United Fresh
Technical Advisory Group

Research and Knowledge Compilation related to Returnable Plastic Crates and the Management of Tomato Brown Rugose Fruit Virus and Pepino Mosaic Virus

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Table of Contents

Introduction and Background

Returnable Plastic Crates (RPCs) are an integral part in moving produce both domestically and internationally between the different steps of the supply chain. In New Zealand they are predominantly used to transfer produce within domestic supply chains. Disruption to RPC supply or distribution would have a severe impact on fresh produce distribution.

The opportunity to review and publish this compilation came from the incursion of Pepino Mosaic Virus[1] (PepMV) into New Zealand in 2020/2021, which is a notifiable organism and impacted the tomato industry. An earlier detection of Tomato Brown Rugose Fruit Virus[2] (ToBRFV) resulted in the destruction of tomatoes in an Auckland greenhouse.

Internationally the focus is on ToBRFV, while in New Zealand the current focus is on PepMV.

One of the international hire crate companies, which has undertaken a considerable amount of research into risks associated with crate hygiene issues is IFCO[3]. Specifically, IFCO is, on an ongoing basis, conducting applied research towards better understanding the efficacy of current RPC cleaning methods and any possible process improvements that can be made when sanitising the RPCs to prevent the spread of the Tomato Brown Rugose Virus.

United Fresh, as the pan industry body for the fresh produce industry in New Zealand, has taken a keen interest in the evolution of RPCs, right from inception 30 years ago. This interest was initially driven by the sustainable nature of the RPC concept, long before sustainability became the buzzword it is these days, as well as the fact that RPCs are used across the entire fresh produce range and travel the fresh produce supply chain from grower to packhouse, to wholesale, to retail, and back again, in their tens of thousands, across the entire country, every day of the week.

Tomatoes New Zealand and the Ministry for Primary Industries started to investigate to what extent commercial solutions needed to be supported through biosecurity focused regulatory interventions. The United Fresh Technical Advisory Group (TAG)[4] conducted desk-based research into the matter at hand, exchanged views within its local and global networks on RPC hygiene management in other countries, facilitated an exchange of information and arranged for an industry workshop on the matter via Zoom, with IFCO presenting at that workshop.

The assistance of Jeff Mitchell, IFCO's Food Safety Manager, was invaluable in understanding the scale of the issue based on their experience and the willingness to share documents from a range of sources.

This compilation pulls together the relevant documents that were assessed during the information exchange phase. These documents formed either part of the IFCO presentation or support the points made by IFCO as well as the TAG representative, Anne-Marie Arts.

The key points and pieces of information from IFCO provided documents and/or other research papers on the topic of RPC sanitation have been identified in the following sections.

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[1] PepMV is a Potexvirus.
[2] ToBRFV belongs to the category of tobamovirus.
[3] IFCO is a globally active crate company. More information can be found here: https://www.ifco.com/
[4] https://www.unitedfresh.co.nz/technical-advisory-group

Note

Returnable Plastic Crates are commonly referred to as RPCs in New Zealand. Several of the documents in this compilation are using the term Reusable Boxes and Containers (RBCs). The only difference between RPCs and RBCs is the name by which they are known.

The various documents comprising this compilation are not necessarily referring to indicated temperatures in their analysis and discussion. Temperature values referred to, therefore, need to be treated within the context of analysis contained within individual documents, as the Standards and research used by crate washing companies when defining their processes for washing may not be the same.

Research on Hygiene and Cleanliness of RPCs

Introductory Statement

The following research papers provide information on the international research conducted towards understanding the significance of cleanliness and the methods used to accurately measure it. This is a critical step in the work towards preventing the spread of ToBRFV and PepMV in case they are found within growers' or packhouses' facilities.

The expression 'cleanliness' is generally used in relation to visual cleanliness of a surface, while 'hygiene', in general, relates to the microbial loading on an RPC, i.e., the invisible part of cleanliness.

Much of the published research has focused on food borne pathogens causing illness. Pathogens of Biosecurity concern (Viruses, Bacteria or Fungi) will generally be managed using the similar methodologies and equipment.

Microbiological Standards for Reusable Plastic Containers within Produce Grower Facilities

> Warriner, K. (2013). Microbiological Standards for Reusable Plastic Containers within Produce Grower Facilities. *Ontario Agricultural College Department of Food Science.* https://26mvtbfbbnv3ruuzp1625r59-wpengine.netdna-ssl.com/wp-content/uploads/PDFs/Package_Cleanliness/RPC_Sanitation_Testing_and_Research_a.pdf

The tests performed were visual inspection, ATP (Adenosine triphosphate) Cleanliness readings, microbial testing included Total Aerobic Counts, Enterobacteriaceae and E. coli/coliform counts. Visual assessment was made with respect to damage, un-removed labels and general cleanliness. ATP readings provide an estimate on the viable cells present on a surface that is primarily a result of microbial contamination but can also include plant residues. The Total Aerobic Count (TAC) provides a more accurate assessment of the microbial load with E. coli/Coliform count and Enterobacteriaceae as indicators of potential faecal contamination (i.e., presence of pathogens). The standards set were those expected of a cleaned surface of a food contact surface within the food industry with a 20% failure rate being deemed as acceptable.

There was significant variation on the sanitary status of RPCs at different growers. RPCs were sampled as delivered, thereby ruling out contamination at the packing facility. Collectively, 64% of RPCs failed in terms of ATP readings with 56% of trays having higher TAC expected of a cleaned surface. Visual inspection of RPCs revealed a proportion that were damaged or had labels affixed from previous use. Yet, 92% of RPCs did not exceed the levels of Enterobacteriaceae with no coliforms being recovered on any of the trays tested. From the results it can be concluded that although there was no evidence of a food safety issue it is recommended that the decontamination method for RPCs be reviewed to prevent carriage and transfer of human pathogens.

It was evident that the sanitary status of the containers was dependent on the batch tested at the different growers. Given that there was minimal contact of the containers with the workers it can be concluded that the RPCs were insufficiently cleaned prior to delivery to the growers. Although there was no indication of a food safety threat (i.e., presence of pathogens) it would be recommended that the RPC decontamination process should be reviewed to enhance efficacy.

Assessment of General RPC Cleanliness As Delivered for Use in Packing and Distribution of Fresh Produce

Suslow, T. V., Danyluk, M., Hughes, A., Smith, K. (2014). Assessment of General RPC Cleanliness As Delivered for Use in Packing and Distribution of Fresh Produce. *The University of California.*
https://ucfoodsafety.ucdavis.edu/sites/g/files/dgvnsk7366/files/inline-files/208433.pdf

The RPC Cleanliness survey was conducted on six dates representing six different deliveries of RPCs from the regional distribution centre of the provider. The results confirm that there is a high degree of heterogeneity (variability) in numbers of viable bacteria on the interior, direct product contact RPC surfaces across all evaluated pallets and among all dates.

These values are more informative of the overall elevated populations of recoverable indicators of 'cleanliness', due to the potential for individual RPC units to impact food safety, rather than only focus on the collective 'cleanliness' value.

Across the six-date survey time-course, the Random Sample per-pallet range of TTC exceeded log 5 Colony-forming Units (CFU; approximately equivalent to cells)/swab nine of twenty-four times or 37.5% and exceed log 6 CFU/swab two times or 8.3%. These are equivalent to more than 100,000 cells per RPC unit and 1,000,000 cells per RPC unit, respectively.

The fundamental conclusion from this survey of multiple-use RPCs in the common reuse pool for direct packing of Raw Agricultural Commodities intended for fresh consumption supports a similar survey conducted by Warriner (2013) in that a significant number of packing units exceed a reasonable expectation for general cleanliness and frequently fail expected microbiological standards for surface sanitation. Although there are currently no regulatory critical limits or microbial standards for food contact surfaces (FCS) or established and widely recognized industry standards, studies of a similar nature cite values of 125 CFU/50 cm2 Aerobic Plate Count (APC) as the upper limit for a clean and sanitized FCS (Cunningham et.al., 2011).

The concern and potential for RPC-to-product cross-contamination may be substantiated by the observed free water and evidence of multiple instances of decaying plant matter (Fig 3) and sporulation of mould on adherent plant debris.

This may suggest a lapse in implementation of internal standards and procedures for inspection of RPCs passing through the multiple wash phases at the processing facility. The potential for microbial growth, including human bacterial pathogens, on the water saturated and senescing or decaying nutrient source presents a risk of contamination. This is an area of RPC management that clearly needs attention.

The following recommendations appear warranted based on the cumulative evidence:

- RPC providers should re-assess the current validation of sanitization process under a range of controlled and standardized surface bio-burden challenge studies.
- Growers, contract harvesters, or handlers should implement a regular inspection SOP for acceptance or rejection of palletized or otherwise delivered RPCs.
- RPC users that elect to wipe down RPCs on-site due to residual water and/or soil and debris should carefully consider evaluating the potential for this procedure to spread microbial contamination from unit to unit, potentially increasing risk.
- Harvest crews and packing operations staff should be trained to recognize and inform supervisors if RPC, or any multiple-use packing container, do not meet company standards for 'cleanliness'.
- Growers and Handlers should establish a Master Schedule for routine ATP bioluminescence testing or rapid Total Bacterial Load swabbing of RPCs prior to packing into un-lined units.

Note

The purpose of this paper was to assess and measure the cleanliness of RPC in a quantitative manner. From their analysis, it was concluded that growers, shippers, and re-packers that choose or are required by their customer specifications to pack into RPC should develop and implement a Standard Operating Procedure for receiving and inspecting incoming loads of RPCs or any multiple use packing container.

Comparative study of microbiological transfer from four materials used in direct contact with apples

> Aviat, F., Bayon, I. L., Federighi, M., Montibus, M. (2020). Comparative study of microbiological transfer from four materials used in direct contact with apples. *International Journal of Food Microbiology*. https://doi.org/10.1016/j.ijfoodmicro.2020.108780

Several materials such as plastic, wood, cardboard or stainless steel are used as working surfaces or packaging in direct contact with foodstuffs.

For food industries in Europe, the hygienic surface status is one of the criteria to product conform packaging as described in the European regulation ECR 1935/2004, which specifies that materials intended for safe foodstuff contact must not modify food characteristics in terms of chemical, microbiological and sensorial properties.

This study aims to compare the survival and transfer of Penicillium expansum conidia and Escherichia coli cells from several materials to apples. These were poplar wood used to make cartons, cardboards, newly manufactured plastic, and reusable plastic crates were artificially inoculated with both microorganisms, subsequently put in contact with apples and stored under realistic storage conditions. After incubation for up to 1 week, apples and materials were analysed to assess the survival of the microorganisms and their transfer from materials to apples.

While P. expansum survived and did not grow on any of the materials, E. coli mortality was observed after 1h on wood and cardboard and after 1 week on both plastics. The proportion of microorganisms transferred was different according to the considered material. This transfer was lower than 1% for wood.

The goal of the study was to adequately analyse wood, cardboard and plastics intended for direct contact with foodstuffs. Once inoculated on the material samples and incubated, viable E. coli cells decreased drastically after 1h of contact, whereas P. expansum conidia was observed to have survived both testing conditions of up to 1h and up to 1 week.

Our study shows that the transfers differed among the different materials: they were higher on plastics than on wood or cardboard for both microbial species. Wood is a rough and porous material. This supports our second hypothesis that porosity plays an important role in the survival of microorganisms.

It might be possible to develop packaging labelled as 'natural' to oppose packaging from non-renewable resources, retaining their natural properties. In the case of wood, we pose the question whether it would be possible to retain its antibacterial properties, as demonstrated in this work, to obtain a package to impede food microbiological spoilage. Further studies are needed to elucidate these interrogations.

Note

What is not being covered in this paper is the effectiveness of the washing processes in eliminating the biofilm and microorganisms that may be present in the surface and/or within the pores of the wooden materials.

While the wooden materials seem to be better at preventing/obstructing the development of a biofilm in the surface of the crate than plastic crates, the non-porous nature of the plastics may also prove helpful in the washing process, as there is nowhere for the microorganisms to 'take shelter' and avoid the washing chemicals.

Determining, which is the best material to use, will require detailed analysis of the pros and cons for those materials, as well as determining the purpose and intended use of the crates. For example, if the crates are to be used exclusively within a property, the cleanliness needs are likely to be different if the crates were used to transport produce during export transit.

Key Learnings from the "Research on Hygiene and Cleanliness of RPC" Section

- There was significant variation on the sanitary status of RPC at different growers.
- Collectively, 64% of RPC failed in terms of ATP readings with 56% of trays having higher TVC expected of a cleaned surface. Visual inspection of RPC revealed a proportion that were damaged or had labels affixed from previous use.
- Although there are currently no regulatory critical limits or microbial standards for food contact surfaces (FCS) or established and widely recognized industry standards, studies of a similar nature cite values of 125 CFU/50 cm2 Aerobic Plate Count (APC) as the upper limit for a clean and sanitized FCS.
- Transfers of microbiological pathogens differed among the different materials. Transfer was higher on plastics than on wood or cardboard.
- The frequency of plant residues within the palletised RPC having passed through the multiple wash phases, may suggest a lapse in implementation of internal standards and procedures for inspection of RPC after washing.

Mitigating Spread Through Equipment Management

Introductory Statement

The following papers provide insight on how to better mitigate the spread of ToBRFV and PepMV. Effective sanitisation of the equipment used to handle the crops at risk of infection helps to prevent the spread of the viruses to other sites and along the supply chain.

Effectiveness of disinfectants against the spread of tobamoviruses (2021)

> Chanda, B., Shamimuzzaman, Md., Gilliard, A., Ling, K. (2021). Effectiveness of disinfectants against the spread of tobamoviruses. *Virology Journal, 18 (7)*. https://doi.org/10.1186/s12985-020-01479-8

This paper looked at the efficacy of a selection of chemical disinfectants in eliminating tobamoviruses, such as Tomato Brown Rugose Fruit Virus (ToBRFV) and Cucumber Green Mottle Mosaic Virus (CGMMV), and preventing their transmission through mechanical pathways (e.g., On the surface of Reusable Plastic Containers (RPCs) and any other surfaces that these may come into contact with during the washing process).

The paper analysed 16 chemicals for their effectiveness in combating the two tobamoviruses mentioned above. Of the 16 chemicals, 3 chemicals, at specific concentrations, were effective against ToBRFV, while 4 chemicals, at specific concentrations, were effective against CGMMV. These were:

For Brown Rugose Fruit Virus:

1. Lactoferrin at 0.5%
2. Virocid at 0.5% and 2%
3. Clorox at 10%

For Green Mottle Virus:

1. SP2700 at 1.2%
2. Lactoferrin at 0.5%
3. Virocid at 2%
4. Clorox at 10%

These chemicals were the most significant, generating 0% infectivity on test plants (See Fig 2 and 3, pages 5-6).

Paths of cucumber green mottle mosaic virus disease spread and disinfectant-based management

Darzi, E., Lachman, O., Smith, E., Koren, A., Klein, E., Pass, N., Frenkel, O., Dombrovsky, A. (2020). Paths of cucumber green mottle mosaic virus disease spread and disinfectant-based management. *Annals of Applied Biology,* 177(3), 374-384. https://doi.org/10.1111/aab.12629

Cucumber Green Mottle Mosaic Virus (CGMMV) assigned to the genus Tobamovirus, is considered a major disease cause of cucurbits worldwide. A primary route for CGMMV disease spread is via mechanical contact.

The virus is highly stable and adheres to various agricultural equipment, such as grafting knives. In the current study, we examined means to inactivate the virus and reduce disease spread via planting equipment and supplies using various chemicals.

We have found that incubations of CGMMV-infected cucumber plant extracts with MENNO-Florades 2%, Virocid 3% or Green Up D 20% inactivated the virus and prevented disease spread in a biological assay. Stabilised chlorine formulation (KlorBac), which has the active ingredient troclosene-sodium (sodium dichloroisocyanurate, SDIC) at 2,000 ppm, was efficient in disinfecting CGMMV-contaminated grafting knives in 2s. Similarly, immersing virus contaminated grafting knives for 2s in 20% (wt/vol) non-fat milk powder[5] reduced infectivity of the contaminated knives.

CGMMV-contaminated nursery sowing trays could constitute a primary infectious viral source transmitted via irrigation water. CGMMV-contaminated sowing trays immersed in KlorBac 2,000 ppm or active oxygen (Huwa-San TR-50) 1%, were efficiently disinfected. Interestingly, hydrophobic insulation of the CGMMV-contaminated trays using dry silicone layers reduced initiation of the viral primary infection in CGMMV-contaminated new sowing trays but was less efficient in CGMMV-contaminated re-used trays.

Importantly, Septadine (0.5% chlorhexidine gluconate) was not effective in disinfection of grafting knives. Notably, CGMMV-infected cucumber plant extract incubated with 20% (wt/vol) non-fat milk powder was refractory to the milk suggesting that virus release from surfaces did not necessarily involve virus inactivation.

[5] According to paper milk powder seemed to contain compounds that assist in preventing the virus from adhering to the surfaces of the agricultural equipment.

Key Learnings from the "Mitigating Spread Through Equipment Management" Section

- Effective selection of the right chemical disinfectant and the right concentration it needs to be applied at, is critical for preventing the transmission of ToBRFV and PepMV through mechanical pathways, such as RPC and any other surfaces the crops may come into contact with.

- The chemical disinfectants Lactoferrin (at 0.5%), Virocid (at 0.5% and 2%), Clorox (at 10%) appeared to be the most effective in virus inactivation.

The DIN Standard

Introductory Statement

The following paper summarises the Standard for food hygiene regarding cleaning of reusable boxes and containers for unpacked foodstuffs, created by the German Institute of Standardisation (DIN). This document could potentially be the Standard the RPC cleaning companies can operate under.

The Standard uses the term 're-usable boxes and containers' (RBC) while we are more familiar with RPC. These need to be considered to be identical for the purpose of this compilation.

DIN 10522:2006-01: Food Hygiene – Commercial cleaning of reusable boxes and reusable containers for unpackaged foodstuffs – Hygiene requirements, testing.

> Staff (2006). DIN 10522. *German Institute for Standardization (DIN)*. Accessed from: https://www.beuth.de/en/standard/din-10522/84289587 on 13/12/2021.

According to the Standard, the washing process can be divided into several steps that can run separately in time and space. These are pre-wash, cleaning and disinfecting steps (one or several), intermediate rinsing, a final fresh-water rinse and drying.

Temperatures required for cleaning are dependent on the kind of dirt needs to be cleaned off the RBC. According to the Standard, pre-wash temperature should not exceed 45°C.

When thermal disinfection is required, the cleaning solution temperature must be at least 60°C. The rinse aid solution must be at least 80°C. This thermal or chemical-thermal decontamination must guarantee that the RBC are free of micro-organisms, in compliance with the most stringent requirements.

Instructions regarding treatment agents can be found in Appendix B of the DIN 10522:2006-01 Standard (pages 16 and 17).

The surfaces of the RBC must be easy to clean and to disinfect. Once sufficient cleaning and disinfection can no longer be achieved (due to scratched or other damage to the surface) the RBC must be removed from use (cannot be used to transport fruits and vegetables).

All RBC that are treated in cleaning and disinfection machines (CDM) with a spray-water or immersion system must be optically/visually clean.

The requirements for RBC washing have three defined levels. This relates to the end use of the RBC and is dependent on how critical it is for an RBC to be disinfected.

The following table compares the micro-organism requirements at each of the three levels of microbiological requirements.

Less Critical RBC (Fresh Produce)		**Critical RBC (Dairy and Eggs)**		**Highly Critical RBC (Fish and Meat)**	
Micro Organisms	**Req.**	**Micro Organisms**	**Req.**	**Micro Organisms**	**Req.**
N/R	N/R	Aerobic mesophile germ count	<500 cbu per 100 cm^2	Aerobic mesophile germ count	Allowed value: < 100 cbu per 100 cm^2.
N/R	N/R	Yeasts and moulds	<20 cbu per cm^2	Enterobacteriaceae	Allowed value: = 0 cbu per 100 cm^2 [a].
N/R	N/R	Aerobic mesophile germ count in the cleaning solution	Warning value - 500 cbu/ml Recommended value - 200 cbu/ml	Aerobic mesophile germ count in the cleaning solution	Warning value – 500 cbu/ml. Recommended value – 200 cbu/ml.
				Bio indicators	90% must show a reduction of 5 log_{10}. 10% must show a minimum reduction of 4 log_{10}.

*N/R = no requirement

The Standard also lists the RBC and the required tests at each level of microbiological requirements (see Table 4 of the DIN 10522:2006-01 Standard).

Thorough cleaning of the CDM must happen at least once a day at the end of the running hours. The cleaning process of the CDM includes emptying the tanks, thoroughly cleaning the screen systems, inner spaces and nozzles according to the manufacturer's specifications.

Additionally, all means of transport, as well as working surfaces, need to be cleaned and disinfected at least once a day.

Key Learnings from the "DIN Standard" Section

- The RPC washing process can be divided into multiple steps, which run at separate times and spaces. The equipment used at each site will determine how the washing process is managed.

- The critical factors in ensuring that the cleaning process is as effective as possible in inactivating the viruses are:
    - Temperature (minimum of 60°C for the cleaning solution and 80°C for the rinse aid solution).
    - Pressure (the amount of pressure used when applying the water with cleaning solution).
    - Cleanliness of the washing and rinsing solution.

- Frequent monitoring and testing ensure that the processes are working as intended and prevent the washing stations from becoming spreading points for the pathogens.

- The hygienic requirements depend on the hygienic risk regarding the use of the RBC. Based on their hygienic risk, RBC are classified in three different groups:
    - Less critical RBC (Fresh Produce).
    - Critical RBC (Dairy and Eggs).
    - Highly critical RBC (Fish and Meat).

RPC Guidelines – US Reusable Packaging Association

Introductory Statement

This best practice document takes a 'whole of supply chain' approach to RPCs and outlines the responsibilities of all participants. Topics covered are Maintenance and Surveillance of Food Safety, Food Defence, Sanitation, Transportation, Receiving, Storage, Returning, Usage and Testing.

The document drew on the considerable experience of US and Canadian produce industry participants, including growers, industry bodies, crate companies, and retailers.

RPA Guidelines & Best Practices for Safe Use of Returnable Containers in Food Supply Chains

> Recycling Packaging Association (2015). RPA Guidelines & Best Practices for Safe Use of Returnable Containers in Food Supply Chains. Accessed from: https://www.reusables.org/wp-content/uploads/2020/07/RPA-Guidelines-Best-Practices-for-Safe-Use-of-Returnable-Containers-in-Food-Supply-Chain-v2018.pdf on 10/5/2022.

The document highlights the circular processes that crates travel through and importantly the responsibilities of each participant in the supply chain. In particular, this is useful in addressing the responsibilities of users and transporters of the crates. The circular processes discussed include:

Transportation:

- Recommendations are provided regarding truck inspection and loading diagrams for RPCs only and RPCs filled with product.
- Receiving Procedures: Recommended best practices is that the grower receives fully wrapped crates

Storage:

- Store RPCs undercover when grower facilities accommodate. Do not store in areas where active pest activity likely or present. Do not store near hazardous materials.

RPC pallets:

- Should be handled like any other packaged commodity in a warehouse environment.

Retailer Management:

- Use a single pallet footprint, wrap tightly before starting another returns pallet. Minimise rubbish and do not leave anything inside the used RPCs that are being returned to the providers.

Returning:

- Stack empty or used RPCs in a uniform interlocking manner to the designated height. Separate damaged crates and wrap the finished return pallet.

Usage:

- Crates should be rewashed and sanitised after every use. Treat RPCs with respect as a critical part of the food supply chain.

- Only use RPC compliant labels. Do not place waste, food, or excessive stickers on or in RPCs.

- For approved adhesives and substrates contact your RPC supplier.

Key learnings from the RPA Guidelines

- Specific advice on RPC management at each step is available and highlights the impact of user and handler decisions that can affect the wider supply chain.

- RPCs are a product and need to be managed at all stages of the journey through the supply chain in holistic manner. This includes the storage and transport between each step in the RPC supply chain.

- Washed RPCs should be held indoors in suitable storage facilities, The pallets should be wrapped

- Specific advice on RPC management at each step is available and highlights the impact of user and handler decisions that can affect the wider supply chain.

- The type of adhesive used on labels and use of RPCs as waste receptacles are two issues raised.

IFCO Presentation Notes

Introductory Statement

The following document was produced by United Fresh to summarise the information shared in a meeting between United Fresh members, crate companies active in New Zealand, and IFCO, who has experience in dealing with an incursion of ToBRFV in the USA.

The key learnings of this presentation can be found at the end of the following document.

United Fresh RPC Food Safety and Brown Rugose Virus Control Presentation

8 December 2021

Attendees

Jeff Mitchell, IFCO USA

Paula Dudley United Fresh

Jerry Prendergast, United Fresh

Stephanie Wrathall, United Fresh

Anne Marie Arts, United Fresh

Antony Heywood, VNZI

Priscila Freitas, MPI

Adam Pfeiffer, CHEP

Catherine Mitchell, CHEP

Hans Wouters, Loscam

Ben Smith, T&Gs

Roelf Schreuder, NZ Gourmet

Sam Young, Food Stuffs QA

Jeremy Thompson, MPI

Claire Morgan, Supermarkets Food Safety

Helen Barnes, Tomatoes NZ

Tiago Inacio, United Fresh (minutes)

Summary

United Fresh has been working with industry colleagues globally to understand the controls and validation of crate washing systems from a food safety and biosecurity viewpoint.

Jeff Mitchell is the Director of Global Food Safety for the International Food Crate Organisation (IFCO), which is the world's largest provider of reusable packing containers (RPC). Jeff's presentation guided participants on how IFCO RPC washing systems globally have been validated to address Food safety and Biosecurity concerns such as Tomato Brown Rugose Fruit Virus (ToBRFV) and Pepino Mosaic Virus (PepMV). Afterwards a Q&A session was held to clarify any questions from the participants regarding the learnings from IFCO in combating viruses like the brown rugose virus,

Transmission of these viruses is usually attributed to the contact with infected surfaces. These can be infected seeds, plant material, and/or surfaces (e.g., RPC, belts, forklifts, etc.).

Research has shown that the brown rugose virus can survive for up to 6 months, under lab conditions, on hard surfaces like plastic, glass, and metal.

IFCO has developed a model to address the food safety and biosecurity concerns related to the presence of pathogens, including plant viruses in RPC.

Washing and drying of RPCs has several main steps, which will vary depending on the equipment used. These are pre-wash, wash, sanitiser rinse, and drying.

The washing process and controls used are based on scientific research, with monitoring and verification controls in place to ensure maximum effectiveness. The combination of the research, monitoring and verification controls is critical in ensuring effective processes, as such, the science-based research, monitoring and verification processes have been externally validated.

Washing Process

IFCO's washing stations are divided into a 'pre-wash', a 'main-wash', and a 'rinse'. Throughout these sections, variables such as temperature, concentration, contact time and agitation are constantly monitored to ensure the best results.

Within the pre-wash section of the washing stations, the 'dirty' RPC are subjected to high pressure water, at a temperature of 50-60°C, from all angles to ensure effective cleaning. Within the main wash section, the RPC are subjected to a detergent, and water sprays. After the main wash, the RPCs are rinsed, and a manual or automatic inspection is conducted before the RPCs are sent off for drying.

Multiple variables, such as pressure, temperature, and detergent concentration within each section of the washing system, are continuously monitored. If temperature goes over 66°C the antimicrobial agent begins to 'gas off', which decreases its effectiveness. In addition, if the RPC are subjected to high temperatures for long periods of time, deterioration of the plastic can occur.

The standard employed by IFCO requires a minimum of 30 seconds of exposure for each RPC during the washing and drying process.

Data on the variables is collected in real time and is used to maintain the maximum effectiveness of the washing process in removing the pathogen of concern (e.g., brown rugose virus) from the surface of the RPC.

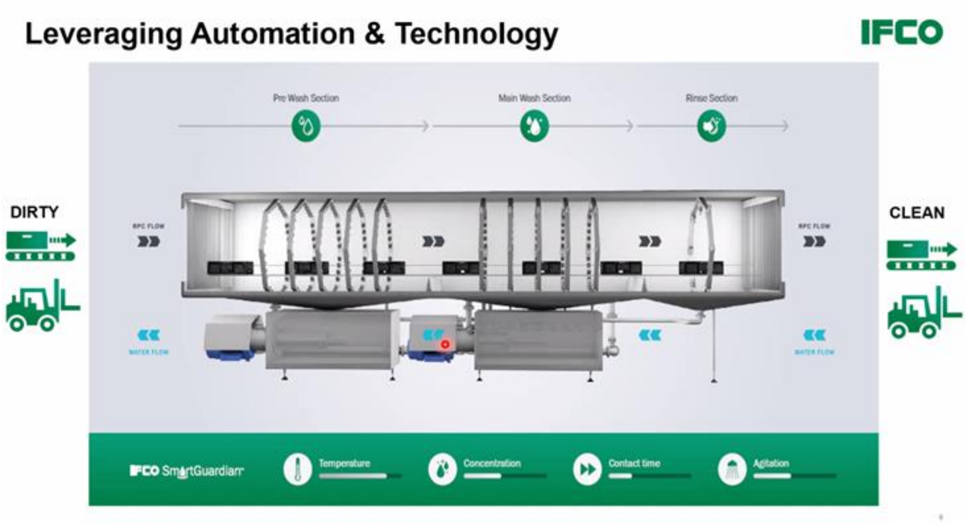

Figure 1: Illustration of IFCOs washing line.

<u>Science Based Research to Validate the Process</u>

Research is conducted to determine what are the best control/combination of controls to remove the virus from the surface of the RPC. This is done by exposing the virus to the different controls/combination of controls.

IFCO's washing process uses a combination of detergents, temperature, high pressure and antimicrobial controls to thoroughly clean and disinfect the RPC, that go through their washing facilities, of the viruses of concern.

Research has found that oxidizing antimicrobials are a good control for the viruses of concern, due to their quick action and effectiveness.

Jeff also mentioned the case of a propagator in Europe that was treating the washed crates he received with sodium hypochlorite, which prevented the spread of the virus.

<u>System Monitoring</u>

IFCO's washing processes are divided into 'pre-wash', 'main wash', and 'rinse' sections. Within the washing stations, variables such as temperature, concentration, contact time and agitation, are constantly monitored to ensure that these variables are kept at the correct levels to ensure the highest degree of effectiveness from the control methods applied during the washing process of the RPC.

<u>Verification of Processes and Controls</u>

In the case of IFCO's washing methodology, verification refers to the act of verifying the processes implemented and ensuring that the processes and values/parameters for the controls used are in line with the science used to set up said processes.

This step of the process is very important in ensuring and maintaining the effectiveness of the RPC wash process, especially as many IFCO clients now require hard facts/data to back up the claims that the wash process used is effective in eliminating the pathogen of concern (e.g., brown rugose virus).

IFCO conducts ATP (Adipose triphosphate) testing daily, and in real time, for each of its machines. This test gives a general cleanliness measure. However, there are different ATP systems used for different purposes.

Weekly pathogen testing looks for the presence of the pathogens of concern on the inside and outside surfaces of the RPC and any other surfaces they may come into contact with (e.g., conveyor belts).

IFCO also in-trials uses 'swabbing' as the method of testing the surfaces for the presence of the pathogen of concern (e.g., brown rugose virus). They would inoculate the plastic crates with the brown rugose virus, which were then put through their washing process, and finally tested at the end of the line.

For the past 3 years, IFCO has been continuously testing for the presence of brown rugose viruses on the RPC but have not found any signs that the pathogen can survive the washing cycle.

There is variability between each machine model used to clean the RPC, but the washing process used is fundamentally the same. In their washing process, IFCO employs total segregation of equipment and space, meaning that the space used to store, and the equipment used to handle the 'dirty/incoming' RPC is totally separated from the space/equipment used to handle the 'clean/outgoing' RPC, for example, IFCO goes as far as to ensure that designated forklifts are only used in the 'clean' areas and only handle 'clean' RPC.

Research Into Chemicals

Various chemicals and antimicrobial agents are tested to determine their efficacy in inactivating or destroying the brown rugose virus. Their research tested 16 chemicals for efficacy and found that 3 chemicals, at specific concentrations, were found to be ablet to completely remove the brown rugose virus from the surface of the RPC.

These were:

1. Lactoferrin (0.5%).
2. Virocid (0.5% and 2%).
3. Clorox (10%).

Palletisation and Storage of Washed RPC Prior to Dispatch

After the going through the washing process, the clean RPC are then palletised. IFCO places a slip sheet at the bottom in between each pallet and the washed RPC, as well as a plastic cover over the RPCs to prevent contamination during storage and shipment of the RPCs to the client site. The pallets are then shrink wrapped and labelled with extra information relating to the individual machine used to wash the RPC and its site.

The inclusion of the machine & site-specific information into the labels allows for fast and effective traceback in case of contamination being detected. This information also allows IFCO to recall specific pallets of washed RPC in the event of the washing process data revealing that the controls used are not at the appropriate levels to ensure maximum effectiveness of the washing process, for example, the temperature is too high, which causes the antimicrobial agents to gas off, or there being a blockage on the spray mechanisms, which compromises the coverage of the RPC during the washing process.

Work regarding the management of the RPCs after they are washed, to minimise the chance of contamination during the time it takes for the RPC to reach the client, is still ongoing.

From the Q&A session after the presentation, the following key points were made:

- Research has shown that, whilst bacteria require moisture to survive, viruses are very hardy and do not desiccate. Viruses can also survive for extended periods of time in hard surfaces (up to 6 months in lab conditions). A pathologist at UC Davis, believes that the virus needs organic material present in the surface to survive. IFCO is currently testing for the survivability of the brown rugose virus under real life scenarios (e.g., by simulating the conditions in a glasshouse).
- The concentrations of the detergents and antimicrobial agents used all play a role in determining the final efficacy of chemicals in dealing with the brown rugose virus. IFCO found, through its research, that using a combination of control methods, such as, temperature and antimicrobial agent, allowed for the use of the chemicals at a much lower concentration that what was previously used as standard (e.g., concentrations 60-70ppm of antimicrobial agent, caustic detergents, and temp versus the concentrations of 600-700ppm when used on its own).
- Research on the topic is still ongoing and building on from what was initially established 3 years ago. Currently there are no agreed parameters to use within the industry, but there is information available to help deal with brown rugose viruses or other pathogens of concern on the surface of the RPC.

With thanks to Helen Barnes, then General Manager of Tomatoes New Zealand, for sharing her notes.

More detailed information on the research conducted on the disinfectants and antimicrobial agents can be found in the paper entitled "*Effectiveness of disinfectants against the spread of tobamovisuses: Tomato brown rugose fruit virus and cucumber green mottle mosaic virus*", published in January 2021 (Link: https://virologyj.biomedcentral.com/articles/10.1186/s12985-020-01479-8), with more resources becoming available soon.

Summary Table of Crate Washing Steps with Monitoring and Controls

It was mentioned both by IFCO and within the DIN standard that the crate washing process will be different from company to company, based on the equipment used at each site and their individual processes. Despite this, the RPC washing process follows 4 main steps:

- Pre-wash
- Wash
- Rinse
- Drying

The following table provides a summary of the information contained within the DIN Standard and the resources provided by IFCO regarding washing processes, the monitoring methods, and the control factors in place.

RPC Generalised Cleaning Process Steps	Practices Contributing to a Clean Crate
Clear rubbish	• Removal of rubbish, dirt, and plant residues.
Pre-wash	• Generally reused water from the washing process.
Wash	• Water Temperature, • High Pressure, • Agitation, • Contact time, • Detergent.
Rinse	• Potable Sanitizing water, • Pressure, • Water Temperature.
Dry	• Air Pressure.
Post-wash	• Visual or optical check • Label scrape • ATP Testing, • Microbiological Testing, • Slip-sheet on pallet, • Wrapping pallets, • Traceability.

Note

The post-wash step mentioned in the table above refers to the processes in place after the RPC have exited the washing lines to ensure that they meet the requirements and remain uncontaminated until they are used by their clients.

Monitoring The Effectiveness of RPC Washing Systems

Introductory Statement

There are two main processes commonly used to ensure that a food production process is working as it should from a food safety viewpoint. These are Validation, confirming that the system delivers the results required, and Verification, continually verifying the system is working within the defined parameters. The following summarises the validation and verification processes generally utilised in a crate washing plant.

Validation of the Washing System

Validation is a process used to ensure food safety processes are achieving the intended controls needed. The overall RPC washing system is tested to prove that the processes and controls are working and delivering clean crates.

Validation can be achieved through a carefully planned project which deliberately infects specific crates and then tests for the presence or absence of the test organism used after washing and drying. This may be done when commissioning a new wash line or when significant changes are made to the system.

The work described by IFCO involved the deliberate infection of crates with an organism and the testing of various machine settings, chemicals, and concentrations, pressures etc. Through this process they identified the controls needed to manage various pathogens, from both a food safety and biosecurity viewpoint.

Verification of the RPC Washing system

Various aspects of washing systems are monitored including temperature, water pressure, chemical concentration, nozzle blockages etc. Some tests are ongoing such as water temperature. Others may be monitored routinely such as verifying chemical injector pump accuracy by specialist contractors.

The cleanliness of the RPC is routinely monitored visually and though ATP hygiene monitoring as well as routine microbial testing by an accredited laboratory.

<u>ATP Hygiene Monitoring</u>

The purpose of ATP (Adenosine triphosphate) bioluminescence for hygiene monitoring is to provide a direct and objective test for cleanliness verification. ATP is an indicator test to instantly determine the hygienic status and potential risk of the object being sampled.

A swab of a crate is taken and inserted into a machine that reads the swab result as Relative Light Units (RLUs). This is a quick and efficient indicator that the crate is clean i.e., free of biological residues. In general, this is undertaken regularly during the washing process such as during each work shift.

ATP tests are not intended to replace microbial tests rather offers a quick check that the RPC are free of any biological material and tare therefore clean. There is generally a direct correlation between the ATP and microbial results. Cleaning in general simultaneously removes both organic residues and microbes.

Microbial Testing

Regular microbial testing is undertaken, for the main pathogens of concern from a food borne illness viewpoint. In general, these will generally include E. coli, Listeria, Salmonella, and Aerobic Plate Count.

The identified DIN standard outlined the standards for RPCs with a differentiation between low risk (fresh produce) dairy products and then high-risk fish and meat from a food safety perspective.

Post Washing RPC Management

Storage of the washed pallets especially for high risk uses should be under cover.

IFCO recommended all pallets had a slip sheet between the crates and the pallet. They also recommended the pallets are wrapped.

Post washing practices should include effective traceability processes of the cleaned crates to the shift it was washed on.

The RPC management post washing include covered storage space requirements, price sensitivity as well as sustainability of slip sheets and wrapping every pallet.

Storage at the grower prior to use is also a consideration.

Collated Key Learnings

- There was significant variation on the sanitary status of RPC at different growers (Page 10).

- Collectively, 64% of RPC failed in terms of ATP readings with 56% of trays having higher TVC expected of a cleaned surface. Visual inspection of RPC revealed a proportion that were damaged or had labels affixed from previous use (Page 9).

- Although there are currently no regulatory critical limits or microbial standards for food contact surfaces (FCS) or established and widely recognized industry standards, studies of a similar nature cite values of 125 CFU/50 cm2 Aerobic Plate Count (APC) as the upper limit for a clean and sanitized FCS (Page 9).

- Transfers of microbiological pathogens differed among the different materials. Transfer was higher on plastics than on wood or cardboard (Page 9).

- The frequency of plant residues withe palletised RPC having passed through the multiple wash phases, may suggest a lapse in implementation of internal standards and procedures for inspection of RPC after washing (Page 9).

- Effective selection of the right chemical disinfectant and the right concentration it needs to be applied at, is critical for preventing the transmission of ToBRFV and PepMV through mechanical pathways, such as RPC and any other surfaces the crops may meet. (Page 12).

- The chemical disinfectants Lactoferrin (at 0.5%), Virocid (at 0.5% and 2%), Clorox (at 10%) appeared to be the most effective in virus inactivation (Page 12).

- The RPC washing process can be divided into multiple steps, which run at separate times and spaces. The equipment used at each site will determine how the washing process is managed (Page 15).

- The critical factors in ensuring that the cleaning process is as effective as possible in inactivating the viruses are (Page 15):
  - Temperature (minimum of 60°C for the cleaning solution and 80°C for the rinse aid solution).
  - Pressure (the amount of pressure used when applying the water with cleaning solution).
  - Cleanliness of the washing and rinsing solution.

- Frequent monitoring and testing ensure that the processes are working as intended and prevent the washing stations from becoming spreading points for the pathogens (Page 15).

- The hygienic requirements depend on the hygienic risk regarding the use of the RBC. Based on their hygienic risk, RBC are classified in three different groups (Page 15):
  - Less critical RBC (Fresh Produce).
  - Critical RBC (Dairy and Eggs).
  - Highly critical RBC (Fish and Meat).

- Specific advice on RPC management at each step is available and highlights the impact of user and handler decisions that can affect the wider supply chain (Page 17).

- RPCs are a product and need to be managed at all stages of the journey through the supply chain in holistic manner. This includes the storage and transport between each step in the RPC supply chain (Page 17).

- Washed RPCs should be held indoors in suitable storage facilities, The pallets should be wrapped (Page 17).

- Specific advice on RPC management at each step is available and highlights the impact of user and handler decisions that can affect the wider supply chain (Page 17).

- The type of adhesive used on labels and use of RPCs as waste receptacles are two issues raised (Page 17).

- Research has shown that, whilst bacteria require moisture to survive, viruses are very hardy and do not desiccate. Viruses can also survive for extended periods of time in hard surfaces (up to 6 months in lab conditions). A pathologist at UC Davis, believes that the virus needs organic material present in the surface to survive. IFCO is currently testing for the survivability of the brown rugose virus under real life scenarios (e.g., by simulating the conditions in a glasshouse) (Page 21).

- The concentrations of the detergents and antimicrobial agents used all play a role in determining the final efficacy of chemicals in dealing with the brown rugose virus. IFCO found, through its research, that using a combination of control methods, such as, temperature and antimicrobial agent, allowed for the use of the chemicals at a much lower concentration that what was previously used as standard (e.g., concentrations 60-70ppm of antimicrobial agent, caustic detergents, and temp versus the concentrations of 600-700ppm when used on its own) (Page 21).

- Research on ToBRFV interaction with RPC is still ongoing and building on from what was initially established 3 years ago. Currently there are no agreed parameters to use within the industry, but there is information available to help deal with brown rugose viruses or other pathogens of concern on the surface of the RPC (Page 21).

Discussion and Recommendations

Discussion

The United Fresh TAG team is pleased that it was already able to add value through connecting the local tomato industry with international research and knowledge through its workshop on RPC management in light of the biosecurity incursions of PepMV and ToBRFV. The team also hopes that this compilation of research data and presentations, which were presented and discussed at the workshop, will go some way towards our inevitable need to live and manage the presence of these virus incursions.

The arrival of Pepino Mosaic Virus and Brown Rugose Fruit Virus in New Zealand led Tomatoes New Zealand Inc. to focus on their specific need, i.e., finding a solution to reduce potential risk of RPC spreading the viruses within the tomato industry and beyond.

These two viruses are, in the first instance, plant diseases. Their presence in New Zealand constitutes a biosecurity risk.

Research on food safety microbial issues in RPCs is nevertheless relevant, even though the focus is not on biosecurity itself. The equipment and management tools available are, broadly speaking, the same.

The key learnings summarised after each topic covered in this compilation, inform both the food safety and biosecurity considerations and possible actions needed towards effective management of PepMV and ToBRFV, as well as food hygiene.

The rate of penetration RPCs has achieved into most domestic fresh produce categories, and supply chains is huge.

Finding specific crop related remedies is an appropriate strategy for managing internal (closed) crate pools used to move crops from a glasshouse to a packhouse. Applying crop specific remedies to RPCs from external crate pools used to move a given crop between packhouse and retailer, is not an option.

There are several reasons for this position.

1. Empty RPCs returned to the washing plants/depots from supermarkets and other retailers are not segregated by the most recent crop they had carried.
2. Once at the washing plant all RPCs are treated the same, in terms of the wash cycle. This means they are washed for the same amount of time and at the same temperature. The key focus being each RPC needs to have been cleaned to a sufficient standard that allows it to be suitable to transport the next fruit or vegetable crop.
3. Segregating, in this instance, RPCs used for the movement of tomatoes and treating them to longer wash cycles and at higher temperatures, simply was not an option. Nor was applying such proposed remedies to every crate in circulation, as washing plant capacities and hours in the day ensured this to be an impossible equation.

That point is where the United Fresh position really comes into play. There is a plethora of plant diseases, including viruses, capable of disrupting produce supply. Each industry sector trying to tackle RPC hygiene in the commercial supply chains on their own, in order to optimize crop specific positions is not viable or sustainable risk management.

Understanding as an industry what the common risk factors of RPC hygiene are, enables economies of scale to become a factor and also leads to accelerated learning for the entire industry, as opposed to a sector-by-sector basis.

The existence of a Washing Standard for RPCs (DIN 10522:2006-01) demonstrated the efforts by IFCO and other organisations to contribute towards crate users being able to effectively and efficiently manage those RPC which are used to transport fresh produce from the production areas to the consumers.

Producers who are utilising internal crate pools on their properties, should consider the information contained within the DIN Standard to assess how they can improve practices behind hygiene before the crops are packed in external hire crates.

Recommendations

Analysis of the Key Findings generated at the conclusion of each document section reviewed and consolidated on pages 25 and 26 suggests that the following recommendations could assist the industry to reduce any biosecurity and/or food safety related risks posed by RPC in the produce supply chain.

- The practice in mitigating the risk viruses present in glasshouse properties should include where possible a suitably managed internal crate pool for the harvest and transport to packhouse with external crate pool RPC used for transport to market.

- Organisations with their own internal crate pools should review washing and hygiene monitoring practices of the RPC.

- Frequent monitoring and testing of RPCs is conducted to ensure that the crate washing processes are working as intended and that the cleaning process and stations do not become a route for the spread of pathogens. This includes routine quality control processes, regular ATP testing and Microbial testing for pathogens that could cause food borne illness. It also includes minimising the use of RPCs as waste receptacles.

- United Fresh encourages its crate hire pool company members issuing RPCs in this country to share their biosecurity and food safety risk mitigation plans with other United Fresh members. This includes Validation and Verification processes.

- The three crates hire pool companies operating in New Zealand should be requested to operate their facilities to the DIN 10522:2006-01 Standard, or equivalent.

- The Crate companies review their supply agreements with RPC users regarding minimum handling, storage, and cleanliness expectations. All members of the supply chain have a responsibility to manage RPCs to minimise the risk of contamination and spread of pathogens whether biosecurity or food borne illness.

- Growers should develop a standard operating procedure (SOP) for receiving and inspecting incoming loads of RPCs or any other multiple use packaging containers. Appendix 1 consists of a component list growers should consider when developing their own SOP.

- United Fresh maintains contact with IFCO and other international industry bodies to ensure we have access to updates on research outcomes as they become available.

- The crates users, label providers and suppliers work together to address the impact of label adhesive on crate cleaning and retention on the crate for traceability purposes.

Appendix 1

Component Suggestions for Growers Writing an RPC Standard Operating Procedure		
Component	**Specifics**	**Questions to Consider**
Transportation	Empty RPC arrival method on property	- Grower transport or contractor transport? - Collection after-market delivery/ DC delivery or separate trip?
	Vehicle cleanliness status	- What is best practice for avoiding empty RPC contamination during transport?
	Maximum load and load safety	- What is the volume of crates required and at which frequency? - How does that information relate to current or future trucking capacity? - How is the load stacked, wrapped, and palletised?
	Full RPC departure from the property	- Grower transport or contractor transport? - Optimum load structure vs retailer specifications (where applicable)? - Loading methodology? - Load safety requirements? - No other loads in the truck that could contaminate the crates?
Management of empty RPCs	Arrival procedure	- Where do RPCs get unloaded? - How do RPCs get unloaded?
	Storage	- Does the property have a designated storage area? - Is the designated storage area sufficient in size for the volume received? - Is the storage area clean from a phytosanitary perspective? - What is best practice to maintain phytosanitary cleanliness of the storage area?

Component Suggestions for Growers Writing an RPC Standard Operating Procedure		
Component	**Specifics**	**Questions to Consider**
	Usage	- How are RPCs drawn from storage and positioned for use? - How is phytosanitary cleanliness maintained during the process of positioning RPCs for use and filling RPCs with produce? - Once filled, are the crates kept away from the clean and empty crates? - What are the RPC supplier's usage instructions? - How are RPC supplier usage instructions being adhered to on the property?
Labeling	Product identification	- Is the adhesive used on product identification labels as per RPC Provider specifications
Record keeping	Documentation	- How are records of RPC arrival, numbers, and usage maintained?
Internal RPC pools	Dirty/used RPCs	- How are dirty/used RPCs washed, to prevent contamination? - How are clean RPCs kept separate from dirty/used RPCs? - What systems are in place to prevent RPCs from being used repeatedly without washing? - Once cleaned, how are the RPCs handled and stored?