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Local knowledge of maturity indicators for priority fruits and vegetables in Uganda

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Local knowledge on maturity indicators is important in determining optimal time of harvesting fruits and vegetables. These farm products are increasingly becoming a valuable source of livelihood for many rural families through household consumption and trade. Unfortunately, there is a dearth of literature on the integration of local knowledge and practices in improving maturity assessment techniques with the view of promoting optimal harvesting and consumer acceptability of fruits and vegetables in Uganda. A study was undertaken between April and September 2014 to prioritize viable fruits and vegetables, ascertain socio-economic characteristics influencing maturity assessments, assess local knowledge on maturity indicators and document maturity assessment challenges faced by fruit and vegetable farmers, transporters and traders in Kampala, Rubirizi and Sheema districts. A total of 102 respondents were interviewed as corroborative measure to field visits and focused group discussions involving 27 participants. The findings indicate that passion fruit, watermelon and pineapple were the most preferred fruits while tomato, cabbage and eggplant were highly ranked among vegetables. About 99% of the respondents were knowledgeable about fruit and vegetable maturity indicators. The knowledge of maturity indicators appears to be associated with gender, age, education level, marital status, household size and occupation of the respondents. The maturity indicators used include colour for pineapple (100%, N=102), passion fruit (100%), tomato (90%) and watermelon (11%). Size is used as a maturity indicator for pumpkin, eggplant and cabbage by 100%, 85% and 50% of the respondents, respectively. Respondents felt that the maturity indicators they use are inaccurate (53%) and are influenced by pest and disease infestation (40%), weather (5.8%) and soil (1.4%) conditions. To leverage adoption, participatory design and development of noninvasive maturity assessment tools is, therefore, recommended.

Key words: Farmer, fruit, local knowledge, maturity indicator, trader, Uganda, vegetable.

INTRODUCTION

Local knowledge of maturation periods is essential for optimal harvest, correct handling and packaging, good post-harvest quality and high market prices for fruits and vegetables (Gil et al., 2012; Rajkumar et al., 2012; Okiror et al., 2017).

Mattheis and Fellman (1999) assert that fruits and vegetables develop their full characteristic flavor, taste and colour during storage if picked during an optimum period. Although fruits and vegetables harvested at an early stage of maturity may have long storage life, they are susceptible to shriveling and mechanical damage. More still, poor flavor and taste is usually attributed to early harvests. To the contrary, delayed harvest produces fruits and vegetables that have good taste and flavor but short shelf life (Dadzie and Orchard, 1997).

There are other key factors that make proper knowledge and use of maturity indicators critical to the fruit and vegetable farmers, transporters and traders. For example, optimal harvest has twin benefits including high economic returns to the producers and quality maintenance for handlers and traders (Kader, 2002; Shewfelt, 2009). Gil et al. (2012) argue that because the physiological response of plants under refrigerated storage conditions has a correlation with time of harvest, it is, therefore, important to harvest fruits and vegetables at the right maturity stage to match the desired market and purpose.

However, research efforts on fruits and vegetables in Uganda have tended to emphasize on vector transmission, emergence of pests and diseases, fruit production challenges and opportunities and post-harvest losses (Kubiriba et al., 2001; Tushemereirwe et al., 2004; Nyombi, 2013). Elsewhere, there have been some attempts (Santulli and Jeronimidis, 2006; Shewfelt, 2009; Wanitchang et al., 2011; Rajkumar et al., 2012) to examine non-destructive techniques for measuring internal quality of fresh fruits. Muchui et al. (2010) assessed the maturity indices for only tissue cultured banana cultivars in Kenya. Much as we acknowledge recent efforts by Okiror et al. (2017) who used on-farm propagation trials and intricate laboratory procedures to determine maturity indices in central Uganda, they focused on one cultivar of tomato (*Solanum lycopersicum*) cv. Ghalia 281.

Further analysis of existing literature shows that, Uganda being one of the tropical countries coupled with high demand for fruits and vegetables in East Africa and world over, has a high potential of generating high foreign revenue and scaling down food insecurity through improved pre-and postharvest handling, processing, value addition to fruit and vegetable products (FAO, 2014; IPC, 2017). Since a majority of the fruit and vegetable farmers, transporters and traders are peasants, deliberate efforts are needed to:

(1) Document their local knowledge of maturity indicators and to

(2) Apply participatory approaches in fabricating and testing customized and low cost maturity assessment tools (Kato, 2011; Muzaale, 2014; Okiror et al., 2017).

Successful development and wide-scale adoption of maturity assessment technologies ought to be premised on local knowledge and practices (Winkler, 2008). Thus, failure to narrow the gaps between local knowledge and new technologies in maturity assessment, harvest and post-harvest handling of fruits and vegetables may reciprocate with increasing post-harvest losses, low income and food insecurity among small scale farmers in Uganda (IPC, 2017). This study was, therefore, aimed at

(1) Participatory prioritization of viable fruits and vegetables
(2) Ascertaining socio-economic characteristics influencing maturity assessments
(3) Assessing local knowledge on maturity indicators and
(4) Documenting maturity assessment challenges faced by fruit and vegetable farmers, transporters and traders in Kampala, Rubirizi and Sheema districts.

MATERIALS AND METHODS

Description of the study area

The study was conducted in six administrative sub-counties in Kampala, Rubirizi, Sheema districts in central and western Uganda (Figure 1). Some respondents were interviewed in one of main fruit and vegetable markets located in Kalerwe, Kawempe division, Kampala district. Kampala is the capital city of Uganda and is situated in the central part of the country. The surface area is 195 km^2. The city lies between latitude 0°19'N and longitude 32º35'E (UDIH, 2005; Agea et al., 2008).

Kampala has a population of 1,557,300 people but the city has a daily transient population of over 2.3 million people (UBOS, 2016). With an average density of 51 inhabitants per hectare, the city population growth rate is at 3.9% per annum (Akankwasah et al., 2012). Kampala receives a bi-modal rainfall regime which peaks from March to May and September to November of the year. The mean annual rainfall is reported to range between 1750 to 2000 mm, respectively. In 2015, Kampala received 122 rain days, resulting in 554 millimeters of rainfall (UBOS, 2016). According to Akankwasah et al. (2012), the temperature is moderately high with a minimum of about 17ºC and a maximum of about 28ºC. The major economic activity in Kampala city is trade. The major fruits and vegetables traded include banana, pineapple, tomato, eggplant, cabbage, watermelon, orange, onion and amaranths (UBOS, 2016).

Geographically, Rubirizi district is located in western Uganda between latitude $00^0$16'S and longitude $30^0$06 E with an elevation of 1,300 m above mean sea level. In 1991, the national population census estimated the district population at 75,361. The national census in 2002 placed the population of Rubirizi at 101,804. In 2014, the population of Rubirizi district was reportedly 129,149 people. The statistical abstract of 2016 presented 133,500 as the number of people in Rubirizi (UBOS, 2016).

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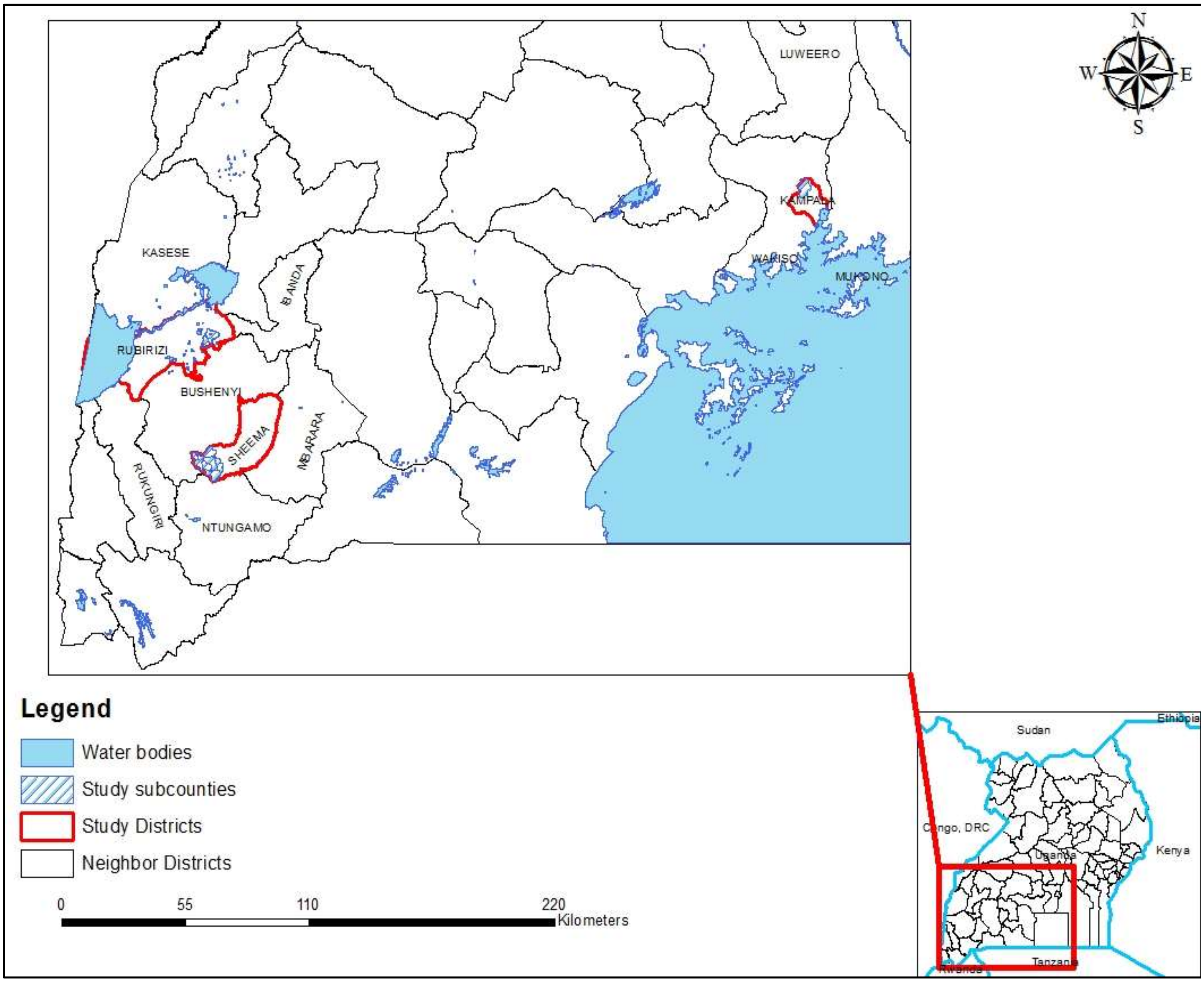

Figure 1. Map of Uganda showing the study area.

On the other hand, Sheema district is located on coordinates 00°32'S, 30°24E and at an altitude of 1,500 m above mean sea level. It covers an area of 699 km^2 in western Uganda. The population of Sheema district has been increasing steadily over the past two decades. In 1991, the national population census indicated the district population at about 153,009. By 2002, the population in Sheema had hit 180,234 people. In 2014, the population of Sheema district was 207,343 people. The statistical abstract of 2016 presented 211,100 as the population of Sheema district (UBOS, 2016).

According to NEMA (2016), Rubirizi and Sheema fall in a tropical climatic zone. The average temperature in the region is 19.3°C in a year and the mean rainfall is 1233 mm. February is the warmest month of the year with an average temperature of 19.7°C. The lowest average temperatures in the year occur in June, when it is around 18.9°C. The hailstorm that occurred in 2009 greatly affected the production of fruits and vegetables especially bananas in the western region leading to a shortage in the staple food and a spike in food prices and other consumer commodities.

Rubirizi and Sheema fall in the South Western Agro-ecological Zone (SWAEZ) characterized by the banana-coffee-cattle farming system. The SWAEZ is further characterized by a rugged terrain and several hills and high population. The average land holding is 1 to 3 hectares per household, though land is heavily fragmented and households cultivate on 5 to 8 tiny plots scattered over several hills (UGADEN, 2005).

Both crops and livestock are raised, primarily on a subsistence level, but several commercial farms are located in the region. The crops grown are; banana plantain, sweet bananas, beans, sweet potatoes, Irish potatoes, millet, cabbage, tomatoes, pineapples, avocado, passion fruit, guava, paw paws and mangoes (NEMA, 2016). Soil degradation, poor marketing and processing systems, and frequent out-breaks of crop and livestock diseases are some of the challenges faced by the farmers in Rubirizi and Sheema districts (NEMA, 2016).

The vegetation in the study region includes natural forests such as Maramagambo and Kasyoha-Kitomi (Rubirizi) and Kalinzu (Sheema) and several *Eucalyptus spp.* and *Pinus spp.* plantations spread over private estates and licensed central forest reserves (NFA, 2005). However, there is increasing demand for other tree species like temperate fruits (apples and grapes), fodder shrubs and fast growing timber trees (UGADEN, 2005). The variability in the elevation, location in the Pleistocene refugia and proximity to the Albertine rift would have meant high biodiversity but the high population growth, over exploitation of forest resources for firewood and poles and habitat degradation is threatening biodiversity in the sub-region (FAO, 2010). This trend may be worsened if agricultural productivity continues to decline owing to soil degradation, unoptimized harvests and pre- and postharvest losses in the region.

As is the case of other parts of Uganda, the farmers do not have specialized techniques but rely on traditional knowledge for assessing the maturation levels of crops before harvest. The farmers rely on subjective judgment of firmness, colour, size and aroma to harvest fruits and vegetables. The overreliance on indigenous knowledge may lead to low farm productivity and high postharvest losses because the application of traditional knowledge in farm management is usually influenced by several variables such as gender, age, religion, education and socio-demographic factors (Tabuti, 2006).

Research design

This study closely followed research designs described by Akankwasah et al. (2012) and Badri (2016). A cross-sectional survey design was applied to fruit and vegetable growers and traders in the three districts in Uganda representing six administrative sub-counties of Kawempe South, Katanda, Katerera Town Council, Kitagata, Kyabakara and Mwogyera. These sub counties were included in this study because they are among the prominent fruit and vegetable production and trading areas in Uganda. The farmers, transporters and traders usually rely on non-destructive characteristics such as external colour, aroma and size as maturity indicators (Okiror et al., 2017).

Sources of data

The study used both primary and secondary data. The primary data were obtained through questionnaire, interview, on-farm observations and focused group discussion; while secondary data were sourced from books, journals and research publications. Several reports from the Uganda Bureau of Statistics (UBOS) and the National Environment Management Authority (NEMA), National Forestry Authority (NFA) and other published articles were reviewed to ascertain socio-economic activities, human population, state of environment, land use patterns, topography, soils, climatic conditions and fruit and vegetable production and trade patterns and maturity indicators used in the study areas. Amin (2004), Agea et al. (2008) and Okiror et al. (2012) agree that a combination of primary and secondary data approaches is desirable for triangulation of study results.

Sampling techniques and procedures

Data collection took place between April and September 2014. Besides literature review, preliminary discussions were held with the scientists at the Presidential Initiative on Banana Industrial Development (PIBID) and other experts in the National Agricultural Research Organization (NARO), National Agricultural Advisory Services (NAADS) and District Local Governments (DLGs) to map out potential districts for inclusion in the study. The study sites were selected based on their performance in fruit and vegetable production, transportation and trade. Accordingly, three districts including Kampala, Rubirizi and Sheema were selected purposively for the study. Market, Local Council and Farmer Association lists were subsequently used to randomly select 102 household heads for the interview, with the belief that they were representative of the entire population due to the homogeneous characteristics of the population.

Data collection instruments

Secondary data were collected from relevant published and unpublished documents. This process included a desk review of the districts that are renowned for fruit and vegetable production, value chains, postharvest losses, maturity indicators for priority fruits and vegetables.

A peer reviewed semi-structured questionnaire, field observation checklist and a focused group discussion (FGD) guide were developed and used to collect primary data. Leaders of farmer groups were interviewed to ascertain the farmers' skills and capacity to participate on the study. Prior to conducting the interviews, local enumerators were recruited from amongst the community in Kampala, Rubirizi and Sheema districts. Enumerators were trained on how to conduct the survey and how to interpret and translate the questions as done by Ofgeha (2017).

The questionnaire and checklists were pre-tested before administration and some re-arrangement, reframing and correction in accordance with respondent level of understanding were done. Informed consent was sought from respondents before the interview. In addition, respondents were allowed to opt out of the interview at any stage. Some respondents found some questions especially regarding age, land ownership and family size sensitive and preferred not to give responses. Respondents' perceptions on socio-economic variables, maturity indicators and challenges they face in maturity assessment were collected by this technique. A total of 102 household heads were interviewed.

Field visits were held in all selected villages and markets, guided by the respective key informants, who were also asked to give their opinions regarding seasonal fruit and vegetable maturity indicators and challenges they face in maturity assessment. A similar technique was used by Ofgeha (2017).

In addition, two focused group discussions were held with 27 participants drawn from the fruit and vegetable producing association, traders, the National Agricultural Advisory Services (NAADS), and socially respected farmers who were known to have better knowledge on seasonal fruit and vegetable yields and postharvest losses, maturity indicators, social and economic status of the study areas. Species prioritization was conducted by tasking the FGD participants to assign scores of 1-10 to the fruits and vegetables grown and traded in the study areas. A score of 10 meant the fruit or vegetable was highly preferred. Previous studies have used FGDs reportedly because they are useful in corroborating information collected through individual farmer interviews (Agea, 2010; Okiror et al., 2012).

Data analyses

Quantitative data obtained from sample respondents were sorted, coded and subjected to analyses using the Statistical Package for Social Sciences computer software version 16.0 (SPSS Inc., 2005). Descriptive (means and percentages) and inferential statistical procedures were used to analyze the data obtained from fruit and vegetable farmers, transporters and traders, at 5% significance level (Munthali et al., 2016; Hei et al., 2017). Qualitative data gathered from focused group discussions were sorted into three major themes (demographic characteristics, maturity indicators and challenges faced by communities during maturity assessments) that subsequently guided the discussion of results (Krippendorff, 2004).

Table 1. Result of FGDs ranking of fruits and vegetables.

Fruit/Vegetable	Scientific name	Family	Fruit and vegetable prioritization			
			FGD 1	FGD 2	Average Score	Rank
Fruit						
Guava	*Psidium guajava* (L.)	Myrtaceae	7	8	7.5	5th
Passion fruit	*Passiflora edulis* Sims	Passifloraceae	10	9	9.5	1st
Pineapple	*Ananus comosus* (L.) Merr.	Bromeliaceae	8	9	8.5	3rd
Sweet banana	*Musa acumunita* Colla	Musaceae	10	7	8.5	3rd
Watermelon	*Citrullus lanatus* (Thub.)	Cucurbitaceae	9	9	9.0	2nd
Vegetable						
Amaranths	*Amaranthus caudatus* (L.)	Amaranthaceae	8	8	8.0	5th
Cabbage	*Brassica oleracea* L.	Brassicaceae	10	9	9.5	2nd
Eggplant	*Solanum melongena* L.	Cucurbitaceae	9	9	9.0	3rd
Pumpkin	*Cucurbita maxima* Duchesne	Cucurbitaceae	8	9	8.5	4th
Tomato	*Solanum lycopersicum* L.	Solanaceae	10	10	10	1st

RESULTS AND DISCUSSION

Prioritization of fruits and vegetables

A species prioritization exercise that included fruit and vegetable farmers, transporters and traders shows that passion fruit, watermelon, pineapple and sweet banana were the most preferred fruits while tomato, cabbage, eggplant and pumpkin were highly ranked among vegetables by the focused group discussants (Table 1). Akankwasah et al. (2012) argue that Ugandans have been trading in both wild and domesticated plants for several decades. Okiror and Okia (2011) also documented high value Indigenous Fruit Trees and demonstrated the potential of IFTs in ameliorating rural nutritional and income security in Uganda.

The prioritization results from the current study however differ in that short maturing fruits and vegetables (watermelon, passion fruit, pineapple, tomato, cabbage and eggplant) are preferred compared to the perennials such as Shea butter (*Vitellaria paradoxa*), Tamarind (*Tamarindus indica*), Carandus plum (*Carrisa edulis*), Black plum (*Vitex doniana*) and Desert date (*Balanites aegyptiaca*) recorded by Okia (2010) and Okiror and Okia (2011).

The current preference for fast maturing fruits and vegetables can be attributed to increasing incidences of prolonged drought and crop pests and disease, unreliable rainfall and food insecurity that make farmers to propagate tomatoes, eggplant, watermelon, pumpkin and cabbage to generate quick incomes for buying other foods (IPC, 2017). Even then, the preferred fruits and vegetables documented in this study (Table 1) should be harvested at optimal maturity stages to enhance farm productivity and income returns and nutritional security among rural farmers in Uganda.

Demography and knowledge of maturity indicators by respondents

A majority of respondents (81%, N = 102) interviewed were males and 19% were females. In addition, over 87% of the respondents were from male headed households (Table 2). Within Uganda and Africa as a continent, most studies on farming have been dominated by male respondents. Okiror et al. (2012) found 55% male and 45% female farmers in eastern Uganda.

Badri (2016) reported more fathers (80%) than mothers as the key sources of information regarding vegetable production and trade in Sudan. The sample population contained 88% males and 12% females in a study of farmers' production constraints in Ethiopia (Hei et al., 2017). A study of bee farmers in Ethiopia established that 99.4% of the sampled population was male headed and the rest 0.6% were female headed households (Tesfaye et al., 2017). This is mainly because the decisions on whether to grow or plant fruits and vegetables are mainly made by men (Okiror et al., 2012).

In Sierra Leone, women usually comply with men's decisions related to fruit and vegetable propagation, harvest and trade (Leach, 1990), making it critical to consider men's power, influence and decision-making role during the design and dissemination of new technologies on fruit and vegetable maturity assessment in Uganda. More still, Okullo et al. (2003) assert that men are the most influential in families since they are regarded as owners of land the family occupies and in most cases have the discretion to plant, harvest, transport and/or trade in any fruit or vegetable product.

In contrast, Tabuti (2006) reported women to be more knowledgeable about the ecology, use, concoctions, maturation and harvesting regimes of herbal medicinal plants than men. This scenario resonates with the pivotal

Table 2. Socio-economic characteristics of respondents (N=102).

Variable	Sex		Total	Response (%)
	Male	Female		
Gender	83	19	-	-
	81.40	18.60	-	-
Age (years)				
19-35 yrs	47	-	58	56.86
36-55 yrs	29	11	35	34.31
Over 55 yrs	5	6	5	04.90
No response	-	0	4	03.92
Education				
None	9	2	11	10.78
Primary	39	5	44	43.14
Secondary	22	9	31	30.39
Tertiary and above	10	2	12	11.76
No response	-	-	4	3.92
Land ownership				
Yes	73	14	87	85.30
No	8	1	9	08.80
No response	-	-	6	5.88
Land size				
1-2 acres	35	12	47	46.08
3-5 acres	36	4	40	39.22
Over 10 acres	1	0	1	00.98
No response	-	-	14	13.73
Land acquisition				
Inherited	44	-	50	49.02
Bought	30	6	40	39.22
Rent	1	10	1	00.98
No response	-	0	11	10.78
Household head				
Father	82	7	89	87.30
Mother	1	11	12	11.80
No response	-	-	1	01.00
Household size				
1-4 people	20	7	27	26.47
5-10 people	43	11	54	32.94
11-15 people	12	0	12	11.76
Over 15 people	1	9	1	00.98
No response	-	-	8	07.84
Marital status				
Never married	21	3	24	23.53
Married	58	12	70	68.63
Divorced	3	0	3	02.94

Table 2. Contd.

Separated	1	1	2	01.96
Widowed	0	3	3	02.94
Number of children				
None	1	1	2	01.96
1-4	52	10	62	60.78
5-10	22	8	30	29.41
Over 10	3	0	3	02.94
No response	-	-	5	04.90
Occupation				
Farmer	76	13	89	87.25
Employed	3	3	6	05.88
Petty business	3	2	5	04.90
No response	-	-	2	01.96
Knowledge of fruit and vegetable maturity indicators				
Yes	83	18	101	99.02
No response	-	-	1	00.98

role played by women in ensuring the nutritional and health security of their family members especially children in Uganda. A majority of the traders encountered in the study of wild food and medicinal plants were women in Kampala, Uganda's capital city (Akankwasah et al., 2012). De Caluwe (2011) and Agea et al. (2011) also reported that trade in wild food and medicinal plants were generally dominated by women in the West and East Africa. Thus, the findings from the current study coupled with previous reports (e.g. Tabuti, 2006; De Caluwe, 2011; Agea et al., 2011) make a strong justification for scientists and development agencies to involve both men and women in programs aimed at improving the propagation, maturity assessment, postharvest management and trade of fruits and vegetables in Uganda (UBOS, 2016).

The survey further revealed that about 57% of the respondents were aged 19-35 years, while 5% were over 55 years (Table 2). In Uganda, a person below 35 years is considered a youth (UBOS, 2016). According to Kiyemba (2017), there is an increasing surge of youths in the country and 80% of the Ugandans that are 10-24 years old live in rural areas. To harness this demographic dividend, Uganda needs to

(i) Make agriculture more profitable through policy reviews and subsidized agro inputs,
(ii) Improve youth access to land,
(iii) Create platforms for youth to share information on agriculture,
(iv) Increasing access to credit facilities, and
(v) Introducing new technologies and innovations such as maturity assessment tools for fruits and vegetables (Kiyemba, 2017).

The active participation of youth and the elderly in fruit and vegetable production and trade, may make the promotion of new technologies on maturity assessment easily adoptable among rural communities in Uganda and beyond.

About 43% of the study group had attained primary education whereas 11% had never acquired any formal education (Table 2). These results are close to findings by Akankwasah et al. (2012) who noted that 44% of the wild food and medicinal plant traders in Uganda had attained primary education. In a related study, Okiror et al. (2012) established that whereas 39% of respondents had studied up to primary level, 28% had never attained any formal education in eastern Uganda. The low levels of education have implications in the fruit and vegetable propagation, and maturity, yield and postharvest management because farmers, transporters and traders that lack formal education usually find difficulties in accessing, interpreting and sharing farm and market information and undertaking proper agribusiness book keeping (De Caluwe, 2011). They need to be helped. Thus, a deliberate training/farmer extension programme targeting the less educated farmers and traders will be a precursor for the successful design and adoption of improved maturity assessment techniques in the study area.

More than 2 in every 3 (69%) of the respondents were married, 61% had 1-4 children and 33 % of the families consisted of 5-10 people (Table 2). In a related study,

Table 3. Maturity indicators of fruits and vegetables (N=102).

Product	Maturity indicator	Household heads' responses	
Fruit		**No.**	**(%)**
Watermelon	Colour	11	10.50
	Size	27	26.30
	Sound made by a watermelon fruit after hitting with a bare hand	32	31.60
	Drying of stalks	32	31.60
Pineapple	Colour	100	100.00
Passion fruit	Colour	100	100.00
Vegetable			
Tomato	Colour	90	90.00
	Size	7	06.70
	Drying stalks	3	03.30
Cabbage	Size	50	50.00
	Firmness	38	38.90
	Drying of leaves	6	05.60
	Drying of stalks	6	05.60
Pumpkin	Size	100	100.00
Eggplant	Size	85	84.60
	Sound made by an eggplant fruit after hitting with a bare hand	15	15.40

more than half (55%) of the respondents were married (Akankwasah et al., 2012). More still, Okiror et al. (2012) recorded 72.5% couples with 67.5% households having 5-9 persons. According to Okiror et al. (2012), households with 5–9 people tend to be more willing to plant and protect fruits and vegetables because of the commercial and nutritional values. Large families in the rural parts of Uganda usually experience financial and food insecurity. These challenges could be ameliorated through efficient fruit and vegetable propagation, maturity assessment, consumption and trade.

Farming was the mainstay of most (87%) respondents. Overall, 99% of the respondents were familiar with fruits and vegetable propagation and trade (Table 2). These results are in tandem with the national statistics. UBOS (2016) showed that over 80% of Ugandans depend on agriculture for a living. A report by IPC (2017), indicated that there is a general shift among Ugandan farmers from usual crops such as sweet potatoes, maize, banana, Irish potatoes, cassava, millet, coffee and tea to high value quick maturing fruits and vegetables including tomato, eggplant, cabbage and carrots as a way of adapting to climate change, pests and disease, prolonged drought and intermittent rains. This therefore presents a great opportunity for the promotion of fruits and vegetables as key drivers of the local economy and as major exports of Uganda. Currently, the top exports in the country are coffee, raw tobacco, cement, tea and corn.

Fruit and vegetable maturity indicators

The maturity indicators used by farmers, transporters and traders include colour for watermelon (10.5%, N=102), pineapple (100%), passion fruit (100%) and tomato (90%). Size is used as a maturity indicator for pumpkin, eggplant, cabbage and watermelon by 100%, 85%, 50% and 26% of the respondents, respectively. Other maturity indicators include sound made by watermelon (32%) and eggplant (15%) after being hit with bare hands.

Firmness was reported as a maturity indicator for cabbage by 39% of the study group (Table 3). Farmers, transporters and traders could be compelled to devise local means of detecting maturity of fruits and vegetables because of their high perishability. Kader (2002) and Shewfelt (2009) assert that maturity at harvest is one of the main factors influencing quality and the rate of quality changes during postharvest handling and shelf life. Furthermore, it is recommended to harvest fruits and leafy vegetables at optimal maturity stage because of the potentially higher economic benefits for producers and traders. Barg et al. (2008) opined that plants harvested earlier or later than the optimal maturity stage have poor physiological response during refrigerated storage and less optimal quality maintenance.

Elsewhere, colour has been used as a maturity indicator for decades. For example, the United States Department of Agriculture has relied on external colour for classifying fresh tomatoes since 1990s. A colour chart with an ordered six colour sequence notably; green, breaker, turning, pink, light red and red is used to gauge the progress of tomato maturation and ripening (USDA, 1991).

In Ghana, Nigeria and Honduras, farmers, traders and consumers have developed distinct correlations between colour and the overall quality of specific farm products (Dadzie and Orchard, 1997) through practice and indigenous knowledge accumulated for generations. In Uganda, Okiror et al. (2017), used intricate propagation, laboratory and inferential statistical procedures to prove that colour correlates with physico-chemical and nutritional characteristics of vegetables. The revelation by Okiror et al. (2017) reinforces rural farmers, transporters and traders' perception of colour as one of the most important indicators of fruit and vegetable maturity.

Size is one of the most important indicators of maturity (Table 3). Depending on the country, most producers and consumers of fruits and vegetables usually compare the diameter, length and shape as pre-harvest decision criteria while weight, length, circumference and volume are important post-harvest selection criteria (Dadzie and Orchard, 1997). Muchui et al. (2010) made strong arguments on the relevance of the changes in fruit length and diameter in maturity determination. This study therefore recommends the application of size based indicators in the development of calibrated calipers and diameter tapes for assessing fruit and vegetable maturity on-farms and in markets.

The hitting of fruits and vegetables, with bare hands, to ascertain the level of maturity is a traditional practice among most African farmers, transporters, traders and consumers (Table 3). Fortunately, several scholars have dedicated efforts to study the correlation between sound and maturity of fruits and vegetables. These include Mizrach et al. (1997) who used ultrasound acoustic wave attenuation to determine firmness of mango fruit. There was a strong association between velocity measurement and compression test during ripening of mango fruits (Al-Haq and Sugiyama, 2004). Mizrach et al. (1997), Al-Haq and Sugiyama (2004) and Santulli and Jeronimidis (2006) agree that as the fruits or vegetables mature, sound outputs change in a regular sequence thus providing a basis for the application of acoustics techniques in maturity assessment by farmers in Uganda. However, the current interpretation of sound outputs is subjective and varies from farmer to farmer. It therefore calls for deliberate development of calibrated acoustic tools for assessment of fruit and vegetable maturity on-farm, inspection points and markets.

The drying of flower and fruit stalks reported by the respondents in Table 3 could be attributed to the various physiological changes that occur during fruit and vegetable maturity. It is reported that characterization of the intricate process of maturity and ripening poses a challenge to farmers and scientists (Zhang and McCarthy, 2012). However, incidence of pests and disease, drought and fruit abortion may result in early or delayed drying of stalks. Therefore, drying of stalks should not be used as a single indicator of maturity but rather be complemented with colour, sound and other physico-chemical and nutritional parameters like pH, moisture content, total soluble solids, total titrable acidity and protein content to corroborate results, especially if the fruits and vegetables are destined for foreign markets. However, for local consumption and markets, the farmers can use non-destructive indicators such as drying of stalks, colour and size as maturity indicators.

Shortcomings of the reported maturity indicators

About 53% of the respondents felt the maturity indicators they use are inaccurate, affected by pest and disease infestation (40%, N=102), weather (5.8%) and soil (1.4%) conditions (Figure 2). Indeed there is a debate regarding effectiveness of some of the maturity indicators enlisted by this study. For example Zhang and McCarthy (2012) recognize outer color as an index for maturity of tomato fruit but consider it unreliable for a mixture of cultivars.

External color may vary between cultivars despite the cultivars falling within the same maturity stage (Molyneux et al., 2004). Some farmers and traders with visual impairments may not find colour an appropriate maturity indicator. In addition, there may be dismal variations in some colours for example there a slight difference between breaker and turning tomatoes that many not easily be detected without the aid of colour charts.

However, reports by Dadzie and Orchard (1997), Carvalho et al. (2005) and Caron et al. (2013) strongly support external color as noninvasive and nondestructive indicator that correlates with internal carotenoid synthesis and thus can be used to assess fruit and vegetable maturity in the farms, inspection points and markets. The findings from the current and previous studies, therefore, support farmer- and trader-led design of customized colour charts for assessing the maturation and ripening of fruits and vegetables in Uganda.

As indicated in Figure 2, pest and disease infestation, weather and soil conditions can influence the maturity of a fruit or vegetable. According to Dadzie and Orchard (1997), invasion by pathogens may trigger a breakdown of plant or fruit tissue thus affecting its size, colour, and firmness. This can significantly alter fruit and vegetable maturity trend. Even then, there are physiological disorders that can develop largely in response to an adverse environment especially; unsuitable temperatures or nutritionally deficiency soils during growth and development (Wills et al., 1989). Most physiological disorders affect discrete areas of plant tissue. Some disorders may affect the skin of the fruit but may leave the underlying flesh intact; others affect only certain areas of the flesh or the cortical region (Wills et al., 1989).

According to New and Marriott (1974), immature drying of flower stalks and fruit drop can be associated with rapid ripening precipitated by prolonged drought in the farm or too high temperatures in the ripening room. These scenarios do not only justify the challenges faced by the famers and traders in predicting optimal time of harvest but also provide a basis for fruit and vegetable

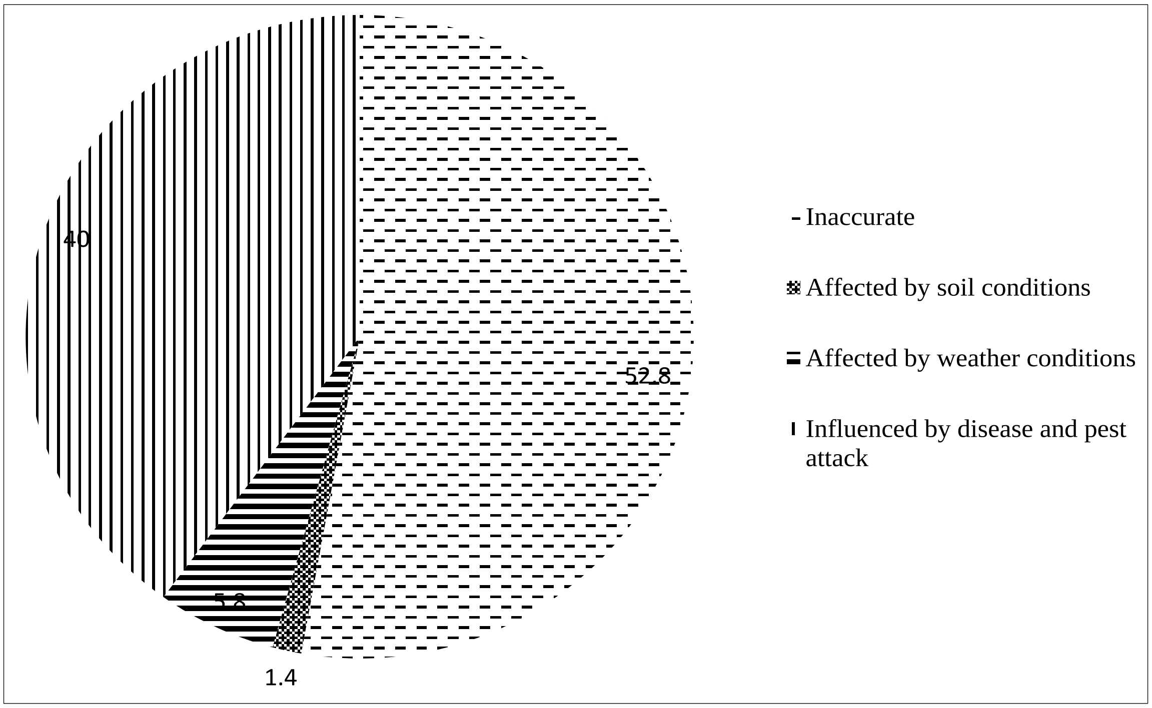

Figure 2. Shortcomings of the maturity indicators used by fruit and vegetable farmers and traders (N=102).

breeders to screen new hybrids for susceptibility to these major physiological disorders prior to dissemination and wide scale adoption by the farmers in Uganda.

CONCLUSION AND RECOMMENDATIONS

This study shows that passion fruit, watermelon, pineapple, sweet banana and guava were the most preferred fruits while tomato, cabbage, eggplant, pumpkin and amaranths were highly ranked among vegetables during the focused group discussions (Table 1). There is, therefore, need to undertake propagation trial in order to develop fast maturing varieties and cultivars of the preferred fruits and vegetables. In addition, horticultural extension programmes, value addition, proper marketing of products and access to proper market information are required to sustain the fruit and vegetable production in Uganda.

In addition 99% of the 102 respondents (farmers, transporters and traders) were knowledgeable about maturity indicators for fruits and vegetables and thus have indigenous practices for assessing maturity. It was also established that respondents' age, gender, education level, marital status and household size influenced the use of indigenous knowledge in fruit and vegetable maturity assessment (Table 2).

The study findings further suggest that farmers, transporters and traders assess fruit and vegetable maturity by largely visual means (color, size, shape) and physical means (firmness, drying of stalks and leaves and sound). In particular, the maturity indicators used include colour for watermelon (10.5%, N=102), pineapple (100%), passion fruit (100%) and tomato (90%). Size is used as a maturity indicator for pumpkin, eggplant, cabbage and watermelon by 100, 85, 50 and 26% of the respondents, respectively (Table 3). These findings have elucidated a need to determine the optimal maturity indices for the priority fruits and vegetables and tools to detect their maturity.

More than half (53%) of the respondents perceived their traditional maturity assessment techniques to be inaccurate. Others thought the maturity indicators are influenced by fruit and vegetable pest and disease infestation (40%) and site weather (5.8%) and soil (1.4%) conditions (Figure 2). This provides an opportunity for the improvement of the maturity assessment techniques through further research and development of low cost maturity assessment tools. Moreover scientists and other rural development experts should build on the traditional knowledge of farmers, transporters and traders when designing maturity assessment tools if meaningful contribution is to be realized towards reduced pre-and postharvest losses and increased incomes from fruit and vegetable farms.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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