

Editorial

Recent Innovations in Post-Harvest Preservation and Protection of Agricultural Products

Dirk E. Maier *  and Hory Chikez

Department of Agricultural and Biosystems Engineering, Iowa State University, 3325 Elings Hall, 605 Bissell Road, Ames, IA 50011-3270, USA; horych@iastate.edu

* Correspondence: dmaier@iastate.edu

1. Consortium for Innovation in Post-Harvest Loss and Food Waste Reduction

Food loss and waste is a global problem that negatively impacts the bottom lines of producers and agri-businesses, wastes limited resources, and contributes to climate change. The Foundation for Food and Agriculture Research (FFAR), The Rockefeller Foundation, Iowa State University, University of Maryland, Wageningen University and Research, Volcani Center, Zamorano University, Stellenbosch University, University of São Paulo, University of Nairobi, and Kwame Nkrumah University of Science and Technology partnered to establish the Consortium for Innovation in Post-Harvest Loss and Food Waste Reduction.

The Consortium is committed to training the next generation of food system leaders, researchers, and entrepreneurs. Undergraduate and graduate students from these institutions are conducting innovative research that improves drying, handling, storage, and distribution, develops monitoring and tracking technology, extends shelf-life and minimizes spoilage, and changes behavior and practices to reduce post-harvest loss and food waste from field to fork. Innovative entrepreneurs trained by these institutions are commercializing technology, adding value to agricultural crops, and developing nutritious food products.

2. Review Process

All articles published in this Special Issue “Recent Innovations in Post-Harvest Preservation and Protection of Agricultural Products” underwent peer review by independent subject matter experts in the field of post-harvest science, technology, engineering and management.

3. Recent Innovations in Post-Harvest Preservation and Protection of Agricultural Products: Summarized Articles by Area

a. Stored Product Protection

- (1) Determine grain quality and pesticide residue concentrations of maize stored in porous versus hermetic storage bags. Maize stored in air-tight (hermetic) bags were shown to have higher grain quality and lower aflatoxin and pesticide residue concentrations than maize stored in porous woven polypropylene bags. Educating smallholder farmers on the benefits of hermetic storage bags, and promoting adoption of this innovative chemical-free protection technology, should continue to be a priority among supply chain actors to ensure food-safe maize from producers to consumers [1]–Consortium;
- (2) Apply dynamic controlled atmosphere technologies to reduce incidence of physiological disorders and maintain quality of apples. ‘Granny Smith’ apples stored under repeated low oxygen stress (RLOS) in combination with ultra-low oxygen (ULO) or controlled atmosphere (CA) conditions, and under dynamic controlled atmosphere (DCA) conditions in combination with chlorophyll fluorescence (CF) treatment had significantly ($p < 0.05$) higher flesh firmness and total soluble



Citation: Maier, D.E.; Chikez, H. Recent Innovations in Post-Harvest Preservation and Protection of Agricultural Products. *Agriculture* **2021**, *11*, 1275. <https://doi.org/10.3390/agriculture11121275>

Received: 3 December 2021

Accepted: 8 December 2021

Published: 15 December 2021

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solids. The post-harvest treatments and storage conditions reduced superficial scald by possibly suppressing the oxidation of volatiles implicated in its development [2]–Consortium;

- (3) Investigate effects of hot-air and freeze drying on the physicochemical, phytochemical, and antioxidant capacity of dried pomegranate arils during long-term cold storage of whole fruit. Results from this one-time experiment showed that quality attributes such as color, total phenolic content (TPC), total anthocyanin content (TAC), and radical scavenging activity (RSA) improved distinctly due to freeze-drying and subsequent storage at 7 ± 0.3 °C and $92 \pm 3\%$ relative humidity. Freeze-drying was therefore recommended over hot-air drying as the preferred preservation treatment [3]–Consortium;
 - (4) Analyze different storage conditions in terms of profitability based on market prices for pears during three storage seasons. Storage conditions had a strong influence on perishable fruit quality parameters. They were found to affect most visibly mass loss and incidence of postharvest diseases and disorders. The storage of ‘Conference’ cultivar pears for 180 days in normal atmosphere was not economically viable, even when the fruit was subjected to treatment with 1-methylcyclopropene (1-MCP), a synthetic plant growth regulator used commercially to slow down fruit ripening. However, it was profitable to store ‘Conference’ pears under controlled atmosphere conditions each season, no matter whether 1-MCP was applied or not [4].
- b. Post-Harvest Handling and Drying
- (5) Evaluate a 500 kg portable column dryer with a biomass burner heat source for maize drying. Indicators such as drying rate, drying efficiency, and moisture extraction rate were used to assess technical operations performance. Results showed that maize moisture content was reduced from 22.3% to $13.4\% \pm 2.6\%$ in 5 h at an average drying rate of 1.81 percentage points per hour with a drying efficiency of 64.7%. Utilization of such low-capacity mobile dryers to provide drying services was found to be economically viable based on net present value analysis resulting in internal rates of return (IRR) above 70%, pay-back periods (PBP) of less than two years, and positive benefit-cost ratios (BCR) greater than 2.5. Affordable access to drying services in maize-growing communities has potential to improve the socio-economic status of smallholder maize farmers in sub-Saharan Africa [5]–Consortium;
 - (6) Analyze the effect of vibration on grape berry drop during vertical transportation and of different packaging materials on grape clusters during robotic placement. Dropping and shattering of grape berries reduces quality during harvest and post-harvest handling. This study developed an objective method to observe and analyze damage and detachment force for cluster fruits during robotic post-harvest handling. Higher speeds and acceleration excitations during vertical transportation tests increased hanging force positively ($R^2 = 0.92$) while the force after striking the grape cluster with packaging materials decreased negatively ($R^2 = 0.97$) and the corresponding index of berry deflection increased. High-speed camera images revealed that rigid plastic boxes caused maximum deflection of grape berries, with the highest change in force of 8.6 N after impact. Experimental results showed a negative correlation between hanging force signals and the force after impact of the cluster, with a goodness of fit of $R^2 = 0.95$ at different speeds [6].
- c. Crop End-Use Quality Sensors
- (7) Effect of numbers and placement of temperature sensors on aeration cooling of a stored grain mass. Results predicted by a 3D finite element computational model demonstrated that temperature cables in the center or near the edges of the silos were not representative of average temperatures in the grain mass,

resulting in too infrequent or excessive aeration, respectively. Placement of “wireless” sensors at fixed grain depths but randomized horizontally along the diameter resulted in similar average temperatures, while an increase in randomized sensor numbers reduced variability among years of weather data simulated [7]–Consortium;

- (8) Use of near infrared hyperspectral imaging to evaluate color, firmness, and soluble solid content (SSC) of Korla fragrant pears. This study acquired hyperspectral imaging data for 200 samples to construct statistical evaluation models for predicting these quality parameters using iteratively retaining informative variables (IRIV) and least square support vector machine (LS-SVM) analysis. Results demonstrated that the combination of IRIV and LS-SVM can be used to predict values for color parameter, a *, firmness, and SSC to define grade of Korla fragrant pears with correlation coefficients of the validation set measuring 0.927, 0.948, and 0.953, respectively [8].
- d. Post-harvest loss reduction
- (9) Evaluate the effects of five harvest and post-harvest technologies (harvesting tools, cold stores, plastic crates, fruit fly traps, ground tarps) promoted by the Rockefeller Foundation Yieldwise Initiative (YWI) on post-harvest loss (PHL) incurred at three stages of the mango value chain (harvest, transportation, point of sale) in Kenya. Results indicated that plastic crates used to transport or store mangos and fruit fly traps used to attract and kill fruit flies were statistically significant ($p < 0.05$) in reducing PHL at the point of sale. Interestingly, no statistical evidence of PHL reduction was observed from smallholder farmers using harvesting tools, cold stores, and ground tarps [9]–Consortium;
 - (10) Assess four on-farm maize storage technologies with and without chemical protectant in two locations of the Republic of Benin. The analysis showed that in central and northern Benin hermetic bags and polypropylene bags recorded less storage losses and were more profitable than improved and closed clay earth granaries and unsealed metal silos. Gastight (hermetic) bag storage technology recorded the lowest post-harvest loss in the two locations when grain was initially treated with the chemical protectant 2% pirimiphos-methyl (central $9.42 \pm 4.64\%$, northern $2.69 \pm 0.77\%$) versus without (central $11.71 \pm 2.78\%$, northern $7.71\% \pm 1.74\%$). Maize stored in woven polypropylene bags recorded losses due to insect pests with chemical protectant (northern $4.02 \pm 1.23\%$) versus without (northern $9.64 \pm 2.73\%$). Financial analysis indicated that the most profitable storage technologies were hermetic bags without an initial chemical treatment in central Benin, a more humid region, and woven polypropylene bag with an initial chemical protectant treatment in northern Benin, a more arid region [10];
 - (11) Review of mango fruit processing options for small-scale processors in low-income countries. Processing mango fruit into a number of shelf-stable food products makes the seasonal fruit more broadly available to consumers year-round. Research and food product development have resulted in several unique processed mango products with specific qualities and nutritional attributes in demand by consumers. These include pulp (puree), juice concentrate, ready-to-drink juice, nectar, wine, jams, jellies, pickles, smoothies, chutney, canned slices, chips, leathers, and powder. Minimum processing of mango fruit as a fresh-cut product is popular among health-conscious consumers. Mango pulp and powder can be used to enrich or flavor secondary products such as yoghurt, ice cream, beverages, and soft drinks. Byproducts of mango processing, such as peel and kernels, are rich in bioactive compounds including carotenoids, polyphenols, and dietary fibers, can be used in food fortification and manufacture of animal feeds. This adds value to the fruit while reducing food loss and waste [11]–Consortium.

4. Outlook with Regard to Continued Research in Post-Harvest Preservation and Protection

Despite continued progress, several challenges pertaining to reducing post-harvest loss and food waste reduction remain unresolved and need further basic and applied research including:

- (1) Electricity and financing to reliably and affordably power the refrigerated and controlled atmosphere storage chains to ensure perishable agricultural crops can be preserved with net-zero carbon dioxide equivalent emissions by 2030;
- (2) Non-chemical technologies and practices to mitigate spoilage agents and protect stored products from post-harvest quality degradation and food safety pathogens;
- (3) Alternative energy drying (dehydration) technologies and practices to reduce moisture content (water activity) of agricultural crops to safe storage levels as close to the producer as possible and preserve them for handling, storage, processing, packaging, transportation and marketing throughout the supply chain.

Author Contributions: Conceptualization, writing—original draft preparation, writing—review and editing, were contributed equally by the authors. Funding acquisition, D.E.M. All authors have read and agreed to the published version of the manuscript.

Funding: Funding to support publication of research results by members of the Consortium for Innovation in Post-Harvest Loss and Food Waste Reduction was provided by The Rockefeller Foundation (2018 FOD 004), the Foundation for Food and Agriculture Research (DFs-18-0000000008), and the Iowa Agriculture and Home Economics Experiment Station.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Acknowledgments: The authors would like to thank the funders and collaborators of the Consortium and all manuscript contributors and peer reviewers of this special issue of Agriculture.

Conflicts of Interest: The authors declare no conflict of interest.

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