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Farmers' knowledge and perception of postharvest physiological deterioration in cassava storage roots in Ghana

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Abstract

Background: In spite of the essential role of cassava in ensuring household food security and employment for most rural farm households, postharvest physiological deterioration (PPD) of the roots which is serious abiotic stress in cassava renders the roots unmarketable, thereby reducing the economic value of the crop. This paper investigates farmers' knowledge and perception of PPD in the storage roots of cassava among smallholders in Ghana.

Methods: A participatory rural appraisal and a formal survey involving 137 farmers across four agro-ecological zones were conducted using focus group discussion and semi-structured questionnaires, respectively. With the appropriate perception indices, farmers' perceptions of each PPD attribute were assessed by the use of a 5-point Likert scale. The Kendall's coefficient of concordance was used further to rank identified cassava production constraints.

Results: The result shows that a significant number of farmers were aware of PPD and the corresponding changes in the roots. It was also confirmed that PPD commences from 2 to 3 days after harvest. Farmers perceived PPD to be caused by pathogens, sunlight, mechanical injuries during harvesting and atmospheric air. The results further indicated that farmers have in-depth knowledge of PPD in cassava. The findings suggest the importance of PPD which is ranked as one of the major constraints in cassava production with about 40% agreement among the farmers. Storing of cassava roots in polythene and jute sacks were found to delay PPD for a few days.

Conclusion: There is the need to concert cassava research and development efforts to tap into, and investigate further the adaptability and sustainability of these storage practices and methods to minimize both PPD and deterioration of cassava roots during storage.

Keywords: Cassava, Constraints, Perceptions, Postharvest physiological deterioration, Storage roots, Ghana

Background

Cassava (*Manihot esculenta* Crantz) is the sixth most important food crop in the world (Food and Agriculture Organization [1]). It is the third most important source of carbohydrates in Africa [2] and the second most important staple crop in Ghana [3]. Cassava serves as food for over 800 million people worldwide [4], providing about 500 calories daily for more than 70 million people [5]. It is estimated that 250 million people in sub-Saharan Africa (SSA) derive half of their daily calories from cassava [1]. The roots are used for animal feed, industrial starch production and income generation for many small-scale farmers [6]. Cassava roots and leaves are available all year round [7] making it an important food security crop, even in drought-prone areas [5]. Cassava occupies a key position in Ghana's agricultural economy contributing 22% of the agricultural gross domestic product [8]. It is the most important crop in terms of area cropped and total production. Cassava is produced by over 70% of Ghanaian farmers and consumed by more than 80% of the population [9], indicating its importance in food security.

In spite of the importance of the crop in the Ghanaian economy, its production is faced by a number of

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challenges. The key among these challenges is its short shelf life termed postharvest physiological deterioration (PPD). PPD is an oxidative reaction that starts immediately after harvesting when the root is detached from the mother plant [10, 11]. It starts from the central vascular bundles of the root, spreading to the adjacent storage parenchyma, and subsequently, the stored starch undergoes structural changes [12]. The roots deteriorate 24–48 h after harvest and subsequently changes colour. Visible signs of PPD are vascular streaking with blue or black discolouration, rendering the roots unpalatable and unmarketable [11]. PPD is a serious challenge confronting farmers, processors and consumers. To delay PPD, storage roots have to be consumed or processed immediately after harvesting. However, this is only practical on smaller scales but not on commercial levels. Participatory rural appraisal has been employed successfully in crop improvement. It recognizes the importance of farmer indigenous knowledge and skills to understand the target area and identifies production constraints, which result in the breeding of demand driven crop varieties that meet the needs of farmers. This paper evaluates farmers' knowledge and perception on PPD as a major constraint in cassava production. Besides PPD tolerance, this paper identifies and ranks other characteristics that farmers prefer in a new cassava cultivar. Such information is vital for guiding the development of improved demand driven cassava cultivars for increased productivity and incomes of farmers.

Methods

Study areas

The study was conducted in the Rain Forest, Semi-deciduous Rain Forest, Forest Savanna Transition and Coastal Savanna agro-ecological zones in Ghana (Table 1). The selected communities were Nkawie and Seidi in the Atwima Nwabiagya District of the Ashanti region, Ayigbe, Amangoase and Akrofrom in the Wenchi District of the Brong Ahafo region. Other communities were Ohawu in the Akatsi South District of the Volta region and Abodobi and Yeyaso in the Fanteakwa District of the Eastern region. These communities were selected because cassava farming and processing are the major occupation of the inhabitants. In addition, cassava is one of the major staples in these communities and plays an important role in ensuring household food security.

These agro-ecological zones are characterized by bimodal rainfall pattern ranging between 800 and 2500 mm per annum with an average of about 950 mm per annum. The major season begins in March and ends in July for the Rain Forest, Semi-deciduous and Coastal Savanna and April to July for the Forest Savanna Transition agro-ecological zone. The minor rainy season is from September to October for the Forest Savanna Transition and Coastal Savanna while that for the Rain Forest and the Semi-deciduous zones begin in September and ends in November.

Table 1 List of agro-ecological zones, districts and communities the study was conducted

Agro-ecological zone	District	Community
Rain Forest	Fanteakwa	Yeyaso
		Abodobi
Semi-deciduous Rain Forest	Atwima Nwabiagya	Nkawie
		Seidi
Forest Savanna Transition	Wenchi	Ayigbe
		Amangoase
Coastal Savanna	Akatsi South	Ohawu

Sampling procedure

Multi stage sampling procedure was employed to obtain the sample respondents for this study. One region was purposefully selected from each of the four agro-ecological zones. One district was randomly selected from a list of major cassava-growing districts in the region. From each of these districts, two communities were sampled with the exception of Akatsi South. Participatory rural appraisal (PRA) was conducted using focus group discussion (FGD) and a carefully constructed checklist. This was followed by a formal survey in which data were collected through interviews using semi-structured questionnaires. The FGD was used to elicit information on constraints in cassava production and marketing, perceptions of PPD, existing methods used to delay PPD and preferences for improved varieties with delayed PPD among the farmers at the community level. In each community, the FGD involved two main focus groups (male and female focus groups) after which they were merged into a single group for synthesis and confirmation of the issues discussed at the group level. After the FGD, a minimum of 15 farmers per community were randomly selected for the semi-structured interviews. Farmers were interviewed individually to solicit their views on the different topics. Overall, 137 farmers were interviewed.

Data analysis

Data collected were coded and analysed using Statistical Package for Social Sciences (SPSS). Descriptive statistics were used to summarize the data. Farmers' perceptions of each PPD attribute were assessed by the use of a 5-point Likert scale (Likert 1932). The following perception indices; $2 =$ strongly agree: $1 =$ agree: $0 =$ indifferent: $-1 =$ disagree: $-2 =$ strongly disagree were used. The mean perception for each PPD attribute was measured using Eq. 1.

$$\bar{x} = \frac{\sum n_i - x_i}{N} \quad (1)$$

where n_i = number of individuals who chose the ith response, x_i = the ith response, N = the total number of respondents.

For the Likert scale, a positive mean denotes agreement, whereas negative implies disagreement. To evaluate the importance of cassava production constraints among the farmers, the Kendall's coefficient of concordance (W) described by Mattson [13] was used to rank the constraints. A lower mean rank indicates the importance of the constraint and vice versa. The Kendall's W was computed as shown in Eq. 2.

$$W = \frac{12\sum \overline{R}_i^2 - 3N(N-1)^2}{N(N-1)} \quad (2)$$

where W = Kendall's value, N = total sample size, R = mean of the rank.

The Kendall's coefficient of concordance (W) is a measure of the extent of agreement or disagreement among farmers of the rankings obtained. The value of W is positive and ranges from zero to one where one denotes perfect agreement among farmers of the rankings and zero denotes maximum disagreement. This approach was further applied to identify and examine farmer preferred varietal characteristics in a new cassava cultivar.

Results and discussions

Characteristics of farmers

Distribution of the cassava farmers and their characteristics are presented in Tables 2, 3, respectively. Over 50% the sampled farmers were males with an average age of 45 years. The total number of farmers constituted of about 35% from the Ashanti region, 32% from Brong Ahafo region, 24% from the Eastern region and 8% from the Volta region (Table 2).

The farmers cultivated an average of 1 ha of cassava and travelled an average of 26 km from their farm to the market. Mixed cropping was practised by over 80% of the farmers and the cassava is largely intercropped with other food crops such as maize. Over 80% of respondents conserve their planting materials before planting.

Cassava production constraints

Seven major cassava production constraints were identified and ranked by farmers (Table 4). Overall, inadequate capital was ranked as the most important constraint and this was consistent across all the four agro-ecologies. This was followed by inadequate processing centres as this was also consistent across all the agro-ecologies.

Table 2 Distribution of cassava farmers by community and gender

Community	Males	Females	Total	Percentage (%)
Nkawie	14	9	23	17
Seidi	20	5	25	18
Ayigbe	10	18	28	20
Amangoase	7	10	17	12
Yeyaso	14	8	22	16
Abodobi	8	3	11	8.5
Ohawu	7	4	11	8.5
Total	80 (58%)	57 (42%)	137	100

Table 3 Characteristics of sampled farmers

Variable	Percent/mean (SD)
Age of farmers (years)	45.13 (12.87)
Farm sizes (hectares)	1.0 (0.7)
Distance from farm to market (km)	25.7 (22.7)
Cropping system	
Monocropping (%)	19.6
Mixed cropping (%)	80.4
Major cassava intercrops	
Plantation/tree crops (%)	8.8
Food crops (%)	73.7
Vegetable crops (%)	17.5
Conservation of plant material (%)	84.8

As fresh cassava roots cannot be stored for long due to the high moisture content and had to be processed immediately after harvest in order to increase the shelf life, deterioration of cassava roots after harvest was indicated as the next most important production constraint by the farmers.

Other constraints identified were high cost of labour (due to the long cropping cycle and harvesting in the dry season), pests and diseases and high cost of agrochemicals. At the agro-ecological zone level, however, pest and diseases were of priority to the farmers in the Coastal Savanna as they ranked it as the fourth most important constraint. The extent of agreement among the farmers of the rankings as indicated by the Kendall's 'W' suggests that overall more than 40% of the farmers are in agreement with the rankings. However, the highest agreement was recorded by farmers in the Semi-deciduous zone (44.7%) and the least by farmers in the Coastal Savanna (38.4%) agro-ecological zone.

Farmers' indigenous knowledge on postharvest physiological deterioration

Majority of the farmers (95.3%) were aware of PPD and its associated changes in the roots (i.e. colour change to

Table 4 Cassava production constraints across agro-ecological zones

Production constraints	Coastal		Forest		Semi-deciduous		Transition		Overall	
	Mean rank	Rank	Mean rank	Rank	Mean rank	Rank	Mean rank	Rank	Mean rank	Rank
Inadequate capital	1.91	1	1.94	1	1.94	1	1.85	1	1.91	1
Inadequate processing centres/buyers	2.27	2	2.12	2	1.94	1	2.34	2	2.14	2
High cost of transportation	4.82	5	4.47	3	4.52	4	4.73	4	4.31	3
Deterioration of roots after harvest	4.27	3	4.53	4	4.48	3	3.93	3	4.58	4
High cost of labour (in the dry season)	5.09	6	4.65	5	4.69	5	4.82	5	4.74	5
Pests and diseases	4.55	4	4.79	6	5.04	6	4.84	6	4.89	6
High cost of agrochemicals	5.09	6	5.5	7	5.4	7	5.49	7	5.43	7
W ($p < 0.000$)	0.384		0.4137		0.447		0.411		0.416	

brown, blue–black or black and subsequently the roots becoming dry, hard and dark) (Table 5). PPD was perceived to generally commence between 2 and 3 days after harvest. The main causes of PPD as perceived by the farmers were pathogens, sunlight, mechanical injuries during harvesting and atmospheric air. A number of methods were identified for storing cassava roots after harvest in order to reduce deterioration. However, it was common among the farmers that no PPD-tolerant cultivars exist, but rather, some cultivars were perceived to deteriorate faster than others.

Farmers' perception of PPD in cassava storage roots

For better understanding of the dynamics among farmers regarding their perceptions of PPD, the general perception among the farmers was evaluated using a 5-point Likert scale.

The results of farmers' perception of PPD are presented in Table 6. Perceived challenges with deteriorated roots were difficult to pound, reduced root quality and reduced market value. Also, PPD was perceived to start between 2 and 3 days after harvest and it was believed to be caused largely by mechanical injuries during harvesting.

Table 5 Farmers' knowledge on PPD in cassava

Attribute	Response by farmers
Symptoms of PPD	Roots change colour to brown or blue black and becomes dry, hard and dark
Number of days for cassava roots to deteriorate after harvest	3 days
Causes of PPD	Air, mechanical injuries, sunlight and heat
Methods for cassava root storage	In water or polythene bags, sacks, pits, under shade
Availability of PPD-tolerant cultivars	No PPD-tolerant cassava cultivars available

These perception attributes had mean score values between 1.17 and 1.42, implying that largely farmers were in agreement with the attributes represented by these indices. All the other indices had negative mean score values (−0.01 to −0.69) indicating their disagreement with those perception attributes. Farmers were somehow indifferent in some attributes with the fact that deteriorated roots taste better and also that PPD was caused by micro-organisms and thus can be prevented. Conversely, the farmers disagreed on the perception that PPD roots were easy to process and PPD roots can be used to prepare many dishes.

Bulk harvesting and methods for cassava root storage

The methods used by farmers to store cassava roots after harvest are presented in Fig. 1. Farmers harvest cassava roots in bulk only when there is availability of buyers; otherwise, harvesting is mostly done in bits for contingency purposes such as for sale and home consumption. Over 68% of farmers store the roots after harvest while the remaining farmers do not store but sell or consume immediately after harvest. However, among the farmers who store their roots, about 34% store in sacks; about 27% in polythene; about 26% in water; about 8% in pits and a little below 6% store the roots under shade.

Ranking of farmer preferred traits

On the whole, high yield was identified as the most preferred varietal trait and this was similar across the different agro-ecological zones (Table 7). This was followed by early maturity, high dry matter, delayed PPD, poundability, large roots, resistance to pests and diseases and peel colour (in order of importance).

More than half of the farmers were in agreement with the rankings (67.1%); however, the highest agreement was recorded by farmers in the Semi-deciduous Forest (69.4%) while farmers in the Coastal Savanna recorded the least (64.1%).

Table 6 General perception on PPD among sampled farmers

No.	Perception attribute	Strongly agree (2)	Agree (1)	Indifferent (0)	Disagree (−1)	Strongly disagree (−2)	Mean score
1	Deteriorated roots taste better	35	23	5	54	20	−0.01
2	Deteriorated roots are difficult to pound	64	69	1	3	0	1.42
3	Deteriorated roots affect root quality	30	105	0	2	0	1.19
4	Roots deteriorate 2–3 days after harvest	46	88	0	2	1	1.28
5	Mechanical injuries cause PPD	69	55	1	11	1	1.31
6	Micro-organisms cause PPD	7	42	26	22	39	−0.32
7	PPD reduce market value of roots	36	95	0	5	1	1.17
8	Deteriorated roots are easy to process	9	16	9	75	27	−0.69
9	Deteriorated roots can be used to prepare many dishes	3	36	2	61	35	−0.65
10	PPD can be prevented	9	34	27	39	24	−0.26

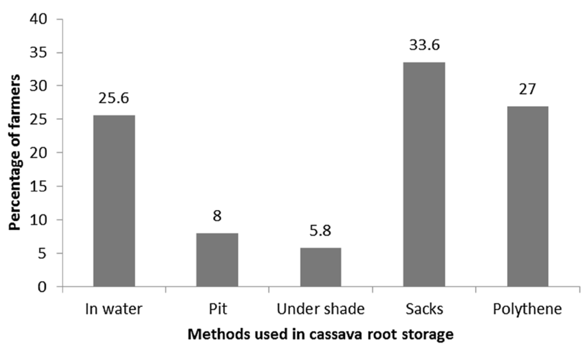

Fig. 1 Methods of storing cassava roots after harvesting

Discussion

Major constraints ranked by the famers were inadequate capital to expand their businesses, poor bargaining ability resulting in low pricing as well as the physiological deterioration of roots 2–3 days after harvest. These findings concert with that of [14], under the collaborative study of cassava in Africa project, in which two-thirds of Ghanaian farmers identified postharvest losses as a major risk factor in cassava production. This makes postharvest physiological deterioration a serious issue for farmers and other stakeholders involved in the cassava value chain. Other constraints identified were inadequate processing centres and high cost of transportation from farm gate to processing centre/market. This could be due to poor accessibility to farmers' field, poor road conditions and inappropriate means of transport to carry the bulky and highly perishable roots. This agrees with report by [15–17]. Thus, identifying ways of reducing the deterioration of cassava roots has a high potential of increasing the incomes of farmers.

The results further indicate that farmers have in-depth knowledge of postharvest physiological deterioration in cassava. This could be explained by their experience acquired over the years and indigenous knowledge in cassava cultivation. The discolouration of the roots and the number of days it takes before PPD sets in as perceived by farmers confirm earlier studies [12, 18, 19]. This implies that PPD has been known among farmers for a while and has been a constraint in production, marketing

Table 7 Ranking of farmer preferred cassava traits

Desirable trait	Coastal		Forest		Semi-deciduous		Transition		Overall	
	Mean rank	Rank	Mean rank	Rank	Mean rank	Rank	Mean rank	Rank	Mean rank	Rank
High yield	1.64	1	1.53	1	1.52	1	1.5	1	1.52	1
Early maturity	3	2	2.71	2	2.77	2	2.64	2	2.7	2
High dry matter	4.36	5	4.47	5	4.65	5	4.43	5	3.59	3
Delayed PPD	3.82	4	4	4	3.4	3	3.91	4	3.76	4
Poundability	3.27	3	3.41	3	3.6	4	3.64	3	4.5	5
Larger roots	5.98	6	5.98	7	6.2	7	5.76	6	5.97	6
Resistance to pests and diseases	6	7	5.91	6	5.98	6	6.02	7	6.72	7
Peel colour	7.27	8	7.26	8	7.29	8	7.18	8	7.25	8
Kendal's W, $p < 0.000$	0.641		0.666		0.694		0.663		0.671	

and processing of cassava. Farmers' indigenous knowledge on PPD makes them to believe that PPD cannot be prevented or controlled because it is a natural process. It is also evident from the results that there are no PPD-tolerant cultivars although some cultivars deteriorate faster than others; thus, developing cultivars that are tolerant to the PPD is very essential. This will not only erase the perception of no PPD-tolerant cultivars but also reduce PPD in harvested roots and increase the income of farmers and other stakeholders along the cassava value chain.

One of the ways of reducing PPD in cassava roots is through the storage of roots using appropriate methods. Several researchers have designed and evaluated cassava storage methods that have the potential of extending PPD in cassava roots [19–21] such as refrigeration at 4 °C and coating with paraffin or waxing. However, farmers have not adopted any of these cassava storage methods but have rather improvised their own means of storage. This may be due to the fact that these methods have not been well adapted to their local conditions and may also be cost-ineffective. In Ghana, most cassava farmers are poor and live in rural areas, and thus may not be able to afford refrigerators for storing the roots. Subsequently, even in situations where farmers are able to obtain refrigerators, they may not be able to afford the associated high cost of electricity. This makes such a storage method non-viable and cost-ineffective especially for storing large quantities of roots for the markets.

The findings suggest that storage of cassava roots in water is not an appropriate method while storage in polythene and jute sacks could delay PPD for a few days. Hence, these methods could be modified and adapted well into farmers conditions to be more effective and sustainable for minimizing both PPD and root rot during storage. The key reasons why farmers use their own storage methods could be attributed to the fact that their methods are less expensive and user-friendly. Although farmers perceived that PPD could not be solved, their preference for an improved cassava cultivar with delayed PPD was substantial as delayed PPD was ranked after high yield, early maturity and high dry matter. The rankings confirm the assertion that high yield is a very important attribute that farmers always desire in improved cultivars. The long maturity of the crop with its associated high cost of labour was also identified as another important constraint; hence, they prefer early maturing cultivars to late maturing cultivars that they currently cultivate. Since about 50% of the total production of cassava is consumed as *fufu*, the roots should also have good cooking qualities particularly for pounding. The peel colour was also of interest to the farmers because they perceived pink peel delays PPD more than the cream and white peels.

The high market value of cassava cultivars with such preferred traits could possibly explain the selection of those traits. This finding is in parallel with that of [22] where these traits were identified as farmer preferred traits in improved cassava variety. Adequate considerations should therefore be given to these varietal attributes in the development of improved cassava cultivars with delayed PPD. This would ensure that stakeholders obtain the best from the cassava roots and subsequently increase their incomes and improve their livelihoods.

Conclusion and recommendation

The study examined farmers' knowledge and perception of PPD in the storage of cassava roots among smallholders in Ghana. Major cassava production constraints identified were inadequate capital, low pricing, physiological deterioration, inadequate processing centres, pests and diseases, high cost of labour and transportation. Due to the pivotal role played by processing in managing post-harvest losses in cassava, establishment of more processing centres is vital to the development of a more effective and efficient cassava value chain in Ghana.

Farmers prefer cassava cultivars with good and stable yield, early maturing, high dry matter, delayed PPD, larger roots, poundability, resistance to pests and diseases and pink peel colour. Combination of these cultivar traits would facilitate their adoption by farmers and other stakeholders along the cassava value chain. Polythene and jute sacks were found to be the best storage technique for the cassava roots.

Farmers were aware of and had some indigenous knowledge about PPD. Research and development need to direct efforts at investigating this indigenous knowledge in relation to the available storage methods to develop sustainable cost-effective storage techniques capable of minimizing PPD during storage. The findings revealed that PPD is a major problem that needs to be addressed. It was evident that there are no PPD-tolerant cassava cultivars available to the farmers. However, some cultivars were found to deteriorate faster than others. This suggests that genetic diversity exist in farmers materials for improvement on delayed PPD. Determining the extent of diversity among cassava germplasm from farmers collections, research institutes and genetic resource centres could help in the identification of new sources of tolerance for PPD as well as other important economic traits. This would improve the storability of cassava roots and enhance cassava value chain in Ghana.

Abbreviations

PPD: postharvest physiological deterioration; FAO: Food and Agriculture Organization; SSA: sub-Saharan Africa; MoFA: Ministry of Food and Agriculture;

FGD: focus group discussion; PRA: participatory rural appraisal; SPSS: Statistical Package for Social Sciences; NRI: Natural Resources Institute; GCP: Generation Challenge Program; WACCI: West African Centre for Crop Improvement.

Authors' contributions
RP was responsible for designing the study and drafting of the manuscript. JAM provided technical advice in the stud design. BOA was responsible for analysis of the data. IKA assisted with the preparation of the manuscript. SKO and EYD provided technical advice in formulation of the research objectives and the review of the manuscript. All authors read and approved the final manuscript.

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Competing interests
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Ethical approval and consent to participate
The ethical approval and consent of participants in the survey were sought from the participants before allowed to willingly participate in the survey.

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