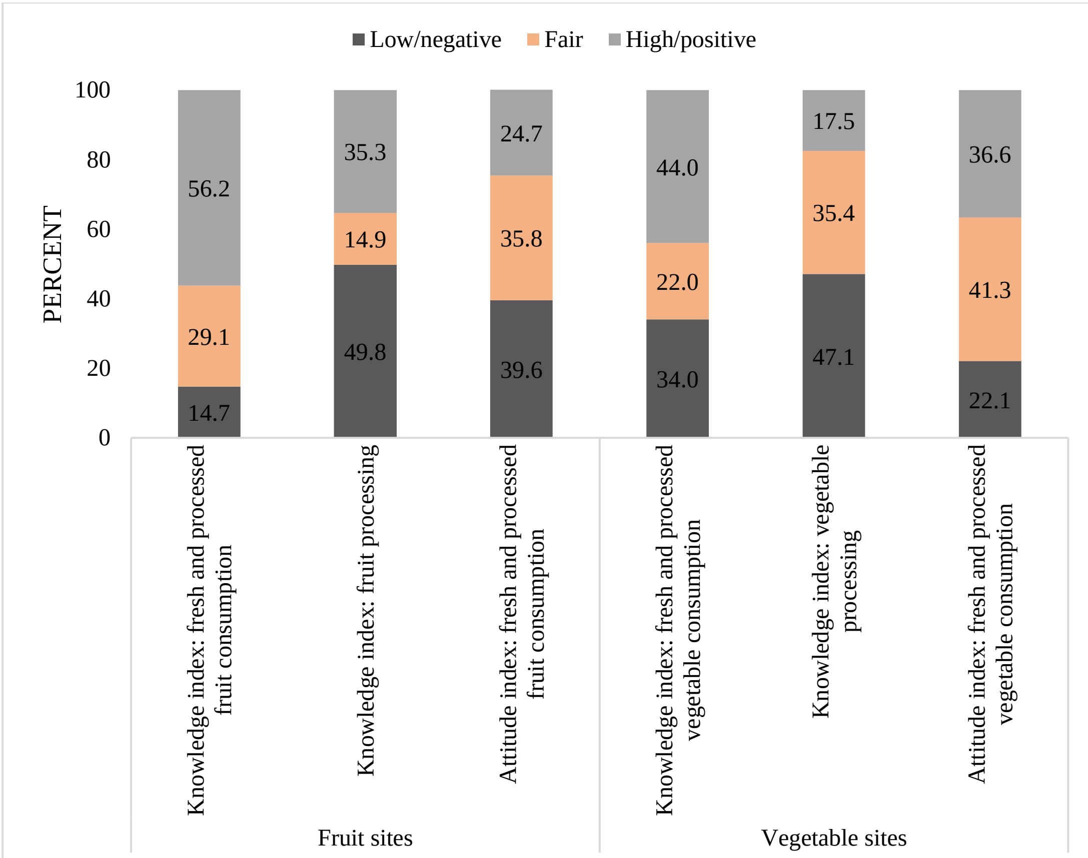

Figure 4.3 Percentage of knowledge and attitude indices attained by the women towards fruit and vegetable processing and consumption for better nutrition at the fruit (n= 584) and vegetable sites (n=732) in East Africa.

4.3.6. Attitude towards fresh and processed fruit and vegetable consumption for better nutrition

The attitude of the women towards fresh and processed FV consumption was in general positive (Figure 4.4). More than 60% of the women stated that they would like to eat minimally processed fruits or vegetables, while more than 50% declared to not like consumption of highly processed fruits or vegetables. Most women indicated that they were open to accepting and consuming newly processed fruit or vegetable products developed by the FruVaSe project, which includes dried fruits, fruit juice and dried vegetables. Additionally, a greater proportion (>90 %) of the women showed interest in being trained on FV processing techniques or methods (Figure 4.4). The attitude index constructed and shown in figure 4.3 indicated that more than 60% of the women showed a fair to positive attitude towards fresh and processed FV consumption for better nutrition.

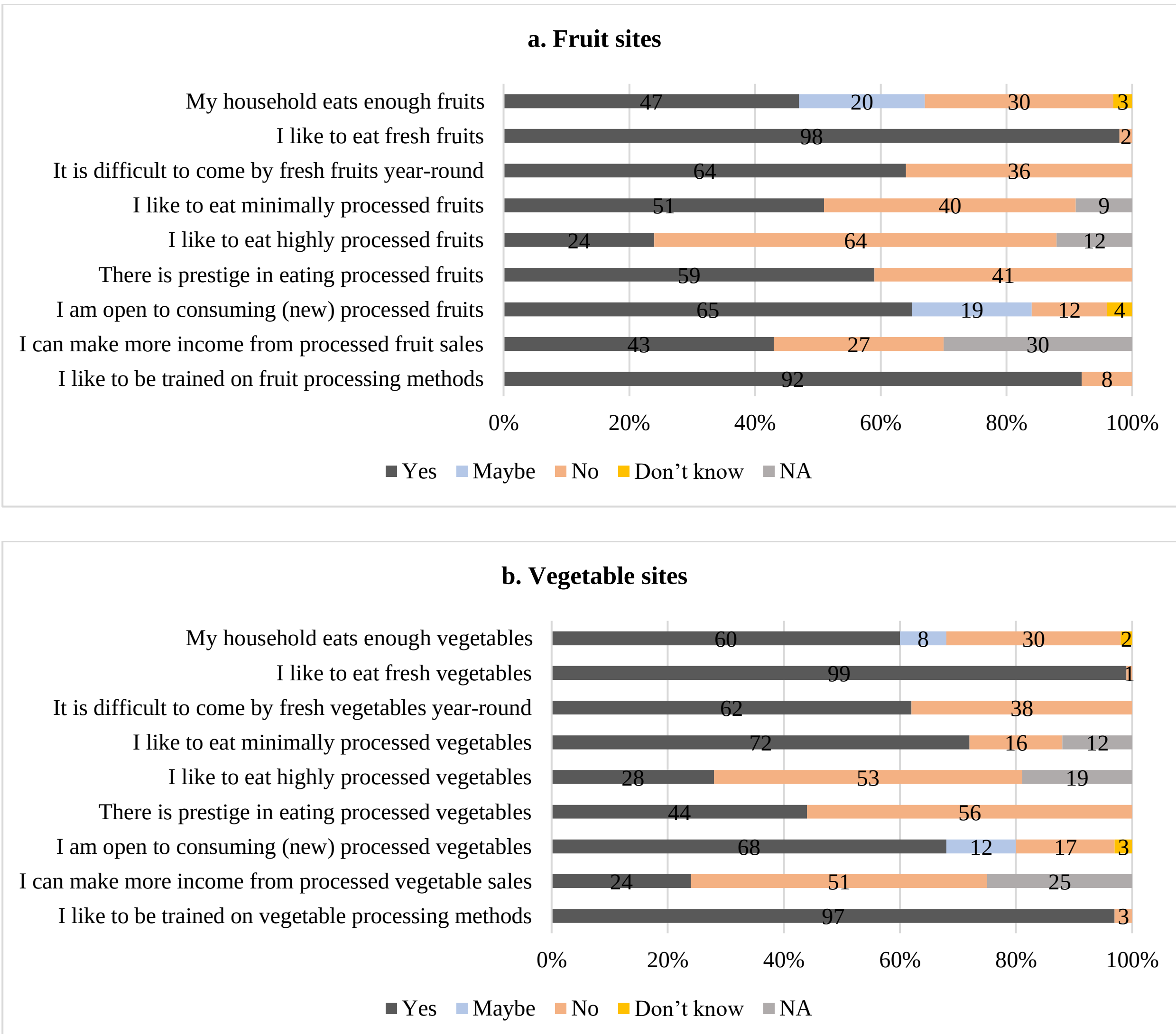

Figure 4.4 Attitude of the women towards fruit and vegetable processing and consumption for better nutrition at the (a) fruit (n= 584) and (b) vegetable sites (n=732) in East Africa.

4.3.7. Practices regarding fruit and vegetable processing

A small number of women were involved in the processing of FVs. Overall, only 13 women at the fruit sites and 95 women at the vegetable sites processed their FVs. Some FVs that were processed included guava, cashew apple, avocado, cowpea leaves, African nightshade, sweet potato leaves, cassava leaves, and others, as shown in table 4.6. Almost all the women who processed FVs heavily relied on the traditional drying method. For fruit processing, they justified the choice of this method as either the best technique, or readily available to them, or the cheapest option. The reasons provided for vegetable processing were because of its simplicity and being the cheapest (Table 4.6). Averagely, according to the information from the women, their processed fruits lasted for 5 months, while the processed vegetables lasted for 2 months. The chunk of the women who did not process their FVs largely attributed that to the lack of or limited technical knowledge of processing and processing equipment – 72% and 48% of the women indicated so at the fruit and vegetable sites, respectively (Figure 4.5).

Table 4.6 Fruit and vegetable processing practices performed by the women in the fruit and vegetable sites in East Africa.

Sites	Fruit sites	N	Vegetable sites	N
Fruits/vegetables processed	Guava	1	Cowpea leaves	75
	Cashew apple	7	African nightshade	11
	Avocado	2	Amaranth	1
	Banana	1	Sweet potato leaves	11
	Orange	1	Cassava leaves	6
	Pawpaw	1	Mushroom	1
	Passion fruit	1	Pumpkin leaves	5
	Pineapple	1	Kale	1
			Spinach	1
			Tomato	1
			Eggplant	2
Processing techniques adopted	Drying	13	Drying	94
	Fermentation	2	Fermentation	3
	Freezing	1	Glass/can preservation	2
	Juicing	2	Freezing	3
Reasons for preferred processing technique	Simple	1	Simple	47
	Cheapest	4	Cheapest	28
	Readily available	4	Readily available	16
	Best method	4	Best method	5
	No reason	0	No reason	1
Processing frequency/month	Once	3	Once	34
	Twice	2	Twice	48
	Thrice	0	Thrice	8
	More than thrice	8	More than thrice	6
Average shelf-life (months)	5.2		2.1	
N		13		95

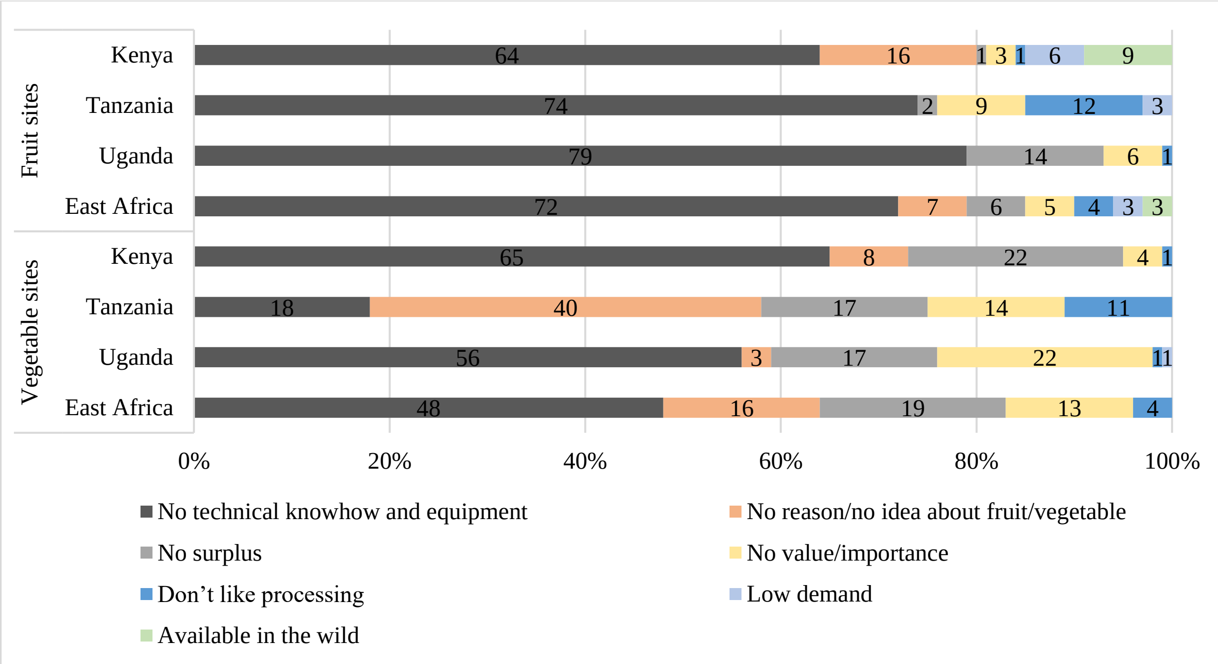

Figure 4.5 Reasons attributed by the women for non-processing of fruit and vegetables in the fruit sites of Kenya (n= 222), Tanzania (n= 131), Uganda (n= 218), and East Africa (n= 571) and the vegetable sites of Kenya (n= 242), Tanzania (n= 176), Uganda (n= 219), and East Africa (n= 637).

4.3.8. Correlations between socioeconomic and demographics, knowledge and attitude indices and g/week consumption of fruits or vegetables.

The correlation results presented in table 4.7 showed that at the fruit sites, in the plenty season, household size and fruit cultivation slightly positively correlated with weekly fruit consumption (r_{pb} =0.08; r_{pb} =0.09, respectively). On the other hand, there were negative correlations between weekly fruit consumption and nutrition education (r_{pb} = -0.17), education (ρ = -0.25) and wealth (ρ = -0.10). The knowledge index on fresh and processed FV consumption correlated negatively with weekly fruit consumption, although weak (ρ = -0.08). No significant relationship was detected for the attitude index. During the lean season, no significant correlations were found, including the indices, except for age, where the correlation was negative.

For the vegetable sites, there were positive correlations between household size (ρ = 0.07) and being married (r_{pb} = 0.06) and weekly vegetable consumption in the plenty season. Negative correlations existed between vegetable cultivation (r_{pb} = -0.07) and education (ρ = -0.08) and weekly vegetable consumption. While no relationship was identified for the knowledge index, the attitude index was slightly negatively correlated (ρ = -0.09). Women from households with higher wealth consumed more vegetables in the lean season, as depicted by the positive relationship between the two variables. There was no association between the indices and weekly vegetable consumption in the lean season (Table 4.7).

Table 4.7 Correlation between socioeconomic and demographics, knowledge and attitude indices and g/week consumption of fruits or vegetables among rural women in East Africa

Socio-economic and demographics/KAPs	Fruit sites		Vegetable sites	
	Plenty season	Lean season	Plenty season	Lean season
Age	0.05	-0.08^{+}	-0.01	-0.05
Household size	0.08^{+}	0.03	0.07*	-0.09*
Household head (yes =1, no = 0)	0.03	-0.06	-0.05	-0.07^{+}
Nutrition education (yes = 1, no = 0)	-0.17***	-0.05	0.01	-0.02
Fruit/Vegetable cultivation (yes = 1, no= 0)	0.09*	0.03	-0.07^{+}	-0.06
Dietary Diversity Score (DDS)	-0.01	0.03	0.01	0.06*
Education (years spent schooling)	-0.25***	0.03	-0.08*	0.02
Marital status (Married = 1, Widowed or divorced or single = 0)	-0.06	-0.04	0.06^{+}	-0.01
Wealth index	-0.10*	0.01	-0.03	0.14***
Knowledge index: fresh and processed FV consumption	-0.27***	-0.07	0.03	-0.04
Attitude index: fresh and processed FV consumption	-0.06	0.07	-0.09*	-0.03
N	570	454	721	719

Spearman correlation method was used for age, wealth index, household size, education, knowledge index (FV processing and consumption for better nutrition), and attitude index (towards FV processing and consumption for better nutrition) and the weekly FV consumption. Point-biserial method was used for household head, marital status, nutrition education, fruit/vegetable cultivation, and the weekly FV consumption. The Kendall's rank-correlation method was applied between the DDS and the weekly FV consumption. +,*,**,***, represent statistical significance of $p < 0.1$, $p < 0.05$, $p < 0.01$, $p < 0.001$, respectively.

4.4. Discussion

4.4.1. Fruit and vegetable consumption

In this study, the kind of FVs cultivated by the women was essentially the same FVs that they consumed, as shown by the 7-day recall. The FVs cultivated by women in East Africa have also been well documented by other studies, including Wakholi et al. (2015) and Keding et al. (2017). Despite the abundance of FV cultivation in East Africa, consumption remains low, as evidenced in this study. The proportion of women that achieved the recommended consumption levels of 200g/day for either fruit or vegetable and 400g/day for both FVs was low across sites. Equally, average consumption amounts were below recommended levels. However, this is not surprising as many studies that have gauged the consumption of FVs in Africa have documented this phenomenon well. In 2005, Ruel et al. (2005) showed that most countries in Africa, including those in this study, significantly consumed low quantities of FVs. Relatively recent findings established that inadequate consumption of FV is still prominent: 95% of the sampled population in Kenya did not consume adequate FVs (Keding et al., 2017), about 82% of study participants in southern Tanzania also had inadequate FV intake (Msambichaka et al., 2018), and as early as 2019, in a country-wide study in Uganda, only 12% had adequate intake of FV (Kabwama et al., 2019). These findings, coupled with that from the present study, indicate that there seemed not to have been concrete interventions in East Africa over the years to address insufficient consumption of FV. Average consumption amounts from the 7-day recall indicated that there might be days where recommended consumption levels were met, particularly for the fruit sites in the plenty season except in Kenya. This shows that there could be variabilities in consumption that a single 24-hour dietary recall may not reveal.

Additionally, there were significant seasonal differences in FV consumption which affirm the arguments by Rickman et al. (2007) and FAO (2020) that seasonality is a significant factor for FV consumption. For instance, using the 7-day recall, which shows more variability in consumption, fruit consumption was higher in the plenty season while vegetable consumption was higher in the lean season. However, it would have been expected that vegetable consumption during the plenty season would be higher. This was because the two seasons used were the seasonality periods of the selected FruVaSe vegetables, and these seasonality periods did not correspond to that of other vegetables. Indeed, the results showed that different vegetables were consumed during the lean periods of the FruVaSe vegetables. In contrast, the seasonality periods of the selected FruVaSe fruits were in line with other fruits available for consumption. This implies that while vegetable harvest and consequently fresh produce seems to be more equally distributed across the seasons, fruits in the study areas were only available during certain periods with no fresh produce at hand during off-season. This could be countered by applying “fruit tree portfolios” that suggest different varieties of local fruit tree species on one farm or in one area to ensure year-round harvest (McMullin et al., 2019).

The type of FVs that are consumed also matters. Consumption of dark green leafy vegetables and vitamin A-rich fruits are essential to provide the required micronutrient needs (FAO and FHI 360, 2016). Of the fruits consumed by the women in this study, only two falls under the vitamin-A-rich category. Similarly, only two vegetables can be classified as dark-green leafy vegetables per site except in Tanzania. This underscores the need to accelerate efforts that would draw much attention to consuming these categories of FVs to a greater extent and also in a greater variety. Generally, the consumption of FVs at both sites in Kenya was the lowest relative to Tanzania and Uganda. This could stem from the fact that more FVs were found in Tanzania (20) and Uganda (25) as compared to Kenya (15) for consumption. The less FV available for consumption in Kenya could lead to women consuming less nutrient-dense foods. Therefore, it is no surprise that an earlier study (Sarfo et al., 2021) found high malnutrition rates, especially in the form of overweight and obesity among rural women in Kenya.

4.4.2. Fruit and vegetable processing

The cultivation of more fruit trees and even promoting and domesticating nutritious wild FVs to ensure increased FV consumption and address seasonality issues have been suggested (Keding et al., 2017; McMullin et al., 2019; Sarfo et al., 2020). However, high perishability levels and post-harvest losses of fresh FVs (Rickman et al., 2007; Wakholi et al., 2015; FAO, 2020) may still hinder their continuous availability year-round for consumption. Hence, extending shelf life and reducing post-harvest losses is key to realizing FV availability and ensuring food security (Wakholi et al., 2015). Processing of FVs promotes seasonal availability and varied products for consumers (Floros et al., 2010; Keding et al., 2017). However, FV processing was low in this study, largely due to a lack of or limited processing know-how and equipment. The same reason was attributed to the non-processing of guava in Kenya (Omayio et al., 2020). This huge constraint could be attributed to the fact that over the years, funding for post-harvest techniques of horticultural products has been inadequate – only 5% of the funds for horticultural promotion (Wakholi et al., 2015). It probably could be an integral reason as to why FVs produced in East Africa are largely consumed unprocessed with little quantities processed for consumption (Wakholi et al., 2015) and as also confirmed by the results of this study where almost all fruits consumed were unprocessed, and vegetables consumed were minimally processed through cooking/boiling for direct consumption.

The few women that processed FVs did so through drying. It is assumed that most women still rely on the traditional sun-drying method as processing at the household level in rural areas is mainly through this drying technique (Ibeanu et al., 2011). For instance, cowpea leaves – which are also largely processed by the women in this study – were sun-dried by most households in Kitui and Taita-Taveta (Owade et al., 2021). Owade et al. (2020) expressed that the sun-drying technique is feasible and economical for most households. Most women in this study justified the same reasons for opting for this technique for processing FVs. The shelf-life periods as reported by the women for their processed FVs appeared to be below that of carefully processed FVs. Within the FruVaSe project, carefully solar-dried cashew apple and African nightshade lasted for 6 months (Tepe et al., 2021); compared to, for instance, processed leafy vegetables, which lasted around 2 months, as reported by the women. This highlights the need to extend modern processing technologies – such as solar drying methods, which can ensure much nutrient retention and are also an inexpensive method (Dimoso et al., 2020) – to households for them to not only have a longer shelf-life for their products but produce products that are nutritionally adequate and safe. This is especially important in light of the fact that the majority of the women expressed interest in being trained on new processing techniques. Also, these women can realize additional incomes through FV processing, as affirmed by some of them. However, safe and sustainable packaging of FV products is a challenge in the study areas and local solutions are required (Chen et al., 2021).

4.4.3. Knowledge and attitude towards fruit and vegetable processing and consumption

The level of knowledge expressed by the women at both the fruit and vegetable sites showed that they know the benefits of unprocessed and minimally processed FVs consumption. They responded that both types of FVs are good for their bodies and their infant children. Attitudinally, the women also expressed their likeness to consuming both unprocessed and minimally processed FVs. In a study in Kenya by Keding et al. (2017), almost all the women interviewed also correctly indicated the health benefits of fruit consumption for them and their children as well as their likeness for fruits. For health benefits of minimally processed FVs, Sarfo et al. 2022 reported that the inclusion of such processed FVs into diets can address micronutrient deficiencies in diets. Also, the women exhibited good knowledge on the adverse effects of highly processed FVs consumption, based on the information provided to them, as fewer women indicated their preference for highly processed FVs. The information provided to them was to help solicit their understanding of the health impacts of highly processed FV consumption. This was especially of interest because consumption of highly processed foods, in general, is often associated with adverse health outcomes (Monteiro et al., 2011; Popkin et al., 2012; Sarfo et al., 2021). Despite this, not all highly processed foods are associated with adverse health outcomes in rural East Africa (Sarfo et al., 2021). On processing of FVs, study participants demonstrated extensive knowledge, including agreeing to the fact that nutrients and supply of FVs become limited when they perish, and hence, post-harvest losses can be curtailed through processing. This knowledge level expressed by the women could be a good platform to leverage to introduce suitable processing techniques for them, and also considering the fact that more than half of the women believed FVs could be available year-round through processing.

Several studies from the US (Dissen et al., 2011; Halloran et al., 2018), Australia (Hill et al., 2020) and Uganda (Lomira et al., 2021) have shown positive associations between nutritional knowledge and/or attitudes and FV consumption and, in general, quality diet intake. In this study, it was expected that the knowledge and attitude indices would positively be associated with the FV consumption as measured in g/week. But the association was either negative or none. This could be from the fact that the variables used for the indices do not reflect the overall knowledge and attitudes of the women. For instance, only four variables were used for the attitude index. Also, the scoring system adopted clustered together "strongly agree" and "agree" as well as "disagree" and "strongly disagree," which might have omitted the variability in the responses of the women. Moreover, the neutral answer option of "neither agree nor disagree" was not provided, forcing the women to choose between the options provided when they actually do not agree nor disagree. In addition, the question "Have you received nutrition education in the last six months?" was trying to capture all kind of education on nutritional topics and not necessarily on fruit and vegetable consumption, which may have been also a reason for no association between FV consumption and nutritional knowledge. In a study to assess the relationship between nutrition knowledge and optimal mealtime behaviors, Halloran et al. (2018) also attributed similar factors, as indicated above, for a non-association, despite high levels of nutritional knowledge. Also, the negative or no association between FV consumption and knowledge and attitude measures has been attributed to non-knowledge and attitudinal factors such as production constraints, limited markets and postharvest methods, health issues, and policy constraints (Lomira et al., 2021). Nonetheless, in a former study in Kenya, an integrated nutritional knowledge and attitudinal approach that is participatory and considers people's social and cultural dimensions was found to be suitable to inform good dietary behavior (Waswa et al., 2015).

4.4.4. Policy implications and areas for future research

We propose that there should be interventions towards equipping farmers/households and small and medium enterprises (SMEs) with the technical know-how and the necessary equipment for processing. These interventions could be in the form of providing adequate training on nutritious processing of FVs, and other nutritious yet highly perishable foods alike. Equally, providing processing equipment and technologies to FV production areas could be highly significant, especially for value-addition purposes and additional income generation. In addition, science and technology investment that would develop more innovations and a subsequent transfer of these innovations for nutritious processing of FVs and other similar foods is needed (Sarfo et al., 2021). Also, market solution channels must be created for small processors to market their processed products easily as there is demand for processed FVs in East Africa (Tepe et al., 2021). Furthermore, the benefits of nutritious processed FVs for better nutrition must be amplified to ensure their increased consumption, particularly during off-seasonality periods of FVs. This can be done through their addition to nutrition guidelines/standards and programs and nutrition education structures (Sarfo et al., 2022).

As this study applied a simple correlation to establish a link between knowledge and attitude and FV consumption – which limits the understanding of the extent of the relationship, further studies establishing the causal effect of the relationship between these variables are needed. For policymakers to understand the importance of processing and act on instituting interventions required, providing more data-driven evidence on FV processing and their outcomes for better nutrition and food security is highly recommended. Lastly, similar research should be carried out in different study settings – particularly in urban areas where processed foods consumption is predominant – to better understand the knowledge, attitude, and practices towards processed FVs and how these parameters shape consumption.

4.4.5. Study limitations

One limitation of this study is the sampling technique adopted. Sampling of study areas was restricted to areas that cultivated the selected FruVaSe project FVs; however, there was an error in the selection of Morogoro in Tanzania for the study of African nightshade, a key vegetable, as few women knew about this vegetable. Also, the purposive selection of these areas could restrict the results to these areas, neglecting other areas in East Africa where food processing might be prominent, yet the method still provides a good example of areas in which highly perishable FVs are available in abundance during peak seasons. Furthermore, some constraints with data collection were found. Questions on the KAPs and the 7-day recall were limited to fruits for the fruit sites and vegetables for the vegetable sites, which could have led to some restricted responses which otherwise would have been obtained with unrestricted questions. The reduced sample during the second survey could also restrict valuable information which otherwise could have been obtained from the women and hence could cause some bias in the results. Additionally, the answer options provided for the Likert-type questions did not include a neutral choice; that is, women who did not agree nor disagree were forced to decide, which may cause some bias in the results. Although we recruited university students/graduates with food and nutrition backgrounds, adequately trained them, and pre-tested the questionnaires, there could be some information loss in the explanation and understanding of the different processed FVs for the women, leading to some bias in the results. Furthermore, there could be a recall bias during the 24-hour dietary and 7-day recalls as well as an over or under estimation of the quantities of FV consumption, particularly for the vegetables, as the recipes used for estimation were based on servings from only two women.

Despite these limitations, there were some strengths worth pointing out. One major strength was applying a single research design and methodology for all six study areas in the three countries, providing a solid basis for comparing the results. Also, this study provided data points for different study areas within the countries studied and regional overviews. To the best of our knowledge, this study is the first to assess KAPs on FV processing in rural areas, especially within the African context.

4.5. Conclusion

This study sought to assess the knowledge, attitude, and practices towards fruit and vegetable processing and consumption and its relationship with actual fruit and vegetable (unprocessed and processed) consumption among rural women in East Africa. Current fruit and vegetable consumption measurements showed that few women consumed the recommended daily fruit and vegetable amounts. Significant consumption differences across seasons were also found. Almost all fruits consumed were unprocessed, while vegetables were largely minimally processed for direct consumption. Most women expressed high knowledge of the benefits of fruit and vegetable processing and their consumption and showed a positive attitude towards fruit and vegetable processing and consumption. Yet, in practice, only few women process fruits and vegetables, relying heavily on the drying technique. Many women who did not process fruits and vegetables largely attributed this to the lack of or limited technical know-how on processing and processing equipment. The relationship between the knowledge and attitude parameters and fruit and vegetable consumption was negative or none. However, the high knowledge and positive attitude towards fruit and vegetable processing and consumption, yet the lack of or limited processing know-how and equipment, should be a basis for interventions to increase fruit and vegetable processing into nutritious products that ensure better nutrition and health and fruit and vegetable availability year-round.

Supplementary materials

Table S4.1 Questions constructed to determine the knowledge, attitude, and practices of the women towards fruit and vegetable processing and consumption.

Knowledge questions	Attitude questions	Practice questions
Do you in general consume fruits/vegetables? **If yes:** Why do you consume them?	I like to eat fruits/vegetables	I eat more fresh fruits/vegetables than processed ones (minimally or highly processed) during their availability season
If not: Why don't you consume them?	It is difficult to come by fruits/vegetables year-round for own consumption	I/household process my surplus fruit/vegetable (here only the FruVaSe FVs) for future use. **If yes:** What processing techniques do you use? How many times a month do you process? For how long do you keep the processed fruit/vegetable? Which processing technique do you prefer most? Why do you prefer this processing technique? I am the one who decides to process the surplus fruit/vegetable, **if not,** who makes the decision?
Name one micronutrient derived from fruit/vegetable intake.	My family and I like to eat minimally processed fruits/vegetables	Do you process other fruits/vegetables apart from the FruVaSe FVs? **If yes:** What fruits are these? What processing technique(s) do you use?
Name one benefit of fruit/vegetable intake to the body Have you ever heard of the term food processing? **If yes:** What fruit/vegetable processing technique (s) are you aware of? Mention any product made from fruits/vegetables that you know	My family and I like to eat highly processed fruits/vegetables In general, my household eat enough fruits/vegetables (fresh and processed combined)	**If not:** Why don't you process your fruits/vegetables?

Can you mention one benefit derived from processed fruits/vegetables?	
	There is some prestige to eating or being able to afford processed fruits/vegetables such as fruit juices, dried fruits etc.
	I can make more income from processed fruits/vegetables sales than from fresh.
	If yes: Why do you think you can make more income from processed fruit/vegetable sales?
	I am open to consuming (new) processed products from our fruits/vegetables
	I would like to be trained on simple processing techniques

Table S4.2 Commonly cultivated fruit and vegetables in Kenya, Tanzania, Uganda, and East Africa aside the FruVaSe crops in the respective study area.

	Percentage of women who cultivate the FruVaSe crops	Percentage of women who cultivate other fruits/vegetables(in addition to or excluding the FruVaSe crops)	N	Other widely cultivated fruits/vegetables aside the FruVaSe crops[a]	Percentage of women who cultivate the fruit/vegetable	N
Fruit sites:						
Kenya (Taita-Taveta)	76.7	84.6	227	Avocado	75.0	192
				Passion fruit	47.3	
				Banana	30.2	
Tanzania (Mtwara)	79.0	35.5	138	Orange	69.4	49
				Mango	36.7	
				Papaya	22.4	
Uganda (Kayunga)	85.4	87.7	219	Papaya	68.7	192
				Mango	64.1	
				Avocado	49.5	
				Orange	29.2	
				Guava	22.9	
East Africa (pooled data)	80.5	74.1	584	Avocado	55.4	433
				Mango	40.9	
				Papaya	38.3	

				Passion fruit	23.6	
				Orange	22.6	
Vegetable sites:						
Kenya (Kitui)	98.2	2.2	278	Kale	66.7	6
				Amaranth	33.3	
				Tomato	50.0	
				Spinach	33.3	
Tanzania (Morogoro)	8.3	80.9	204	Sweet potato leaves	71.5	165
				Pumpkin leaves	60.0	
				Cowpea leaves	35.8	
				Cassava leaves	33.4	
				Amaranth	20.6	
Uganda (Jinja)	51.6	74.8	250	Amaranth	77.0	187
				Eggplant	52.9	
				Kale	48.6	
East Africa (pooled data)	57.2	48.9	732	Amaranth	49.5	358
				Sweet potato leaves	33.0	
				Pumpkin leaves	32.7	
				Eggplant	29.1	
				Kale	27.7	

[a] Fruit and vegetable cultivated by more than 20% of the women shown.

Table S4.3 Percentage of women who consumed fruit and vegetables during the previous 24 hours of visit across two seasons in the fruit and vegetable sites of Kenya, Tanzania, Uganda, and East Africa.

	Fruit sites				Vegetable sites			
24-hour period	Kenya (Taita)	Tanzania (Mtwara)	Uganda (Kayunga)	East Africa (Pooled data)	Kenya (Kitui)	Tanzania (Morogoro)	Uganda (Jinja)	East Africa (Pooled data)
Plenty season (%):								
Fruits								
Yes	16.74	34.78	51.60	34.08	2.16	9.31	34.4	15.16
No	83.26	65.22	48.40	65.92	97.84	90.69	65.60	84.84
Vegetables								
Yes	98.47	89.86	91.78	94.86	98.56	98.53	97.20	98.09
No	1.53	10.14	8.22	5.14	1.44	1.47	2.80	1.91
Lean season (%):								
Fruits								
Yes	4.84	1.45	26.48	12.16	4.32	30.39	18.40	16.39
No	95.16	98.55	73.52	87.84	95.68	69.61	81.60	83.61

Vegetables								
Yes	94.71	92.75	91.32	92.98	89.57	98.53	99.20	95.36
No	5.29	7.25	8.68	7.02	10.43	1.47	0.80	4.64
N	227	138	219	584	278	250	204	732

Table S4.4 Percentage of women who consumed the recommended food intake (RFI) for fruits (200g), vegetables (200g), and fruits and vegetables (400g) during the previous 24 hours of visit across two seasons in the fruit and vegetable sites of Kenya, Tanzania, Uganda, and East Africa.

RFI consumption	Fruit sites				Vegetable sites			
	Kenya (Taita)	Tanzania (Mtwara)	Uganda (Kayunga)	East Africa (Pooled data)	Kenya (Kitui)	Tanzania (Morogor o)	Uganda (Jinja)	East Africa (Pooled data)
Plenty season (%):								
Fruits (200g)								
Yes	5.29	20.29	29.22	17.81	1.08	4.90	17.60	7.79
No	94.71	79.71	70.78	82.19	98.92	95.10	82.40	92.21
Vegetables (200g)								
Yes	25.55	12.32	15.98	18.84	18.71	16.67	26.40	20.77
No	74.45	87.68	84.02	81.16	81.29	83.33	73.60	79.23
Fruits and vegetables (400g)								
Yes	5.73	16.67	18.26	13.01	3.60	4.90	17.60	8.74
No	94.27	83.33	81.74	86.99	96.40	95.10	82.40	91.26
Lean season (%):								
Fruits (200g)								
Yes	0.44	0.72	8.68	3.60	0.36	17.16	5.20	6.69
No	99.56	99.28	91.32	96.40	99.64	82.84	94.80	93.31
Vegetables (200g)								
Yes	19.38	9.42	22.83	18.32	10.07	28.92	32.00	22.81
No	80.62	90.58	77.17	81.68	89.93	71.08	68.00	77.19
Fruits and vegetables (400g)								
Yes	2.64	2.17	10.50	5.48	1.44	10.78	14.80	10.93
No	97.36	97.83	89.50	94.52	98.56	89.22	85.20	89.07
N	227	138	219	584	278	250	204	732

Chapter 5. General discussion

5.1. Background and research questions

Malnutrition in all forms poses vast health and economic challenges for individuals, societies and countries at large (Swinburn et al., 2019; Committee on World Food Security, 2021). Yet malnutrition figures continue to rise rapidly, especially in Africa, with women and children most affected (FAO et al., 2021; Committee on World Food Security, 2021). For instance, in rural areas, overweight and obesity are widely rising (Afshin et al., 2017; Shekar and Popkin, 2020). However, several studies analyzing patterns and overweight and obesity have been urban-centered; to the best of my knowledge, only two studies, Keding et al. (2011) and Pisa et al. (2015) have been rural-focused in SSA. Moreover, analyzing patterns from the angle of processed foods, including FVs and how they relate to overweight and obesity in SSA has been limited. Micronutrient deficiencies are also prominent. Meanwhile, FVs have excellent nutrient sources that could help address micronutrient deficiencies, but the high perishability levels and seasonality of FVs pose a huge challenge for their year-round consumption (Rickman et al., 2007; FAO, 2020). Therefore, processed FVs could help address this; however, studies on the impact of processed FVs to ensure nutrient adequacy have been limited. Within SSA and rural areas, studies on them are non-existent. To address the malnutrition scourge through processed FV consumption, it is essential to assess the knowledge and perceptions towards the processing of FVs and their consumption which could inform the acceptance or otherwise of processed FVs. Thus far, such assessments are limited in the literature, particularly in rural areas where FV production is high.

Therefore, the objective of this study was to characterize patterns by processed foods, including FVs and how they affect overweight and obesity, assess processed FVs impact on diet cost and nutrients and investigate the knowledge, attitude, and practices toward FV processing and consumption in rural East Africa. The following research questions were posed to achieve the above objective:

1. What are the rates of overweight and obesity among rural women in East Africa?
2. What dietary patterns exist in rural East Africa as explained by the different food processing categories?

3. How do the dietary patterns characterized by the different food processing categories – and FVs – relate to overweight and obesity?
4. What are the costs and nutrient gaps (if any) in standard diets from local food sources for women and children in rural Tanzania year-round?
5. Are processed FVs able to reduce the standard diet costs and fill nutrient gaps (if any)?
6. What are the consumption estimates of FVs for women in rural East Africa?
7. What are the KAPs towards FV processing and consumption?
8. Is there a relationship between the women's knowledge and attitude towards FV processing and consumption and their actual FV consumption?

5.2. Key findings

The studies in this dissertation have contributed new knowledge on processed FVs – and processed foods in general – to ensure better nutrition and health outcomes, as highlighted by the salient results below:

- Several patterns were identified, yet two patterns, plant-based and purchase patterns, were dominant across countries, which were characterized by three processed food categories **(Chapter 2)**.
- The plant-based pattern was characterized mainly by unprocessed and minimally processed foods and had an inverse or no association with overweight and obesity, while the purchase pattern distinguished by highly processed foods had a positive or no association with overweight and obesity. Patterns with FVs were characterized by unprocessed and minimally processed FVs and were negatively or not associated with overweight and obesity **(Chapter 2)**.
- The addition of processed FVs to diets reduced diet costs by up to 49% and 61% for women and children. However, diet costs went up for infants 6-11 months **(Chapter 3)**.
- Processed FVs addressed all micronutrient gaps in diets except for infants 6-11 months, where some micronutrients like iron, vitamin B_{2}, and B_{6} were unfulfilled **(Chapter 3)**.

- Fruits were largely consumed unprocessed, while vegetables were largely minimally processed for direct consumption. However, consumption estimates showed consumption was below the recommended intake amounts **(Chapter 4)**.

- Most women expressed high knowledge on the benefits of FV processing and consumption. Also, they showed a positive attitude towards FV processing and consumption. But, in practice, a small number of women processed FVs, largely due to limited processing know-how and equipment **(Chapter 4)**.

- There was a negative or no relationship between the women's knowledge and attitude and their FV consumption **(Chapter 4)**.

5.3. General discussion

5.3.1. Processed foods and malnutrition

In this study, the several patterns identified in rural East Africa showed that each pattern is characterized by different forms of processed foods – unprocessed, minimally, and highly processed – as shown in Chapter 2, tables 2.3 – 2.6. This indicates that processed foods are an integral part of the diets of rural households. Though, in general, nearly all foods consumed are processed (Reardon et al., 2021). Food processing can provide significant interventions for the continued flow of nutritious foods (Floros et al., 2010; Khonje et al., 2020). Foods can be enhanced with increased nutrient bioavailability during processing which could contribute to achieving SDG target 2.2 –"End all forms of malnutrition" (Mensi and Udenigwe, 2021). Within the food systems framework, food processing can help reduce food losses and waste and better nourish people (Westhoek et al., 2016). Minimally and highly processed foods can provide the calorie and micronutrient needs for the poor, who otherwise would suffer from malnutrition due to high food perishability and food scarcity (Khonje et al., 2020). This particularly fits the context of this study as it focuses on women and children who are usually considered vulnerable and poor in societies. For example, the underweight women (although small percentage) identified in Chapter 2 could rely on both minimally and highly processed foods to meet their nutrients needs. Again, women with a high likelihood of being underweight during periods of food scarcity could depend on these foods to avert such phenomenon. The findings from this study suggest that, in the study areas, patterns with minimally processed foods had a negative or no relationship with overweight and obesity. In addition, some highly processed foods identified in the patterns from Tanzania and

Uganda were not associated with overweight and obesity (Chapter 2, table 2.7), which reiterate the point that through processed foods quality diets can be provided for vulnerable individuals.

On the other hand, in Chapter 2, table 2.7, some patterns with highly processed foods were positively associated with overweight and obesity. These foods included bread and snacks such as "mandazi" (a wheat dough fried in oil), sugar and sugary drinks, tea (with milk, sugar, or both), rice, and pasta, which are sometimes considered poor in micronutrients (Monteiro et al., 2011). There is a seemingly rapid shift toward the increased consumption of such foods, which has been termed the "nutrition transition" (Popkin, 2006; Popkin et al., 2012). In SSA, the nutrition transition is accelerating as there is a high retailing of these foods on the market (Reardon et al., 2021). Therefore, it can be concluded that the retailing of these foods by street food vendors and small/local shops in rural East Africa could play an active role in their high consumption and, consequently, increased risk of overweight and obesity. The increased consumption of highly processed foods also adversely affects the environment and tends to diminish traditional food cultures (Seferidi et al., 2020).

The heterogeneous results regarding the impact of processed foods on overweight and obesity (Chapter 2) require that clear distinctions between processed foods are made for healthy food choices, as the current classification of processed foods, mainly according to their degree of processing, is confusing and highly debatable and does not help consumers make healthy food choices (Petrus et al., 2021; Sadler et al., 2021). This is particularly essential for nutritious yet highly perishable foods like FVs that could be processed for year-round consumption.

5.3.2. Processed fruit and vegetable consumption and malnutrition

The overweight and obesity rates recorded in this study, as depicted in Chapter 2, figure 2.1, were high, with a regional rate of 38.4%. Other studies on some countries in East Africa have recorded similar or higher rates (Ajayi et al., 2016; Kenya Ministry of Health, 2016). Despite these rates, the results from Chapter 2, tables 2.7 and 2.8, indicated that patterns with unprocessed and minimally processed fruits and/or vegetables were negatively associated with overweight and obesity and high BMI or had no association. Similar findings were reported by He et al. (2004) when they recruited 74,063 women in the US and found that FV intake is associated with up to 28% lower risk of being obese. This indicates the potential of FVs in addressing malnutrition; however, their seasonal nature and subsequent non-availability year-round could be a hindrance to mitigating malnutrition. This was demonstrated in the findings where there were seasonal variations in the consumption of FVs as well as low consumption amounts, particularly in Kenya (Chapter 4). The lowest FV consumption amounts in Kenya relative to Tanzania and Uganda could therefore partly explain for the high rate of overweight and obesity recorded in Kenya in Chapter 2. Hence, processing of FVs could provide a feasible option for year-round FV consumption, especially in light of the fact that fruits were consumed in their raw form, while vegetables were processed through cooking or frying for direct consumption in rural East Africa (Chapters 2 and 4). Again, through FV processing the high perishability levels of FVs could be addressed to also reduce food loss and waste (Rickman et al., 2007; Floros et al., 2010).

Processed FVs included in diets reduced the diet cost for women and children except for infants between 6-11 months substantially. In addition, micronutrient gaps in the diets were filled up except for iron, vitamins B_2 and B_6 in the diets of infants between 6-11 months (Chapter 3, figures 3.3 and 3.4). The increase in diet cost for the infants is explained by the fact that at that stage of growth, nutrient demands are high, and at the same time, careful and appropriate complementary feeding is critical to ensure healthy development (Sawadogo et al., 2006; Daelmans et al., 2009; Imdad et al., 2011). However, food choices for these infants are limited in quality and quantity (Imdad et al., 2011) compared to older children and adults. Also, the low absorption rate for nutrients in complementary foods fed to infants accounts as well for the shortfall in nutritional adequacy (Zimmermann and Hurrell, 2007; Lopez et al., 2016; Peechakara and Gupta, 2021). The ability of the processed FVs to fill nutrient gaps in diets is in line with studies like Dwyer et al. (2012), where frozen, dried, or canned FVs contributed 35% of dietary fiber, 62% of vitamin E, 51% of vitamin C, 40% of folate and 25% of vitamin A to diets in the USA. These findings suggest that processed FVs can contribute to addressing malnutrition issues for women and children.

Among others, the high price levels of FVs have been documented as a contributing factor to expensive nutritious diets (Hirvonen et al., 2020) and the low accessibility of foods like FVs by the poor and vulnerable (Bachewe et al., 2017). Therefore, high prices could also account for the abysmally low proportion of women who achieved the recommended fruit or vegetable consumption level of 200g/day and 400g/day for both FVs, as shown in Chapter 4. Meanwhile, processed FVs could provide cheap options to meet recommended consumption amounts. For example, a study conducted by Miller and Knudson (2014) in the USA revealed that aside from the longer shelf-life of processed FVs, the price of canned vegetables was 20% cheaper than fresh-packaged vegetables, with both having similar nutrient content. The price of canned fruits was competitive with fresh fruits with comparable nutrients in some cases. FV consumption also increased with processed FVs. Consumers of frozen FVs in the USA increased their FV consumption significantly compared with non-consumers of frozen FVs, including nutrient amounts (Storey and Anderson, 2018). In the countries under this study, frozen FVs might not be an option right now as cold chains and energy provision may pose a huge constraint.

5.3.3. Acceptance and perception of processed fruits and vegetables

Despite the potential for processed FVs to mitigate different forms of malnutrition in rural East Africa (Chapters 2 and 3), their processing was low – 13 and 95 women processed fruits and vegetables, respectively (Chapter 4, table 4.6) – largely due to a lack of or limited processing know-how and equipment (Chapter 4, figure 4.5). The same reason was attributed to the non-processing of guava in Kenya (Omayio et al., 2020). Inadequate funding for post-harvest techniques of horticultural products has been identified as a contributing factor to this huge constraint (Wakholi et al., 2015). The few women that processed FVs did so through drying (Chapter 4), as traditional sun-drying is still the widely used method in rural areas (Ibeanu et al., 2011). This might be because the sun-drying technique is considered feasible and economical for most households (Owade et al., 2020), as also confirmed in this study in Chapter 4.

In general, a high proportion of the women expressed high knowledge level on unprocessed and processed FV consumption for better nutrition. Additionally, the knowledge on the benefits of FV processing was high. Attitudinally, there was generally a fair to positive attitude towards both unprocessed and processed FVs consumption (Chapter 4). These results could serve as a good platform to leverage to introduce suitable processing techniques for the women, and also considering the fact that more than half of the women believed FVs could be available year-round through processing. Nonetheless, there was a negative or no relationship between the knowledge and attitude indices and FV consumption, as indicated in Chapter 4, table 4.7. This, however, could be from the fact that the variables used for the indices do not reflect the overall knowledge and attitudes of the women. Additionally, due to the clustering of the responses, the variability in the responses could be limited. Also, there were no neutral responses, as such answer options were not provided. Halloran et al. (2018) attributed similar factors for a non-association between nutrition knowledge and optimal mealtime behaviors, despite high levels of nutritional knowledge. In addition, a variable such as nutrition education captured all kinds of education on nutritional topics for the last six months and not necessarily on fruit and vegetable consumption, which may have been also a reason for no association between FV consumption and nutritional knowledge. External factors not examined in this study including production constraints, limited markets, health issues and policy constraints – as also reported by Lomira et al. (2021) – may have contributed as well have to the negative or no relationship.

The two fruit nut bars added to diets (Chapter 3) were largely accepted by panelists during sensory studies (Xing et al., 2021), indicating consumers' acceptability of processed FVs. Additionally, in Morogoro, Tanzania, processed cassava leaves were acceptable by consumers compared to fresh cassava leaves. Also, consumers were willing to pay the prevailing price (Pato Dickson Innocensia, 2013). Again, in Uganda, solar-dried cowpea leaves were acceptable in taste, flavor, and texture (Natabirwa et al., 2017). The shelf-life periods for processed FVs are long. For instance, carefully solar-dried cashew apple and African nightshade within the FruVaSe project lasted for 6 months (Tepe et al., 2021). The trend shows that consumers have general acceptability for processed FVs. They can provide the longevity needed to help bridge nutrient gaps, especially for vulnerable groups like women and children.

5.4. Policy implications and areas for future research

Based on the results of this study, the underlisted measures are being suggested for policy implications. Equally, areas for further research have been discussed below.

5.4.1. Policy implications

- **Investment in processing innovations and technologies.** In order to provide nutritious processed FVs, processing innovations and technologies are needed. Therefore, investment in research, science, and technology is vital to spur (new) innovations or adapt established processing techniques to develop FVs and other nutritious foods into cheap but nutritious products. With this, there could be a food environment where there is constant availability and accessibility of nutritious foods (see also last point under policy implications) that have the potential of addressing malnutrition-related issues, especially for the poor and vulnerable like women and children.

○ **Establish appropriate channels to transfer processing innovation and technologies.** Innovation and technologies that are developed could be highly significant if placed in FV production areas and to SMEs, as this could drive value-addition and income generation in addition to the provision of nutritious foods. In that regard, adequate training on FV processing and the supply of necessary equipment for processing must be pursued. Also, market channels must be created for SMEs to market their processed products easily, as there is demand for processed FVs in East Africa (Tepe et al., 2021).

○ **Provide subsidies to SMEs to spur FV processing.** To encourage FV processing and make processed FVs cheap for the poor, subsidies for SMEs could be helpful in this direction. For instance, taxes at the sub-national level can be increased for unhealthy processed foods. The income generated can be invested or used as incentives for promoting and/or rewarding the production and processing of nutritious foods like FVs. Such intervention could also spur employment.

○ **Integrate processed FVs into food-based dietary guidelines and nutrition programs.** Food-based dietary guidelines that help shape better nutrition must be integrated with nutritious processed FVs while at the same time being used as a tool to shift consumption from unhealthy processed foods to healthy ones. Countries without food-based dietary guidelines must develop one – at present, in East Africa, only Kenya has food-based dietary guidelines (FAO, 2021). Furthermore, nutritious processed FVs must be integrated into nutrition programs and nutrition education structures, such as school feeding programs for children and nutrition education for women.

○ **Engage SMEs retailing processed foods.** Food manufacturers, street food vendors, and small shops owners must be fully engaged at the national or sub-national levels when designing interventions to curb malnutrition. This is important because most control mechanisms like portion size control, food additive/ingredients control can be pursued at that level. Equally, the promotion of nutritious processed FVs on the market could be achieved through this channel.

5.4.2. Areas for future research

○ **Research on the classification of processed foods based on some nationally or internationally accepted benchmarks.** One major challenge for processed foods is differentiating between nutritious and rather unhealthy choices such as pure fruit juice *versus* fruit drink with flavor and sugar or carefully solar-dried vegetables *versus* open sun-dried ones. There is no consensus on the current processed food categories that classify foods into healthy or unhealthy. Hence, comprehensive research from an interdisciplinary approach of nutritionists, food scientists and technologists, food economists, and other food disciplines to clearly define processed foods as healthy or unhealthy based on some nationally or internationally agreed benchmarks on nutrients, calorie quality, salt, sugar, fat, and other additives must be done. Benchmarks on portions of intake must be enacted as well.

- **Exploring the impact of highly processed FVs in diet modeling.** Since, in this study, only minimally processed FVs were added to the modeled diets, studies analyzing the impact of highly processed FVs and other processed foods in general in diets in terms of cost reduction and nutrients for the rural poor are needed; especially because not all highly processed foods are unhealthy.

- **Performing similar studies under different geographical settings.** Studies are needed under different locations to provide more elucidation on the contribution of processed FVs to households' diets and in addressing malnutrition. This will also provide more data-driven evidence needed by policymakers to institute the necessary policy frameworks for food processing.

- **Investigate the causal-effect relationship between nutrition knowledge and attitude and FV consumption.** In this study, a simple correlation analysis was used to establish a link between knowledge and attitude and FV consumption. This limits the understanding of the extent of the relationship; hence, further studies showing the causal-effect relationship between these variables could provide some comprehensive results.

Chapter 6. Conclusion and summary

6.1. Conclusion

This study sought to characterize patterns by processed foods, including FVs and how they affect overweight and obesity, assess processed FVs impact on diet cost and nutrients and investigate the knowledge, attitude, and practices towards FV processing and consumption in rural East Africa. Two dominant patterns – plant-based and purchase patterns – amid several were identified and were characterized by three food processing categories. The plant-based pattern, primarily characterized by unprocessed and minimally processed foods, had an inverse or no association with overweight and obesity, while the purchase pattern, identified by highly processed foods, had a positive or no association with overweight and obesity. Patterns with fruits and vegetables were characterized by unprocessed and minimally processed fruits and vegetables and were negatively or not associated with overweight and obesity. The addition of processed fruits and vegetables to diets reduced diet costs except for infants 6-11 months, where the cost went up. On nutrient adequacy, the integration of processed fruits and vegetables was able to fill up the micronutrient gaps that persisted in the standard diets for women and children, except in some cases for infants 6-11 months, where some of the micronutrient gaps were not fully bridged. However, actual fruit and vegetable consumption was below recommended amounts. Almost all fruits consumed were unprocessed, while vegetables were largely minimally processed for direct consumption. There was a high knowledge level on the benefits of fruit and vegetable processing and their consumption and a positive attitude towards their processing and consumption. Yet, in practice, processing of fruits and vegetables is limited, largely due to the lack of or limited technical know-how on processing and processing equipment. The traditional drying technique is heavily relied on for processing. The relationship between the knowledge and attitude parameters and fruit and vegetable consumption was negative or none. These findings indicate the need for policy interventions to promote the processing of fruits and vegetables and other nutritious foods in order to provide options where cheap, but nutritious foods could be available and accessible to the poor and vulnerable like women and children year-round.

6.2. Summary

Malnutrition in all its forms continues to be widespread in Africa, especially in rural areas and for women and children. Adequate consumption of fruits and vegetables could help address this malnutrition scourge, yet fruit and vegetables are seasonal and highly perishable and, as a result, are unavailable year-round. Processed fruits and vegetables could address this challenge. Hence it is also necessary to understand how processed fruits and vegetables could impact diets and help mitigate rising levels of malnutrition. Therefore, this study aimed to assess the impact of processed fruits and vegetables to address malnutrition through the characterization of patterns, diet modeling, and the assessment of knowledge, attitude, and practices – focusing on women and children in rural East Africa. The findings showed that among several patterns identified, two were dominant – plant-based pattern (characterized by unprocessed and minimally processed foods) and purchase pattern (characterized by highly processed foods). The plant-based pattern had a negative or no association with overweight and obesity, while the association with the purchase pattern was positive or none. Patterns with fruits and vegetables were characterized by unprocessed and minimally processed fruits and vegetables and had the same association results with overweight and obesity as the plant-based pattern. Adding processed fruits and vegetables to diet models reduced diet costs by up to 49% and 61% for women and children, respectively. However, for infants 6-11 months, diet costs rose. Additionally, processed fruits and vegetables addressed all micronutrient gaps in diets except for infants 6-11 months, where some micronutrient intakes were unfulfilled. Almost all fruits consumed were unprocessed, while vegetables were largely minimally processed for direct consumption. However, consumption amounts were below the recommended intake amounts. Most women expressed high knowledge on the benefits of fruit and vegetable processing and consumption. Also, they showed a positive attitude towards fruit and vegetable processing and consumption. But, in practice, a small number of women processed fruits and vegetables, largely due to limited processing know-how and equipment. The relationship between the knowledge and attitude parameters and fruit and vegetable consumption was negative or none. These results show that processed fruits and vegetables could provide a feasible option to address the increasing malnutrition among women and children. As a result, policy interventions to promote the processing of fruits and vegetables should be pursued at national and international levels.

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Published manuscripts in peer-reviewed journals:

- *Sarfo J,* Pawelzik E and Keding GB (2023). Fruit and vegetable processing and consumption: knowledge, attitude, and practices among rural women in East Africa. *Food Security*. https://doi.org/10.1007/s12571-022-01343-3.
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Policy Brief:

- *Sarfo J*, Pawelzik E and Keding GB (2022). Overweight and obesity in rural East Africa and related dietary patterns. Kenya Policy Briefs, 3(1), University of Nairobi, Kenya.

Conference presentations:

- *Sarfo J,* Pawelzik E and Keding GB (2021). Processing and consumption of fruits and vegetables: knowledge, attitude, and practices of rural households in East Africa. **Oral presentation** at Tropentag Hybrid Conference, 14 – 17 September, Hohenheim, Germany.
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Declaration

I, hereby, declare that:

- This Ph.D. dissertation has not been submitted in the same or similar form to other examination offices.

- I have not applied for a doctoral degree at any other universities.

- This dissertation was conducted independently and without undue assistance.

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PUBLICATIONS

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Household survey questionnaire

FruVaSe project – Baseline survey (work package three)

This baseline survey is being undertaken under the Project: Fruits and vegetables for all seasons. This project aims to ensure the continual availability of nutrient-rich fruits and vegetables all year round for households within your community. It is funded by the German Ministry for Food and Agriculture. We are carrying out this baseline survey to assess some basic characteristics of the community to better inform us of what interventions are needed.

This survey is led by the University of Goettingen in Germany in collaboration with the University of Nairobi and University of Eldoret (in the case of Kenya); Nelson Mandela Institute of Science and Technology (in the case of Tanzania); and Makerere University (in the case of Uganda). Please do make sure you have signed the consent form before you partake in this interview.

First, we will begin with questions on your household demographics and socio-economic status. After this, we will assess the food you ate over the past 24 hours as well as the fruits and vegetables you took over the last seven days. We would also take measurements of your weight and height, and lastly, we would like to know your perceptions about fruits and vegetable processing and consumption.

Household demographics and socio-economic factors

This interview will be with women between the ages of 15-49 years. Pregnant women are excluded.

Region/district		Enumerator's Name	
Village Name		Food crop	
Household ID			
Date (dd/mm/yyyy)		Name of woman	

1.	What is your age?	
2.	What is your level of education?	0= no schooling ***If no, go to Q4*** 1= primary 2= secondary 3= tertiary 99=other (specify):
3.	What is the size of your household?	
4.	What is the number of years spent schooling?	

5.	What is your marital status?	1= Married monogamous 2= Married polygamous 3= Widowed 4= Divorced or separated 5= Single
6.	What is your occupation?	0=None 1= Farmer 2=Trader 3= Teacher 4=Civil servant 99=other(specify):
7.	Which ethnic group do you align yourself with?	1= Wamakonde 2=wamakua 3=other: specicy
8.	Were you born in this village?	1=no 2=yes
9.	Why did you move to this village? **If Q8 is "no"**	1=Farming 2=Business 3=Employment 4=Family and friends 5=Policy 6=Others (specify)
10.	Are you the head of the household?	1= no 2= yes **If yes, skip to Q14**
11.	What is the sex of the head of this household?	1= Male 2= Female
12.	What is the age of the head of your household?	
13.	What is the level of education of household head?	0= no schooling 1= primary 2= secondary 3= Tertiary 99=Other (Specify): ________________
14.	Do you/household cultivate the FruVase fruit and vegetables?	0= no **If no, skip to Q16** 1= yes
15.	How many fruit trees/ acres are they?	
16.	Why don't you/household cultivate the FruVase fruits and vegetables ?	
.	Do you/household cultivate other fruits?	0= no **If no, skip to Q20** 1= yes
18.	What fruits are these? Mention maximum 3	
19.	How many fruit trees/acres of are they? Mention size of each	

20.	Did you consume fruits and vegetables in the last seven days?	0= no **if no, go to Q22** 1= yes
21.	Why did you not consume any?	
22.	Have you/household received nutrition education in the last six months?	0= no 1= yes
23.	Which market do you usually buy food items from?	
24.	What is the distance of the market from your home? (in km)	
	Wealth Indicator	
25.	What is the floor of your main residence made of?	1=earth floor 2=stone 3=wood 4=cement 5= tile 99= Other (specify)_________________
	What are the walls of your main residence made of?	1=earth wall 2=wood 3=stone 4=brick 5=iron sheet 6=cement 99=Others (specify)_________________
	What is the roof of your main residence made of?	1=Straw/grass 2=bamboo 3=cement 4=iron sheet 99=Others (specify)________________
	Does any member of this household own any land that can be used for agriculture purposes?	0= no 1= yes
	Does this household own any livestock herds, or farm animals, or poultry, or fishponds?	0= no 1= yes
	What is the main source of drinking water for members of you and your household?	1= piped water into dwelling, to yard or plot, public tap/standpipe, tube-well / borehole, protected dug well, protected spring, rainwater collection
		2= unprotected spring unprotected dug well, cart with small tank/drum, tanker truck, surface water (river, stream, dam, lake, pond, canal, irrigation channel)
26.	Does this household have access to a toilet facility?	0= no 1= yes
	What kind of toilet facility do you and your household usually use?	1= Pit latrine with slab, composting toilet

		2= Pit latrine without slab/open pit, bucket, hanging toilet/hanging latrine, bush or field or lake.

Nutritional assessment

a. Dietary recalls for women between 15-49years

Provide ample time to recollect all foods and drinks consumed by the woman/ interviewee from morning till night the previous day. First ask her the food she had in the morning, and whether afterwards she took some snacks or drinks in between. Continue asking until she went to bed.

Quantitative 24-hour recall

Interview Date: Season:	Day of the week for recall:	Recall number:
Enumerator Name:	Region/district:	Village name
Woman's Name:	Age:	Household ID _ _ _
Yesterday: Was yesterday a celebration or feast day where you ate unusual foods? 1= Yes 2= No Did you feel unwell yesterday? 1= Yes 2= No		

Time	[1]Meal	[7]Place of preparation	Dish	Ingredients		
			Description of dish/food	Description	Quantity	[8]Source

[1] 1= breakfast, 2=snack 3= lunch, 4=dinner/supper

[7] Place: 1= Home 2= Outside home

[8] 1= Own production 2= Purchase 3 = Gifts/Aid 4= wild 5= Others (specify)

Quantitative 7-day recall of fruits/vegetables (FVs)

Provide the interviewee ample time to recollect all fruits and vegetables consumed from morning till night each day (until she went to bed) over the last seven days.

Interview Date:	Season:	
Enumerator Name:	Region/district:	Village name
Woman's Name:	Age:	Household ID _ _ _
Over the last seven days: Was there a celebration or feast day where you ate an unusual amount of fruits and vegetables? If yes, which day(s)?.................... Did you feel unwell? If yes, which day(s)		1= Yes 2= No 1= Yes 2= No

Name fruit/vegetable	[8]Source	Quantity consumed		[10]State Consumed
		Quantity	Number per week	
Cashew apple				
Apple				
Avocado				
Jackfruit				
Guava				
Watermelon				
Orange/Lemon				
Passion fruit				
Physalis/goose berry				
Pineapple				
Ripe bananas				
Mango				
Pawpaw				
Other fruits				
Cowpea leaves				
African nightshade				
Cassava leaves				
Amaranth leaves				
Tomato				
Cabbage				

Jute mallow				
Pumpkin leaves				
Kales				
Egg plant				
Sweet potato leaves				
Carrot				
Other vegetables				

b. Knowledge, attitude and practices (KAPs) of women between 15-49 years towards the intake of processed and unprocessed fruits and vegetables.

Knowledge		
Fruits/vegetables		
1.	Do you in general consume fruits/vegetables? 1=no 2=yes If yes, why? If no, why?	
2.	Name one micronutrient derived from fruit/vegetable intake	
3.	Name one benefit of fruit/vegetable intake to the body	
4.	Have you ever heard of the term “food preservation or processing”? 1=no 2=yes If yes, what fruit preservation/processing technique are you aware of? If yes, please mention any product made from fruit/vegetable that you know.	
5.	Can you mention one benefit derived from preserved/processed fruit/vegetables?	
Now, please read out the following statements to the interviewee and ask her to respond/answer whether they do: strongly agree, agree, disagree or strongly disagree		
6.	Fresh fruits/vegetables are good for the body 1=strongly agree 2=agree 3=disagree 4=strongly disagree	
7.	Fresh fruits/vegetables are not good for the health of children between 6 and 23 months of age 1=strongly agree 2=agree 3=disagree 4=strongly disagree	
8.	Fresh fruits/vegetables are not perishable 1=strongly agree 2=agree 3=disagree 4=strongly disagree	

9.	Nutrients are lost as well as supply is curtailed when fruits/vegetable perish. 1=strongly agree 2=agree 3=disagree 4=strongly disagree	
10.	Minimally processed fruits/vegetables are not good for the body 1=strongly agree 2=agree 3=disagree 4=strongly disagree	
11.	Minimally processed fruits/vegetables are good for children below between 6 and 23 months of age 1=strongly agree 2=agree 3=disagree 4=strongly disagree	
12.	Highly processed fruits/vegetables are not good for the body 1=strongly agree 2=agree 3=disagree 4=strongly disagree	
13.	Highly processed fruits/vegetables good for children between 6 and 23 months 1=strongly agree 2=agree 3=disagree 4=strongly disagree	
14.	With processed fruits/vegetables, availability of fruits all year round is not assured. 1=strongly agree 2=agree 3=disagree 4=strongly disagree	
15.	Processed fruits/vegetables ensure reduction in post-harvest losses 1=strongly agree 2=agree 3=disagree 4=strongly disagree	
Attitudes		
Again, read out the following statements to them and solicit a yes or no answer or non-applicable where stated.		
16.	I like to eat fruits/vegetables 1=no 2=yes	
17.	It is difficult to come by fruits/vegetables year-round for own consumption 1=no 2=yes	
18.	My family and I like to eat minimally preserved/processed fruits/vegetables. 1=no 2=yes 3=non-applicable	
19.	My family and I like to eat highly preserved/processed fruits/vegetables. 1=no 2=yes 3=non-applicable	
20.	There is some prestige to eating or being able to afford preserved/processed fruits/vegetables such as juice, dried fruits/vegetables. 1=no 2=yes	
21.	I can make more income from preserved/processed fruits/vegetables sales than from fresh 1=no 2=yes 3=non-applicable If yes, why do you think you can make more income?	
22.	I am open to consuming (new) preserved/processed products from our fruits/vegetables 1=no 2=yes 3=maybe	
23.	I would like to be trained on simple preservation/processing techniques 1=no 2=yes	
24.	In general, I think my household eats enough fruits/vegetables. 1=no 2=yes 3=maybe	

Practices		
25.	I eat more fresh fruits/vegetables than preserved/processed ones (minimally and/or highly processed) during this lean/plenty season 1=no 2=yes	
26.	I/my household preserve/process surplus fruits/vegetable for future use 1=no 2=yes If yes, how many times a week or month? If yes: What processing or preservation techniques do you use? 1=drying 2=freezing 3=cooking for direct consumption 4=cooking plus canning/ preservation in glasses 5=fermentation 6=other, specify…… For how long can you keep the processed/ preserved food and under which conditions? Technique: No. of weeks/ months: Which technique do you prefer most and why?	
27.	**If no,** Why don't you process or preserve your surplus fruit/vegetable?	
28.	I am the one in the household who decides to process the surplus fruits/vegetables 1=no 2=yes If no, who makes the decision? Specify:	
29.	Do you preserve/process any other fruits/vegetables ? 1= no 2=yes If yes, what fruits/vegetables are these and what preservation/ processing techniques are applied?	

c. Anthropometric measurements for women between 15-49 years

Measures are to be taken twice to confirm the accuracy of weights and heights. Refer to interviewer protocol for measurement guidelines.

Season:

Measurement 1	Measurement 2	Measurement 1	Measurement 2
Weight (kg)		Height (cm)	

d. Dietary recalls for children between 6-23 months

For each household, a child between 6-24 months old and a child of primary school age 6-13 years must be chosen for the survey. If there are more than one in the household, randomly select one. Recalls for children between 6-24 months will be done with the mother or caregiver.

During the recall, provide the child (or the mother for 6-23 months old children) ample time to recollect all foods and drinks consumed from morning till night the previous day. First ask her/him the foods she/he had in the morning, and whether afterwards she/he took some snacks or drinks in between. Continue asking until she/he went to bed.

Quantitative 24-hour recall

Interview Date: Season:	Day of the week for recall:	Recall number:
Enumerator Name:	Region/district:	Village name
Child's Name:	Age:	Household ID _ _ _
Yesterday: Was yesterday a celebration or feast day where you ate unusual foods? 1= Yes 2= No Did you feel unwell yesterday? 1= Yes 2= No		

Time	[2]Meal [1]	[7]Place of preparation	Dish	Ingredients		
			Description of dish/food	Description	Quantity	[8]Source

[1] 1= breakfast, 2=snack 3= lunch, 4=dinner/supper

[7] Place: 1= Home 2= Outside home

[8] 1= Own production 2= Purchase 3 = Gifts/Aid 4= wild 5= Others (specify)

Quantitative 7-day recall of fruits and vegetables

Provide ample time to recollect all fruits and vegetables consumed from morning till night each day (until she/he went to bed) over the last seven days.

Interview Date:	Season:	
Enumerator Name:	Region/district:	Village name
Child's Name:	Age:	Household ID _ _ _
Over the last seven days: Was there a celebration or feast day where you ate an unusual amount of fruits and vegetables? If yes, which day(s)?.................... Did you feel unwell? If yes, which day(s)		1= Yes 2= No 1= Yes 2= No

Name fruit/vegetable	[8]Source	Quantity consumed		[10]State Consumed
		Quantity	Number per week	
Cashew apple				
Apple				
Avocado				
Jackfruit				
Guava				
Watermelon				
Orange/Lemon				
Passion fruit				
Physalis/goose berry				
Pineapple				
Ripe bananas				
Mango				
Pawpaw				
Other fruits				
Cowpea leaves				
African nightshade				
Cassava leaves				
Amaranth leaves				
Tomato				
Cabbage				
Jute mallow				

Pumpkin leaves				
Kales				
Egg plant				
Sweet potato leaves				
Carrot				
Other vegetables				

e. Dietary recalls for children between 6-13 years

For each household, a child between 6-24 months old and a child of primary school age 6-13 years must be chosen for the survey. If there are more than one in the household, randomly select one. Recalls for children between 6-24 months will be done with the mother or caregiver.

During the recall, provide the child (or the mother for 6-23 months old children) ample time to recollect all foods and drinks consumed from morning till night the previous day. First ask her/him the foods she/he had in the morning, and whether afterwards she/he took some snacks or drinks in between. Continue asking until she/he went to bed.

Quantitative 24-hour recall

Interview Date: Season:	Day of the week for recall:	Recall number:
Enumerator Name:	Region/district:	Village name
Child's Name:	Age:	Household ID _ _ _
Yesterday: Was yesterday a celebration or feast day where you ate unusual foods? Did you feel unwell yesterday?		 1= Yes 2= No 1= Yes 2= No

Time	[3]Meal	[7]Place of preparation	Dish	Ingredients		
			Description of dish/food	Description	Quantity	[8]Source

Quantitative 7-day recall of fruits and vegetables

Provide ample time to recollect all fruits and vegetables consumed from morning till night each day (until she/he went to bed) over the last seven days.

Interview Date:	Season:	
Enumerator Name:	Region/district:	Village name
Child's Name:	Age:	Household ID _ _ _
Over the last seven days: Was there a celebration or feast day where you ate an unusual amount of fruits and vegetables? If yes, which day(s)?.................... Did you feel unwell? If yes, which day(s)		1= Yes 2= No 1= Yes 2= No

Name fruit/vegetable	[8]Source	Quantity consumed		[10]State Consumed
		Quantity	Number per week	
Cashew apple				
Apple				
Avocado				
Jackfruit				
Guava				
Watermelon				
Orange/lemon				
Passion fruit				

[1] 1= breakfast, 2=snack 3= lunch, 4=dinner/supper

[7] Place: 1= Home 2= Outside home

[8] 1= Own production 2= Purchase 3 = Gifts/Aid 4= wild 5= Others (specify)

Physalis/goose berry				
Pineapple				
Ripe bananas				
mango				
pawpaw				
Other fruits				
Cowpea leaves				
African nightshade				
Cassava leaves				
Amaranth leaves				
Tomato				
Cabbage				
Jute mallow				
Pumpkin leaves				
Kales				
Egg plant				
Sweet potato leaves				
Carrot				
Other vegetables				

f. Knowledge, attitude and practices (KAPs) of primary school age children towards processed and unprocessed fruits and vegetable intake.

Knowledge		
Fruits/vegetables		
1.	Do you in general consume fruits/vegetables? If yes, why? If no, why?	
2.	Can you tell me three fruits/vegetables that you know?	
3.	Do you know what a preserved or processed fruit/vegetable is? 1=no 2=yes If yes, please mention any product made from fruits/vegetables that you know.	
4.	Which fruits/vegetables do you like best? Mention maximum three Why do you like them?	
5.	Can you mention one benefit of fruit/vegetable intake to the body?	
6.	Have you ever been taught about fruits/vegetables in school? 1=no 2=yes 3=non-applicable If yes, what were you taught?	

Now, please read out the following statements to them and they are to respond/answer whether they do: strongly agree, agree, disagree or strongly disagree		
7.	Fresh fruits/vegetables are good for the body 1=strongly agree 2=agree 3=disagree 4=strongly disagree	
8.	Minimally processed fruits/vegetables are not good for the body 1=strongly agree 2=agree 3=disagree 4=strongly disagree	
9.	Highly processed fruits/vegetables are not good for the body 1=strongly agree 2=agree 3=disagree 4=strongly disagree	
Attitudes		
10.	*Again, read out the following statements to them and solicit a yes or no answer*	
11.	I like to eat fruits/vegetables 1=no 2=yes	
12.	I eat more fresh fruits/vegetables than preserved/processed 1=no 2=yes	
13.	I think my mother adds enough fruits/vegetables to my meals 1=no 2=yes 3= maybe	
14.	**If no to Q13, I pick them outside/ along the road etc.** 1=no 2=yes If yes, please name the fruits/ vegetables. Maximum 3	
15.	I am unable to eat fruits/vegetables year-round 1=no 2=yes	
Practices		
16.	Do you eat fruits/vegetables while in school? 1=no 2=yes 3=non-applicable If yes, who provides them?	
17.	If yes, how many times a week in school? 1= one 2=two 3=three = more than three	
18.	Which fruits/vegetables are they? Mention maximum 3	

Market Survey

This survey is to make an inventory of the foods you sell, their prices and weights to better inform. Please do make sure you have signed the consent form before we proceed.

Date:	Season:
Enumerator's Name:	Region/District:
Trader's name:	Village:

Food	Price	Weight			[5]Source
		1	2	3	

[5] 1= own farm 2= farmgate 3= wholesalers 4=retailers 5=others, specify: