New Apple Storage Technologies Can Reduce Energy Usage and Improve Storage Life

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Abstract

*This paper reviews recent developments in fruit storage that are relevant for both integrated and organic fruit producers and storage operators. Between 2012 and 2015, a cooperative INTERREG IV project, involving researchers and commercial storage operators in both Germany and Switzerland, investigated a range of technical and strategic management measures to reduce energy usage in fruit storage and a summary of the key findings are presented. Energy savings of ~15 % to 50 % appear feasible by using elevated storage temperatures of 1 to 4 °C when compared to the usual ultra low oxygen (ULO) storage recommendations. A range of apple cultivars stored at elevated temperatures for periods of 5 to 7 months showed no negative effects on fruit quality. Storage at elevated temperatures may reduce the incidence of storage rots (*Neofabraea *spp.) in the apple cultivar 'Pinova'. Dynamic controlled atmosphere (DCA) provides a strong inhibition of fruit ripening processes with potential application to achieve energy saving during storage and further research work is planned to test DCA with apple cultivars used for organic production.*

Keywords: Dynamic controlled atmosphere (DCA), *Neofabraea* spp., *Malus domestica,* Pinova, rots

Introduction

Continued developments in fruit storage and quality maintenance make it possible for apple and pear consumers to enjoy a wide choice of near harvest ripe fruit over the whole year. This steady intensification in the area of fruit storage technology, however, has also led to a substantially higher energy expenditure. While energy usage and costs for fruit storage are increasing, the demand to produce food more sustainably, and the need to reduce energy consumption are gaining importance. Under the framework of the INTERREG IV Project (Alpenrhein-Bodensee-Hochrhein) No. 255 'Energy Savings during Fruit Storage', technical measures and management strategies to save energy during the fruit storage were developed at the Competence Centre for Fruit Growing at Lake Constance (KOB) together with the Württembergian Fruit Cooperative (WOG) and four Swiss partners: ACW Wädenswil; Arenenberg Education and Advisory Centre; St. Margrethen Fruit Cool Storage and Tobi Seeobst AG.

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Elevated Storage Temperatures to Save Energy

One approach used in these investigations involved the use of modern storage technologies, such as dynamic controlled atmosphere (DCA) and ultra low oxygen (ULO), both of these being acceptable technologies for storing organic fruit (Kittemann *et al*., 2015). Studies also used the ethylene inhibitor SmartFresh® (not allowed for use on organic fruit within the EU and of interest to IP growers only). Based on the strong inhibition of fruit ripening possible with these modern storage technologies, the potential negative effects of elevated storage temperatures (temperatures higher than usually recommended) can be reduced. Investigations at the KOB were conducted over several years using three identical CA storage rooms, in which the energy usage for the cooling compressors, evaporator ventilation fans, defrosting of the evaporators as well as the CO_2 absorber were recorded separately.

Results show that increases in storage temperatures of 1 °C to 5 °C can give potential energy savings of ~15 to 50 % during 5 to 7 months ULO storage (Table 1). The energy saving potential is highest for the cooling compressors and evaporator fans.

Table 1: Energy consumption (% of total energy) by storage machinery and total energy (kWh) used in an apple ULO storage room (11 t) at 1 °C or 3 °C for 6 months in 2013/14.

Treatment	Cooling Compressors	Evaporator Ventilation fans	Evaporator Defrosting	CO_2 Absorber	Total Energy Usage (kWh)
ULO 1°C	62 %	30 %	5 %	3 %	1350
ULO 3°C	57 %	40 %	0 %	3 %	1180

A surprising result that has also been observed in previous studies, was a reduction in the incidence of storage rots with the cultivar ‘Pinova’ when stored at elevated temperatures (Fig. 1). This is especially interesting since achieving adequate control of bitter rots (*Neofabraea spp.*, syn. *Gloeosporium*) can be a considerable problem in CA storage for both integrated and organic fruit, following very wet growing seasons. The elevated storage temperature treatments led to a slightly yellower background colour of ‘Pinova’ apples. Further studies are now planned at the KOB to investigate the possible reduction of storage rots in organic produced fruit.

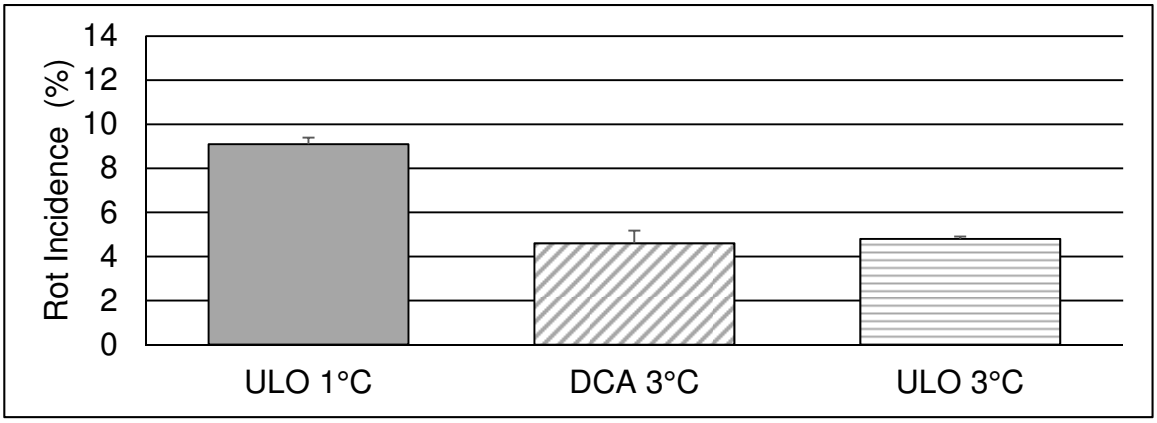

Figure 1: Incidence of storage rots (*Neofabraea spp.*) in ‘Pinova’ apples after 6 months in ULO CA at 1 °C and DCA or ULO at 3 °C, respectively, in the 2013/14 storage season. Bars= SE, n=4.

The fruit firmness of ‘Golden Delicious‘, ‘Jonagold‘ and ‘Pinova‘ was not negatively influenced by storage at elevated temperatures (3 to 4 °C) with the ULO, ULO+MCP or the DCA treatments, when compared to ULO storage at 1 °C. Moreover, other quality parameters (i.e. soluble solids and acidity) were not detrimentally affected by the storage treatments.

A lower fruit weight loss has been consistently observed under elevated storage temperatures compared to the 1 °C treatments. Fruit held in the colder room can lose more moisture when the refrigeration machinery run times (air movement) are higher.

Further Technical Measures for Energy Savings

Within the framework of this project, the potential energy savings made possible from a range of additional technical modifications in the storage room were determined. This included for example studies on the optimal airflow within a storage room as well as possible methods for heat recovery during fruit storage (Neuwald *et al*., 2015). An adequate room insulation is an important requirement for minimising energy use while maintaining fruit quality. With proper wall, floor and ceiling insulation, the heat transfer between inside and outside the storage room is minimised, thereby reducing the run time for the cooling machinery as was well as the weight loss from the stored apples. The insulation of the wall panels should be a minimum of 120 mm and for the ceiling 140 mm. Of critical importance is the air circulation in the room. This can be improved by directing the air flow, e.g. with air-ducting shields fitted to the evaporator, by maintaining the distance between the bin stacks in the direction of the air flow, as well as fitting purpose-built baffles on the room ceiling opposite the evaporator. By achieving faster heat dissipation in the stored fruit, ripening processes and the respiration losses can be reduced.

Further Projects

In the context of this work, a new cooperation project entitled ‘COOL – Energy Saving and Reduced Losses’ was initiated. The research objective is to investigate and improve the various technical components in scientific and commercial fruit and vegetable storage facilities for reducing energy consumption.

Strategic Measures for Energy Saving

In addition to any technical or constructional improvements to reduce energy usage during fruit storage, there are a range of strategic measures that can be implemented (Table 2). At room loading, a faster cooling of the fruit can be achieved by using the cold night temperatures when freshly harvested fruit bins are left overnight in the orchard or by pre-cooling a smaller quantity of fruit bins in a separate room. When the room is cooled at the same time as the room is being loaded, the coolstore doors should be closed as quickly as possible. Depending on the specific cultivars loaded into a mixed storage room, the CO_2 concentration of the atmosphere should be set to the maximum value possible. In CA storage, CO_2 acts as a brake on fruit ripening and it should not be lower than the cultivar specific requirements. With this approach, the run-time of the CO_2 absorber can be reduced.

Summary

During fruit storage a range of different measures are available to reduce energy usage (Table 2). In the best-case situation, an energy saving concept would have been applied from the start of planning and construction of a new storage facility with the optimal selection of technical equipment. A range of often simple to apply measures can be considered to improve the airflow within a storage room and with this to achieve a better use of the available cooling capacity under elevated storage temperatures in combination with 1-MCP, ULO or DCA. In view of the steady increase in energy costs as well as the discussions about sustainable food production systems, measures to reduce energy usage in fruit storage are of increasing importance and relevance for both IP and organic fruit growers.

Table 2: Summary of potential energy saving measures for fruit storage

Technical / Construction	**Strategic**
Correct capacity of the cooling system	Pre-cooled fruit
Use of waste heat (heat exchanger)	Closed doors
Energy saving fans	Consistent ULO storage
Attention to good air circulation (stacking plan!)	CO_2 no lower than necessary
Cleaning of dirty evaporators / condensers	Raising the temperature of ULO storage ~1°C
Sufficient insulation	1-MCP + regular air storage as an alternative to ULO
Floor insulation	Elevated storage temperatures with 1-MCP and/or DCA.
Choice of defrosting method	
Correct capacity of the CO_2 absorber / N_2 generator	

Acknowledgements

INTERREG IV Project (Alpenrhein-Bodensee-Hochrhein) No. 255 ‘Energy Savings during Fruit Storage’ and the Central Innovation Programme project ‘COOL – Energy Saving and Reduced Losses’ for financial support.

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