

**Post-harvest losses of fruits and vegetables and prospects for use of solar energy for conservation of agricultural products in Benin**

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**Abstract:** This study aims to estimating the post-harvest losses of fruits and vegetables (F&V) in Benin and examining the possibility of using solar energy to improve their conservation and the preservation of their nutritional potential. Data were collected through literature review and investigations through F&V value chains in the different agricultural development poles (ADP) or agro-ecological zones of Benin. In different ADP, losses of almost all seasonal F&V have been estimated at more than 50% of production. The most important losses (at least 80% of the quantity produced) are recorded for tomatoes. The quantities of most produced F&V (pineapple, mango, Solanum leaves and tomato) lost, could have covered the annual needs of nearly four million children for vitamin A, more than 700,000 children for iron and more than 400,000 children for zinc. The use of solar energy could therefore be considered as a solution to either facilitate the sustainable conservation of food products or to produce energy for the operation of small processing units at the local level.

**Keywords:** Post-harvest losses, Fruits and vegetables, Food preservation, Solar drying, Benin

**Introduction**

Storage and preservation of agricultural products is a critical issue in low- and middle-income countries where production is concentrated in harvest periods that are generally short in duration. In Africa in particular, nearly 40% of agricultural products are lost or wasted; this constitutes a loss of earnings estimated at \$48 billion, equivalent to the GDP of Ghana in 2017 (Lundqvist et al., 2008; Parfitt et al., 2010; FAO and World Bank, 2010; Prusky, 2011; Agence Ecofin, 2019).

Losses are notably observed after the harvest of agricultural products and throughout the value chains; from the fork to the storage system and the entire marketing circuit. They concern almost all agricultural speculations in a worrying context of food insecurity. Fruits and vegetables (F&V) are the group of agricultural crops most prone to post-harvest losses. The lack of control of post-harvest storage methods, the high water content and the physiological activities of F&V make them highly perishable products. Globally in 2016, post-harvest losses of F&V from the end of harvest had been estimated at more than 20% (FAO, 2019). In developing countries, post-harvest loss data can be estimated to be at least 45% (Kitinoja and Kader, 2015). This constitutes not only a significant loss of financial resources for producers but also and above all a significant loss of micronutrients for the population. Indeed, F&V are excellent sources of vitamins and minerals essential for good health, nutritional status and prevention of diseases due to micronutrient deficiencies.

In Benin, F&V are cultivated all over the country and the sector is in expansion. The main fruits produced are: pineapple, citrus, mango, bananas, avocado, papaya and guava. As far as vegetables are concerned, the range is very varied. Tomato production is by far the most important, with more than 60% of the market garden tonnage. Other important productions are leafy vegetables, okra, chili and onions. Unfortunately, data on post-harvest losses of F&V at the national level are scarce, and those that do exist are not relative to the entire national territory.

The present study therefore aims at making a quantitative and qualitative estimate of post-harvest losses of main F&V and identifying factors that contribute to these losses in order to consider options for reducing losses.

1. Methodology

1.1 Framework of the study

Benin's agricultural sector is currently structured around the Agricultural Development Poles (ADP) (called *Pole de Développement Agricole* in French). There are seven ADPs in which locomotive speculations and associated speculations have been selected according to the potentialities of the agro-ecological zones that each pole covers (Figure 1) (Presidency of the Republic of Benin, 2017; Akponikpe et al., 2019). The management body of the ADP is the Territorial Agency for Agriculture Development (TAAD) (called *Agence Territoriale de Développement Agricole* in French).

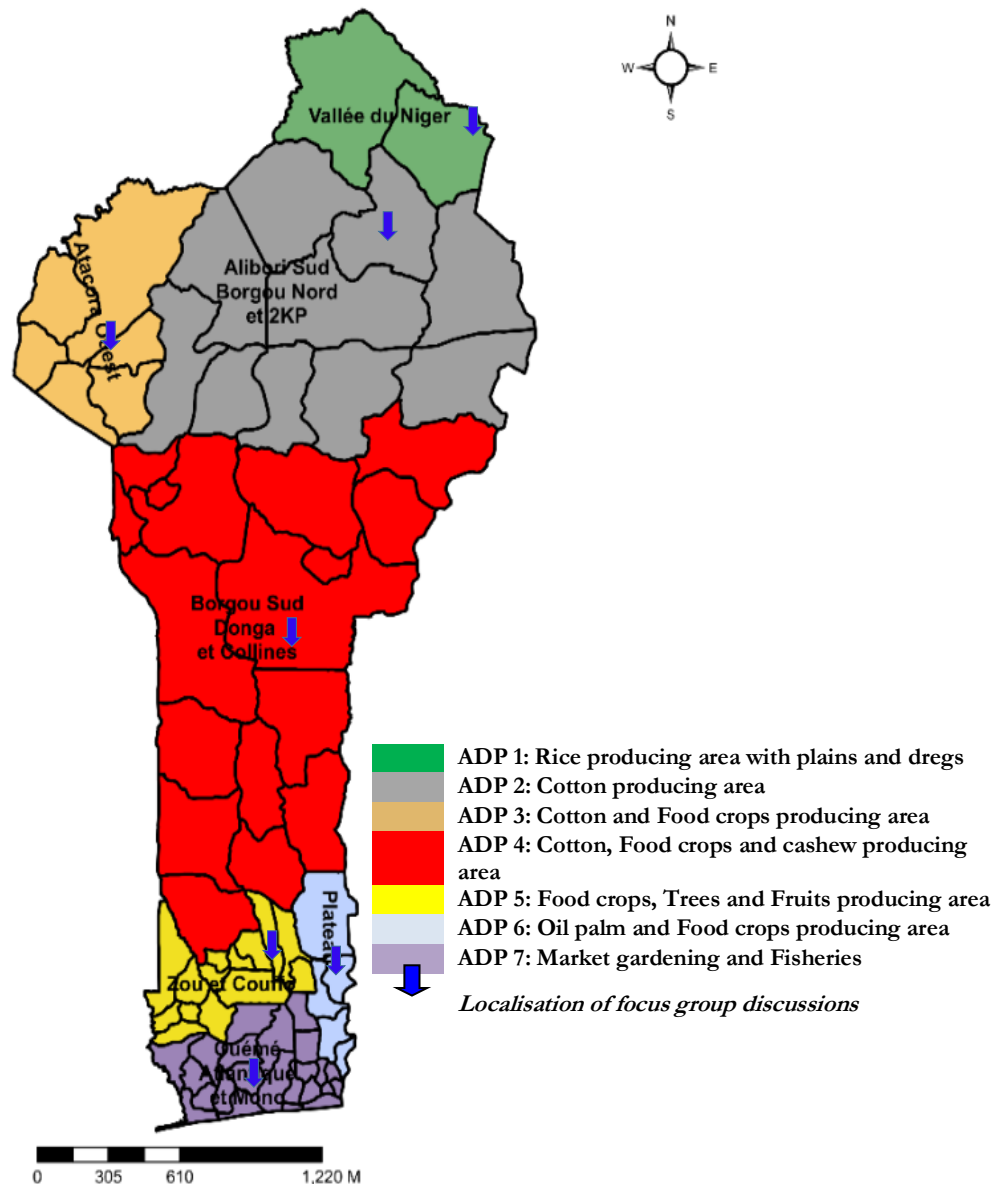


Figure 1: Map of Benin showing the agricultural development poles (Akponikpe et al., 2019) and localisation of focus group discussions

The present study used two methodological approaches. First, we conducted a literature review on the main agricultural crops in Benin and other countries in the West African sub-region as well as the post-harvest losses recorded for each crop. Then we collected data in each of the seven (7) ADPs in Benin.

## 1.2 Literature review

We collected data among agricultural production statistics at national level from the National Institute of Agricultural Statistics and from the various ADPs. Some TAADs provided documents related to the evaluation of post-harvest losses of agricultural products in their intervention zone.

## 1.3 Field surveys

In each TAAD, individual interviews were conducted with a specialist of crop production and post-harvest management. These interviews focused first on the identification of priority crops and diversification crops that are grown at the ADP level. We then discussed the post-harvest losses observed, their causes and the strategies implemented to reduce them.

Focus group discussions (FGD) were then held with producers and different actors from the value chains that are subject to significant post-harvest losses. For some agricultural crops, the value chain actors are organized into several associations according to their activities or roles in the value chain. For example, in the case of pineapple, there are three different groups of actors: producers, processors and traders. As losses can occur at these different levels, discussions were held with actor at each level separately. But for most crops, such an organization does not exist, so we organized the discussions with the producers. During the FGD, we estimated post-harvest losses either as a percentage of total production or using traditional units for estimating agricultural crops (basins, sacks, etc.) before returning to a volume-weight equivalence. Factors that influence food preservation and storage were also discussed.

FGD lasted an average of 1.5 hours and were conducted in the main local language of each community. The groups generally consisted of about ten people, both men and women, who are involved in different aspects of agricultural production. The discussions were recorded with the permission of the participants. We obtained also verbal consent from all participants in both the individual and group interviews.

Figure 1 showing a map of Benin indicating the ADPs indicates the geographical location of the places where we held FGD with producers.

## 1.4 Data processing and analysis

The recordings of the FGD were transcribed and then analyzed by theme. We were thus able to estimate the main post-harvest losses and identify the stages in the value chain where losses are most important, determine factors that contribute to post-harvest losses, provide information on current conservation methods and identify their strengths and weaknesses through a participatory diagnosis.

For each speculation, we calculated the average percentages of losses recorded from the estimates made together with the producers of the seven (7) different ADPs and the few data provided by institutions in charge of agricultural production. The estimates of losses were quantified (in tons) from the production data of the 2018-2019 production year (National Statistics Data) which is the closest to the period of data collection and statistics of FAO (2021). Then, for the main F&V (pineapple, tomato, greater nightshade, and mango), these losses were reported in quantities of micronutrients lost taking into account the nutritional composition of species (Vincent et al., 2020). We considered micronutrients of interest namely iron, zinc and vitamin A. These micronutrients are necessary for the growth of children aged 6-23 months and their deficiency for such young children leads to malnutrition. Finally, we calculated the approximate number of children aged 6-23 months whose annual micronutrient needs could have been met by the amount of agricultural produces lost. Annual requirements were estimated from the recommended daily micronutrient intakes for children aged 6-23 months (FAO and WHO, 2004), considering the 365 days of a year.

## 2. Results

### 2.1 Estimation of post-harvest losses

In the different agro-ecological zones of Benin, losses of seasonal fruits have been estimated at values well above 50% of production (Table 1). When processing technology is well developed and marketing channels are well defined, as is the case for pineapple in the Atlantic Department, losses are reduced but remain significant (above 50%) (Agri ProFocus, 2017). For other fruits such as mango and citrus, which are little valued in processing units, losses are greater than 60%. Other fruits such as cashew apples are not or hardly valorized; almost the entire quantity produced is lost (85-100%).

In general, F&V are marketed in a fresh state. Post-harvest losses are significant in case of poor sales. The most illustrative case is that of tomatoes. Large quantities of tomatoes are often lost during harvest periods. Post-harvest losses are estimated at more than 80% of the production.

Quantitative estimates of these losses for the main fruits and vegetables (pineapple, mango, african eggplant leaves and tomato) show that they lead to significant nutrient losses (Table 1). Tomato losses are the most significant because post-harvest losses are greater than those of the other crops.

Table 1: Estimated post-harvest nutrients losses

Parameters	Qty produced *	Loss of product		Loss of nutrients		
		% Loss	Qty	Iron	Zinc	Vitamin A
<i>Units</i>	<i>Tons</i>	<i>%</i>	<i>Tonnes</i>	<i>kg</i>	<i>kg</i>	<i>gER</i>
Tomato	360 195	80	288 156	2 017	634	253 577
African eggplant leaves	55 040	60	33 024	1 420	241	195 832
Pineapple	400 000	50	200 000	1 200	480	24 000
Mango	30 000	60	18 000	126	18	72 720
TOTAL	845 235	-	539 180	4 763	1 373	546 130

\*Data from national agricultural statistics and FAO statistics (2021); Qty = Quantity

These losses could have been used to cover the annual needs of nearly four million children for vitamin A, more than seven hundred thousand children for iron, and more than four hundred thousand children for zinc (Table 2).

Table 2: Estimated post-harvest losses in child-years

Parameters	Chidren needs/year*	Number of children corresponding to the lost quantities				Total number of children	
		Tomato	African leaves	eggplant	Pineapple		Mango
Iron	6 789 mg	297112	209167		176 757	18 560	701 594
Zinc	3 066 mg	206766	78629		156 556	5 871	447 821
Vitamin A	146 000 µg	1736831	1341318		164 384	498 083	3 740 614

\* Estimated from the Recommended Daily Allowance for Micronutrients (FAO and WHO, 2004).

## 2.2 Loss factors

Post-harvest losses are due to several climatic, agronomic and technological factors, the most important of which are presented below.

An **inadequate drying** linked to the atmospheric conditions: The quality of the drying is determining for the conservation of the majority of agricultural products at national level. Without sufficient sunlight and when humidity is too high due to rain, dew or other phenomena, the products rot and post-harvest losses are significant. The level of sunshine depends generally on the region of the country and the periods/seasons.

**Pest attacks:** F&V are subject to parasitic attacks ranging from microorganisms to insects, birds and rodents. These attacks can occur at all stages of plant development (from sowing to ripening through the entire vegetative stage) and also after harvest if storage and preservation conditions are not optimal or if drying has not been well done.

**The quality of fertilizers used and the low purchasing power of producers:** Producers do not have always the purchasing power to take the exact quantities of fertilizers needed. They therefore reduce the necessary doses or play with the quality of the fertilizer to be used, which makes the final products more vulnerable to pests. According

to most actors in the vegetable production system, the use of chemical fertilizers and pesticides has a negative impact on shelf life; vegetables that have been treated rot more quickly.

**Slum in sales and lack of processing and preservation technology:** In case of slum in sales, due to the lack of an adequate processing or storage/preservation system, producers are often forced to throw away harvested produce. Most of the existing technologies for processing/preserving fruits and vegetables are not affordable for small-scale producers. For example, efficient drying equipment uses too much energy.

**Transport conditions:** Poor transport and conveying conditions of foodstuffs from production to sales (heat, crowding, etc.) also lead to significant losses.

### 3. Discussion

The purpose of this study was to estimate post-harvest losses of F&V in Benin. It revealed that F&V, grown throughout Benin, are subject to significant post-harvest losses. The most lost F&V in Benin are respectively mango and tomato with 60 and 80% losses. An analysis of data collected by the AgriProFocus Benin team (2017) had estimated post-harvest losses of tomato at 86% in ADP 7 (in southern Benin). In contrast, a study conducted in Parakou (in the northern part of the country) by Yolou in 2019 on the risks of post-harvest losses and endogenous methods of preserving vegetable products, had given a percentage loss of 32% for tomato. The literature reports different percentages of losses depending on the region, and this could be linked to the differences in climate between the regions of Benin. Indeed, the drier climate of the northern part favors the drying of vegetables as well as their conservation, contrary to the climate in the southern part which is more humid. This also explains the difference between our results, which are relative to the entire country, and those of Vayssières et al. in 2008 for the Borgou department (in the northern part of the country). These authors had obtained, between the months of April and June 2006, average losses of mangoes varying between 20% and 50% (Vayssières et al., 2008). Since our data are more recent, we can also suggest that post-harvest losses of mangoes may have increased over time; this points out the urgent need to develop effective storage, preservation and processing methods.

Fruits, and to some extent vegetables, are generally marketed and consumed fresh. And this form of consumption is actually more appropriate since it preserves micronutrients (Hama-Ba et al., 2017). Thus, fresh F&V should be sold within a period not exceeding the "freshness" period; otherwise, they should be preserved in some way (Brisebois, 2017). However, in most developing countries, there are almost no reliable harvesting systems and/or post-harvest management facilities (Gillet and Kestemont, 2015). The most significant losses are, therefore, incurred during storage and marketing of the products (Yolou, 2019). Producers generally use traditional techniques including drying by direct exposure to the sun. This type of drying is a common process throughout Benin depends on the weather conditions in each region and when it is not done well, losses are inevitable and significant. Drying by direct exposure of the product to the sun can greatly decrease the amount of provitamin A in vegetables due to their hypersensitivity to heat (Mulokozi and Svanberg, 2003; Vyankatrao, 2015). On the other hand, the use of solar dryer allows for temperature control and thus increases carotene retention (Mulokozi and Svanberg, 2003).

Our study also highlighted crop attack by pests as another important loss factor. According to FAO (1989), produce infected with fungi, bacteria or viruses becomes unusable due to deep decay, which is also the result of contamination in the field before harvest. When the disease only affects the surface of the goods, there may be a loss of consistency. Fungal and bacterial diseases are transmitted by microscopic spores that travel through the air, soil and decaying plant material. Infections can strike at any time after harvest. They often result from injuries sustained during processing or handling of the crop. They affect the viability and quality of the grain and reduce the yield of the consumable product (Kossou, 1995).

Pest attacks and excessive use of fertilizers also contribute to the loss of quantity and quality of agricultural products in the post-harvest period. In addition, the transport and delivery of produce to markets is another critical point (FAO, 1989), with much damage resulting from vibration or shaking of vehicles due to road conditions and excessive loading, overheating of produce due to lack of ventilation in vehicles or use of vehicles that offer no protection from the sun, vehicle breakdowns, and careless handling of packaged produce during loading and unloading. Also, sometimes when law enforcement officers board illegal shipments, the length of time it takes to clear the shipments is so long that the products rot. The cost of these formalities also means that some drivers prefer to flee, abandoning the load.



Finally, in the marketing system, cases of poor sales generally lead to rapid deterioration of products and significant losses due to the lack of adequate methods of preserving of F&V (FAO, 1989). Indeed, when the harvest season arrives for a fruit or a vegetable, supply often greatly exceeds demand, forcing traders to either sell off their products or to dispose of them. It is therefore necessary to develop a policy of processing perishable foodstuffs in order to limit losses.

Post-harvest losses in F&V are all the more worrying as these crops are essential elements of the dietary balance of people in difficult economic situations (Temple and Moustier, 2004). Indeed, with their high content of fiber, minerals, vitamins and antioxidants, F&V contribute to improving the health of the population. They provide essential nutrients in the fight against micronutrient deficiencies. According to the results of the Global Analysis of Vulnerability and Food Security conducted in 2014 (INSAE-Benin and WFP, 2014), the consumption of fruits and foods that are sources of iron and vitamin A is globally very low especially in food insecure households. One of the consequences of this situation is the high prevalence of forms of malnutrition, particularly those affecting vulnerable groups of the population. Thus, stunting, which is the result of a chronic deficiency of several micronutrients, affects about one third of children aged under 5 years. Anemia, which is a sign of iron deficiency, affects 72% of children under 5 years old and 58% of women of childbearing age (INSAE and ICF, 2019). The large amounts of F&V lost, if available, could perhaps have contributed to the resolution or reduction of these nutritional problems.

However, low F&V consumption cannot be linked solely to post-harvest F&V losses. Indeed, eating habits are often determined by socio-cultural considerations. According to Amoussa Hounkpatin et al. (2014), foods that are sources of energy are prioritized; foods such as fruits are generally considered less appropriate even for infants and young children in Benin. Their consumption is often perceived as a snack whereas WHO (2004) recommends consuming 5 F&V per day for the promotion of good health. As for vegetables, most of the time, their consumption is essentially limited to the preparation of sauces (Nago et al., 2012) and in this case, the cooking methods generally cause significant losses of micronutrients. Indeed, Vodouhe et al (2012) noted that cooking leafy vegetables in boiling water could lead to Calcium losses of 23.7%, 34.9% and 20.7% and Potassium losses of 61.8%, 55.0% and 44.3% respectively for *Solanum macrocarpum*, *Amaranthus hybridus* and *Ocimum gratissimum*. There is therefore a real need to take action to help communities, especially those living in rural areas, with low instruction and facing poverty, to become aware of the enormous potential of traditional F&V. Indeed, at country level, when moving from rural to urban areas, household consumption of fruit roughly doubles (INSAE-Benin and WFP, 2017). Education in the broad sense (Agueh et al, 2016) and nutrition education in particular could, in this regard, play an important role.

### Conclusion

Significant post-harvest losses of F&V in the different agro-ecological zones of Benin are responsible for huge financial losses for producers. They also contribute to the poor nutritional status of vulnerable groups of the population. Improving traditional preservation techniques, particularly through the use of solar energy for the transformation and preservation of F&V, therefore represents a real opportunity to curb post-harvest losses, extend the consumption of agricultural products to non-production periods. This will contribute to the resolution of malnutrition problems.

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### Abbreviations

ADP: Agricultural Development Poles  
FGD: Focus Group Discussions  
F&V: Fruits and Vegetables  
TAAD: Territorial Agency for Agriculture Development

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