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The diversity of postharvest losses in cassava value chains in selected developing countries

Diego Naziri [a,*], Wilhelmina Quaye [b], Bernard Siwoku [c], Sittichoke Wanlapatit [d], Tu Viet Phu [e], Ben Bennett [f]

[a]*Natural Resources Institute (NRI), University of Greenwich, UK and International Potato Centre (CIP), Lima, Peru*
[b]*Food Research Institute (FRI), Council for Scientific and Industrial Research (CSIR), Ghana*
[c]*Federal University of Agriculture, Abeokuta (FUNAAB), Nigeria*
[d]*Cassava and Starch Technology Research Unit, National Center for Genetic Engineering and Biotechnology (BIOTEC), Thailand*
[e]*School of Biotechnology and Food Technology (SBFT), Hanoi University of Science and Technology, (HUST), Vietnam*
[f]*Natural Resources Institute (NRI), University of Greenwich, UK*

Abstract

The extent of physical and economic postharvest losses at different stages of cassava value chains has been estimated in four countries that differ considerably in the way cassava is cultivated, processed and consumed and in the relationships and linkages among the value chain actors. Ghana incurs by far the highest losses because a high proportion of roots reach the consumers in the fresh form. Most losses occur at the last stage of the value chain. In Nigeria and Vietnam processors incur most of the losses while in Thailand most losses occur during harvesting. Poorer countries incur higher losses despite their capacity to absorb sub-standard products (therefore transforming part of the physical losses into economic losses) and less strict buyer standards. In monetary terms the impact of losses is particularly severe in Ghana and estimated at about half a billion US dollar per annum while in the other countries it is at the most about USD 50 million. This comparison shows that there are no “one-size-fits-all" solutions for addressing postharvest losses but rather these must be tailor-made to the specific characteristics of the different value chains.

Keywords: physical losses, economic losses, cassava, Ghana, Nigeria, Thailand, Vietnam

1 Introduction

Since the onset of the food crisis initiated in 2006/2007 there has been a change in development priorities, bringing an increased focus on agriculture and a renewed interest in the reduction of postharvest losses (PHL) as a means of increasing food availability. The review “The Future of Food and Farming” (Foresight, 2011) and the “Missing Food” report (World Bank, 2011) highlighted the reduction of PHL as key response to global food availability concerns.

Food losses take place at production, post-harvest and processing stages in the supply chain. Losses at the end of the chain (retail and consumption) are often called “food wastes”, which relates to retailers’ and consumers’ behaviours (Parfitt *et al.*, 2010). In this study, with the term “losses” we refer to both losses and wastes but clear distinction is made about the value chain stage where they occur.

PHL reduction offers the particular advantage of increasing food availability without requiring additional

[*] Corresponding author
Natural Resources Institute, University of Greenwich, Central Avenue, Chatham Maritime, ME4 4TB, UK
Email: d.naziri@greenwich.ac.uk
Phone: +44.1634.88.30.69; Fax: +44.1634.88.37.06

land, water, labour, energy and agricultural inputs. In view of these advantages an in-depth analysis of the cassava value chains in four countries (Ghana, Nigeria, Thailand and Vietnam) was undertaken to identify the extent and causes of physical and economic losses and estimate their impact in monetary terms.

Cassava (*Manihot esculenta*) is the third most important source of calories in the tropics, after rice and maize; and the second one in Africa (FAO, 2004). In Sub-Saharan Africa (SSA) it is mainly grown by smallholder farmers often on marginal land where it is productive even on poor soils and under drought conditions. As such cassava is a vital crop for both food security and income generation in least developed countries. In South-East Asia cassava is grown almost exclusively as cash crop, sometimes in large plantations, primarily for industrial processing into dry chips and starch.

SSA is the most important cassava production region in the world and Nigeria the world's leading producer (FAOSTAT, 2013). South-East Asia ranks second as largest production region, where the main producers are Indonesia, Thailand and Vietnam. Thailand and Vietnam are the largest world's exporters of cassava starch and chips.

Once harvested cassava root is highly perishable and the rapid postharvest deterioration that cassava incurs actually restricts its storage potential to two to three days (Iyer *et al.*, 2010). As storage of roots is rare, the most common and sensible way to minimise losses is to consume or process them as soon as possible after harvesting. Unfortunately, this does not always happen and significant amount of roots spoil or incur various degrees of quality deterioration.

These losses have a broad range of negative impacts such as loss of income and food intake and represent an obstacle for transforming cassava from a subsistence to a cash crop, particularly in SSA. Fresh cassava roots (FCR) are affected by two types of postharvest deterioration: primary physiological deterioration that involves internal discoloration and secondary deterioration due to microbial spoilage (Booth & Coursey, 1974). As well as direct physical loss of the crop, postharvest deterioration causes a reduction in quality, which has implications on marketing of cassava leading to price discounts. Furthermore, there can be additional losses due to change in use. For example, in countries where cassava is mainly eaten in fresh form, if the roots cannot be marketed within two or three days from harvest they may be processed into dried products of lower value (Westby, 2002).

Little reliable information is available that quantify the extent of losses. Several studies have commented on the high levels of losses in the cassava value chain but without attempting to estimate them (Scott *et al.*, 2000; Vowotor *et al.*, 2010). In some documents these estimates seem to be only gross values based on anecdotal evidence. Wenham (1995) reports that PHL in a number of SSA and Asian countries range between 5 % and 30 % but does not indicate their cause or the value chain stage where they occur.

FAO (2011) has attempted a systematic assessment of losses for a number of commodities worldwide. The estimates refer to physical losses only while economic losses are not reported. Losses of root and tuber crops in developing regions have been estimated at 40 % in SSA, 31 % in South and South-East Asia and 35 % in Latin America.

GIZ has assessed cassava PHL in Nigeria focusing on *gari* and starch value chains only (Oguntade, 2013). The study found that most losses occur at the processing stage and affect almost exclusively FCR rather than processed products. Other studies have focused on PHL incurred during traditional processing, for instance during *gari* (Boahen, 2004) and *agbelima* processing (Dziedzoave *et al.*, 1999) in Ghana.

Our study allows comparison between countries that differ considerably in the way cassava is cultivated, processed and consumed and in the relationships and linkages among the value chain actors.

2 Materials and methods

In order to estimate the extent of PHL along a commodity chain and to identify appropriate strategies and technologies to reduce them, the full range of activities required to bring a product through different stages of production, processing, and marketing until it reaches the end-user has to be evaluated. A Value Chain Analysis (VCA) provides one approach for such an understanding in that it is a process of tracing a product's flow from the point of production to the point of consumption along with identifying the roles and relationships of different stakeholders at different points of the chain (Kaplinsky & Morris, 2001).

Following Yin (2003) a mix of both quantitative and qualitative approaches were adopted. The VCAs have been designed in such a way to gather specific additional layers of information on how much, where and when PHL occur and what are the main causes and remedies adopted by the different actors.

A semi-structured questionnaire was specially designed for data collection. The questionnaire covered core processes, traded volumes, prices and price mechanisms, seasonality, standards, types and major causes of losses, and information on loss quantities and mitigation measures for each cassava product.[1] The data collection has been carried out by individual country teams between July and October 2012. In addition to individual interviews with value chain actors, focus group discussions were organised for triangulation purposes.[2] Key-expert interviews were held with relevant public officers, managers of other cassava projects and initiatives, agricultural inputs and credit suppliers. Furthermore, observations of production, processing and distribution activities were conducted to cross check information given by respondents.

In order to ensure consistency two preliminary workshops have been held in Vietnam and Ghana to design the methodology and develop a common definition of PHL. In fact the definition of PHL is a contended subject, often defined on a situational basis, and attempting to find a universally accepted definition is beyond the scope of this study. Based on the inputs provided during the workshops and discussions held with postharvest experts we have defined two distinct categories of losses, namely physical losses and economic losses.

For the purposes of this study, physical losses are losses incurred in the value chain which do not have alternative uses or residual value. Physical losses include the following: (a) product left behind in the field after harvesting; (b) spoiled or damaged product that is thrown away; and (c) product that disappears at any value chain stage (e.g. eaten by pests).

Physical losses can affect either FCR or processed products. Value chain maps were developed based on literature and validated during the survey. In line with Gustavsson *et al.* (2011) physical losses have been categorised according to the value chain stage where they occur, namely: (i) on-farm losses, including harvesting and postharvest losses; (ii) losses during trading, transport and handling of cassava and cassava products; (iii) losses at the processing sites;[3] and (iv) losses at distribution, retail and consumption level.[4]

Based on the information gathered from the interviews, we have estimated the most likely level of losses incurred at each stage of each sub-chain in percentage. Using as a starting point the national annual production statistics or relevant literature, we calculated the extent of losses in absolute terms at each sub-chain stage, net of losses incurred at previous stages in order to avoid double counting (therefore we have been more rigorous than simply summing up the relative losses of all stages and then applying this figure to the overall annual production). Once we have determined how much is physically lost at each stage, we have then calculated the monetary value of physical losses by taking into account the average market price at the relevant point of the chain.

As far as economic losses are concerned these, unlike physical losses, have alternative uses. In this study economic losses refer to (a) spoiled or damaged product whose market price is discounted and (b) spoiled or damaged product that cannot be used for what it was initially meant (e.g. damaged roots processed into lower value products). Since the major problem is the deterioration of the root we have assumed that only FCR incur economic losses. For FCR we have identified two typical levels of quality deterioration sold at discounted price to either final consumers or processors. For each level we have determined the level of price discount relative to the price of good quality roots at that point of the chain. The market value lost due to quality deterioration has been used to estimate the extent of monetary losses.[5]

3 Results and discussion

3.1 Cassava production, processing and products in target countries

In Ghana, cassava production in 2011 was estimated at 14.2 million tonnes. Cassava is cultivated by over 90 % of the farming population, mostly intercropped in small plots (0.4 to 12 hectares). About 95 % of harvested cassava is commercialised and mainly used for the preparation of traditional food such as *fufu*, *gari*,

[1]Cassava can reach the final consumer or user in either fresh form or processed in a number of ways. The term value chain encompasses the whole array of different products (and hence processes) a single commodity can be traded as. Since very different losses can be incurred when cassava is consumed and traded in one form rather than another, for each country, we have broken down the value chain in his different ramifications (to which we refer to as "sub-chains") and estimated the losses for each of them. However, in this study, sub-chains absorbing less than 1 % of the country production have been neglected.

[2]Due to the different characteristics of the cassava value chain and the heterogeneity in the answers of the value chain actors the number of respondents varied from country to country and ranged between 99 (Thailand) and 145 (Ghana).

[3]Excluding on-farm processing.

[4]Excluding farmer household's own consumption.

[5]In some cases the assessment of the quality losses might be very difficult, such as when a partially spoiled FCR is used to increase the organic matter in the soil. In such a case quality losses have been assimilated to physical losses.

agbelima and *kokonte*. *Fufu* is prepared at household level and, at less extent, by caterers such as restaurants and hotels by boiling and pounding peeled FCR. *Gari* is a creamy-white, granular flour usually made by small-scale women processing groups nearby the cassava production areas. *Agbelima* is a fermented wet paste (called *fufu* in Nigeria) that, similarly to *gari*, is largely produced by women groups around cassava farms. *Kokonte* consists of dry cassava chips and chunks and is usually produced by the farmers themselves, particularly in the regions where the consumption of *fufu* is not popular. Small volumes of roots are used for industrial purposes such as for the production of starch and high quality cassava flour (HQCF). About half of the harvested roots are processed into *fufu*. *Gari* and *agbelima* are also very popular. Table 1 shows the estimated allocation of FCR to the different sub-chains.

Nigeria is by far the world leading producer of cassava (in 2010 the production was estimated at around 37 million tonnes). However, our study covered only the South-West zone whose annual production is reported at about 7.5 million tonnes.[6] Cassava is largely grown intercropped by small-scale farmers on small plots (0.2 to 5 hectares) for both food and income purposes but there are a few farmers who practice larger scale monocropping and target processing factories. About 80 % of production is marketed. The majority of roots is processed into *gari* (Table 1) by village processing groups usually located nearby the plantation areas. Substantial amounts are processed into *fufu* that, differently from Ghana, is a fermented wet paste produced by processors around the cassava farms. Small volumes of roots are used for industrial processing into HQCF and starch.

In Thailand the most recent figures estimate annual production at around 22 million tonnes (2011). Cassava is cultivated with extensive adoption of improved agronomic practices (including chemical inputs, irrigation and mechanisation) in plantations of 4 to 8 hectares but farms larger than 80 hectares exist too. Cassava is grown exclusively as cash crop for industrial processing into starch and dry chips. It is estimated that 55 % of harvested roots are supplied to large-scale starch factories (Table 1). About 65 % of starch produced is for the export market. The rest of the roots is processed into dry chips by medium-scale processors. About 70 % of chips are exported, almost exclusively to China where they are used for livestock feed and as feedstock by the emerging biofuel industry.

[6]Information about cassava processing and consumption patterns in other parts of Nigeria is extremely scarce, and often unreliable. As such we should be extremely careful in extrapolating these results to Nigeria at large.

In Vietnam annual production is estimated at about 10 million tonnes (2011). The production scale significantly differs between North and South of the country. In the North farmers are mainly small-scale with an average land size of less than one hectare. Improved agronomic practices are not widely adopted leading to considerably lower productivity than in the South where cassava value chain is characterised by higher level of development in both production and processing. In the latter cassava is mostly produced by large commercially-oriented farms with a size of 20–30 hectares and up to 300 hectares. In Vietnam cassava is almost exclusively processed into starch and dry chips. About 55 % of roots are processed by medium and large-scale modern dry starch processing firms (Table 1) primarily located in the South. In this part of the country there is also some limited rudimental dry chip production carried out by micro and small-scale processors using almost exclusively low-quality roots and cassava harvested from very small plots (such as in the backyard) or left in the field after the main harvest. In the North, starch factories cannot absorb entirely the local production and a considerable amount of FCR are locally processed into dry chips or transported to surrounding provinces, mainly to specialised so-called “craft villages” producing wet starch in the outskirts of Hanoi. In the North chip processing is much more developed than in the South and is carried out by relatively larger-scale chip processors usually equipped with slicing machines and coal kilns and exporting mainly to China for its livestock feed and biofuel industries. Wet starch (a semi-processed product that is further refined into dry starch) is produced using simple equipment by micro and small-scale processors.

3.2 *On-farm physical losses*

Two main types of on-farm losses have been identified. The first one refers to losses occurring during harvesting due to either the whole roots accidentally left behind in the field unnoticed or broken roots that are voluntary left behind in the field because they would not find a market. The second type refers to the postharvest deterioration when the roots are not immediately consumed or processed. On-farm losses of processed products are negligible.

In Ghana, with the exception of the FCR sub-value chain the roots are always harvested by either the farmer for immediate use (for own-consumption or processing into *kokonte*) or the processor that arrange their prompt transportation to the nearby processing site (for *gari* and *agbelima*). In these cases the losses are negligible since the roots can be left in the ground for a long time without getting overripe or spoiled. On the other hand, in some cases, fresh roots that have to reach the final consumer without further processing (FCR sub-value chain) are harvested by the farmer and sold to an intermediary at the farm gate. In such a case the collection may be delayed for several reasons and, therefore, some losses occur (estimated to affect 0.5 % of harvested roots).

In South-West Nigeria roots for own-consumption are harvested a few at a time by the farmer and usually immediately processed. Again, losses can be assumed as negligible in this case. However, for *gari* and *fufu*, unlike in Ghana, most roots are harvested by the farmers themselves and sold at the farm gate to assembling agents in charge of transporting and selling the roots to the nearby processors. When delays occur, these may determine some spoilage of roots (estimated to affect 1 % of roots).

In Thailand physical losses occur during harvest due in particular to breakages from mechanised uprooting. Unlike in poorer countries, broken roots are usually left in the field because they would incur rapid deterioration, thus not meeting the standard of the processor and being rejected. Moreover, due to the relatively large size of the farms some roots remain unnoticed and unharvested in the soil. Besides, the roots are often sold to the processors through an intermediary that collect them from the production areas. Whenever the intermediary is not in charge of harvesting and has to collect the roots at the farm gate, some physical losses may occur due to delays. Overall on-farm losses have been estimated at 1.5 % for both the starch and chip sub-chains.

In Vietnam, in the dry starch sub-chain typical of the South of the country, cassava is usually purchased by the trader well before the harvest. He will be then in charge to organise the harvest and immediate transport of the roots to a nearby factory. Even when the farmer decides to sell directly to the factory he often relies on local traders for harvesting and transport. Whatever is left unharvested in the field is usually gleaned by local villagers and therefore consumed, even though not by the intended value chain actors. Therefore losses can be assumed as negligible at this stage. Conversely in the North, although the harvesters are less likely to leave unharvested roots in the typical small plots, some losses occur in the wet starch and chip value-chains because often there is an intermediary that purchases the harvested roots and transport them to the processing site. As such some physical losses may occur in case of delays. These have been estimated at 0.5 % for both sub-chains.

In conclusion, losses due to unnoticed roots seem to be of some importance only in Thailand due to the combination of three factors: large farm size; mechanised harvesting; and lack of poor locals looking for unharvested roots. In the other three countries on-farm losses are less substantial mainly because of the small plot size (Ghana, Nigeria and North Vietnam) or the presence of nearby villagers willing to glean (South Vietnam). Breakages of roots during harvesting occur in all countries but are more substantial in Thailand due to the widespread use of mechanical harvesters. This is the only country were broken roots are left in the field and represent a physical loss. In other countries they are collected and sold at discounted price or processed into lower value products, such as *kokonte* in Ghana. Therefore, in these countries, breakages represent an economic loss rather than a physical one. On-farm postharvest deterioration of roots affects all countries but seems more important in Nigeria where roots are typically harvested by the farmer, rather than by the buyer, and sold at the farm gate.

3.3 Physical losses in trading, transport and handling

Physical losses at this stage can affect both FCR and processed products. However, we found that losses of processed products, for instance due to damaged packaging, are always negligible. Obviously no losses at this stage are incurred when the roots are for domestic consumption or processed on farm because, in these cases, the roots never leave the farm. Two types of losses have been identified at this stage. The first type refers to roots that either have to be thrown away because of spoilage during transport and trading (e.g. due to breakdown of the vehicle or delays of the sale) or drop off during the journey. These represent physical losses. The second type refers to breakages in particular during loading and off-loading of the vehicle. These broken roots are then sold at discounted price and, therefore, represent an economic loss rather than a physical one.

In Ghana, in the FCR sub-value chain, roots have to be transported over considerable longer distances than when processed into *gari* and *agbelima* whose processing occur nearby the cassava production area. As such, it has been found that physical losses at this stage are higher in the former case than in the latter one and they were estimated at 1 % and 0.5 %, respectively.

In South-West Nigeria the vast majority of roots to be processed into *gari* and *fufu* are transported to nearby processing sites. Again, since very short distances are covered, the extent of physical losses is low and estimated at 0.5 %.

Table 1: *Estimation of physical losses by stage of the sub-value chains.*

	Sub-value chain	*Allocation FCR by sub-chain (%)*	*On farm (t)*	*Trading, transport and handling (t)*	*Processing (t)*	*Retail and consumption (t)*	*Total physical losses (t)*	*Total physical losses (%)*	*Share by sub-chain (%)*
Ghana Production: 14,240,867 t/yr	Own-consumption	5 %	0 (NEGL)	N/A	N/A	N/A	0	0 %	0 %
	Fresh root	48 %	33,822 (0.5 %)	67,306 (1 %)	N/A	1,332,657 (20 %)	1,433,785	21.2 %	82 %
	Gari	24 %	0 (NEGL)	16,911 (0.5 %)	168,265 (5 %)	0 (NEGL)	185,176	5.5 %	11 %
	Agbelima	17 %	0 (NEGL)	12,176 (0.5 %)	121,151 (5 %)	0 (NEGL)	133,327	5.5 %	8 %
	Kokonte	6 %	0 (NEGL)	N/A	N/A	0 (NEGL)	0	0 %	0 %
	Total	100 %	33,822	96,393	289,415	1,332,657	1,752,287	12.4 %	100 %
	Losses by stage (%)		2 %	6 %	17 %	76 %	100 %		
SW Nigeria Production: 7,500,820 t/yr	Own-consumption	20 %	0 (NEGL)	N/A	N/A	N/A	0	0 %	0 %
	Gari	52 %	39,004 (1 %)	19,307 (0.5 %)	307,369 (8 %)	0 (NEGL)	365,681	9.4 %	76 %
	Fufu	27 %	18,002 (1 %)	8,911 (0.5 %)	88,664 (5 %)	0 (NEGL)	115,577	6.4 %	24 %
	Total	100 %	57,006	28,218	396,033	0	481,258	6.7 %	100 %
	Losses by stage (%)		12 %	6 %	82 %	0 %	100 %		
Thailand Production: 21,912,416 t/yr	Starch	55 %	192,829 (1.5 %)	1,186 (0.01 %)	1,186 (0.01 %)	0 (NEGL)	195,201	1.6 %	39 %
	Chips	45 %	157,769 (1.5 %)	970 (0.01 %)	970 (0.01 %)	145,513 (1.5 %)	305,223	3.1 %	61 %
	Total	100 %	350,599	2,156	2,156	145,513	500,424	2.3 %	100 %
	Losses by stage (%)		70 %	0.4 %	0.4 %	29 %	100 %		
Vietnam Production: 9,870,000 t/yr	Dry starch	55 %	0 (NEGL)	27,154 (0.5 %)	27,018 (0.5 %)	0 (NEGL)	54,172	1.0 %	18 %
	Wet starch	5 %	2,455 (0.5 %)	9,772 (2 %)	4,788 (1 %)	4,740 (1 %)	21,755	4.4 %	7 %
	Chips	39 %	19,248 (0.5 %)	19,152 (0.5 %)	190,565 (5 %)	0 (NEGL)	228,965	5.9 %	75 %
	Total	100 %	21,704	56,078	222,371	4,740	304,893	3.1 %	100 %
	Losses by stage (%)		7 %	18 %	73 %	2 %	100 %		

Note: In brackets the share of cassava roots and products affected by physical losses; N/A = not applicable; NEGL = negligible.

In Thailand minor losses are reported during the transportation of roots to the processing sites. The fact that the processing sites are within the main cassava production areas implies that the roots have to be transported over short distances. Therefore the spoilage of roots is extremely rare and physical losses at this stage have been estimated at just 0.01 %.

In Vietnam, in the wet starch sub-value chain, FCR have to be transported over considerable longer distances than the roots processed into dry starch and chips. Moreover, in the wet starch chain, it might take several hours to sell all FCR, which usually are delivered the day after the harvest. As such, physical losses in the wet starch chain are considerably higher than in other sub-chains and estimated at 2 % and 0.5 %, respectively.

In conclusion, unsurprisingly, the extent of physical losses during transport, trading and handling is strictly related to the distance that has to be covered to reach the sites where the root are processed or retailed. Accordingly, the processing sites are usually located near the farming areas. However, the wet starch sub-chain in North Vietnam is an exception and roots have to be transported over long distances from the mountainous areas to the outskirts of Hanoi. Other significant losses occur in the FCR chain in Ghana because cassava is often retailed in fresh form and has to reach usually distant urban markets.

3.4 Physical losses at processing sites

At processing sites the quantities of processed products that are exceptionally lost (e.g. due to flooding of the store) are negligible and, therefore, it can be assumed that only fresh roots are affected by physical losses.

In Ghana these losses are relevant for *gari* and *agbelima* sub-chains only. Significant amount of roots spoils at the processing storage yard when processing is delayed despite attempts to minimise losses by covering the roots, especially in case of rains (e.g. with polyethylene sacks). Average losses occurring at these sites have been estimated at 5 %.

In South-West Nigeria the *gari* and *fufu* sub-value chains are the only ones affected by losses at the processing sites when something impedes the immediate processing of the roots (e.g. shortage in peeling capacity or mismanagement leading to excess of FCR on the yard). The average losses have been estimated at 8 % and 5 %, for *gari* and *fufu* respectively.

In Thailand, processors apply good management practices and have the capacity to quickly process a large amount of roots. It is rare that roots are not processed within two days from the harvest and, as such, spoilage of roots at this stage is extremely uncommon and estimated to affect just 0.01 % of roots.

In Vietnam, good coordination of the actors exists in the dry starch chain in the South. Traders schedule the deliveries of FCR together with the factories that have the capacity to rapidly process them. However, some delays may occur and therefore some physical losses that have been estimated at 0.5 %. In the wet starch and chip sub-value chains in the North the considerably weaker coordination, the lower processing capacities and the higher humidity determine higher losses. These have been estimated at 1 % and 5 %, respectively.

In summary, losses at the processing sites can be substantial and it appears that they affect particularly the traditional processing sub-chains in the two African countries and the dry chip sub-chain in North Vietnam. In this country significant losses also incur by wet starch processors. Losses are minimal in Thailand thanks primarily to well-executed just-in-time procurements of FCR, excellent coordination among the actors, large processing capacity and favourable weather conditions.

3.5 Physical losses at distribution, retail and consumption level

These losses are not relevant when roots are used for own-consumption and are often negligible for processed products.

In Ghana these losses affect the FCR sub-chain only and can be extremely high. It has been estimated that physical losses at retail stage are about 5 %. At household and caterer level, despite the fact that some mitigation measures are undertaken (e.g. just-in-time purchases and, sometimes, packaging and refrigeration of peeled roots), it is estimated that 15 % of the roots spoil and are thrown away.

In Nigeria some losses at this stage can occur in the *gari* and *fufu* sub-chains. However, in those sub-chains losses are extremely rare (e.g. when packages are damaged) and, therefore, have been assumed as negligible.

In Thailand a substantial amount of dust is produced during the transport and mechanical handling of chips, mainly due to the abrasion of the chip surfaces against the cement floor. It is estimated that an average of 1.5 % of chips' weight is lost in the form of dust. Conversely, in the starch sub-chain physical losses occur only in exceptional cases, e.g., breakages of the bags or flooding of the store. These losses have been considered as negligible.

In Vietnam losses of dry starch and chips have been assumed as negligible. Conversely some physical losses occur in wet starch sub-chain when the starch block, typically stored in underground pit, is exposed to aerobic conditions. In this case the outer part of the block has to be thrown away. These losses were estimated at 1 %.

In conclusion, losses at distribution, retail and consumption level are exceptionally high in Ghana since in this country large volumes of roots reach the final users in the very perishable fresh form. Conversely, in Nigeria where cassava is usually distributed and retailed in processed form losses at this stage are negligible. In the two South-East Asian countries, the processed products are the ones that incur most losses at this stage: namely, dry chips in Thailand and wet starch in Vietnam.

3.6 Economic losses

According to our definition, no economic losses are incurred if the roots are used for own consumption or on-farm processing (e.g., *kokonte*) since, in these case, the roots are not traded and, therefore, not priced.

In Ghana, breakages occur mainly during harvest (15 % of roots are estimated to be affected) and transport (estimated at 3 % and 1 % for the FCR and the *gari-agbelima* sub-value chains, respectively, due to the longer distance that has to be covered in the former). Partial spoilage leading to discounted price mainly occurs at retail level and in the FCR sub-chain only (affecting 10 % of roots on average). As such, altogether, in the FCR and *gari-agbelima* chains, 28 % and 16 % of roots incur some economic losses, respectively.

In Nigeria it is estimated that between 10 % and 30 % of roots suffer economic losses on farm due either to breakages during harvest or deterioration when delays in marketing occur. Moreover, about 2 % of roots are affected by economic losses, mainly due to breakages, during transport to the processing sites. As such, altogether, in the *gari* and *fufu* sub-chains around 20 % of roots are sold at discounted price.

Based on price information gathered during the survey it has been estimated that, in Ghana and Nigeria, approximately half of FCR incurring economic losses receive around 20 % price reduction and the remaining half a 40 % reduction.

In Thailand and Vietnam, more often than not, the roots are sampled at the time of the delivery to the processor and their starch content is determined by using Reimann balances (standard quality is 25 %). The price is then set accordingly but, beyond a certain level of quality deterioration, FCR are simply rejected. While starch content is dependent on the variety, agronomic practices and other production factors, in these countries a starch content below 25 % is found only when cassava incur considerable postharvest deterioration.

In Thailand when starch content in FCR is lower than 25 % a price reduction is applied for each point below the standard. In the starch and chip sub-value chains about 5 % of roots delivered have 23 % starch content. Only a minimal amount of roots have lower starch content (0.35 % of roots with 22 % starch content in the starch sub-chain and 0.5 % with 21 % starch content in the chip sub-chain).

In Vietnam a similar but less rigorous system is applied (sometimes relying on visual examination). As rule of thumb, a so-called “point system” mechanism reduces the price of roots by about 10 % and 20 % in the first and second day after harvest, respectively. In the dry starch and chip value chain it has been estimated that 75 % of roots are processed the day of harvest, 20 % the day after and 5 % two days after. In the wet starch value chain, due to the long distances and frequent delays, only 10 % of roots are processed the same day of the harvest. Around 80 % are sold the next day and the remaining 10 % the following one.

3.7 Comparative analysis of postharvest losses

The extent of physical losses at each stage of the different sub-chains was estimated by taking into account the estimated cassava production in 2011, the share of roots allocated to the different sub-value chains and the relevant percentages of physical losses (Table 1).

Ghana, with about 12.5 % of roots annually produced lost (equivalent to over 1.7 million tonnes of FCR), is by far the country that incurs the highest physical losses. This is primarily due to the fact that a high proportion of roots (48 %) have to be transported, distributed and stored in the fresh form until consumption. Accordingly, over 80 % of these losses are ascribable to the FCR sub-value chain. PHL occur at each value chain stage but are particularly relevant (76 %) at the final one (retail and consumption), which is similar to what is reported to occur in developed countries (Table 1 and Figure 1). This challenges the generally accepted view that in developing countries losses occur mainly in the first stages of the chain. While other important losses are incurred at the *gari* and *agbelima* processing sites it must be noticed how the good organisation of these sub-chains allows keeping on-farm losses at an extremely low level and this should be taken as an example of good practice.

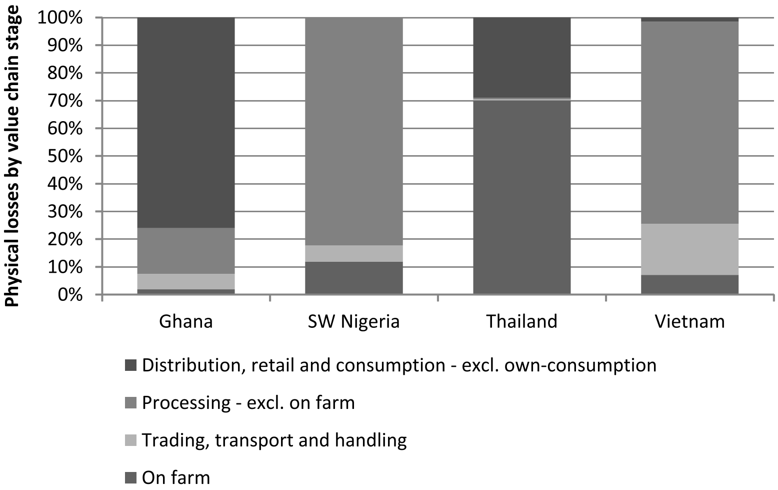

Fig. 1: *Level of physical losses by value chain stage.*

South-West Nigeria ranks second in terms of extent of physical losses with an estimated 7 % of harvested cassava physically lost (corresponding to almost half a million tonnes of FCR per year). Unlike Ghana and Thailand, most root spoil at the processing stage (over 80 % of physical losses occur at the *gari* and *fufu* processing yards).

Vietnam ranks third in terms of extent of physical losses. It is estimated that about 3 % of annual cassava production is lost (equivalent to 300,000 tonnes of FCR equivalent).[7] Losses affect almost exclusively cassava in the fresh form even though some relatively minor losses occur due to the spoilage of wet starch. As shown in Figure 1, most of these physical losses are incurred either at the processing stage (73 %) or during transport and trading of FCR to the processing sites (18 %). The dry starch value chain in Vietnam is efficient in minimising the losses and this is proved by the fact that, while absorbing about 55 % of cassava roots, it is responsible for just 18 % of physical losses. Conversely, the dry chip and wet starch sub-chains in northern Vietnam are the most affected by losses: in the former because of spoilages at the processing yards; in the latter because of transportation over long distances.

Thailand is the country that incurs the lowest physical losses. Due to the highly efficient chain coordination only 2.5 % of total annual production is lost (equal to about half a million tonnes of root equivalents). Unlike in Ghana, physical losses in Thailand occur mainly at farm level (70 %) due to roots remaining accidently unharvested or, when broken, voluntarily left in the field. In Thailand other significant losses (29 %) occur at the final value chain stage and are due to the dust produced during the handling of chips. The dry chip sub-chain contributes to over 60 % of physical losses.

In terms of monetary value lost due to physical PHL, again, Ghana outpaces the other countries. As shown in Figure 2, the worth of physical losses in Ghana has been estimated at almost USD 390 million per annum, much higher than in Thailand, South-West Nigeria and Vietnam (USD 45, 30 and 20 million, respectively). The fact that the value of physical losses in Ghana is about tenfold that of the other countries is explained by the fact that in this country most losses occur at the last stage of the value chain when considerable value has been added and, as such, where the price of the roots is at the highest (actually the vast majority of roots spoil at household level where each unit lost is worth its retail price).[8] It has been estimated that in Ghana physical losses at retail and consumption level are responsible for about 93 % of the lost monetary value.

In all countries more roots are affected by economic losses than by physical losses (Figure 2). We have also found that poorer countries and households have the ability to reduce the impact of PHL by transforming part of the physical losses (no residual value) into economic losses (residual value), e.g. by processing broken roots into lower value products.

[7] For Vietnam and Thailand it was necessary to convert some losses into root equivalents since some of them affect the processed products (wet starch and chips, respectively).

[8] At the time of the survey the farm gate price of cassava roots was about 60 to 80 Ghanaian New Cedi (GNC) per tonne (33–43 USD/t), the rural wholesale market price was about 80 and 120 GNC/t (44–67 USD/t) while the retail price ranged between 210 and 490 GNC/t (114–269 USD/t).

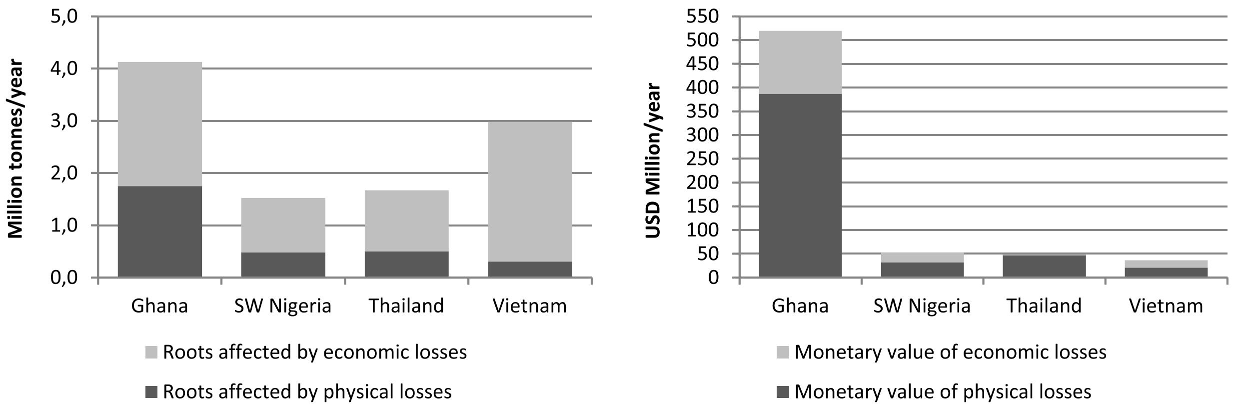

Fig. 2: *Estimated volume (left) and monetary value (right) of physical and economic losses.*

The volume of roots incurring economic losses is particularly substantial in Vietnam where about 28 % of harvested cassava (equal to 2.7 million tonnes per annum, Figure 2) is sold at discounted price due to quality deterioration. The wet starch sub-chain seems particularly affected (only 10 % of cassava reaches the processor within 24 hours from harvest). In the dry starch and chips sub-chains the share of roots incurring some economic loss is lower and estimated at about 25 %.

In Ghana and South-West Nigeria about 19 % and 16 % of harvested roots are sold at discounted price (equal to 2.4 and 1.0 million tonnes per annum, respectively). Again, the FCR sub-chain in Ghana stands out and, in this chain, about 28 % of FCR are sold at a price lower than what would be paid for a quality root.

In Thailand it is estimated that just over 5.5 % of roots (equal to 1.2 million tonnes per annum) are sold at discounted price.

Apart from the volume of roots affected by quality deterioration, the monetary value of economic losses depends on the pricing mechanism in place. This appears to be extremely high in Ghana (over USD 130 million per annum). This is again considerably higher than for any other country studied (Figure 2) and is explained by the fact that about half of FCR reach the final consumers in the fresh form. Furthermore, in Ghana the buyer is quite demanding in terms of quality and tends to considerably discount these roots (up to 50 % of the price paid for quality FCR).

In South-West Nigeria the value of economic losses is estimated at just over USD 20 million. While the share of roots affected by economic losses is not significantly different from Ghana, in Nigeria, *gari* and *fufu* processors, that absorb most of the roots, pay an average price (67 USD/t at the time of the survey) that is much lower than the Ghanaian retail price for FCR. That means that an equivalent percentage price discount has, in monetary terms, in Nigeria a much lower impact than in the case of Ghana.

In Vietnam the value of economic losses is estimated at about USD 15 million. While this is the country where the largest share of roots incurs some price reduction, the magnitude of the quality deterioration and, hence, price reduction is considerably lower than in the two African countries. The price of FCR can be discounted by no more than 10 %. In case of poorer quality the processors simply reject the root.

In Thailand economic losses are minimal. They are estimated at less than USD 2 million per year. Firstly, a small amount of roots (about 5 %) incurs quality deterioration to the point that the processor has to discount their price. Secondly, alike Vietnam, whenever it occurs the price discount mechanism works until a certain threshold. Beyond that point the root is rejected. It is rare that the price is discounted by more than 5 %.

Figure 2 shows the total volume and monetary value of physical and economic losses in the four countries. In Ghana a total of about 4 million tonnes of cassava are affected by either physical or economic losses (29 % of annual production). The combined monetary value of these losses is extremely high and estimated at USD 520 million per annum.[9] This is explained by several factors. Firstly, Ghana is the second largest cassava producer in our sample. Secondly, the vast majority of roots are marketed and about half of the marketed roots reach

[9] As pointed out by Oguntade (2013), in reality, it is not feasible to achieve zero losses, as protection measures to secure 100 % of the harvest will be inevitably disproportionally costly.

the final consumers in the fresh form. This has two implications: on the one hand, more roots incur total or partial spoilage; on the other hand, losses further down the chain have a more profound impact on the total monetary value of PHL because a higher value has become embedded in the product (i.e., the economic cost of the loss accumulates along the chain). Finally, the buyer in Ghana tends to considerably discount lower quality roots. In South-West Nigeria and Thailand PHL affect a similar amount of cassava (about 1.5 million tonnes per annum) and have comparable monetary value (about USD 50 million). However, in relative terms, the share of the country annual cassava production incurring PHL is very different (20 % and 8 %, respectively). Finally, in Vietnam almost 3 million tonnes of cassava incur physical or economic losses (with strong predominance of the latter), representing 30 % of the annual production. However, the monetary value of total PHL is estimated at just about USD 35 million due to the relatively minor monetary impact of economic losses.

The worth of PHL in Ghana represents about 22 % of the total potential retail value of cassava products (net of physical losses). In South-West Nigeria, Vietnam and Thailand this is estimated at 7 %, 4 % and 2 %, respectively.

It is worth noticing how, despite the fact that in all countries more cassava is affected by economic rather than physical losses, the impact of the former in monetary terms is considerably more modest due to the residual value embedded in the affected fresh roots. This clearly emerges by comparing the two graphs in Figure 2.

4 Recommendations

Our study found that very different levels of PHL occur across different countries, value chains and stages of the single value chain. Although our findings reveal considerable lower physical losses than usually reported in the literature, it is crucial to understand where, when, why and how losses occur in order to identify possible solutions for their reduction and maximise the economic, social and environmental benefit of any intervention aiming at reducing them.

While providing solutions for PHL reduction is beyond the scope of our work, we would like to suggest some possible technological, commercial and institutional innovations that can contribute to minimise losses at different points of the chain.

Among the four target countries, on-farm losses appear to be significant in Thailand only due to widespread use of mechanical harvesters. These machines have been considerably ameliorated over the time but further improvements would contribute to reduce left-overs and breakages. In the longer term, this would benefit also less developed countries where the cassava sector is likely to face significant consolidation towards larger plantation, higher inputs and mechanisation in the near future.

The main causes of PHL at the stage of trading, distribution and consumption are, at a large extent, the same, i.e., the short shelf-life of the root combined with delays in marketing and consuming it. These losses affect mainly the FCR sub-chain in Ghana. At this regard a combination of innovations can be envisaged. Several technologies for extending the shelf-life of the fresh root have be validated and adopted in other countries, particularly for targeting distant and export markets. Some of these technologies, including waxing, paraffin coating, and high humidity storage, can be tested and adapted to the specificities of other countries. Even though an in depth cost-benefit analysis should be conducted, this seems particularly promising for Ghana where the retail price of FCR is extremely high. In this country the possibility to address PHL by commercial innovation, and in particular by developing substitutes of unfermented *fufu* with longer shelf-life (e.g., instant *fufu* to be reconstituted at household level) should be explored and, if consumers' acceptability is proved, this could open up a large market for a less perishable value-added processed product. In terms of institutional innovation we have found out that poorer countries, in spite of their better capacity of absorbing sub-standard products and less strict standards applied by the buyers, incur higher losses, mainly because of the weak coordination of the different value chain actors. In this regard the best example is represented by the Thai starch value chain where processors coordinate staggered planting, supply farming input, schedule the harvest and arrange for the transport of roots to the plant in such a way minimising delays and therefore losses. While we have noticed that also in Ghana a good coordination between farmers and processors of *gari* and *agbelima* exists and contributes to minimise losses, other sub-value chains in SSA, particularly for *gari* and *fufu* in Nigeria and FCR in Ghana, still offer considerable room for improvements in order to synchronise harvest, transport, processing and retailing (including by adopting forward contracts with institutional buyers and caterers in Ghana). In Vietnam losses incurred during the transport of the roots to the wet starch processing centres could be reduced by relocating the processing sites nearby the cassava production area but this requires connecting them to the electricity grid and ensuring regular supplies of clean water. In terms of losses of processed products, Thailand is the only country where substantial amount of cassava is lost in the form of dry chips' dust. While palletisation is the most obvious solution for reducing the amount of dust produced this is a technology from which the country has moved away years ago since the additional cost is higher than the price premium paid by the livestock industry and not required for using the chips as feedstock for biofuel production.

Finally, we have found that losses of fresh roots incurred at the processing sites are substantial in the traditional processing sites in Ghana and Nigeria and in the dry chip sub-chain in Vietnam. In the former the main cause is the delay in processing due to shortage in peeling capacity and mechanical peeling would enormously help in tackling this problem although it must be recognised that considerable effort has been put over the last years by several research institutes to develop efficient peelers (e.g., the International Institute for Tropical Agriculture – IITA) but with limited success. In Vietnam delays in processing are mainly caused by limited processing capacity of small-scale chip processors in the North of the country. It is likely that, due to the fast consolidation of the sector, these processors will be progressively replaced by more efficient medium-scale processors that are likely to adopt Thai-style equipment.

The most important recommendation from this study is that there are no "one-size-fits-all" solutions for addressing postharvest losses but rather these must be tailor-made to the specific characteristics of the different value chains taking into account their technical as well as the economic feasibility.

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