Nanotechnology Solutions to Tackle Post-Harvest Losses in Fruits

The world is producing annually 675 million tonnes of fruits to meet the nutrition requirement of its population as per the latest statistics available in 2017. The major part of fruits is being harvest in Asia particularly China which contributes 275 million tonnes followed by India with 100 million tonnes. There is a phenomenal growth in fruit production over the years and both India and China had reached the highest level ever achieved. Despite all the rosy statistics, the global population is struggling to meet the daily requirement of fruits due to the huge post harvest losses which is in the range of 30-35% in Asia particularly India and Sri Lanka, 80-85% in Africa, 15-20% in USA and Canada and 25% in Europe. This depicts the extent of post-harvest losses in perishables which is a global challenge to be addressed. The economic loss of such devastation works out in billions of USD annually. Developing countries have a spectrum of a series of issues such as improper harvesting & handling, transport, poor storage and lack of infrastructure. On the other hand, developed countries like USA and Canada face a challenging energy, environmental and health issues.

In order address a global challenge of post-harvest losses across the world, Global Affairs Canada and International Development (IDRC), Canada, had financially supported a project on "*Enhanced Preservation of Fruits using Nanotechnology*" under the Canadian International Food Research Fund (CIFSRF) for more than five years for the research team lead by University of Guelph, Canada. The other partnering institutes include Tamil Nadu Agricultural University, Coimbatore, Industrial Technology Institute, Sri Lanka, University of Nairobi, Kenya, Sokoine University of Agriculture, Tanzania and University of West Indies, Trinidad & Tobago. The team worked together and developed a basket of technologies to reduce the post-harvest losses in temperate and tropical fruits. During the course of project period, 9 technologies had been developed, tested and proved effective in minimizing the post-harvest losses in fruits. All the products had the active ingredient as "hexanal" which is known to extend shelf-life of fruits and vegetables as a consequence of inhibition of phospholipase D enzyme and slowing down ethylene evolution from the produce. These physiological changes collectively contribute for the fruit preservation during storage and transport. The project has brought out hexanal-based nine technologies that include 1. EFF Pre-harvest spray, 2. EFF Post-harvest dip, 3. Hexanal vapour, 4. Wax formulation, 5. Electrospun fibre wrapper, 6. Nano-sticker 7. Nano-pellets (Sachet) 8. Nano-film and HICM (Hexanal Incorporated Composite Material. These technologies either singly or in combination can help to reduce the post-harvest losses vis-à-vis improved the per capita availability of fruits.

Key messages

- Enhanced Freshness Formulation (EFF) carrying hexanal as an active ingredient can be delivered in horticulture systems as pre-harvest spray, post-harvest dip and vapour form preserve fruits for 2-3 weeks under ambient storage conditions. The technology is economical and eco-friendly and enabling farmers to earn 15-20% higher income
- Farmers in North America, Asia, Africa and Caribbean can use **pre-harvest spray** of EFF to retain the fruits for 2-3 weeks on trees and extend the shelf-life for another 2-3 weeks in storage conditions. The technology is working well for both tropical and temperate fruits. It was unequivocally demonstrated that treated fruits had the less incidence of post-harvest diseases
- In packhouses and exporters can use EFF **dipping technology** alone or combination with wax formulation as an intervention within the sequence of dipping treatments to reduce the post-harvest losses. Huge quantity of fruits can be treated in 5 minutes time and it is easier for the farmers to adopt.
- **Vapour** form of hexanal is equally effective and various dispensing systems such as nano-stickers, nano-wrappers and nano-sachet have developed, validated and patents filed. This is simple and large quantities can be treated without any associated ill-effects.
- More than 12,000 farmers in India adopted the technology and our survey suggested that 80% of them either benefited from the delayed harvest or lucrative income
- The hexanal technology is not unique to a particular fruit or vegetable and thus it can be fine tuned to suit a wide array of perishables. The technology is quite robust and powerful to address the global challenge of post-harvest losses.

Emerging outcomes

1. Pre-harvest spray helped the farmer to tide over economic crisis in the country

Mango farmers in one of the major mango growing domains in Tamil Nadu, India, was devastated after the demonetization in 2016. The price of many horticultural commodities including mango had taken a dive reaching the rock bottom. The farmers were in distress and looking for help to retain the fruits on trees for 2-3 weeks that allow enough time to stabilize the price. **Mr. Ramesh**, Mango grower from Pochempalli, Krishnagiri sprayed EFF as per prescription on 5 acres of land carrying more 200 bearing trees. The adjacent 5 acres were not sprayed and was treated as control. After the spray was done, the farmer closely monitored the sprayed and unsprayed trees for a month. He shared his feedback.

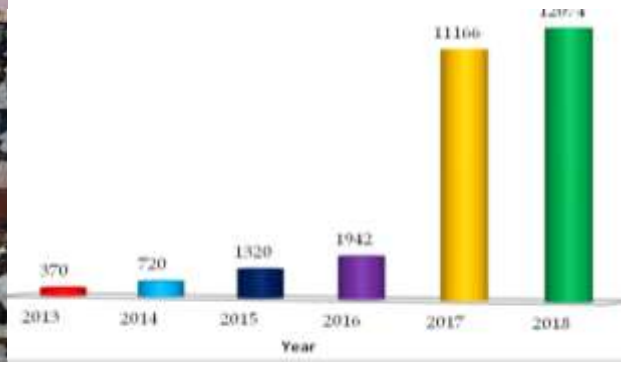
"The EFF technology came out as a savior of my livelihood as I could protect my mango orchards from fruit drop. Fruit retention got extended up to 15 days in comparison to unsprayed trees that eventually resulted in lucrative price for my produce. The profitability of the technology is more than Rs. 10,000 per acre" I should have lost my crop if this technology is not informed during the project period"

Sprayed Mango Trees with Retained 20% more Fruits

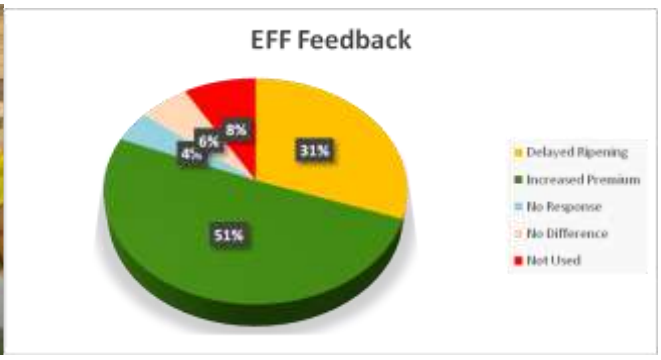
2. Feedback of EFF Technology at the farm gate

More than 12,000 mango growers received EFF from TNAU and used in fruits and vegetables. The feedback survey revealed that post-harvest losses had been reduced by 10-12% in the EFF sprayed fields in comparison to control. Due to the reduction in losses at the field level, the farmers got about 500 kg of additional yield of fruits. Our feedback survey suggested that 55% of the respondents got the premium price for the EFF spray, 31% expressed that the ripening of mango fruits were delayed, and 6% indicated that there was no difference between treated and control. The data clearly suggests that more than 80% of the mango of fruit growers benefitted from the EFF technology.

EFF distribution and its impact



EFF technology is very good for bananas and mangoes in Africa where the post-harvest losses I estimated as > 80%.

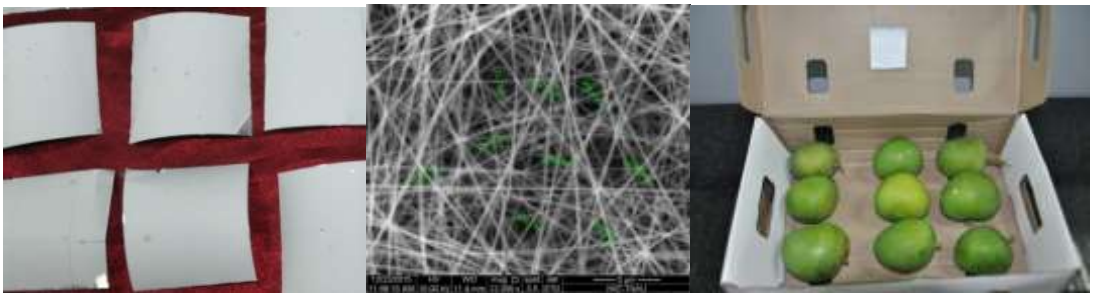


3. Smart delivery systems for hexanal

Hexanal is a highly volatile compound and it vaporizes completely within 2 hrs of exposure to normal room temperature. To regulate the release of hexanal, suitable dispensing system is required. Both University of Guelph and TNAU team worked together to develop four types of delivery systems utilizing nanotechnology approaches. Electrospinning is one of the versatile technologies wherein polymer solution is subjected to high intensity electricity to convert the liquid into a long nano-fibre. It has been estimated that each gram of fibre possesses extensive surface area (> 10 m^2) with a length of > 100 KMs and the dimension in the range of 50-200 nm. Utilizing this principle, the UoG developed a **electrospun fibre wrapper** and the TNAU came up with a **nano-stickers**. In both the cases, hexanal is entrapped in the nano-fibre and the release is regulated. The wrappers have shown to extend shelf-life of high valued temperate fruits. Nano stickers (5 x 5 cm^2) were tested and proved effective in preserving mangoes and bananas. In another case, hexanal is loaded and encapsulated into cyclodextrin inclusion complex (**nano-sachet**) to regulate the vapourization. Further, hexanal can be delivered as a **vapour** directly using a suitable electrified dispensing system. In all the cases, the critical concentrations hexanal can completely eliminate post-harvest pathogens thereby fruits get protected from infestation thereby shelf-life gets extended up to 2-3 weeks. There are simple technologies packaging industries and large scale store houses can adopt. These technologies have been filed for patents.

The packhouses have been provided with nano-stickers for getting the feedback fromfarmers. Even, 50 stickers had been distributed to University of Nairobi, Kenya for getting the farmers views of the technology delivered.

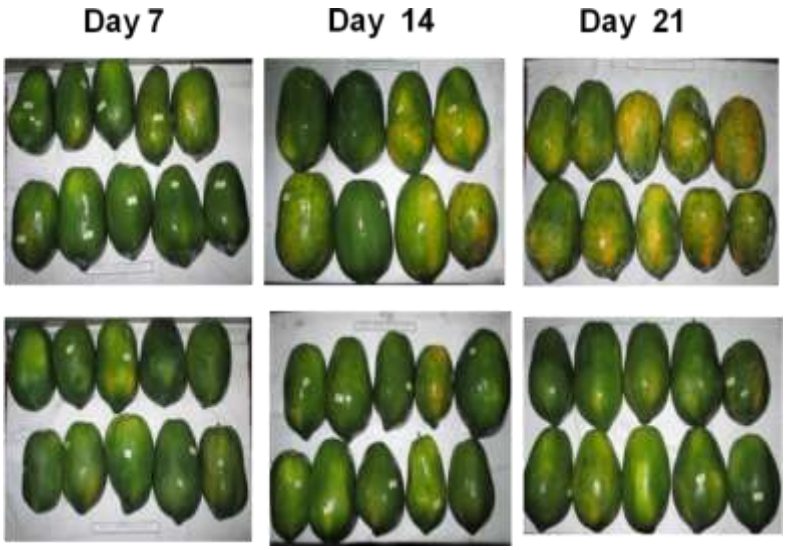
Nano-stickers for fruit preservation



4. Dipping technology enhances shelf-life of fruits

Dipping is one of the simplest technologies wherein fruits are dipped in 1-2% EFF for 5 minutes and the fruits shade dried, packed and transported. This technology was tested in mango, banana, guava, grapes, acid lime, papaya etc. This can be easily fit in the on-going activities of the packhouses. The ITI, Sri Lanka, comes up with wax formulation which is helping the farmers or traders to preserve the fruits up to 3 weeks. The cost of the technology is very cheap (Rs. 2 per kg) and the benefits are many fold. Interestingly, this technology engages primarily women and they get employment in packhouses.

Wax formulation treated fruits



Conclusions

The GAC-IDRC project funded project has helped the team to evolve a series of technologies to reduce post-harvest losses in fruits from the farm till it reaches the consumers. This project has developed bundle of technologies such as pre-harvest spray of EFF for small and marginal farmers to preserve the fruits on trees or off the trees till it reaches the market, post-harvest dipping in EFF or wax for packhouses, nano-packaging (stickers, sachet and wrappers), hexanal vapor for transporters. These technologies singly or in combinations can extend the shelf-life of fruits while minimizing the infestation of pathogens. The outcomes of the project have to be taken forward for extensive adoption and enhance the availability of fruits that ensure nutritional security of the country.