

containing ammonium carbamate on a few pulses, he likewise reported dark changes in colour whereas none of the varieties displayed changes after having been treated with the ammonium carbamate-free product DEGESCH PLATE.

It is known that especially tannic woods display discolouration in the presence of ammonia and on contact with the substance darken in colour (SELL AND KÜHNE, 1967). This circumstance is consciously utilized, for example when "smoking" oakwood, in order to modify the colour of the wood (MARQUARDT, 2005).

MARQUARD (1998) describes that pulses might also contain tannic acid and tannins. The amount can vary from species to species and from type to type and ranges from more or less no tannic acid up to 4.5% in the dry weight of the pulses.

In this respect, it can therefore be assumed that the colour changes in individual pulses are caused by the reaction of the ammonia from metal phosphide formulations containing ammonium carbamate with the tannin contained in the various pulses.

In order to avoid visual changes in the form of dark discolouration in pulses after treatment with metal phosphide formulations the use of formulations which do not contain any ammonium carbamate is recommended for such treatment.

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## The Postharvest Education Foundation's Role in Reducing Postharvest Losses

**Deirdre Holcroft<sup>1</sup>, Lisa Kitinoja**

<sup>1</sup>The Postharvest Education Foundation, PO Box 38, La Pine, Oregon 97739, USA

\*Corresponding Author: D. Holcroft ( [postharvest@holcroft.biz](mailto:postharvest@holcroft.biz))

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### Abstract

The Postharvest Education Foundation (PEF) was founded to address postharvest losses through education and training. Postharvest expertise was identified as a key weakness in many developing countries. The PEF provides innovative programs that motivate and empower people to reduce food losses and waste. At the heart of the PEF is a structured e-learning program that provides a practical curriculum to address the causes of postharvest losses, as well as methods to minimize these losses for horticultural crops and staple foods. E-learning is an efficient and cost-effective way to reach interested parties globally, and keeping costs low enables PEF to train and mentor a large number of candidates in developing countries. The curriculum entails several assignments and participants can conduct these assignments on a crop of their choice, making the training relevant to their situations. Most of the 154 people who have completed the program have in turn trained hundreds of farmers, traders and marketers in their own regions in handling fresh produce, crop storage, and food processing, thereby delivering maximum impact with minimum input. In addition to its e-learning program, the PEF provides education on improved technical practices along the postharvest chain and on extension education. This training includes a wide range of topics from measuring postharvest losses to designing demonstrations on storage, pest management, packaging and temperature management, from building and using low cost cold storage systems to calculating return on investment of changes in handling practices. The PEF also provides advice on designing postharvest training and service centers. This information is available on the organization's website. In addition, mentoring is provided through social media sites, continuing with the philosophy of providing distance education and training.

**Keywords:** E-learning, fresh produce handling, storage

## Introduction

The Postharvest Education Foundation (PEF, [www.postharvest.org](http://www.postharvest.org)) was founded as a non-profit organization in 2011 by Dr. Lisa Kitinoja with the assistance of a small group of like-minded colleagues. The aim of the PEF is to provide innovative programs that motivate and empower people to reduce food losses and waste through education and training. At the heart of the PEF is a structured e-learning program to train participants in how to teach farmers, traders, processors and marketers on handling produce and crops after harvest to maintain quality and reduce postharvest losses for horticultural crops and staple foods. In addition the PEF provides postharvest tool kits, mentoring, access to information through its website, and practical education via hands-on workshops and conferences.

### E-learning program

E-learning is an efficient and cost-effective way to train and mentor a large number of candidates in improved postharvest technologies, extension skills and outreach practices. Participants in the e-learning program include trainers in non-governmental organizations, governmental employees, horticulture companies, extension workers, research scientists, postharvest professionals and graduate students, and are predominantly located in developing countries (Tab. 1). Most of the 154 graduates of the PEF postharvest e-learning program have in turn trained farmers, traders and marketers in their region, extending the impact of the program.

From 2011 to 2016 the 'Global Postharvest E-learning Program' was offered as a mentor-guided learning program. Participants enrolled in January and worked through the assignments at their own pace using a crop of their choice. This allowed those working or studying fulltime to participate and complete the program by the end of December. As of November 2016, the PEF Postharvest E-learning Manual was posted online so individuals or groups can participate at no cost, and on their own schedules (Kitinoja, 2016).

The course consists of 12 chapters and up to 12 assignments (some are optional) as summarized here:

1. Introduction to the PEF training of postharvest trainers e-learning program and the manual
2. Assessing the learning needs, skills and experience of the postharvest trainer/extension worker (Assignment 1)
3. Investigating available resources in the field of postharvest technology (Assignment 2)
4. Performing a commodity systems assessment (CSAM) and identifying the causes and sources of postharvest losses and quality problems for any crop of interest (Assignment 3) (Fig. 1) (La Gra et al., 2016)
5. Identifying and prioritizing research, extension and advocacy needs for the crop based on the CSAM report (Assignment 4)
6. Assessing the suitability of 'best postharvest practices' and appropriate technologies for their respective communities (Assignment 5)
7. Determining the costs and benefits of using improved practices and technologies (Assignment 6) (Tab. 2 and 3)
8. Designing postharvest demonstrations for local farmers, traders, processors and marketers (Assignment 7)
9. Setting measurable goals and objectives for a postharvest training program (Assignment 8)
10. Using postharvest extension methods, simple postharvest tools and basic equipment for quality assessment and as training aids (Assignment 9)
11. Designing local postharvest training and extension programs for various audiences (Assignment 10)
12. Evaluating the effectiveness of postharvest training programs (Assignment 11).

There is an optional assignment (12) of designing a Postharvest Training and Services Center (PTSC) (Kitinoja & Barrett, 2015).

Conducting a CSAM (Fig. 1) helps to highlight crop-specific needs for training, research and advocacy. For example a CSAM conducted on French beans grown in Rwanda by Kangondo (2017) reached the following recommendations for growers, the government and other stakeholders on training, research and advocacy needs.

Training needs:

- Best agricultural practices to increase the quality and quantity of French bean production.
- Postharvest handling, especially after harvesting and during transportation.
- Evaluating affordable storage and transportation solutions for this perishable crop.
- Food safety.

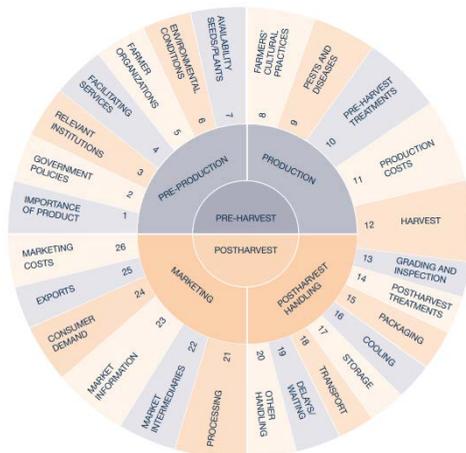
Research needs:

- Evaluating new varieties, in particular, varieties suited to the Rwandan climate and those resistant to pests and diseases,
- Processing methods to prevent waste if the beans are not consumed fresh.

Advocacy needs:

- The government should assist, or facilitate private investors to assist, the industry in developing processing facilities for adding value and minimizing waste.
- Improved infrastructure including roads and constructing collection centers near production areas.

Assignment 6, where costs and benefits of adopting a new practice are evaluated, is a valuable exercise. Tab. 2, prepared by an e-learner, demonstrates the cost of constructing a Zero Energy Cool Chamber (ZECC) for storing passion fruit (Nantambi, 2016). The result was much lower water loss resulting in greater salable weight, and better quality fruit. In addition, the use of the ZECC strengthened the bargaining power of the small farmer and extended their revenue period providing them with a market advantage. The construction of a ZECC takes a few hours of time and labor (neither of which were included in Tab. 2) but the relative profit of this new practice compared to the current practice is clear (Tab. 3).



**Fig. 1** The 26 principal components of the Commodity Systems Assessment Methodology (CSAM) presented in a figure (LaGra et al., 2016).

**Tab. 1** Global impact of the Postharvest Education Foundation e-learning program as indicated by number of graduates per country as of end of 2017 and those currently enrolled.

Country	Graduates	Currently enrolled
Bangladesh	3	
Benin	2	
Bhutan	7	
Botswana	1	
Burkina Faso		30
Cambodia	4	
Cameroon	3	
Chile	1	
Egypt	1	
Ethiopia	15	5
Germany	1	
Ghana	12	2
India	8	
Indonesia	1	
Iran	1	
Kenya	13	1
Lebanon	1	
Malawi	1	
Malta	1	
Namibia	1	
Nepal	2	
Nigeria	5	12
Pakistan	5	1
Peru	1	
South Africa	1	1
Rwanda	14	10
Sri Lanka	1	
Suriname		1
Tanzania	25	
Togo	2	
Uganda	7	1
USA	12	1
Zambia	2	
<b>Total</b>	<b>154</b>	<b>65</b>

**Tab. 2** Costs (in Ugandan shillings USH) of building a Zero Energy Cool Chamber (ZECC) in Uganda measured by an e-learner (adapted from Nantambi, 2016).

ZECC requirements	Quantity	Unit price	Total (USH)	Equivalent in US\$
Clean sand (kg)	700	87	60900	16.92
Burnt bricks	800	200	160000	44.44
Plastic crates	6	27000	162000	45.00
Thatch (bundles)	10	20000	200000	55.56
Spades	2	15000	30000	8.33
Bush knives	2	10000	20000	5.56
Small buckets	4	8500	34000	9.44
Poles	6	9500	57000	15.83
Hessian cloth (m)	2.5	20000	50000	13.89
Basins (medium)	2	5000	10000	2.78
Nails and binding wire			60000	16.67
<b>Total</b>			<b>843900</b>	<b>234.42</b>

**Tab. 3** Postharvest cost/benefit analysis (in Ugandan shillings USH) of using a Zero Energy Cool Chamber (ZECC) when storing on passion fruit in Uganda as performed by an e-learner (adapted from Nantambi, 2016).

Factors	Current Practice	Equivalent in US\$	New Practice	Equivalent in US\$
<b>Situation</b>	Stored open rooms at ambient temperatures		Stored in a ZECC at 95% RH and 13-15C	
<b>Costs</b>				
<b>Fruit amount</b>	10 sacks @ 5000/sack		10 sacks @ 5000/sac	
<b>Fruit weight (kg)</b>	1000 kg		1000 kg	
<b>Fruit cost</b>	USh 50000	\$13.89	USh 50000	\$13.89
<b>Cost of practice</b>			USh 843900	\$234.42
<b>Total costs</b>			USh 893900	\$248.31
<b>Loss</b>	40%		3%	
<b>Fruit available for sale</b>	600 kg		970 kg	
<b>Value/kg</b>	USh 3000	\$0.83	USh 5000	\$1.39
<b>Market value</b>	USh 1800000	\$500.00	USh 4850000	\$1,347.22
<b>Profit on first load</b>	USh 1750000	\$486.11	USh 3956100	\$1,098.92
<b>Profit on subsequent loads</b>	USh 1750000	\$486.11	USh 4800000	\$1,333.33

### Other roles of the PEF

In addition to the e-learning program the PEF provides access to a wide range of postharvest information. Training materials are available on the website and are used by those involved in extension work and training of farmers, produce handlers and small-scale food processors. The resources site of the webpage provides white papers on relevant topics such as the use of returnable plastic crates (Kitinoja, 2013), and measuring postharvest losses of fruits and vegetables (Kitinoja and Kader, 2015).

A postharvest toolkit is available at a discounted price and includes a pulp temperature thermometer, produce caliper and gauges, pH and chlorine test strips, color charts for produce maturity and quality assessment, produce knife, refractometer and digital scale. A smaller version of the Postharvest toolkit is given to those that complete the e-learning program. The PEF website provides links to videos on using these postharvest tools in the white paper on 'Creating fruit and vegetable postharvest videos' (Barrett, 2014).

In addition, the website provides instructional videos and designs for building solar dryers, evaporatively cooled storage structures, cold rooms, hermetic storage of grains, transportation options and reduced energy use, to name a few. PEF e-learning graduates also provide links to their journal articles, research publications and extension materials e.g. 'Mycotoxins contamination in maize alarms food safety in sub-Saharan Africa' (James & Zikankuba, 2018), 'Commodity systems assessment methodology of postharvest losses in vegetable Amaranths: The case of Tamale, Ghana' (Osei-Kwarteng et al., 2017), Vegetable handling, distribution, and wholesale profitability in "Abinchi" night market, Kumasi-Ghana (Zu et al., 2014) and 'Zero Energy Cooling Technology for Storage of Cavendish Banana Fruits' (Abdul-Rahman et al., 2015).

The PEF organizes postharvest workshops for e-learners who successfully complete their online programs, offers long-term mentoring for participants in e-learning programs via social networking websites, conducts short courses, study tours, and workshops and provides advice and guidance for establishing local postharvest training and services centers. As a consequence, postharvest training and services centers have been established in several African countries including Arusha, Tanzania (Kitinoja & Barrett, 2015) as well as 16 additional sites in Tanzania as a component of the Market Infrastructure, Value Addition and Rural Finance support project (World Bank), and in Guinea, Burkina Faso and Rwanda as part of Feed the Future projects managed by the Horticulture Innovation Lab.

### Conclusions

The impact of the PEF in training is not limited to the e-learning graduates but has benefited those trained by graduates, plus the many users of the PEF website. This impact was achieved with a small budget by passionate and committed professionals. Although the focus of The Postharvest Education Foundation is on fruits and vegetables, similar principles can be applied to improved

handling, drying, packing, pest protection, storage and processing of grains and cereals.

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## Evaluation of Plastic and Steel Bins for Protection of Stored Maize against Insect Infestation in Ghana

**Augustine Bosomtwe<sup>1</sup>, Enoch A. Osekre<sup>1\*</sup>, George P. Opit<sup>2</sup>, George N. Mbata<sup>3</sup>, Paul R. Armstrong<sup>4</sup>, Frank H. Arthur<sup>4</sup>, James F. Campbell<sup>4</sup>, Evans P. Nsiah<sup>5</sup>**

<sup>1</sup>Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana

<sup>2</sup>Oklahoma State University, Stillwater, OK 74078, USA

<sup>3</sup>Agricultural Research Station, Fort Valley State University, Fort Valley, GA 31030, USA

<sup>4</sup>USDA-Agricultural Research Service, Manhattan, KS 66502, USA

<sup>5</sup>PENS Food Bank, P. O. Box 143, Ejura- Ashanti, Ghana

\*Corresponding author: E. A. Osekre (osek652001@yahoo.co.uk)

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## Abstract

Maize is a staple food in Ghana where there is ever increasing demand for its use to also support poultry and livestock production. However, post-harvest loss of maize is high in Ghana. This study evaluated the effectiveness of plastic and steel bins as bulk storage structures to reduce maize post-harvest loss in Ejura, Ghana during the period from February 2016 to January 2017. Maize pre-disinfested with a solar biomass hybrid dryer was stored in the following treatments: i. a white 7-ton plastic bin filled with untreated maize, ii. a green 7-ton plastic bin filled with untreated maize, iii. a 6-ton Kikapu steel bin filled with untreated maize, iv. six 50-kg polypropylene (PP) bags filled with maize treated with Betallic Super (80 g pirimiphos-methyl and 15 g permethrin per liter as an emulsifiable concentrate (EC)), and v. six 50-kg PP bags filled with untreated maize as control. Moisture content, insect pests, insect damaged kernels (IDK), grain weight loss, aflatoxin and fumonisin levels data were collected monthly. *Sitophilus zeamais*, *Tribolium castaneum*, *Cathartus quadricollis*, and *Cryptolestes ferrugineus* were the dominant insect species collected from maize samples. At the end of 12 months of storage, % IDK in the control was >17% while IDK values in the other treatments were <3%. Mean grain weight losses of <1% were recorded in the bin treatments. Mycotoxin levels in the control were above the allowable threshold of 15 ppb. Our data suggest that use of plastic and steel bins has potential to reduce post-harvest loss of maize during storage.

**Key words:** Storage bin, post-harvest loss, aflatoxin, fumonisin, grain storage.