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ORIGINAL PAPER

Participatory appraisal of preferred traits, production constraints and postharvest challenges for cassava farmers in Rwanda

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Abstract Physiological postharvest deterioration (PPD) and late bulking are among the traits that make cassava an unattractive crop in many environments. This study aimed at assessing the main constraints of cassava production, the effects of late bulking, the losses due to PPD and the factors affecting adoption of new cultivars in Rwanda. A participatory rural appraisal (PRA) and a baseline survey were conducted in March-May 2014 in three agro-ecological zones in the country using a multistage sampling method. Cassava was grown on 0.29 ha out of 0.69 ha total average land possession per household. The majority of cassava farmers (59.1 %) practised intercropping as their land holding is small. Average yield was 21.8 t ha^{-1}. A number of constraints was identified, particularly the lack of clean cuttings, viral diseases, late bulking cultivars, drought, limited information and knowledge, weathered soils, insufficient fertilizers, land shortage, lack of markets and effective storage techniques. Loss due to PPD was estimated at 11.9 % of total production per year. Piecemeal harvest and underground storage of roots were the main practices used to delay PPD. Change in colour and taste, rotting, difficulty in removing skin and increase of fibres in the flesh were the farmers' methods for assessing PPD. Time to harvest varied from district to district and was attributed to genetic x environment interactions. The use of late bulking varieties and the lack of yield production of other crops resulted in reduced food availability and potential food crises. Farmer preferences, information and extension services, performance, quality, market acceptability and cutting production influenced the adoption of new cassava cultivars. Thus, breeding objectives targeting the end user preferences could enhance the adoption of new cultivars.

Keywords Carotenoid, cultivar adoption · End-user preferences · Farming system · Late bulking · Physiological postharvest deterioration, storage techniques

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Introduction

Cassava (*Manihot esculenta* Crantz) is a staple food for approximately 500–800 million people living in developing countries (Bull et al. 2011; Howeler et al. 2013) and worldwide it is second only to maize (*Zea mays L*) for production of starch (Howeler et al. 2013). In the developing world, cassava is amongst the top four most important crops in terms of production after rice (*Oryza sativa* L), maize and wheat (*Triticum spp.*). The potential yield of cassava is estimated at 90 t ha^{-1} of fresh roots under well managed conditions (El-Sharkawy 2004). Cassava plays a key role as a food security and income-generating crop for many smallholder farmers in developing countries (Ceballos et al. 2004; El-Sharkawy 2004; Tumuhimbise 2013). In East Africa, cassava is eaten after boiling and processing to flour to make porridge, local brew, ugali and bread, and sweet varieties lacking cyanogenic glycosides can be eaten raw (Kamau 2006; Mkumbira et al. 2003; Were 2011). In Rwanda, cassava is an important staple food and is currently being promoted as a cash crop through the establishment of cassava processing plants. In addition to its tuberous root, its leaves are treated as a vegetable called "Isombe". Cassava is consumed in various forms (raw, paste/bread or ugali, boiled for breakfast, mixed with beans, vegetables, etc) and its cooking and preparation methods vary from one individual to another (mixed with beans, boiled, paste or ugali, etc.). It occupies the third place after banana and sweet potato for reducing hunger and poverty in the country (FAOSTAT 2011; Night et al. 2011). Cassava as a cash crop can be used in industries for production of animal feed and starch for use in pharmaceuticals, textiles and more (Ceballos et al. 2004; El-Sharkawy 2004).

Although cassava is a major food crop, its production is threatened by lack of good cultivars (early bulking, high yielding, and disease resistant), low soil fertility, poor agronomic practices and postharvest losses. Postharvest losses are mainly linked to the short shelf-life of cassava storage roots due to physiological postharvest deterioration (PPD), which presents major challenges to its production and utilization (Ceballos et al. 2004). The PPD begins within 24 h of harvest and rapidly renders the storage roots unpalatable, inedible and with a reduced market value (Sánchez et al. 2006). With poor road infrastructure and remote production sites, the short shelf-life severely limits marketing options and increases the likelihood of product losses and higher marketing costs. Physical methods such as underground storage, use of fungicides, pruning plants before harvest and cold storage (2-4 °C) can be used to limit PPD (Ravi et al. 1996). However, these techniques are ineffective and impractical because they are too expensive and complicated when handling large volumes of harvested roots (Sánchez et al. 2013). Subsistence farmers need to store food after harvest for home consumption and, due to limited land size, cassava cannot be stored underground (in the field) for long periods, thus there is a need for a technique that can extend shelf life of cassava for at least some weeks and preferably to several months. Conventional breeding and genetic engineering were suggested as long term strategies to delay the onset of PPD (Salcedo and Siritunga 2011). Recently, studies elsewhere have reported the development of nutritious carotenoid (pro-vitamin A with yellow/orange fleshed cassava) cassava genotypes; these genotypes due to the antioxidant property of carotenoids may retard or inhibit the onset of PPD (Morante et al. 2010; Sánchez et al. 2006; Zidenga et al. 2012). However, the hindrance factors for adoption of yellow fleshed cassava are still unclear in Rwanda.

Moreover, the high population pressure in Rwanda, resulting in small farm land size, can be a constraint in agricultural development by reducing the adoption of a long season or perennial crops such as cassava due to complications in cropping systems (rotation and intercropping practices) (Howeler et al. 2013). Farming systems and farmers preferences vary from country to country and from one culture to another. In Rwanda, cassava is grown as a subsistence crop in ten out of twelve agro-ecological zones and the main farming system is intercropping. The type of farming system and cassava variety preferences depend on the agro-socio environment such as farm size, climate and crop utilization (Were 2011). Thus, cassava is grown as a monoculture on large commercial farms and in intercropping systems on small land holdings for subsistence. Mbwika and Mayala (2001) reported that 46.9 % and 15.0 % of cassava was grown in intercropping and monocroping systems, respectively, while 38.1 % was grown in mixed cropping system in the country. Cassava was mainly intercropped with maize, beans, banana, and occasionally with groundnuts or sweet potato (Mbwika and Mayala 2001) and vegetable crops. Farmers preferred varieties based on traits such as yield, dry matter content, taste, and early maturing or early bulking. Cassava early bulking means shortened growth periods (Tumuhimbise et al. 2014) for accumulating starch and other yield components. Maximum cassava yields are obtained at 12–15 months after planting (Hillocks and Jennings 2003). However, the minimum growing cycle of cassava in Rwanda is around 10 months for the early bulking cultivars (personnel observation). The organoleptic qualities (taste and texture) and ability to cook quickly are important traits of cassava cultivars grown for food in most cassava growing countries. For instance, sweet cultivars are grown for raw consumption or after boiling, while bitter cultivars must undergo processing to reduce the cyanide content.

Despite the popularity and importance of cassava, there is lack of an operational breeding scheme in Rwanda. Thus, the cultivars grown are mostly non-adapted exotics (introduced from other countries) and a few landraces susceptible to the most devastating viral diseases (cassava brown streak disease (CBSD) and cassava mosaic disease (CMD)) in the region. Thus, understanding the adoption hindrance factors and appropriate varietal selection processes could improve cassava yield in the country. The national cassava programme invests much effort in evaluating the adaptability of introduced germplasm and focuses on yield and disease resistance as the main traits, which do not necessarily match all of the critical preferences of farmers. Although, there are some improved cultivars introduced from other countries, their adoption level is low and factors affecting their adoption are still unclear. In addition, relying on varietal introduction, participatory varietal selection is limited in Rwanda. On the other hand, the current research conducted in East Africa shows that the limited involvement of end-users in the formal breeding process affected the level of adoption of new cultivars negatively (Kamau et al. 2011; Tumuhimbise 2013; Were et al. 2014). Many breeding programmes in developing countries fail due to the lack of inclusion of participatory approaches which negatively affects the level of adoption of newly developed cultivars (Kamau et al. 2011; Were et al. 2012). Tumuhimbise (2013) reported that taste, cooking qualities and earliness are just a few of the dozens of crop traits of interest to smallholder farmers. Were et al. (2012) also reported that farmers have indigenous knowledge that could be of value to cassava improvement processes and improve the adoption of newly developed cultivars. In some countries, farmers are conservative and the understanding of information on factors affecting the adoption of new genotypes could be important in enhancing their adoption.

Participatory plant breeding (PPB) utilizes farmers' skills in identification and selection of their preferred traits, breaks the barrier between farmers and breeders, reduces the gap between variety development and adoption and enhances availability of planting materials to farmers (Kamau et al. 2011; Kanbar and Shashidhar 2011; Smith et al. 2001). PPB is convenient for the adoption of new varieties because farmers participate in selection of parents and offsprings. When farmers and breeders select together the parents and new genotypes, the breeding programmes will be more efficient and effective (Ceccarelli 2006). Participatory plant breeding utilizes many approaches such as surveys and focus group discussions in so called "participatory rural appraisal" (PRA) approaches. The PRA relies heavily on participation by the communities. This method is designed to enable local people to be involved, not only as sources of information, but as partners in gathering and analyzing the information. These two approaches provide vital information on what is needed by farmers (Kamau et al. 2011; Were et al. 2012). The involvement of farmers at some breeding stages could change their conservative behaviour and promote the adoption of new genotypes containing preferred traits. Thus, the reorientation of cassava breeding and adoption of decentralised participatory breeding (Were et al. 2014) could enhance the adoption of new cultivars. Participatory rural appraisal (PRA) that is aimed at identifying gaps in cassava production could help to build a strong foundation for a cassava breeding scheme in Rwanda.

Materials and methods

Study sites

This study was conducted in three major cassava growing districts in Rwanda, namely Bugesera, located in East Province, Kamonyi, located in South Province, and Gakenke, located in Northern Province (Fig. 1). Geographically, Bugesera lies at 02°12′18″S 30°08′42″E, Kamonyi, at 2°0′0″S, 29°54′0″E and Gakenke at 1°42′0″S, 29°47′0″E (Fig. 1).

The selection of these districts was based on cassava production levels which could be influenced by different factors including altitude, temperature, rainfall and type of soil (Table 1).

Data collection

In order to assess cassava production constraints, preferred traits, factors affecting the adoption of new cassava cultivars, cassava market aspects and losses due to physiological post-harvest deterioration (PPD), data were collected through focus group discussion (FGD) and farmers' interviews. To facilitate data collection, FGD checklist and questionnaires were translated into the local language (Kinyarwanda). Three FGDs were conducted in each district, making nine for the whole study. Each FGD was composed of ten participants, namely one district agronomist, one district extension officer, one

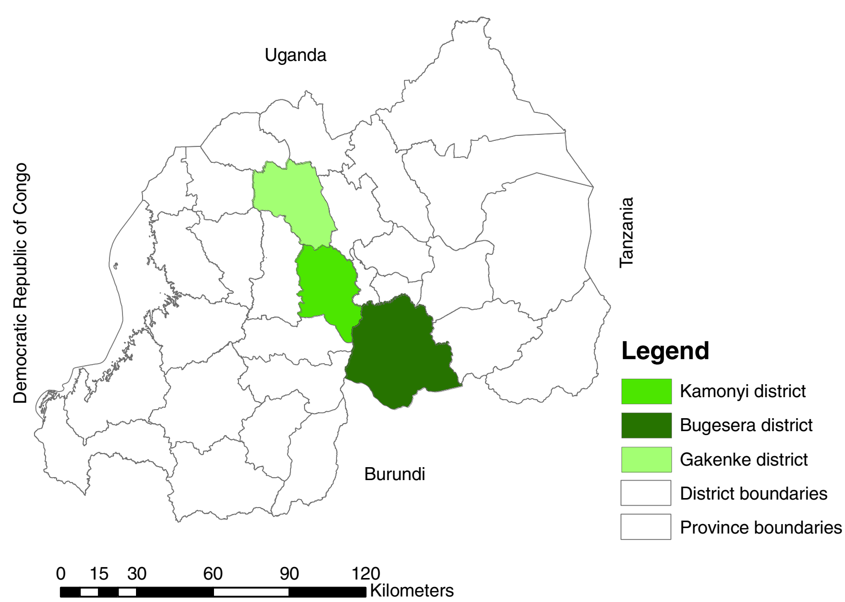

Fig. 1 Map of Rwanda showing the study areas

Table 1 Description of study area

Districts	Altitude (m)	Average precipitation	Temperature (°C)	Soil type	Potential cassava production
Bugesera	1300–1500	900	18–30	Strongly altered clay,	Very Good
Kamonyi	1400–1600	1050	16–30	Clay soils, schist	Good
Gakenke	1500–1900	1200	14–29	Diverse humic soils	Poor

cassava extension specialist from the Rwanda Agriculture Board (RAB), and seven farmer representatives from different groups of farmer field schools (FFSs). Some participants, mainly district and RAB staff, participated in all FGDs within a district. Gender was balanced, with women being two thirds of the group, because they are much more involved in agriculture activities than men in the country.

Semi-structured questionnaires were developed to be administrated to cassava farmers, cassava traders and processors. Sampling was done within FFSs at district level where a total of 60 cassava farmers from each district were selected. Multistage sampling was performed, based on cassava growing areas and three districts were chosen. A random sampling was done within FFSs where ten FFSs were selected from each district. Another random sampling was performed at household level, whereby six household were selected from each FFS to participate in interviews. This makes a total sampling size of 60 participants per district and 180 participants in total.

Data analysis

Pair-wise ranking matrix and scoring matrix (Catley et al. 2007) were used to compute the data from PRA. Data for land size, land allocated to cassava, losses due to PPD, time to harvest and cassava yield were analysed using Post hoc test ANOVA (Hilton and Armstrong 2006). Other social data collected were screened and coded to be analysed using the Statistical Package for Social Sciences (SPSS), 16th version. Percentages, means and cross tabulations are presented in the following results section.

Results

Cassava farming system in Rwanda

Main food crops grown in Rwanda

Cassava, bean (*Phaseolus vulgaris* L), sweet potato (*Ipomoea batatas* L) and maize are the major crops grown in the study areas. In Bugesera and Kamonyi districts, cassava ranked first with 90.0 % and 75.0 % of respondents, respectively, while in Gakenke district, it occupies the fifth place after banana (*Musa spp*. L), bean, maize and sweet potato. Maize occupies the second place in Bugesera district, while bean occupies the same place in Kamonyi and Gakenke districts (Table 2). The places of other crops vary from district to district. Rice, coffee (*Coffea arabica* L), pineapple (*Ananas* comosus L) and sunflower (*Helianthus annuus* L) were ranked as minor crops in all districts.

Land size and cassava production yield

The land allocated to cassava differed significantly from district to district ($p < 0.001$), and in general was greater than the land allocated to other crops. On average the total land was 0.69 ha per household while the average land allocated to cassava was 0.29 ha. The majority of farmers had a total land size less than one ha and hence practised intercropping systems (Table 3). Legumes (beans and soybeans) were the most common crops intercropped with cassava in the study area. However, some farmers mixed cassava with maize, pineapple, shrub crops and young

Table 2 Rank of cassava and other main crops in three districts of Rwanda

Ranking	Districts		
	Bugesera	Kamonyi	Gakenke
1st	Cassava (90.0 %)	Cassava (75.0 %)	Banana (47.5 %)
2nd	Maize (43.3 %)	Bean (46.7 %)	Bean (41.1 %)
3rd	Sweet potato (40.0 %)	Irish potato (38.1 %)	Maize (33.3 %)
4th	Bean (35.0 %)	Soybean (33.3)	Sweet potato (28.8 %)
5th	Groundnut (25.9)	Maize (30.0 %)	Cassava (27.1 %)
6th	Sorghum (23.5 %)	Banana (25.9 %)	Vegetables (28.1 %)
7th	Soybean (21.7 %)	Taro (25.5 %)	Taro (26.6 %)

Table 3 Land size and cassava cropping system in Rwanda

Districts	Land size mean		Farming system		Estimated cassava Yield (t ha^{-1})
	Total Land size	Land allocated to cassava	Monoculture (%)	Intercropping (%)	
Bugesera	0.97	0.46	55.0	45.0	24.5
Kamonyi	0.52	0.23	43.3	56.6	24.2
Gakenke	0.56	0.20	33.3	66.7	16.7
Mean	0.69	0.29	43.9	56.1	21.8
LSD	0.15	0.08	-	-	6.86
P value	<0.001	<0.001	-	-	0.045

LSD = Least significant differences of means (5 % level)

trees such as eucalyptus. The farmers with land size larger than one ha, grow cassava in monoculture (Table 3).

The yield of cassava significantly varied significantly ($p = 0.045$) from district to district. Focus group discussions reported yields of 24.5, 24.2 and 16.7 t ha^{-1} in Bugesera, Kamonyi and Gakenke districts, respectively (Table 3).

Growing cycle, causes and effects of late bulking cultivars

Time to harvest varied significantly ($p < 0.001$) between districts and ranged from 6 to 24 months, but 16 months was the average bulking time for all districts. The early bulking cultivars (6–8 months) were reported in Bugesera and Kamonyi districts while in Gakenke district, the early bulking was at 12 months (Table 4).

The first cause of late harvest was late bulking cultivars (the late bulking inherent in the cassava cultivars) as indicated by the majority of farmers in the study area. Agricultural practices and cold environment were commonly reported as the second causes of late bulking. Farmers from Bugesera district suspected that planting cassava at the wrong time (out of season) of the year is the cause of late maturity (Table 4) and affected yield. In Rwanda, the best planting time is September-October of each year.

Table 4 Time to harvest per district

Districts	Time to harvest (months)	Minimum time to harvest (months)	Maximum time to harvest (months)
Bugesera	13	6	24
Kamonyi	14	8	24
Gakenke	19	12	24
Mean	16	8.6	24
LSD	1.444	-	-
P value	<0.001	-	-

LSD = Least significant differences of means (5 % level)

Food crises (shortage of food, malnutrition and prolonged hunger), lack of cuttings, losses of other crops' yields and delayed return on investments were commonly reported as the main effects of late bulking cassava cultivars. The other effects indicated by farmers in Bugesera and Kamonyi districts were poverty and crop rotation impediment (Table 5).

Clean cuttings availability

The majority of farmers (average of 66.6 % in all districts) confirmed that the availability of clean cuttings was a problem. The sources of clean cuttings were research institutes, farmers groups, cooperatives and NGOs (Fig. 2). Farmers lacked a source of clean cuttings from neighbouring farmers and their own preceding cassava crops (Fig. 2). However, farmers were unsure of the health status of the cuttings available.

Cassava production constraints in Rwanda

The majority of farmers (99.4 %) confirmed the presence of cassava production constraints. Lack of clean cuttings, late bulking cassava cultivars and diseases, especially Cassava Brown Streak Disease (CBSD) and Cassava Moaic Disease (CMD), were the main constraints of cassava production. Drought was the second most challenging constraint in Bugesera district while the lack of clean cuttings ranked the same in Kamonyi and Gakenke districts (Table 6). The other major challenging constraints per rank order were weathered soils, insufficient fertilizers, small land size, limited information (access to information), and lack of market, storage of fresh and dried cassava, theft and animal damage and the agricultural policy of crop regionalization. Several minor cassava production constraints such as cold environment, heavy rainfall and storms, limited knowledge on cassava

Table 5 Farmer perceptions on causes and effects of late bulking cultivars

	Districts			Mean (%)	Rank
	Bugesera (%)	Kamonyi (%)	Gakenke (%)		
Causes of late bulking					
Agricultural practices/farming system	75.7	100.0	25.1	66.9	1
Cold climate and storms	10.5	100	73.1	61.2	2
Drought	97.3	-	-	32.4	3
Planting at wrong time	10.5	-	-	3.5	4
Effects of late bulking					
Losses of other crops' yields	75.4	87.5	99.4	87.4	1
Food crises (lack of food, malnutrition and prolonged hunger)	73.9	59.2	16.7	49.9	2
Poverty	38.9	33.5	-	24.1	3
Crop rotation impediment	-	-	62.8	20.9	4
Delayed return on investment	6.9	15.4	14.9	12.4	5
Lack of cuttings	5.0	4.3	6.4	5.2	6

cropping s were identified by farmers and varied from district to district (Table 6).

Cassava physiological postharvest deterioration

Fresh cassava storage constraints and storage techniques

A total of 96.7, 98.3 and 70.7 % of farmers in Bugesera, Kamonyi and Gakenke districts, respectively, confirmed the lack of effective storage technique (Fig. 3).

The traditional technique of storage of cassava as flour (drying and processing cassava storage roots to flour) was the most widely used technique to deal with PPD, as confirmed by the majority of farmers (89.2 %) across the districts. Piecemeal harvesting (gradual harvest) can conserve cassava storage roots more than one year, as indicated by 71.9 % of farmers interviewed in the study area. However, once harvested, underground storage of cassava roots in the soil (interment) conserves the roots for only four days on average, as confirmed by 53.8 % of farmers (Table 7). Less common techniques highlighted by farmers in one district (Kamonyi) were storage of peeled cassava in water and precooking cassava. However, the latter cannot conserve cassava storage roots for more than three days.

Local methods for detecting PPD in Rwanda

The colour change of cassava flesh was the most common method for measuring PPD as reported by 89.8, 80.7 and 86.4 % of farmers interviewed in Bugesera, Kamonyi and Gakenke districts, respectively. Rotting of cassava flesh and changing taste also were classified as the second and third most common methods to assess damage due to PPD (Table 8). However, FGDs indicated that difficulty of removing skin (peeling) of cassava storage roots and the increase of fibres in cassava flesh were among the local methods of detecting PPD.

Losses due to PPD and value given to damaged cassava storage roots

There was no significant difference ($p = 0.259$) in cassava production losses due to PPD in the three study areas. Losses of 12.6, 10.3 and 13.3 % were reported in Bugesera, Kamonyi and Gakenke districts, respectively. PPD appeared at approximately three days after harvest (Table 9).

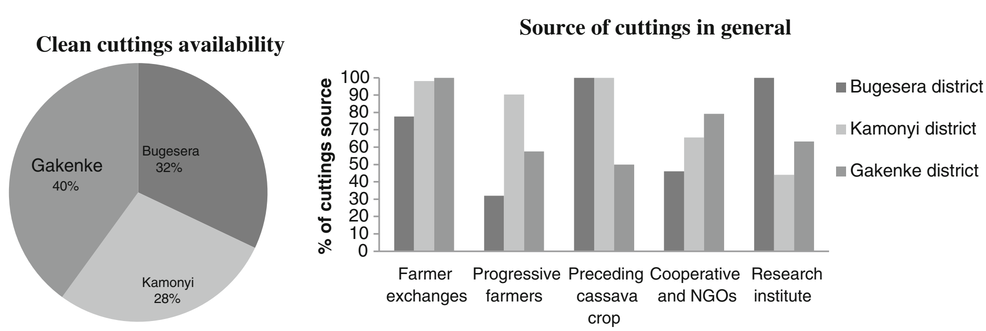

Fig. 2 Availability of clean cuttings

Table 6 Constraints to cassava production per district

	Constraints per districts		
	Bugesera	Kamonyi	Gakenke
Farmers confirmed availability of constraints	98.3 %	100 %	100 %
Rank of constraints			
1st	Lack of clean cuttings	Late bulking cassava cultivars	Diseases (CBSD and CMD)
2nd	Drought	Lack of clean cuttings	Lack of clean cuttings
3rd	Weathered soils	Diseases (CBSD and CMD)	Insufficient fertilizers
4th	Insufficient fertilizers	Small land size	Late bulking cassava cultivars
5th	Limited access to information	Insufficient fertilizers	Limited access to information
6th	Lack of market	Weathered soils	Storage of fresh and dried cassava
7th	Theft and animal damage	Limited access to information	Agriculture policy of crop regionalization
8th	Small land size	Storage of fresh and dried cassava	Cold climate
Other minor constraints	Limited knowledge on cassava cropping systems	Limited knowledge on cassava cropping system	Heavy rainfall and storms
	Agricultural policy of crop regionalization	-	-

CBSD: *cassava brown streak disease*; *CMD*: *cassava mosaic disease*

In cases of total deterioration due to PPD, the deteriorated cassava is processed into flour, given to poor families (low social class), or used to feed animals (especially pigs). In Kamonyi and Gakenke some farmers indicated that deteriorated cassava was processed into flour for constructing their houses (painting and mixed with cements). However, 44.1, 41.0 and 14.5 % of farmers in Bugesera, Gakenke and Kamonyi districts, respectively reported that damaged cassava was considered as garbage (Table 10).

Availability of PPD tolerant cassava cultivars in Rwanda

Based on the fact that PPD signs start appearing after 24 h, farmers indicated that some cultivars showed PPD signs only after three days, an indication of PPD tolerance. The common popular cultivars with delayed PPD were Rwizihiza, Mavoka, Cyizere, Seruruseke and Mbakungahaze (Table 11). Most of these cassava cultivars are introduced (assumed to have high yield, disease resistance and possibly improved dry matter, carotenoid content and other valuable traits). Some landraces

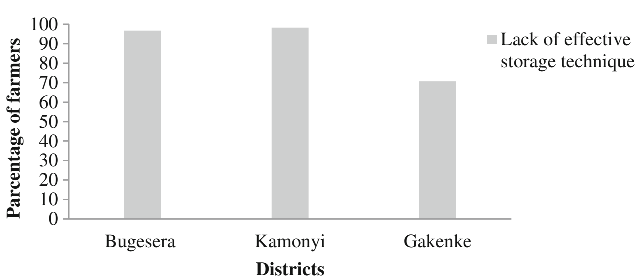

Fig. 3 Effective cassava storage constraints

(Gahene, Nyiramabuye, Rutanihisha, Yangwe, Rwicabana and Gapfutsi) were also reported to tolerate PPD; these landraces are bitter types with high cyanide content which could delay microbial attacks. The only sweet landraces tolerant to PPD were Gacyalicyali and Mushedile. However, none of the cultivars tolerate PPD beyond three days under normal conditions of storage (room temperature) as indicated by farmers. This shows that there is no cultivar in the country tolerant to PPD, compared to cultivars in other countries which have the ability to withstand PPD for one to several weeks.

Farmer preferred cassava traits in Rwanda

The adoption of newly introduced cassava cultivars must respond to farmers and consumers preferences. In order of importance, the preferred cassava traits were sweet taste, high yield, good quality ugali (viscosity and colour), resistance to pest and diseases, early bulking, multipurpose, good colour of flesh and flour, many clients, delayed PPD, dry matter content, good odour/smell, long storage in the field, many cuttings produced and good cookability (Table 12).

Farmer perceptions on yellow fleshed cassava

All farmers confirmed the availability of two yellow cassava cultivars. However, the majority of them (95, 55 and 52.3 % in Bugesera, Kamonyi and Gakenke districts, respectively) dislike yellow fleshed cassava. They highlighted some reasons for the unpopularity of yellow fleshed cassava such as a drying problem (low dry matter), bad colour of flour, lack of taste,

Table 7 Traditional storage techniques of cassava fresh storage roots in Rwanda

Storage techniques	Districts			Means (%)	Rank
	Bugesera (%)	Kamonyi (%)	Gakenke (%)		
Storage of flour (drying and processing into flour)	87.5	80.0	100	89.2	1
In the field (piecemeal harvesting)	72.7	55.9	87.0	71.9	2
Interment in the soil of harvested roots	60.0	56.9	44.4	53.8	3
Precooking	-	25.9	-	25.9	4
Dumping in water	-	17.6	-	17.6	5

rapid rotting, carotene odour from volatile carotenoid compounds, low demand (few clients), poor storage in the field (spoiled when kept in the field) and not cooking well. However, 33 % of respondents liked yellow fleshed cassava cultivars for its early bulking, resistance to CMD, high yield, good ugali, multipurpose (eaten raw or processed into flour for ugali), vitamin A content and cookability (Table 13).

Factors influencing adoption of new cassava genotypes

Focus group discussions revealed some factors affecting the adoption of new cassava cultivars. Pair wise ranking listed the factors in descending order whereby farmer preferences, information and extension services, performance (yield, early bulking, disease resistant), quality (cooking aspect, taste, dry matter, viscosity of ugali, colour of ugali), market acceptability and stake production (Table 14) proved to be the main factors influencing farmers to adopt or reject the new introduced cassava genotypes in Rwanda.

Discussion and conclusion

This study aimed at identifying the main constraints of cassava production, farmer preferred traits, effects of late bulking cultivars, losses due to PPD, and factors affecting the adoption of new genotypes. An understanding of these aspects in cassava farming system provides guidelines for breeding objectives for the cassava breeding programme in Rwanda.

The study found that cassava is among the main food crops in the country, but its place varies from district to district. This agrees with Stephen and Lecumberri (2011), who reported that cassava, beans, maize, banana and sweetpotato are the main foods crop grown in Rwanda. The findings showed that the average farm size was 0.69 ha with 0.29 ha allocated to cassava per household in average. However, many farmers possess less than the average farm size (0.6 ha). This is corroborated by Rurangwa (2013), who reported that the majority of households had less than 0.2 ha in Rwanda. Land allocated to cassava was greater than that for other crops and the predominance of intercropping was attributed to the small size of land available, a result of the dense population of the country (407 people/km^2 according to Rwanda's National Institute of Statistics in 2012), the greatest in SSA (Rurangwa 2013). Land in the study area was fragmented, necessitating subsistence farming. Subsistence farming was associated with the large spacing (1 × 1 m/10,000 plants per ha) required for cassava and the need for food diversification. Households with small plots tended to practise intercropping in contrast to those with larger plots who mostly practised monoculture. This is corroborated by Mbwika and Mayala (2001) who found that the majority of cassava farmers in Rwanda practised mixed cropping. Many scientists (El-Sharkawy 2004; Munga 2008; Were et al. 2012) report that cassava is grown by small scale farmers in intercropping and mixed cropping systems in developing countries.

The results revealed that the lack of clean cuttings, pests and diseases (especially CBSD and CMD) and late bulking

Table 8 Local methods to detect PPD damage

PPD measuring methods	Districts			Mean (%)
	Bugesera	Kamonyi	Gakenke	
Colour change of cassava flesh	89.8 %	80.7 %	86.4 %	85.6 %
Rotting of cassava flesh	55.6 %	28.3 %	43.8 %	42.6 %
Changing taste of cassava flesh	11.1 %	79.2 %	18.8 %	36.4 %
Unclassified methods				
Difficulty in removing cassava skin (peeling)	Yes	Yes	No	-
Increase of fibers in cassava flesh	No	No	Yes	-

Table 9 PPD appearance after harvest and PPD losses in Rwanda 2014

Districts	PPD appearance after harvest (days)	PPD losses %
Bugesera	3.0	12.6
Kamonyi	2.9	10.3
Gakenke	2.7	13.8
Mean	2.9	11.9
P value	-	0.26

cultivars were the main constraints of cassava production in the study area. These findings are in agreement with Tumuhimbise (2013), who showed that virus diseases such as CBSD and CMD are the most challenging constraint in Uganda followed by lack of early bulking cultivars. Kamau (2006) also reported that the lack of early bulking cultivars is a challenging constraint of cassava production in the East Africa region.

The majority of farmers confirmed the lack of effective storage techniques. This was linked to physiological postharvest deterioration (PPD) which starts a few hours after harvest, with most cassava production marketed as fresh roots for consumption as fresh boiled cassava. Fresh cassava roots for raw and boiled consumption, and for processing need to be free from any deterioration (PPD and bacterial rots). PPD differs from bacterial rots in that there is a change in colour of the flesh due to physiological activity. This begins within 24 h of harvest and starts as blue-black to black vascular discoloration (vascular streaking) and then spreads to the parenchyma, thereby rendering the storage root unpalatable (flavour, odour and colour) and unmarketable (Morante et al. 2010; Reilly et al. 2007; Sánchez et al. 2006). Ceballos et al. (2004) also reported that the short shelf-life of cassava roots, due to physiological postharvest deterioration, presents major challenges to increasing production and utilization in developing countries. Tackling the effects of PPD needs much effort; the private sector and government must invest in infrastructures and cassava processing plants in order to reduce the time between harvest and marketing and the initiation of processing activities.

The traditional measure to tackle losses due to PPD in the study area were to keep cassava storage roots in the field with gradual harvesting (piecemeal) and underground storage of harvested cassava roots, which conserves them for at least four days. The former can conserve cassava storage roots for approximately one year, but it can also compromise agriculture practices (rotation) because it occupies land for longer periods. Sayre (2011) reported that harvesting cassava can be delayed by months or even up to three years. On the other hand, cassava storage roots kept in the field for long periods can become woody and quality and flavour may be affected.

Traditional assessment of PPD by farmers included change in colour and taste, rotting, difficulty in removing skin (peeling) and increased fibre. The difficulty in skin peeling could be attributed to the increase of fibres which may be a defence mechanism of cassava after wounding against subsequent bacterial attack (Kpémoua et al. 1996; Luna et al. 2011; Uarrota et al. 2014).

The study found on average 11.9 % of cassava production losses due to PPD. FAO (2000) reported total postharvest losses of 29, 10 and 8 % of cassava in Africa, Latin America and Asia, respectively. In Rwanda, farmers considered cassava totally deteriorated approximately 3 days after harvest. This may be the result of bacterial attack which can cause total rotting of cassava flesh, leading to a total financial loss. For non-bacterial PPD farmers minimize financial loss by feeding the affected cassava to animals (especially pigs) (Ubalua 2007), selling it at low price as food for poor families (low social class) and processing the flour for use in cements and house paints. Okafor (2008) reported that cassava flour performs satisfactorily as a water reducing admixture in concrete. Cassava starch prevents floor cracks by stopping the formation of calcium silicate hydrates (CSH) in concrete mixtures (Abalaka 2012).

The significant differences in harvesting time observed in the districts was attributed to gene x environment interactions and ecological differences among districts as the majority of farmers reported that bulking time is an inherent characteristic of the cultivar and the growing environment. Food crises (lack of some important foods at specific times and locations leading to malnutrition) and lack of other crop yields were linked to the late bulking cultivars occupying land for long periods of time. These findings agree with Tumuhimbise (2013) and Kamau et al. (2011) who reported that the late bulking cultivars occupy land for extended periods and consequently the

Table 10 Place and value given to deteriorated cassava due to PPD

Value given to damaged storage roots	Districts			Mean (%)	Rank
	Bugesera (%)	Kamonyi (%)	Gakenke (%)		
Drying and processing into flour	26.7	87.5	40.5	51.6	1
Garbage	44.1	14.5	41.0	33.2	2
Food for the poor	14.3	41.8	23.1	26.4	3
Flour processing for painting houses	-	50.0	23.1	24.4	4
Animal feed	45.8	-	23.1	23.0	5

Table 11 Some cassava cultivars in which symptoms of PPD were delayed

Delayed PPD cultivars	Districts			PPD delayed time to symptom expression (days)[a]
	Bugesera (%)	Kamonyi (%)	Gakenke (%)	
Gehene	46.5	-	-	3
Nyiramabuye	3.4			1
Rwizihiza	33.7	56.2	6.7	3
Mavoka	26.0	10.7	50.7	3
Gitamisi	21.0	-	36.0	2
Cyizere	48.4	100.0	8.0	2
Improved cultivars	13.1	-	-	3
Rutanihisha	9.6	40.6	-	2
Seruruseke	42.8	33.3	75.0	3
Yangwe	7.2	-	13.3	3
Gacyalicyali	-	20.8	28.0	2
Rwicabana	-		12.0	3
Gapfutsi	21.6	-	-	3
Mushedile	3.8	-	-	1
Mbakungahaze	18.8	34.7	45.0	2

[a] measured from 24 h after harvesting

land cannot be effectively utilised for sequential cultivation of other crops. Additionally, Zidenga et al. (2012) reported that, in a semi-commercial setting, the land may need to be released for other uses. The lack of cuttings was also perceived as the result of late bulking cultivars.

Sweet taste, high yield, good ugali (good quality: taste, colour and ugali viscosity), resistance to diseases, early bulking and multipurpose uses were the most preferred traits of farmers. These traits, except the multipurpose trait, were reported by Tumuhimbise (2013) in Uganda, where farmers selected cultivars largely focused on high fresh root yield, early bulking, resistance to pests and diseases, and sweetness. The needs of farmers, the behaviour of consumers, the priorities of farmers, the production environment, the available transformation technologies and the farming systems should be some of the factors that dictate cassava selection.

The introduction and breeding of yellow fleshed cassava cultivar could be an effective way to reduce postharvest losses

Table 12 Consumers and farmers traits preference

Preferred cassava traits	Districts			Mean (%)	Rank
	Bugesera (%)	Kamonyi (%)	Gakenke (%)		
Sweet taste	95.3	60.7	100.0	85.3	1
High yield	80.0	72.8	64.5	72.4	2
Good ugali (good quality: taste, colour and viscosity)	91.2	38.3	74.8	68.1	3
Resistance to diseases	50.8	40.5	80.3	57.2	4
Early bulking	47.0	53.8	53.4	51.4	5
Multipurpose	32.6	100.0	17.8	50.1	6
Good colour of flesh (preferably white colour)	30.7	94.4	5.3	43.5	7
Many clients (level of acceptability at market)	69.6	21.2	8.3	33.0	8
Delayed to PPD	-	65.0	6.2	23.7	9
Dry matter content	16.5	21.5	30.5	22.8	10
Good odour	42.9	18.6	-	20.5	11
Long storage in field	26.5	3.3	6.2	12.0	12
Many cuttings produced	13.7	-	3.5	5.7	13
Cooked well (cookability)	3.4	-	4.2	2.5	14

Table 13 Farmer perceptions on yellow fleshed cassava

Preferences of yellow cassava cultivar	Districts			Mean (%)	Rank
	Bugesera (%)	Kamonyi (%)	Gakenke (%)		
High preference	5.0	45.0	47.7	32.6	-
Less preference	95.0	55.0	52.3	67.4	-
Reasons for high preference					
Early bulking	100.0	100.0	62.7	87.6	1
Resistant to pest and diseases	66.7	51.9	28.0	48.9	2
High yield	33.3	22.2	52.9	36.1	3
Good ugali	7.7	76.8	13.6	32.7	4
Multipurpose	-	40.7	-	13.7	5
Sweetness	-	-	21.6	7.2	6
Vitamin A	-	8.3	12.0	6.8	7
Cooked well		-	9.1	3.0	8
Reasons for less preference					
Drying problem	16.7	100	16.0	44.2	1
Bad colour	10.9	75.8	44.6	43.8	2
Without taste	77.0	10.0	42.9	43.3	3
Rapid rotting in the field	38.8	6.1	60.0	35.0	4
Carotene odour	26.0	40.0	28.6	31.5	5
Fewer clients	54.2	30.0	8.0	30.7	6
Low dry matter	38.9	-	-	13.0	8
Poor storage in the field	14.5	25.0	-	13.2	7
Not cooking well	15.2		2.9	6.0	9

due to PPD. Many scientists (Bayoumi et al. 2010; Sánchez et al. 2006; Sánchez et al. 2013; Xu et al. 2013; Zidenga et al. 2012), reported carotenoids could delay the onset of PPD owing to their antioxidant properties (Morante et al. 2010; Zidenga et al. 2012). Despite the availability of some yellow fleshed cassava in the country, their adoption is hampered by the yellow/orange colour being linked to traits such as low dry matter and carotene odour when consumed fresh or boiled. However, the carotene odour disappears when improved carotenoid cultivars are processed into flour to produce cassava paste or ugali. This odour could originate from volatile compounds derived from boiling (heating) cassava storage roots with high carotenoid content. Rios et al. (2008) and Zepka et al. (2014) reported that oxidation and thermal treatment cause degradation of carotenoids which influences the aroma and flavour of products containing them. This explains the non-adoption of yellow cultivars with high β-carotene content. Salcedo and Siritunga (2011) reported that several agronomic traits such as starch and dry matter, are negatively correlated with PPD and Wenham (1995) also confirmed that delayed PPD was a associated with reduced dry matter.

Table 14 Pair wise ranking of factors affecting adoption of new cassava cultivar in three districts of Rwanda

Factors	Ranking per district			
	Bugesera	Kamonyi	Gakenke	Overall rank
Farmer consultation before development of a new cultivar	1	2	1	1
Performance (yield, early bulking, diseases resistant)	3	1	2	2
Quality (cooking aspect, taste, dry matter, viscosity of Ugali)	4	3	3	3
Market acceptability	2	4	6	4
Information and extension services	6	5	4	5
Stake production	5	6	5	6

In conclusion, this study revealed the main constraints of cassava production and losses due to PPD, farmers preferred traits and factors affecting adoption of new cultivars in Rwanda. Lack of clean cuttings, pest and diseases (CBSD and CMD) and late bulking cultivars, associated with 11.9 % losses due to PPD, handicap the cassava sector in the country. The newly introduced yellow cultivars, which are resistant to CMD, have early bulking (8 months) and high yield could be an option for reversing the main constraints reported by farmers. However, the lack of a local participatory breeding program has affected the adoption of introduced cultivars. Participatory plant breeding, involving farmers at some stages of the breeding process, can promote the ownership of the developed cultivars and consequently enhance their adoption. The development and adoption of improved carotene content for cassava paste (ugali), earliness, disease resistance and delayed PPD cultivars are expected to promote the cassava sector and improve the livelihoods of cassava growers in Rwanda.

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Compliance with ethical standards

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References

Abalaka, A. (2012). Comparative Effects of Cassava Starch and Simple Sugar in Cement Mortar and Concrete. *ATBU Journal of Environmental Technology*, *4*, 13–22.

Bayoumi, S. A., Rowan, M. G., Beeching, J. R., & Blagbrough, I. S. (2010). Constituents and secondary metabolite natural products in fresh and deteriorated cassava roots. *Phytochemistry*, *71*, 598–604.

Bull, S. E., Ndunguru, J., Gruissem, W., Beeching, J. R., & Vanderschuren, H. (2011). Cassava: constraints to production and the transfer of biotechnology to African laboratories. *Plant Cell Reports*, *30*, 779–787. doi:10.1007/s00299-010-0986-6.

Catley, A., Burns, J., Abebe, D., & Suji, O. (2007). *Participatory Impact Assessment* (p. 63). A Guide for Practitioners. Feinstein International Center: Tufts University, Medford, USA.

Ceballos, H., Iglesias, C. A., Perez, J. C., & Dixon, A. G. (2004). Cassava breeding: opportunities and challenges. *Plant Molecular Biology*, *56*, 503–516.

Ceccarelli, S. (2006). Decentralized-Participatory Plant Breeding. In M. H. D. Desclaux (Ed.), *Lessons from the South-Perspectives in the North*. Besse: Participatory Plant Breeding: Relevance for Organic Agriculture.

El-Sharkawy, M. A. (2004). Cassava biology and physiology. *Plant Molecular Biology*, *56*, 481–501. doi:10.1007/s11103-005-2270-7.

Fao (2000). *The world cassava economy, Treds* (p. 46). Rome, Italy: Facts and Outlook. FAO.

Faostat (2011). *FAOSTAT database*. Rome, Italy: FAO.

Hillocks, R., & Jennings, D. (2003). Cassava brown streak disease: a review of present knowledge and research needs. *International Journal of Pest Management*, *49*, 225–234.

Hilton, A., & Armstrong, R. A. (2006). Statnote 6: Post-hoc ANOVA tests. *Microbiologist*, *2006*, 34–36.

Howeler, R., Lutaladio, N., & Thomas, G. (2013). *Save and grow: cassava*. Rome, Italy: FAO.

Kamau, J., Melis, R., Laing, M., Derera, J., Shanahan, P., Eliud, C., et al. (2011). Farmers' participatory selection for early bulking cassava genotypes in semi-arid Eastern Kenya. *Journal of Plant Breeding and Crop Science*, *3*, 44–52.

Kamau, J. W. (2006). *Participatory-based development of early bulking cassava varieties for the semi-arid areas of Eastern Kenya*. Pietermaritzburg: University of KwaZulu-Natal.

Kanbar, A., & Shashidhar, H. E. (2011). Participatory selection assisted by DNA markers for enhanced drought resistance and productivity in rice (*Oryza sativa* L.). *Euphytica*, *178*, 137–150.

Kpémoua, K., Boher, B., Nicole, M., Calatayud, P., & Geiger, J. (1996). Cytochemistry of defense responses in cassava infected by Xanthomonas campestris pv. manihotis. *Canadian Journal of Microbiology*, *42*, 1131–1143.

Luna, E., Pastor, V., Robert, J., Flors, V., Mauch-Mani, B., & Ton, J. (2011). Callose deposition: a multifaceted plant defense response. *Molecular Plant-Microbe Interactions*, *24*, 183–193.

Mbwika, M. J. and Mayala. (2001). Cassava sub-sector analysis outline. IITA.

Mkumbira, J., Chiwona-Karltun, L., Lagercrantz, U., Mahungu, N. M., Saka, J., Mhone, A., et al. (2003). Classification of cassava into 'bitter'and 'cool'in Malawi: From farmers' perception to characterisation by molecular markers. *Euphytica*, *132*, 7–22.

Morante, N., Sánchez, T., Ceballos, H., Calle, F., Pérez, J. C., Egesi, C., et al. (2010). Tolerance to postharvest physiological deterioration in cassava roots. *Crop Science*, *50*, 1333–1338. doi:10.2135/cropsci2009.11.0666.

Munga, T. L. (2008). *Breeding for Cassava Brown Streak Resistance in Coastal Kenya*. University of KwaZulu-Natal: Republic of South Africa.

Night, G., Asiimwe, T., Gashaka, G., Nkezabahizi, D., Legg, J. P., Okao-Okuja, G., et al. (2011). Occurrence and distribution of cassava pests and diseases in Rwanda. *Agriculture, Ecosystems and Environment*, *140*, 492–497.

Okafor, F. (2008). The Potentials of Cassava Flour As a Set-Retarding Admixture in Concrete. *Nigerian Journal of Technology*, *27*, 1–8.

Ravi, V., Aked, J., & Balagopalan, C. (1996). Review on tropical root and tuber crops I. *Storage methods and quality changes. Critical Reviews in Food Science & Nutrition*, *36*, 661–709.

Reilly, K., Bernal, D., Cortés, D., Gómez-Vásquez, R., Tohme, J., & Beeching, J. (2007). Towards identifying the full set of genes expressed during cassava post-harvest physiological deterioration. *Plant Molecular Biology*, *64*, 187–203. doi:10.1007/s11103-007-9144-0.

Rios, J. J., Fernández-García, E., Mínguez-Mosquera, M. I., & Pérez-Gálvez, A. (2008). Description of volatile compounds generated by the degradation of carotenoids in paprika, tomato and marigold oleoresins. *Food Chemistry*, *106*, 1145–1153. doi:10.1016/j.foodchem.2007.07.045.

Rurangwa, E. (2013). *Land tenure reform*, *The case study of Rwanda. Land Divided: Land and South African Society in 2013, in comparative perspective*. Cape Town, South Africa: University of Cape Town.

Salcedo, A., & Siritunga, D. (2011). Insights into the physiological, biochemical and molecular basis of postharvest deterioration in cassava (*Manihot esculenta*) roots. *American Journal of Experimental Agriculture*, *1*, 414–431.

Sánchez, T., Chávez, A. L., Ceballos, H., Rodriguez-Amaya, D. B., Nestel, P., & Ishitani, M. (2006). Reduction or delay of post-harvest physiological deterioration in cassava roots with higher carotenoid content. *Journal of the Science of Food and Agriculture*, *86*, 634–639. doi:10.1002/jsfa.2371.

Sánchez, T., Dufour, D., Moreno, J., Pizarro, M., Aragón, I., Domínguez, M., et al. (2013). Changes in extended shelf life of cassava roots during storage in ambient conditions. *Postharvest Biology and Technology*, *86*, 520–528.

Sayre, R. T. (2011). Biofortification of cassava for Africa: the BioCassava Plus program. In P. Charles (Ed.), *Access Not Excess: The search for better nutrition* (pp. 113–120). Smith-Gordon.

Smith, M. E., Castillo, F. G., & Gómez, F. (2001). Participatory plant breeding with maize in Mexico and Honduras. *Euphytica*, *122*, 551–563.

Stephen, B. and N. Lecumberri. (2011). Livelihoods zoning "plus" activity in Rwanda. The Famine Early Warning Systems Network (FEWS NET).

Tumuhimbise, R. (2013). *Breeding and evaluation of cassava for high storage root yield and early bulking in Uganda*. Pietermaritzburg, SA: University of KwaZulu-Natal.

Tumuhimbise, R., Melis, R., Shanahan, P., & Kawuki, R. (2014). Genotype × environment interaction effects on early fresh storage root yield and related traits in cassava. *The Crop Journal*, *2*, 329–337. doi:10.1016/j.cj.2014.04.008.

Uarrota, V. G., Moresco, R., Coelho, B., Nunes, E. D. C., Peruch, L. a. M., Neubert, E. D. O., et al. (2014). Metabolomics combined with chemometric tools (PCA, HCA, PLS-DA and SVM) for screening cassava (*Manihot esculenta* Crantz) roots during postharvest physiological deterioration. *Food Chemistry*, *161*, 67–78.

Ubalua, A. (2007). Cassava wastes: treatment options and value addition alternatives. *African Journal of Biotechnology*, *6*, 2065–2073.

Wenham, J. (1995). Post-harvest deterioration of cassava: A biotechnology perspectiveFAO.

Were, V. W., Melis, R., Shanahan, P., & Odongo, O. M. (2014). participatory evaluation methodsof cassava varieties preferred in the mid-altiltude tropical climate of Western Kenya. *African Journal of Agricultural Research*, *9*, 1326–1333. doi:10.5897/AJAR2013.7334.

Were, W., Shanahan, P., Melis, R., & Omari, O. (2012). Gene action controlling farmer preferred traits in cassava varieties adapted to mid-altitude tropical climatic conditions of western Kenya. *Field Crops Research*, *133*, 113–118.

Were, W. V. (2011). *Cassava breeding through complementary conventional and participatory approaches in western Kenya*. South Africa: Thesis (PhD), University of KwaZulu-Natal, Pietermaritzburg.

Xu, J., Duan, X., Yang, J., Beeching, J. R., & Zhang, P. (2013). Enhanced reactive oxygen species scavenging by overproduction of superoxide dismutase and catalase delays postharvest physiological deterioration of Cassava storage roots. *Plant Physiology*, *161*, 1517–1528.

Zepka, L. Q., D. S. Garruti, K. L. Sampaio, A. Z. Mercadante and M. a. A. Da Silva. (2014). Aroma compounds derived from the thermal degradation of carotenoids in a cashew apple juice model. Food Research International 56, 108–114.

Zidenga, T., Leyva-Guerrero, E., Moon, H., Siritunga, D., & Sayre, R. (2012). Extending cassava root shelf life via reduction of reactive oxygen species production. *Plant Physiology*, *159*, 1396–1407. doi:10.1104/pp.112.200345.

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