

Irrigation and food safety

Ensuring the safety of our food from farm to market

In the last few years a number of outbreaks of foodborne diseases worldwide have highlighted the importance of increased awareness around the importance of food safety in the supply chain. A new study, funded by the Water Research Commission (WRC) and led by the University of Pretoria, has examined food safety in the South African food value chain.

Article by Dr Erika du Plessis and
Prof Lise Korsten.



There are various pathogens associated with foodborne disease outbreaks, including *E.coli*, *Salmonella* spp., Hepatitis A and protozoa (*Giardia* and *Cryptosporidium*), among others. The contamination of fresh produce with these pathogens can happen at any stage in the food value chain, from pre-harvest production to post-harvest packaging and processing.

Potential sources of contamination at the pre-harvest level are soil, faeces, irrigation water, reconstituted fungicides and insecticides, dust, insects and

manure. At the post-harvest level the produce could be contaminated by contact with asymptomatic human carriers, harvesting equipment, transport containers, surfaces in processing factories and polluted process water.

Many farmers in South Africa rely on surface water sources to irrigate their produce. Unfortunately, the quality of some of these water resources has been compromised due to factors such as the proximity of growing informal settlements without adequate sanitation and stormwater services, ill-functioning

wastewater treatment plants and intensified urbanisation.

The pollution of irrigation water resources not only poses a risk for the consumers of fresh produce, but also to farmers, especially those supplying the burgeoning export market. In 2013 (the latest figure available from the Department of Agriculture, Forestry and Fisheries or DAFF), around 2.6 million tons of vegetables were produced in South Africa (excluding potatoes), 4% of which was exported.

Outbreaks of foodborne disease in recent years highlight the potential economic impact on farmers. In May 2011, for example, there was an outbreak of *E.coli* in the European Union. The outbreak was initially pinned on cucumbers and tomatoes produced in Spain, but was later linked to a German sprout producer.

The resultant misdiagnosis caused €225-million losses per week for Spanish vegetable producers. This incident highlights the potential economic impact of such outbreaks on an industry. Therefore, ensuring microbiological safety of both local and exported fresh produce is essential in ensuring public health, and keeping the fresh produce industry vibrant through adequate food safety assurance systems based on scientific data.

To investigate the extent of this problem, a solicited research project was funded by the WRC and co-funded by DAFF. The resultant reports, *Quantitative Investigation into the Link between Irrigation Water Quality and Food Safety: Volumes I-IV (WRC Report No. 1773/1-4/12)*, are available from the WRC. (To read more about this project, read the article, 'There's something in the water - Research highlights dangers of pollution to irrigation' in the *Water Wheel* January-February 2014)

The conclusion from this study was that microorganisms on fresh produce surfaces were present as a result of transfer from contaminated irrigation water. Subsequently, the WRC initiated a follow-up project (**project no. K5/1875/4**) to investigate the potential link between irrigation water and fresh produce (fruit and vegetables) at as well as after harvest from the farming to the processing stages of production up to the point of purchase. The study is led by the departments of Plant Science and Food Sciences at the University of Pretoria, with inputs from the Department of Microbiology at the University of KwaZulu-Natal.

Baseline microbiological information (bacteria, fungi, yeasts and/ or viruses) was obtained for irrigation and processing water and fresh produce sampled from farms, processing factories, fresh produce markets, street vendors and retailers. In addition, the prevalence of human pathogenic microorganisms was determined using a combination of optimised basic and molecular methods.

Produce samples were collected from five provinces in South Africa i.e. Gauteng, North West, Limpopo, Kwa-Zulu Natal and the Western Cape. Since the presence of pathogens on different crops has been reported and its prevalence has been linked to the surface characteristics (hairy, smooth, etc.), a broad range of fresh produce including vegetables, frozen vegetables, whole fruit and minimally processed fruit were analysed.

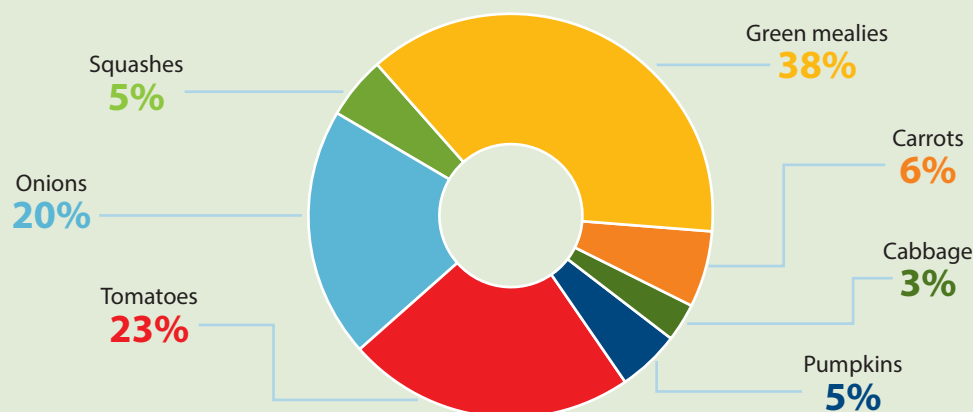
Main findings of the study

Microbial analysis confirmed the results of the previous study, with *E.coli* levels in irrigation water sources often exceeding the maximum allowable levels of 1 000 cfu/100 ml as stipulated by the World Health Organisation and the Department of Water and Sanitation. Further, genotyping of Hepatitis A virus and Sapovirus strains isolated from irrigation water samples showed that they were of human origin. This indicates that human faeces was the most likely source of the contamination. This poses a clear health risk to consumers.

Although agricultural chemicals can be used in the supply chain to reduce foodborne-pathogen-associated hazards, it is important to be aware of the fact that some of the chemicals can support pathogen growth. This should be taken into consideration in a risk assessment study for each crop and spray programme.

The researchers next investigated the extent of microbial contamination on irrigation raw fresh produce up to harvest, at harvest as well as after harvest. The microbial levels on crop

Relative importance of major vegetables types, based on gross value of production 2012/2013



Source: DAFF

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surfaces were found to often exceed the microbiological specification guidelines of the Department of Health (DoH) for ready-to-eat fresh fruit and vegetables. However, levels were generally found to be lower further down the supply chain.

It is important to note that the DoH guidelines provide specifications only for ready-to-eat fresh produce and these values should therefore not be directly used in production or even processing systems. One of the objectives of the current project is to develop realistic specifications for harvested and packed produce.

The microorganism levels on plant surfaces depended on the type of crop planted and growth stage. *Staphylococcus aureus*, *Listeria* spp., *Salmonella* spp., *E. coli*, viruses and protozoa were isolated from fresh produce at certain stages along the supply chain, but not from the beginning to the end of the chain. It was evident that the fresh produce with the highest microbial contamination was leafy

vegetables (lettuce and spinach). The study also for the first time in South Africa reported the presence of norovirus of swine origin on fruit – in this case strawberries.

Researchers found a strong correlation between irrigation water sources and pathogen presence on the fresh produce. In addition, the *E.coli* isolates from irrigation water sources were often found to be resistant to multiple antibiotics (up to 42%).

Generally the percentage of pathogens present on vegetable products was higher when compared to fruit samples. This is an important finding since it confirms the previous reports that fruit in general is by its very nature and production system a lower risk product than vegetables which are mostly grown in closer proximity to the ground.

Environmental conditions, such as exposure to high temperatures, UV and minimal processing (chlorine washing, hydrogen peroxide treatment, cooking,

blanching, microwaving and freezing) steps contribute to a reduction in microorganism numbers including human pathogenic bacteria tested for. It was concluded that the effectivity of minimal processing steps to reduce microbiological surface contamination levels is crop dependant due to the surface characteristics i.e. smooth versus hairy and/or rough. A combination of minimal processing methods led to the greatest reduction of pathogen numbers.

In this study the effect of irrigation methods (drip, sprinkler and flood) on the surface contamination of fresh produce was determined to be crop dependant and results showed that drip irrigation had the lowest risk of microbiological contamination for both tomatoes and lettuce. This is in agreement with previous reports in the literature that irrigation methods that do not allow for direct contact of the contaminated water with the edible regions of the plant facilitate a lower potential risk of contamination.

Special issues investigated

Biofilms have been reported to form rapidly in irrigation water storage facilities, irrigation pipes and wash-bath water in the packhouse or processing factory. Waterborne pathogens may be incorporated in these biofilms and shed over time during irrigation which constitutes a constant source of inoculum. This study highlighted the importance of implementing effective biofilm management systems in all water contact surfaces.

Internalisation studies confirmed the ability of pathogens to attach, survive, internalise and increase in plant tissue. It is now a scientific fact that waterborne pathogens can enter plants through growth cracks, roots and stomata and internalise in plants similar to plant pathogens. The ability of a pathogen to attach, colonise and survive on plant surfaces differ depending on the specific cultivar. However, it should be noted that in our and other studies pathogen concentrations higher than natural pathogen concentrations in the field were used. Although this situation in nature seldom applies, it shows the potential for contamination under extreme conditions such as flooding with highly contaminated water. Once internalised the pathogens are protected against the effect of minimal processing steps employed to promote food safety in the supply chain.

In the current study it was concluded that the accuracy of results can be correlated with sample size and test methods used. Sample size must be adequate to obtain a statistically validated result as far as pathogen presence/absence is concerned. Incidence studies further provide a snapshot of contamination potential at a specific study site and on a specific crop at a particular time during the year. Therefore, caution should be exercised when drawing conclusions from any result based on biased sampling and sample size.

This study confirmed previous research results on the presence of human pathogenic bacteria in irrigation water, the potential transfer to fresh produce and importance of food safety management systems to limit foodborne pathogen presence in the fresh produce supply chain.

The study will be published later this year.



The study confirmed the results of an earlier WRC study, namely that there is a strong link between irrigation water quality and pathogens found on fresh food produce.



This study investigated pathogen levels on food produce throughout the supply chain.