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EFFECT OF FRUIT PICK UP SYSTEMS ON THE MICROBIAL QUALITY OF CITRUS FRUIT SURFACES

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Abstract. **For Florida to effectively compete in the world citrus industry, significant reductions in harvesting costs will be necessary. Mechanical harvesting can be thought of as a two-step process: removal of fruit from the tree and retrieval of fruit from the ground and/or collection area. A citrus fruit pick up machine developed by OXBO International Corporation is being tested for performance and productivity. The machine is being evaluated for its picking up rate, efficiency, field capacity, and its efficiency for removing undesirable fruit and trash. The performance test is being conducted under different ranges of forward speed, orange variety, and grove conditions. A UF-IFAS machine is also being evaluated for the same criteria. This study evaluates the microbiological aspects of mechanically-handled fruit with respect to fruit surface microflora. Three treatments were evaluated: hand-harvested fruit (control), mechanically-harvested and dropped fruit picked up manually from the ground (MH/hand PUfruit), and mechanically-harvested and dropped fruit picked up with the OXBO or UF-IFAS pick up machine (MH/machine PU fruit). Microbial analysis included total plate count (TPC), acidophilic organisms (OSA), generic *Escherichia coli* (as an indicator of potential contamination), and *Salmonella*. In general, hand-harvest control fruit had similar microbial loads on the surface of the fruit as microbial loads on the MH/hand PU or MH/machine PU fruit. Neither *Escherichia coli* nor *Salmonella* were detected in any of the samples. There were substantial differences among the four replicate trials conducted to date, which may have been due to a variety of factors including differing mechanical action of the machines, weather, equipment sanitation, grove location, and tree/fruit treatments during production.**

Various mechanical harvesters and pick up machines for citrus have been developed since 1970 (Whitney, 1995; Whitney and Sumner, 1977). Several systems incorporate a catch pan to collect fruit as it is being removed from the tree. However, there are other systems which drop the fruit directly to the grove floor for subsequent collection. The tractor drawn canopy shaker detaches fruit and allows the fruit to fall to the ground. Trunk shakers and blowers have also been used to detach fruit from the tree for collection by either hand crews or pick up machines. Due to the large amounts of fruit and potential for hand labor shortages in the future, an efficient pick up machine would be preferred by the industry. Use of such machines would be also be useful to collect fruit blown from the trees during hurricanes.

Much of the data collection on mechanical harvesting systems consists of yield, performance and efficiency studies, as well as the effect of tree shaping and grove design (Roka and Rouse, 2004; Whitney et al., 1986). There has been some work in the area of the impact of mechanical harvesting systems on fruit quality. However, there is little information about the microbiological effects of allowing harvesting fruit to drop to the soil surface. What effects, if any, can be attributed to the pick up/cleaning portion of the system? Widespread adoption of particular mechanical systems will require demonstration that the system did not appreciably increase the microbial load on fruit versus traditional harvesting systems. There is also increased sensitivity in the citrus production and processing industries to food safety risks as a result of foodborne disease outbreaks associated with fresh orange juice that occurred in the mid-1990s (Parish, 1998).

There are some data available on the overall prevalence of pathogens such as *Salmonella* on the surface of fruit destined for processing (Parish et al., 2001). There are no recent published studies evaluating the effects of mechanical harvesting systems on *Salmonella* contamination rates on fruit, or on indicator organisms such as *Escherichia coli* that are linked with higher risks for pathogen contamination. The objective of this work was to summarize the 2005-2006 research results from the microbiological surface evaluations of citrus fruit collected by fruit pick up systems.

Materials and Methods

Equipment and fruit sampling. The OXBO International Corp. (Clear Lake, Wisc.) machine is a self-propelled rake, pick up and cleaning system with suitable size and capacity to operate in modern Florida groves. This fruit pick up system is being evaluated for its performance in picking up desirable fruit from the ground and its efficiency in removing undesirable fruit and trash at various forward speeds, orange varieties, and grove conditions. This study evaluated fruit surface microbe loads from harvesting trials that were deemed successful in terms of overall machine performance.

An early version of a pick up machine was utilized for one of the four trials. This machine had been developed under the Florida Department of Citrus Harvesting Program, acquired by UF/IFAS Citrus Research and Education Center, and refurbished by Dr. R. Ehsani. Although this machine performed well in terms of weight fruit picked up per min and efficiency, its large dimensions and personnel requirements of this particular system make its commercialization unlikely. Table 1 summarizes the equipment used for each of the four trials, along with grove and weather conditions at the time of harvest.

Seventy-five pieces of fruit per trial were collected, with 25 wholesome, non-defective fruit randomly selected from each of the three sample groups. Groups were identified as follows: Control (hand picked from tree in a normal manner), MH/hand PU (mechanically harvested from tree, then picked up

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Table 1. Information summary for 2005-2006 citrus harvesting season trials.

Trial	Harvest date	Machine type	Location	Temp/weather	Comments
1	15 Feb. 2006	OXBO	Lykes Grove, Lake Wales	72-73°F/clear	Soil type: Astatula, sludge applied
2	22 Feb. 2006	UF/CREC	North 40, CREC	74-76°F/clear	Soil type: Candler fine sand
3	6 Apr. 2006	OXBO	Lykes Grove, Lake Wales	81-83°F/clear	Same as Trial 1
4	11 May 2006	OXBO	Lykes Grove, Lake Wales	80-83°F/clear	Same as Trial 1

by hand), and MH/machine PU (mechanically harvested from tree, then sampled from collection hopper after mechanical pick up).

Microbiological methods and reporting. Fruit were kept chilled for no longer than 24 h prior to analysis. Each fruit was transferred to an individual, sterile whirl-pak bag using latex gloves. Thirty milliliters (mL) of 0.1% peptone buffer (Becton Dickinson, Sparks, Md.) was poured over the orange in each plastic bag and was manipulated to remove surface microorganisms as previously described (Parish et al., 2001).

All microbiological media were purchased from Becton Dickinson unless otherwise noted. Aerobic plate counts (APC) and acidophilic counts were performed by making appropriate dilutions of the wash buffer which was then spiral plated onto plate count agar (PCA) and orange serum agar (OSA), respectively. The PCA plates were incubated 24 h at 35°C (Morton, 2001) while the OSA plates were incubated 48 h at 30°C (Hatcher et al., 2001). After the appropriate incubation, numbers of colonies were counted and reported as colony forming units (cfu) per fruit. Data were statistically evaluated using Excel software (Microsoft, Redmond, Wash.).

Due to time and expense constraints, assays of *E. coli* and *Salmonella* were performed on separate, pooled samples. Each pooled sample was from 5 mL buffer aliquots from each orange sample which were mixed to yield one 25-mL sample for every five fruit. This resulted in five 25-mL samples for control fruit, MH/hand PU and MH/machine PU for each trial, and a total of 60 sample analyzed for *E. coli* and *Salmonella* over the entire study.

E. coli and *Salmonella* detection was performed by adding each 25 mL composite samples to appropriate media according to Parish et al. (2001). The VIP *Salmonella* test kit (Bio-Control, Bellevue, Wash.) was used as specified by the manufacturer for the *Salmonella* assay, while the E*Colite™ test kit (Charm Sciences, Lawrence, Mass.) was used to detect the presence of generic *E. coli*. Appropriate negative and positive controls were run to ensure performance of test kits. Results were reported as the number of positive composite samples.

Results and Discussion

Microbial populations were enumerated using APC media. This test is also described as 'Total plate count' or 'Standard plate count,' and in this case, represents the number of microorganisms on the surface of the orange that are capable of growing into viable colonies aerobically and at warm temperatures. The APC gives a general indication of the overall microbial load on or in a food product. Similarly, the OSA count represents the number of microorganisms on the surface of the orange that are capable of growing into viable colonies under more acidic conditions than PCA (acidophiles) (Hatcher et al., 2001). OSA is the typical media used in citrus processing quality control laboratories in order to enumerate the acidophilic organisms in the environment or in the product that are capable of surviving and growing in juice-like conditions.

APCs and OSA counts are shown in Table 2 for each of the four trials. We expected APCs to be significantly lower than for control fruit because control fruit were not in contact with the soil surface, the source of many microorganisms on agricultural products. Lower APCs for control fruit was not true for all of the trials. This result suggests that dropping fruit to the ground and/or picking it up mechanically does not always result in significantly higher microbial loads. It is important to note that all trials were conducted under very dry, sunny conditions. Soil moisture or other environmental factors may be very important in the ultimate number of microorganisms that adhere to fruit dropped on the ground. The average APC for the MH/machine PU sample group in Trial 1 was significantly greater than that of the other two groups. It is impossible to determine the reason for this particular result. Any fruit in contact with soil has the potential to become severely contaminated, although that was clearly not the case for many of the fruit that were picked up from the ground, either by hand or mechanically. However, this one result emphasizes the need for proper grove floor observation and maintenance, as well as equipment cleaning and care. Both soil and machines are potential sources of contamination of fruit surfaces.

Results of the OSA analysis follow the same general trend as those for APC. In general, there are no significant differences among the three treatment groups. Only Trial 2 indicated significantly greater acidophilic microbial loads for both of the fruit groups that contacted the soil versus the hand-picked control. Many factors contribute to the surface

Table 2. Fruit surface microflora in colony forming units (cfu) per mL for all trials using mechanical harvesting (MH) with and without pick up (PU) machines.

	Control	MH/hand PU	MH/machine PU
		Results of APC[z] (cfu/mL)	
Trial 1	623,040 a	433,260 a	1,536,125 b
Trial 2	20,172 a	557,352 b	210,696 b
Trial 3	423,504 a	364,272 a	656,280 a
Trial 4	186,084 a	313,380 a	535,056 a
		Results of OSA[y] (cfu/mL)	
Trial 1	532,992 a	667,200 a	730,020 a
Trial 2	19,104 a	1,888,868 c	125,808 b
Trial 3	571,296 a	184,968 a	295,260 a
Trial 4	238,032 a	381,328 a	572,688 a

[z]APC is Aerobic Plate Count expressed as colony forming units per fruit. n = 25 for each mean presented. Mean separation, as denoted by different letters within rows, was by Student's t-Test, 5% level.

[y]OSA is Orange Serum Agar enumeration, expressed as colony forming units per fruit. n = 25 for each mean presented. Mean separation, as denoted by different letters within rows, was by Student's t-Test, 5% level

microflora of a raw agricultural product. These include production practices, natural ecology of the fruit/microorganism system, equipment sanitation, geography and climate, and hygiene of harvest and packinghouse personnel (U.S. FDA, 1998a). All of these factors may have impacted the results obtained from this study.

Table 3 summarizes the number of positive composite samples that were evaluated for the presence/absence of *E. coli* and *Salmonella*. Neither of these organisms was detected in any of the 60 samples analyzed in this study. The overall level of *Salmonella* contamination on any raw agricultural product is quite low (2-3%; U.S. FDA, 1998b), and the result of 0 out of 60 positive samples is not entirely unexpected. However, given the intimate contact of fruit from two of the groups with the soil surface, this result is an encouraging one in the development of harvesting/collection systems that rely on some sort of pick up system. The result for *E. coli* was also 0 out of 60 positive and indicates that there were no significant contamination loads on any of the sample groups of this indicator organism. As discussed previously, while generic *E. coli* are not considered foodborne pathogens, their presence can be indicative of fecal contamination from warm-blooded animals. This is a situation that is linked with higher risk of concurrent contamination of agricultural products with human pathogens.

There is practical importance to the surface microflora of oranges delivered to the processor. Contamination of raw materials is listed as the second most serious food safety problem in the food processing industry, after deficiencies in employee training (Sertkaya, 2006). However, incoming fruit to citrus processing plants is typically washed and sanitized, and the vast majority (>98%) of Florida-processed orange juice is pasteurized or similarly treated to inactivate spoilage enzymes and to miocrobiologically stabilize the product. Wider adoption of mechanical harvest/pick up systems will be somewhat determined by the quality of fruit delivered to the processor. This quality includes potential microbiological contamination as well as the typical measures of machine yield and efficiency, and economics. For these reasons, it is important to continue to collect fruit microbiological quality information for any harvest/collection system that promises commercial viability.

Table 3. Summary of fruit surface indicator and pathogenic organisms for all trials using mechanical harvesting (MH) with and without pick up (PU) machines.

Control	MH/hand PU	MH/machine PU
	Results of *E. coli* tests	
0/20[z]	0/20	0/20
	Results of *Salmonella* tests	
0/20	0/20	0/20

[z](number of positive tests)/(number of total tests).

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