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# Fruit and vegetable processing and consumption: Knowledge, attitude, and practices among rural women in East Africa

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## 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-h 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 4–135 g/day in the plenty season and 4–106 g/day in the lean season. Vegetable consumption was 112–146 g/day and 84–180 g/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

## 1 Introduction

Fruits and vegetables (FVs) are excellent sources of micro-nutrients as well as fiber. Notable nutrients include vitamins A, C, E, iron, zinc, calcium, potassium, phosphorous, and magnesium (FAO, 2020; James & Zikankuba, 2017; Slavin & Lloyd, 2012). Consumption of FVs has been found to be associated with a reduction in cardiovascular diseases, cancers, diabetes, and obesity (FAO, 2020; Slavin & Lloyd, 2012; WHO, 2004). 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 400 g/capita/day or 146 kg/capita/year (Hall et al., 2009; Pomerleau et al., 2004; WHO, 2004). 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

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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 (FAO, 2020; Rickman et al., 2007). Also, nutrients are reduced or completely lost (Global Panel, 2018); for example, spinach can lose up to 27% of its folate in a span 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 innovations ranging from temperature to heat treatments, including drying, freezing, boiling, and canning, have been employed to increase the shelf life of FVs (Floros et al., 2010; James & Zikankuba, 2017; Rickman et al., 2007; Safefood, 2013). 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 (Floros et al., 2010; Garratt et al., 2002; Jaenicke & Virchow, 2013; Rickman et al., 2007). 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 & 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 FV, 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 & 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.

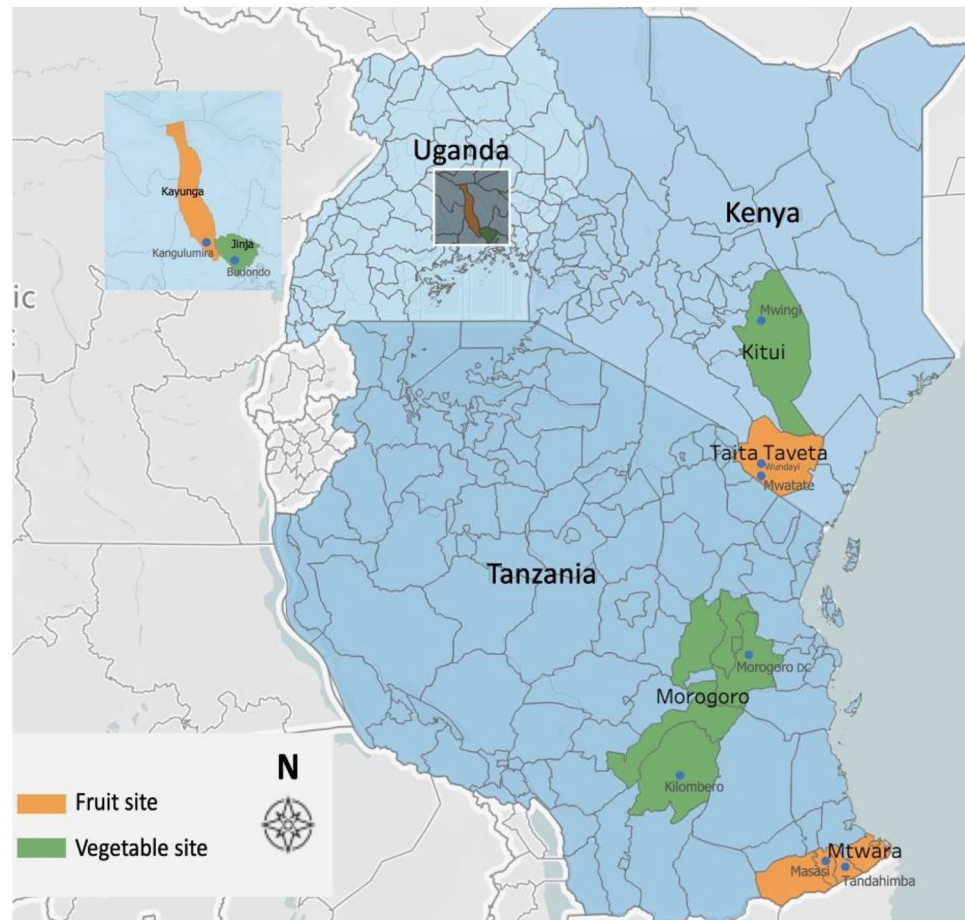
## 2 Materials and methods

### 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 Fig. 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

**Fig. 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](http://www.diva-gis.org))



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 1.

## 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 1).

Additionally, quantitative 24-h dietary and 7-day FV recalls were carried out as longitudinal surveys. These recalls were done across the two seasons, as indicated in Table 1. For the 24-h dietary recall, the amount of all foods and drinks consumed for the previous 24 h 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

**Table 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-h recall; 7-day fruit recall; socio-economic and demographics; KAPs	October 2019	24-h recall; 7-day fruit recall	227
	Tanzania (Mtwara)	October/November 2019	24-h recall; 7-day fruit recall	April/May 2019	24-h recall; 7-day fruit recall; socio-economic and demographics; KAPs	138
	Uganda (Kayunga)	February 2020	24-h recall; 7-day fruit recall	August 2019	24-h recall; 7-day fruit recall; socio-economic and demographics; KAPs	219
Vegetable sites	Kenya (Kitui)	December 2019	24-h recall; 7-day fruit recall	June 2019	24-h recall; 7-day vegetable recall; socio-economic and demographics; KAPs	278
	Tanzania (Morogoro)	June/July 2019	24-h recall; 7-day vegetable recall; socio-economic and demographics; KAPs	January 2020	24-h recall; 7-day fruit recall	250
	Uganda (Jinja)	February 2020	24-h recall; 7-day fruit recall	August 2019	24-h recall; 7-day vegetable recall; socio-economic and demographics; KAPs	204

survey. This included questions on “knowledge” which 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 S1. 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.

### 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 & 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 and 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 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-h recall. Again, only women who consumed FV during the seven days were used. Spearman correlation ( $\rho$ ) was applied to two continuous variables, the point-biserial ( $r_{pb}$ )

**Table 2** Variables and scoring system adopted to construct knowledge and attitude indices towards FV processing and consumption

Variables	Type of questions	Scoring
<b>Knowledge on fresh and processed FV consumption for better nutrition</b>		
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 2 years (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 2 years (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 2 years (6–23 months)		1 = disagree/strongly disagree; 0 = Agree/strongly agree
<b>Knowledge on FV processing benefits</b>		
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
<b>Attitude towards fresh and processed FVs consumption for better nutrition</b>		
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

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).

## 3 RESULTS

### 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 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 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.

### 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 S2). However, there were slight differences across the study areas, as depicted in Table S2.

## 3.3 24-h fruit and vegetable consumption

### 3.3.1 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 S3). In Table 4, which shows the average amount of FV consumption, fruit consumption was between 27-135 g/day in the plenty season, while consumption was between 3-45 g/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 112-145 g/day and 84-137 g/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 200 g/day for either fruit or vegetable (400 g/day in total) was low, as depicted in Table S4. 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 400 g/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.

### 3.3.2 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 122-146 g/day. The lean season was between 88-180 g/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 4-92 g/day in the plenty season and 4-106 g/day in the lean season, with significantly higher consumption amounts in Tanzania and Uganda (Table 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 400 g/day for

**Table 3** Socio-economic and demographic statistics of women in the fruit and vegetable sites of Kenya, Tanzania, Uganda, and East Africa

Variables	Fruit sites				Vegetable sites			
	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 (8.59)	33.07 (9.33)	31.69 <sup>KU</sup> (8.53)	32.84 (8.78)	34.04 <sup>KT</sup> (7.86)	32.1 (8.91)	30.84 <sup>KU</sup> (8.25)	32.41 (8.4)
Household size	4.80 <sup>KT</sup> (1.76)	4.13 <sup>TU</sup> (1.62)	6.67 <sup>KU</sup> (3.13)	5.34 (2.57)	5.59 <sup>KT</sup> (2.31)	5.02 <sup>TU</sup> (2.22)	6.19 <sup>KU</sup> (2.42)	5.64 <sup>**</sup> (2.37)
Household head (yes = 1, no = 0)	0.22 (0.42)	0.24 (0.43)	0.19 (0.39)	0.22 (0.41)	0.24 (0.43)	0.18 (0.38)	0.14 <sup>KU</sup> (0.34)	0.19 (0.39)
Nutrition education received during the past 6 months (yes = 1, no = 0)	0.26 <sup>KT</sup> (0.44)	0.01 <sup>TU</sup> (0.09)	0.09 <sup>KU</sup> (0.29)	0.14 <sup>*</sup> (0.34)	0.08 (0.28)	0.11 (0.32)	0.09 (0.29)	0.09 (0.29)
Fruit/Vegetable cultivation (yes = 1, no = 0)	0.94 <sup>KT</sup> (0.23)	0.85 (0.36)	0.91 (0.28)	0.91 <sup>*</sup> (0.29)	0.98 <sup>KT</sup> (0.13)	0.81 (0.39)	0.78 <sup>KU</sup> (0.41)	0.87 (0.34)
Dietary Diversity Score (DDS)								
Plenty season	4.12 <sup>KT</sup> (1.06)	3.36 <sup>TU</sup> (1.07)	3.83 <sup>KU</sup> (1.23)	3.83 (1.16)	4.07 <sup>KT</sup> (0.81)	3.36 <sup>TU</sup> (0.94)	3.77 <sup>KU</sup> (1.14)	3.77 (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 <sup>KT</sup> (1.06)	2.98 <sup>TU</sup> (1.16)	3.43 <sup>KU</sup> (1.07)	3.47 (1.13)	3.66 (0.97)	3.84 <sup>TU</sup> (0.99)	3.67 (1.07)	3.72 <sup>**</sup> (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 <sup>KT</sup> (2.67)	6.78 (1.75)	6.95 <sup>KU</sup> (3.73)	7.91 <sup>***</sup> (3.22)	7.53 <sup>KT</sup> (3.18)	6.52 <sup>TU</sup> (2.87)	7.24 <sup>KU</sup> (3.68)	7.15 (3.3)
Educational level (%)								
None	0.88	5.07	8.22	4.62	6.47	11.76	10	9.15
Primary	61.23	90.58	59.82	67.64	74.46	71.57	51.2	65.71
Secondary	29.96	4.35	26.94	22.77	14.39	15.69	36.8	22.4
Tertiary	7.93	0	5.02	4.97	4.68	0.98	2	2.73
Marital status (%)								
Married	70.48	76.81	67.12	70.72	80.58	73.53	83.6	79.64
Widowed or divorced or single	29.52	23.19	32.88	29.28	19.42	26.47	16.4	20.36
Main occupation (%)								
None	32.16	1.45	13.7	17.98	3.24	11.76	18.4	10.79
Farmer	40.97	95.65	68.95	64.38	78.06	59.8	58	66.12
Trader	14.98	2.17	4.57	8.05	9.71	18.63	12	12.84
Other (vocational skills, civil servant, teacher)	11.89	0.72	12.79	9.59	8.99	9.8	11.6	10.25
Wealth status (%)								
Low	12.33	23.19	27.4	21.06	37.41	4.41	28.8	32.79
Medium	31.28	32.61	32.88	30.99	34.53	22.06	34.8	30.74
High	56.39	44.2	39.73	47.95	28.06	73.53	36.4	36.48
N	227	138	219	584	278	250	204	732

Standard deviations are in parentheses excluding range under DDS. Significant differences across the countries within each site were tested using the Kruskal–Wallis and Dunnett tests

The Mann–Whitney U test was used to test for significant differences between the pooled data for the two sites

<sup>KT</sup> significant difference between Kenya and Tanzania

<sup>KU</sup> significant difference between Kenya and Uganda

<sup>TU</sup> significant difference between Tanzania and Uganda

+<sup>\*,\*\*,\*</sup> represent statistical significance of  $p < 0.1$ ,  $p < 0.05$ ,  $p < 0.01$ ,  $p < 0.001$



**Table 4** Consumption of fruits and vegetables during a 24-h and one-week period for women across two seasons in the fruit and vegetable sites of Kenya, Tanzania, Uganda, and East Africa

Variables	Fruit sites				Vegetable sites			
	Kenya (Taita-Taveta)	Tanzania (Mtwara)	Uganda (Kayunga)	East Africa (Pooled data)	Kenya (Kitui)	Tanzania (Morogoro)	Uganda (Jinja)	East Africa (Pooled data)
<b>24-h fruit and vegetable consumption (mean in grams)</b>								
<b>Fruit:</b>								
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* (144.7)
Significance between seasons	***	***	***	***		***	***	
<b>Vegetable:</b>								
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)	160.4 (119.35)	180.10***KU (150.24)	139.8+ (127.24)
Significance between seasons	+	*	+		***	**	+	
<b>Fruit and vegetable:</b>								
Plenty season	172.67 (122.28)	200.29**TU (224.14)	248.00*KU (217.11)	207.40*** (190.6)	132.03 (108.69)	149.70***TU (175.1)	238.62***KU (210.87)	173.4 (174.36)
Lean season	137.63***KT (103.78)	87.41***TU (91.15)	182.2 (160.49)	142.48 (130.69)	92.13***KT (91.47)	266.5 (269.24)	213.89***KU (179.62)	182.30** (199.26)
Significance between seasons	**	***	**	***	***	**	***	
<b>7-day fruit/vegetable consumption (mean in grams)</b>								
<b>Fruit:</b>								
Plenty season:	879.80***KT (849.15)	2004 (1454.35)	1672.60***KU (1355.8)	1443 (1296.83)				
Lean season	251.8 (225.72)	287.50***TU (416.85)	547.60***KU (571.19)	371.2 (448.86)				
Significance between seasons	***	***	***	***				
<b>Vegetable:</b>								
Plenty season:					566.50***KT (549.77)	1062.6 (966.64)	853.40***KU (649.86)	802.8 (747.54)
Lean season					1128.20***KT (901.68)	1913.10***TU (1425.39)	1005.9 (899.85)	1305.2 (1137.46)

**Table 4** (continued)

Variables	Fruit sites				Vegetable sites			
	Kenya (Taita-Taveta)	Tanzania (Mtwara)	Uganda (Kayunga)	East Africa (Pooled data)	Kenya (Kitui)	Tanzania (Morogoro)	Uganda (Jinja)	East Africa (Pooled data)
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 Dunnnett tests

UgandaThe Mann–Whitney U test was used to test for significant differences between the pooled data for the two sites and between the seasons

<sup>KT</sup>significant difference between Kenya and Tanzania

<sup>KU</sup>significant difference between Kenya and Uganda

<sup>TU</sup>significant difference between Tanzania

+<sup>\*,\*\*,\*\*\*</sup> represent statistical significance of  $p < 0.1$ ,  $p < 0.05$ ,  $p < 0.01$ ,  $p < 0.001$

FV consumption. No stark differences were observed in the lean season. Detailed study area specifics are presented in Table S4.

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

### 3.4 7-day fruit and vegetable consumption

#### 3.4.1 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). 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 S5). These fruits were also cultivated by most of the women, as already discussed above and shown in Table S2.

#### 3.4.2 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 5), included onion, tomato, cabbage, amaranth, eggplant, and cowpea leaves, were largely connected to the kind of vegetables produced. As documented under 24-h recall, almost all fruits consumed were unprocessed, and the vegetables consumed were minimally processed, which meant cooking/boiling for direct consumption.

### 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 Fig. 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 the body 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 (Fig. 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 (Fig. 3).

Regarding the responses on benefits of FV processing, the women also demonstrated high knowledge. For instance,

**Table 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

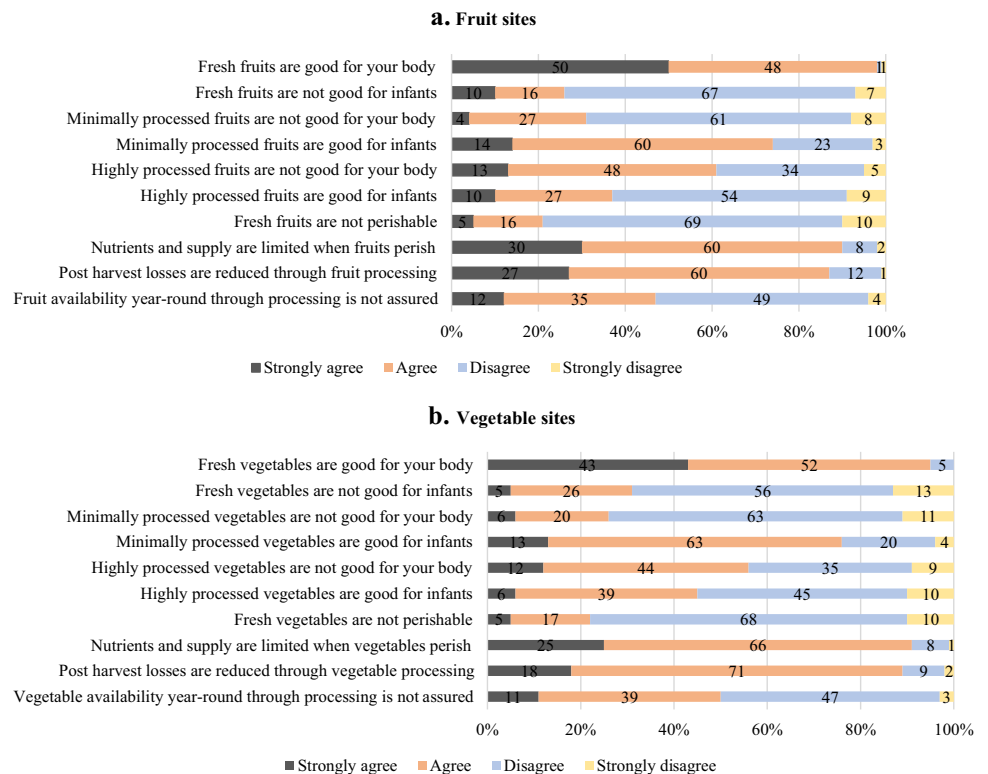
Frequency of fruit/vegetable per week	Fruit sites				Vegetable sites			
	Kenya	Tanzania	Uganda	East Africa	Kenya	Tanzania	Uganda	East Africa
	(Taita-Taveta)	(Mtwara)	(Kayunga)	(Pooled data)	(Kitui)	(Morogoro)	(Jinja)	(Pooled data)
<b>Plenty season (%):</b>								
0 – once	4.4	3.7	6.4	7.7	2.9	7.4	6.4	5.4
2 – 3 times	18.5	21	33.8	24.8	15.1	33.4	19.6	21.2
4 – 5 times	9.2	26.8	24.2	19	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	Mango: 84.8	Jackfruit: 83.6	Avocado: 48.6	Onion: 88.1	Sweet potato leaves: 78.9	Amaranth: 77.2	Tomato: 59.4
	Guava: 66.5	Cashew apple: 35.5	Pineapple: 65.3	Jackfruit: 31.9	Cowpea leaves: 79.5	Cassava leaves: 52.9	Tomato: 58.8	Onion: 57.2
	Banana: 52.0	Papaya: 10.1	Avocado: 50.7	Banana: 30.8	Tomato: 65.1	Pumpkin leaves: 52.9	Onion: 56.4	Cowpea leaves: 51.1
					Cabbage: 21.6	Tomato: 52.5	Eggplant: 50.4	Amaranth: 38.8
					Kales: 15.1	Cowpea leaves: 39.7	Kales: 34.0	Eggplant: 25.8
<b>Lean season (%):</b>								
0 – once	46.3	55.8	37.4	45.4	5.4	3.9	10	6.5
2 – 3 times	37.5	25.4	44.3	37	13	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	Orange: 39.1	Jackfruit: 54.8	Banana: 29.6	Tomato: 88.1	Pumpkin leaves: 73.7	Amaranth: 74.8	Tomato: 59.0
	Avocado: 13.3	Banana: 21.0	Papaya: 32.0	Jackfruit: 20.7	Onion: 84.5	Sweet potato leaves: 59.3	Eggplant: 48.4	Onion: 49.5
	Papaya: 12.8	Papaya: 5.8	Pineapple: 31.5	Orange: 19.2	Cabbage: 66.9	Cassava leaves: 58.8	Kales: 32.8	Amaranth: 42.4
					Kales: 42.5	Amaranth: 56.9	Tomato: 31.6	Cabbage: 37.8
					Cowpea leaves: 39.6	Tomato: 52.9	Cabbage: 28.8	Cowpea leaves: 29.6
N	227	138	219	584	278	250	204	732

as shown in Fig. 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 Fig. 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 (Fig. 3).

### 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 (Fig. 4). More than 60% of the women stated that they would like to eat minimally processed fruits or vegetables, while more than 50%

**Fig. 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



declared to not like the 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 (Fig. 3). The attitude index constructed and shown in Fig. 3 indicated that more than 60% of the women showed a fair to positive attitude towards fresh and processed FV consumption for better nutrition.

### 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 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 6). Averagely, according to the information from the women, their processed fruits lasted

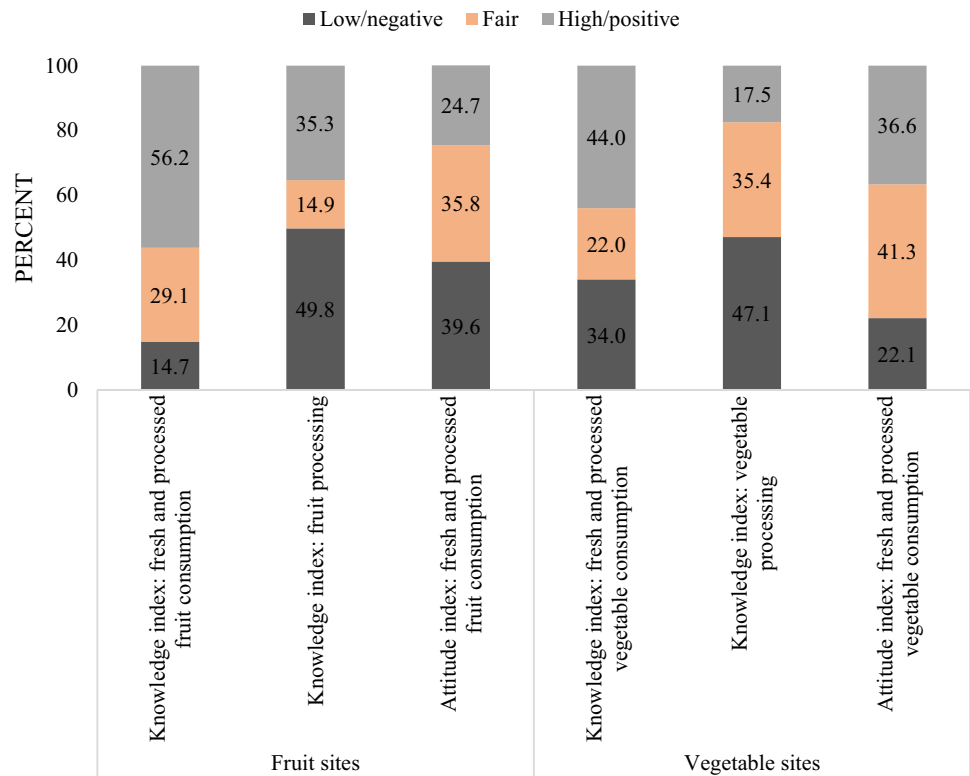
for 5 months, while the processed vegetables lasted for 2 months. The chunk of the women who did not process their FVs largely attributed that to the lack of or limited technical knowledge of processing and processing equipment – 72% and 48% of the women indicated so at the fruit and vegetable sites, respectively (Fig. 5).

### 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 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 ( $\rho = -0.25$ ) and wealth ( $\rho = -0.10$ ). The knowledge index on fresh and processed FV consumption correlated negatively with weekly fruit consumption, although weak ( $\rho = -0.08$ ). 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 ( $\rho = 0.07$ ) and being married ( $r_{pb} = 0.06$ )

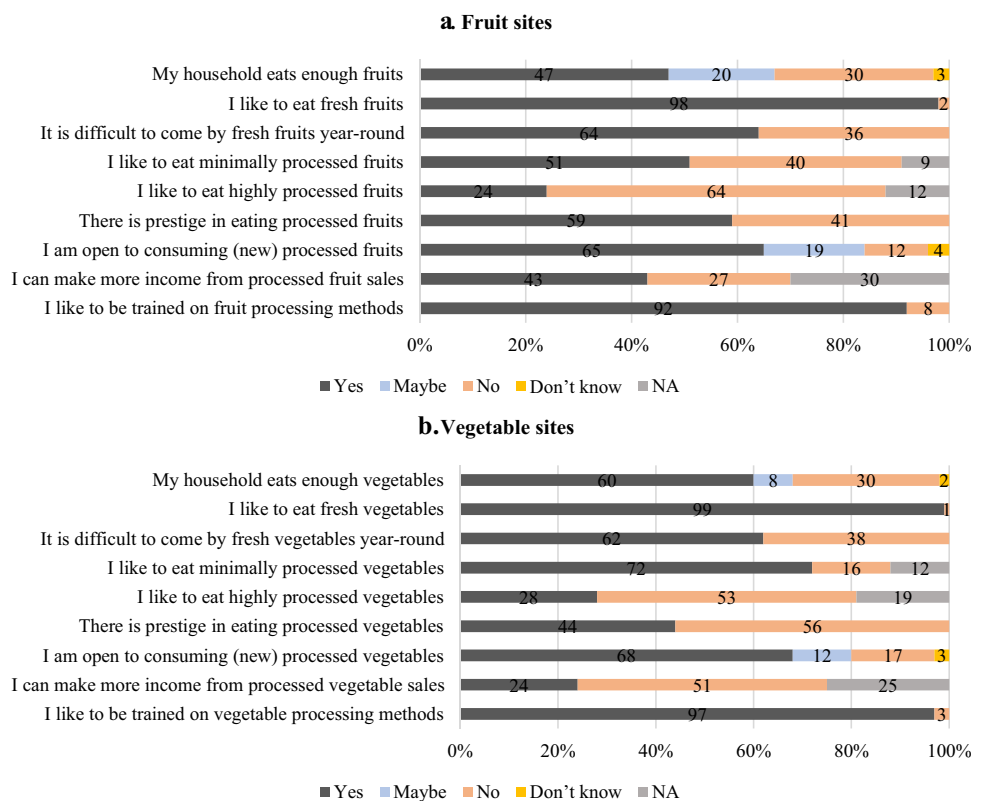
**Fig. 3** Percentage of knowledge and attitude indices attained by the women towards fruit and vegetable processing and consumption for better nutrition at the fruit (n = 584) and vegetable sites (n = 732) in East Africa



and weekly vegetable consumption in the plenty season. Negative correlations existed between vegetable cultivation ( $r_{pb} = -0.07$ ) and education ( $\rho = -0.08$ ) and weekly vegetable

consumption. While no relationship was identified for the knowledge index, the attitude index was slightly negatively correlated ( $\rho = -0.09$ ). Women from households with higher wealth

**Fig. 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



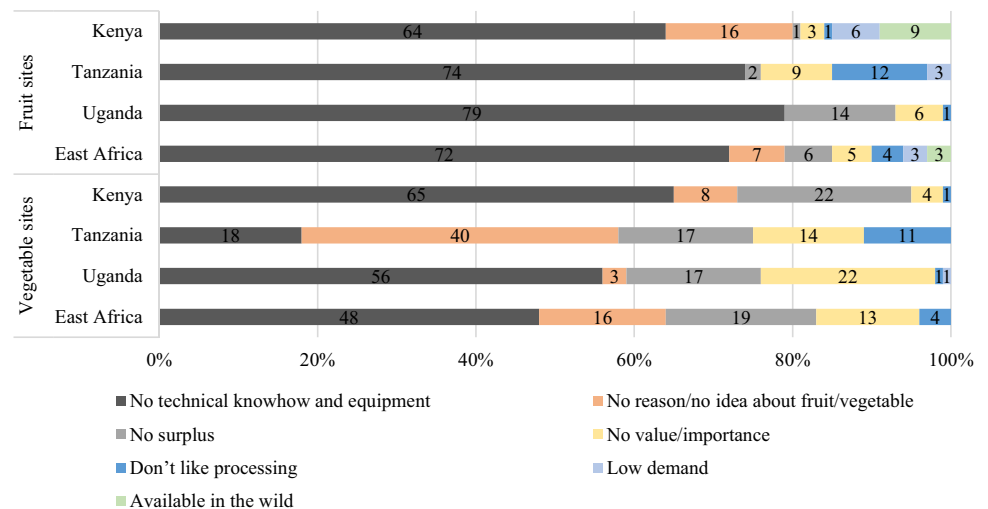
**Table 6** Fruit and vegetable processing practices performed by the women in the fruit and vegetable sites in East Africa

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
Processing techniques adopted	Drying	13	Drying	94	
	Fermentation	2	Fermentation	3	
	Freezing	1	Glass/can preservation	2	
	Juicing	2	Freezing	3	
				Eggplant	2
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	

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 7).

**Fig. 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)



**Table 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 <sup>+</sup>	-0.01	-0.05
Household size	0.08 <sup>+</sup>	0.03	0.07*	-0.09*
Household head (yes = 1, no = 0)	0.03	-0.06	-0.05	-0.07 <sup>+</sup>
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 <sup>+</sup>	-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 <sup>+</sup>	-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 Discussion

### 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 200 g/day for either fruit or vegetable and 400 g/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-h 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 & 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.

## 4.2 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 (FAO, 2020; Rickman et al., 2007; Wakholi et al., 2015) 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).

## 4.3 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. However, 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 kinds 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 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.

#### 4.5 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-h 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.

## 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.

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**Author contributions** Jacob Sarfo conceptualized the research with inputs from Elke Pawelzik and Gudrun B. Keding. Jacob Sarfo collected and analyzed the data and developed the manuscript. Elke Pawelzik and Gudrun B. Keding reviewed the manuscript and made inputs. Finally, all authors read and approved the final manuscript.

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**Data availability** The data for the study is available upon reasonable request from the corresponding author.

## Declarations

**Ethics approval** This study was performed in line with the principles of the Declaration of Helsinki. Approval was first granted by the University of Goettingen's ethics commission. Then research approval was received from Kenya's National Commission of Science, Technology, and Innovation (NACOSTI/P/19/71369/28351). In Uganda, the Makerere University School of Health Sciences' Institutional Review Board provided ethical approval (2019–026), while the National Council for Science and Technology provided research clearance (A54ES). Tanzania's ethical and research clearances were obtained from the National Institute for Medical Research (NIMR/HQ/R.8a/Vol.IX/3041) and the Commission for Science and Technology (2019–61-NA-2019–40), respectively.

**Consent to participate** The women signed or thumb-printed consent forms; however, during the follow-up surveys with the same women, verbal consent was sought.

**Consent to publish** Not applicable.

**Conflict of interest** The authors have no relevant financial or non-financial interests to disclose.

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