Localized Shake-and-Catch Harvesting for Fresh Market Apples

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Abstract

High level of harvest costs and dependence on human labor are the big challenges for fresh market apple production. Mechanical harvesting is a potential solution to address these issues. A localized shake-and-catch harvesting system was proposed in this study. First, some fundamental parameters were investigated. One of such investigation was to evaluate the efficiency of energy transmission and fruit detachment at different locations in the limbs. In addition, fruit impact tests were carried out in the lab to identify potential sources for bruising and to identify catching surface materials that may keep fruit bruising at a low level. Next, a new catching device was designed and fabricated to evaluate the dynamic response of fruits during the catching process. The outcomes of these individual studies were then used to develop an optimized system, which was evaluated for targeted shake-and-catch harvesting of various apple cultivars trained in different canopy architectures. For tested varieties and architectures, fruit removal efficiency varied from 66% to 95% under the shaking frequency of 20 Hz with US Extra Fancy and Fresh Market quality varying from 57% to 89%, and 78% to 94% respectively. It was found that 'Jazz', 'Pink Lady', 'Fuji', and 'Pacific Rose' varieties performed better in terms of fruit removal efficiency and fruit quality. In contrast, 'Gala', 'Envy', and 'Honeycrisp' cultivars were found to be difficult to remove or maintain good quality during targeted shake-and-catch harvesting. In summary, the study showed the potential for mechanical harvesting of fresh market apples for certain varieties.

Keywords: Fresh market apples, mechanical harvesting, shake and catch, impact force, fruit quality

1. Introduction

Apple is one of the most valuable fruit crops in the United States. In 2014, about 130,000 ha apples were planted nationally with approximate production values of 3 billion US dollars (USDA-NASS, 2015). Currently, hand picking is the major harvesting method for fresh market apples, which is labor intensive and costly. This intense labor demand is creating a significant risk of growers not having a sufficient supply of labor to conduct seasonal tasks. Mechanical harvesting is one of the potential methods to address this challenge.

Research on mechanical shaking methods for harvesting apples and other tree fruit crops dates back to the 1960s (Crooke and Rank, 1969; Tennes and Brown, 1985; Peterson et al., 1999; Peterson and Wolford, 2003). Recently, Washington State University (WSU) has been working on a localized shake-and-catch harvesting system in which smaller limbs is shaken with appropriate patterns and detached fruit is collected very close to the target branches (De Kleine and Karkee, 2015). Fruit removal and fruit quality are two major concerns in the mechanical harvesting of fresh market apples. The basic principle of harvesting with a shaking mechanism is to transmit kinetic energy to fruiting branches, which is used to generate a detaching force on the fruit-stem interface to remove fruit from the tree (Erdoğan et al., 2003). During shaking, a tree would respond differently to different excitation frequencies and amplitudes, and fruit removal occurs when the induced detachment force exceeds the pedicel-fruit tensile strength (Markwardt et al., 1964). Normally, the higher input vibrational energy could result in higher fruit removal efficiency but with higher level of fruit and tree damage (Norton et al., 1962). Generally, a certain amount of fruit would remain on the tree after mechanical harvesting, which could be attributed to insufficient detaching force delivered to those fruiting locations (Diener et al., 1965).

However, current shake and catch harvesting systems are limited for commercially adoption to fresh market apples due to the excessive fruit damage caused by fruit-to-fruit, fruit-to-limb, and fruit-to-catching surface contacts during harvesting (Peterson and Wolford, 2003). The principal of apple bruising is that the impact induced stress exceeds the fruit tissue failure stress (Pitt, 1982). In order to reduce the impact induced stress, a lot of studies have been reported to using different kind of padding materials on the catching surface (Robinson et al., 1990). Some other studies focused on reducing fruit falling energy by inserting foam materials to the canopy (Johnson et al., 1983). However, there are very few research reported on the shake-and-catch designed for targeted shaking of tree limbes and its evaluation on fruit removal efficiency and fruit quality. Especially, in Washington State, there are increasing number of orchards trained to modern trellis system providing potential for localized shake-and-catch harvesting system for fresh market apples to keep fruit quality to the desired level while keeping the removal efficiency at the maximum level.

The primary goal of this study was to develop and evaluate a localized shake and catch harvesting system for fresh market apple growing on the modern trellis tree orchards. Specific objectives of this study were to: (1) Develop corresponding systems to investigate these proposed fundamental parameters in the mechanical harvesting; and (2) Evaluate functionality and performance of the developed shake and catch system in commercial apple orchards.

2. Materials and Methods

In this study, some fundamental components related to mechanical harvesting were investigated through indoor or field tests, such as fruit detachment with respect to the fruit location, and the fruit dynamic response during the catching process. Then an optimal shake-and-catch system was designed and fabricated based on the desired parameters identifcfied through component level studies. Finally, a field harvesting test was conducted to evaluate the developed shake and catch prototype in apple orchards with different varieties and tree architectures.

2.1 Fruit detachment, impact, and collection

2.1.1 Energy transfer efficiency

Generally, apples grow on both main limb and twigs growing out of the main limbs. Figure 1a illustrates a random limb with an apple located on a twig. Energy transfer efficiency to a fruit depends on the location of fruit in the canopy with respect to the actuation point. In order to express the effect of fruit location on energy transfer and fruit detachment, a fruit location index was defined and used in this study.

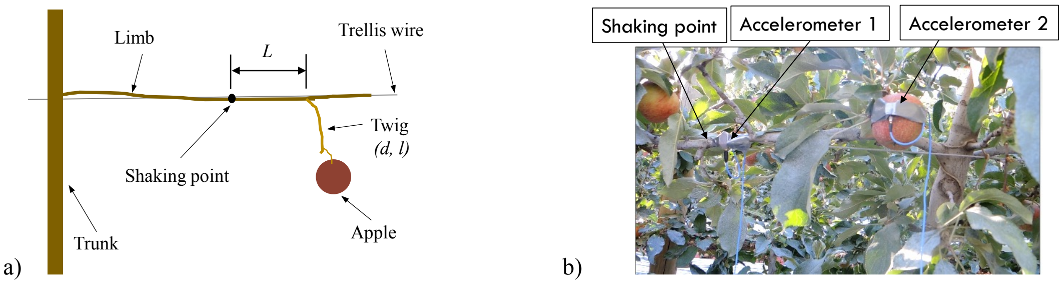


Figure 1. a) An illustration of a typical trellis trained limb (in a formally trained apple orchard) with fruit located in a twig; b) Experimental setup for fruit detachment dynamic test.

For each fruit, three indices (see Equations 1 to 3), distance index, twig diameter index, and twig length index, were defined and used to study the effect of fruit location (with respect to the shaking point) on shaking efficiency. The distance index (or $index_1$) represents the distance from the shaking point to the junction point of limb and twig bearing the fruit; twig diameter index (or $index_2$) indicates the diameter of the twig bearing the fruit in relation to the average diameter of all tested twigs; and twig length index (or $index_3$) represents the length of the twig bearing the fruit in relation to the average twig length of all tested twigs. We defined fruit location index as the sum of these three indices, which was then used as a measure to define fruit location in the limb (Equation 4).

$$index_1 = L_i / L_{mean} \quad (1); \quad index_2 = d_{mean} / d_i \quad (2); \quad index_3 = l_i / l_{mean} \quad (3)$$

Where, L_i, d_i, and l_i are respectively the distance from the twig-limb junction to the shaking point (~middle of the limb), the diameter of the twig, and the length of the twig. L_{mean}, d_{mean}, and l_{mean} are the averages of corresponding variables over all the fruit tested in this study.

$$index_{fruit} = index_1 + index_2 + index_3 \quad (4)$$

Figure 1b illustrated an experimental setup of fruit dynamic response under certain shaking conditions. In our study, the shaking frequency of 15Hz, 20 Hz and 25 Hz were used to shake randomly selected limbs. Eighteen to twenty apples located at different location of selected limbs were tested. The shaking was continuously applied until the targeted fruit was detached or shaking duration reached a maximum of 5 s. Two data acquisition modules (NI CompactDAQ 9234, National Instruments, Austin, TX) were used to record three axes of acceleration at the shaking point and at the tested fruit. The overall accelerations at shaking point and tested fruit were then calculated using Equation 5. In this study, we averaged five maximum accelerations from the recorded data as the maximum acceleration of the fruit during shaking.

$$Acc = \sqrt{Acc_x^2 + Acc_y^2 + Acc_z^2} \quad (5)$$

Where, Acc_x, Acc_y, and Acc_z are the accelerations in x, y, and z axis respectively. These tests were used to identify optimum shaking frequency for developing and evaluating an integrated shake-and-catch harvester.

2.1.2 Fruit catching device development and evaluation

To reduce the possible damages to fruit during collection, a new catching device was developed and a series of indoor experiment was conducted to evaluate its performance (Figure 3). The surface of the catching device is covered by a foam material selected based on experiments described in our previous study (Fu et al., 2016). Additional two buffers were also included to potentially reduce the impact energy (Figure 3). The catching device mainly consisted of a bounce buffer, a rolling buffer, and a collection area. The catching device was built on a wooden plate with a 1.5 cm thick foam (density of 44.9 kg·m^{-3}, and firmness of 4.8 kPa). The base of the catching device was 60 cm wide and 100 cm long. Two sets of bounce buffer bars were mounted 20 cm apart. The rolling buffer consisted of three rows of buffer plates mounted 10 cm apart from each other with six pieces of buffer plates in each row.

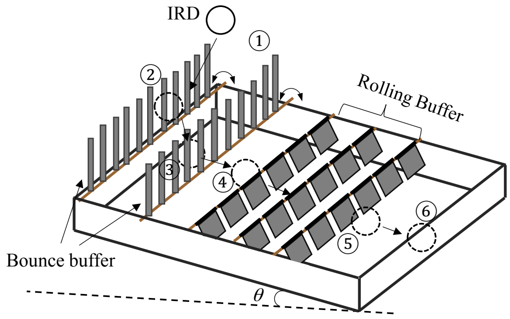


Figure 3. Illustration of the catch device indoor test schematics.

In this experiment, the catching device was set at three different orientation (or tilt) angles of 15°, 25°, and 35°. An Impact Recording Device (IRD: Techmark. Inc, Lansing, MI) was then dropped on to the catching surface from a certain height (location 1, dropping height of 30 cm to the catching surface). The IRD (with 320 g mass and 89 mm diameter) is similar to an apple in terms of shape, size and weight, and was used to record changes in fruit speed (acceleration) during the catching process. As shown in Figure 3, the IRD was dropped onto the bounce buffer (location 2), and then landed on the foam surface (location 3). Since the catching surface was at certain angle, the IRD rolled downward to location 4. There was a rolling buffer to reduce the speed of the apple until it reached location 5. Eventually, the IRD stopped at the position when it hit the edge of the catch frame (location 6). In this experiment, ten repeations were recorded for each test combination (same tilt angle, same buffer condition). With IRD, the impacts with acceleration over 10 g (g=9.8 m·s^2) was recorded. In this study, we assumed 10 g as a threshold acceleration to cause bruising, which helped evaluate the catching device. Through lab test, the functionality and effectiveness of the proposed buffers were investigated, which was used to determine the structure of catching device for mechanical harvesting. Meanwhile, catching device tilt angle will also be determined based on the lab test result, which will then be used in the harvesting tests.

2.2 Harvesting tests with shake-and-catch system

2.2.1 Shake-and-catch system

Figure 4 illustrates the shake-and-catch system used in this study. The system includes a limb shaker and a catching device. The limb shaker (Figure 4a) was adapted from a reciprocating saw (Model: 2720, Milwaukee Electric Tool, Brookfield, WI). The frequency of the shaker ranged from 0 to 33 Hz with an amplitude of 3.2 cm. The catching device (Figure 4b) is the one tested in Section 2.1.3.

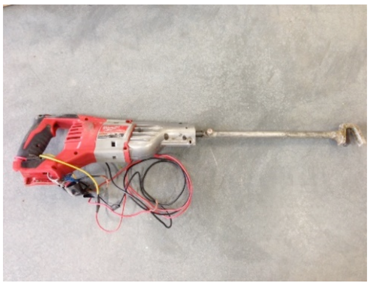
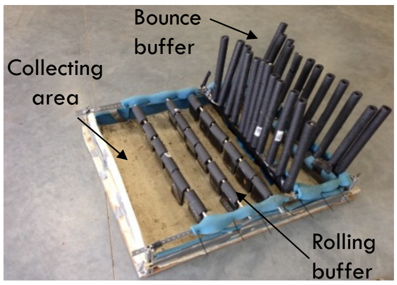
a)  b) 

Figure 4. Illustration of the shake and catch harvesting system. a) A shaker adapted from a reciprocating saw with adjustable frequency; and b) A catching device with buffers to reduce the impact on apples.

2.2.2 Experiment site and experimental design

In order to assess the performance of the developed shake and catch harvesting prototype, field tests were carried out with different varieties of apples produced in different tree architectures around Yakima Valley, WA during 2015 apple harvest season. The tested varieties include: Gala, Fuji, Jazz, Pink Lady, Pacific Rose, Honey Crisp, Envy, and WA 38. The tested tree architectures include: Vertical fruiting wall, V-trellis fruiting wall, and Bi-axis. The detail information about the test orchards is illustrated in Figure 5. In vertical and V-trellis fruiting wall systems, there are six to seven metal trellis wires to train seven different layers of limbs horizontally and parallel to each other. In this study, only layer 2 to layer 4 was used due to the accessibility of the device. In the bi-axis system, there are two main braches for each tree. In the tests, we shook each main branch of the tree as one shaking operation. A predesigned shaking frequency and a tilt angle of catching angle decided by the previous test (Section 2.1) were used for the harvesting test. About 55 randomly selected limbs were used for the test.

Figure 5. Test orchards used in evaluating the shake-and-catch harvesting prototype; a) Gala: V-trellis fruiting wall; b) Fuji: V-trellis fruiting wall; c) Jazz: Vertical fruiting wall; d) Envy: V-trellis fruiting wall; e) Pacific Rose: Vertical fruiting wall; f) Pink Lady: Vertical fruiting wall; g) WA-38: Bi-axis; and h) Honeycrisp: V-trellis fruiting wall

Immediately after the tests, harvested fruit samples were sent to the laboratory with room temperature (about 21°). The quality assessment of the fruit took place after fruits were stored for at least 24 hours. The fruit removal efficiency, fruit collection efficiency, and fruit quality were analyzed.

2.3 Measures for performance evaluation

2.3.1 Fruit removal and collection efficiency

Fruit removal efficiency was defined as the percentage of the number of mechanically harvested fruit against the total number of fruit growing on a test limb (equation 6). Fruit collection efficiency was defined as the percentage of fruit collected by the catching device against the total amount of fruit harvested from a test limb (equation 7). The overall fruit recovery efficiency can be calculated by equation 8.

$$\eta_r = N_r / N \times 100 \quad (6); \quad \eta_c = N_c / N_r \times 100 \quad (7); \quad \eta_o = \eta_r \cdot \eta_c \quad (8)$$

Where, N_r is the number of the mechanically harvested fruit; N_c is the number of fruit collected by the catching device, and N is the number of total fruit on the test limb; η_r is the fruit removal efficiency (%); η_o is the fruit recovery efficiency (%).

2.3.2 Fruit quality

An USDA standard for fresh-market apple quality was used to category the quality of harvested fruit (Peterson et al., 2010) into different quality grades. The percentage of harvested fruit in each category was defined by equation (9).

$$\eta_d = N_d / N \times 100 \quad (9)$$

Where, η_d is the percentage of harvested fruit in a quality category, and N_d is the number of fruit in a quality category.

3. Results and Discussion

3.1 Fruit location vs fruit detachment efficiency

Figure 6a, 6b, and 6c present fruit accelerations with varying fruit location indices for three different test frequencies. The results showed that the relationship between fruit location index and corresponding fruit acceleration could be regressed into a “power function” for all three excitation frequencies. R^2 values for these relationships were found to be 0.68, 0.59, and 0.47 for frequencies 15, 20, and 25 Hz, respectively. The red circles over the black dots in all three plots represent the data recorded for fruits removed within 5 s shaking; those without red circles represent unremoved fruits. In most of the cases, an acceleration of 5 g or greater at a fruit could guarantee the fruit removal. It was found that the fruit acceleration was higher for fruit with location index smaller that than 2.5. The acceleration declined sharply when fruit location index increased beyond 2.5.

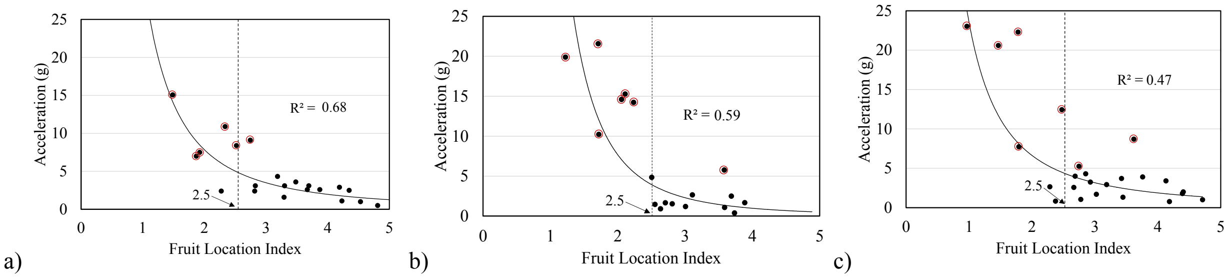


Figure 6. Dynamic response (acceleration) of fruit with varying fruit location indices; dots with red circle represent fruits samples being removed within 5 s of shaking at a) 15 Hz, b) 20 Hz, and c) 25 Hz

Compared to shaking frequency of 15 Hz, the fruit under vibration with 20 Hz and 25 Hz were exerted higher acceleration, especially when the fruit location index was small. However, the difference between those of 20 Hz and 25 Hz was limited. Qualitative observation in the field indicated that fruit motion under 25 Hz of shaking was more intense than other two frequencies, which might cause more fruit damage during harvest. Therefore, 20 Hz of shaking frequency was selected for all field test conducted in this study.

3.2 Fruit collection tests

Based on the ten replications of the drop tests with an IRD, the average of maximum impact acceleration, and the number of impacts over 10 g are illustrated in Table 1.

Table 1. The maximum impact acceleration and number of impacts over 10 g recorded using an Impact Record Device (IRD) simulating the apple drop on different configurations of catching device.

Test Patterns	Maximum impact acceleration（g）			Number of impacts over 10 g		
	Tilt Angle 15°	25°	35°	15°	25°	35°
With bounce and rolling buffers	20.3±2.6	21.2±3.8	17.7±2.0	1.0	1.5	1.4
With rolling buffer, no bounce buffer	37.0±1.9	35.6±1.7	32.1±2.1	1.0	1.2	2.0
No bounce and rolling buffer	39.6±1.4	39.0±2.5	32.6±2.0	1.0	2.0	3.1

For all tilt angles of the catching surface, the maximum impact acceleration was the lowest when the catching device included both bounce and rolling buffers and was the highest without both buffers. When no bounce buffer was used, only a slight difference was observed with and without the rolling buffer. When the catching surface tilt angle was 15°, the number of impacts with 10 g of higher acceleration was 1.0 for all three combinations of buffers. The only such impact occurred when the IRD landed on the catching surface for the first time. When the tilt angle of the catching surface increased, the number of acceleration over 10 g also increased. At 35° tilt angle, the number of acceleration over 10 g was 1.4 in the tests with both buffers, which increased to 3.1 when no buffers were used. The results showed that the fruit acceleration during impact could be reduced in the fruit catching process if proper deceleration buffers are used in the catching device. Even though tilt angle of 15° caused lowest number of impact over 10 g, IRD could not always be transferred smoothly through the rolling buffer during the catching process. Overall, the catching device with both buffers provided the highest level of protection to the collected fruit, and catching tilt angle of 25° was relatively better than other two angles considering both fruit transfer and fruit impact strength in the catching device. In the field harvesting test, the catching device with both buffers was set at 25° tilt angle.

3.3 Shake-and-catch harvesting system

Complete shake and catch system was evaluated in various commercial fields with different varieties and canopy architectures. The results from this test in terms of fruit removal and collection efficiencies, and fruit quality are listed in Table 2.

Table 2. Fruit removal efficiency, collection efficiency, and fruit quality for harvesting tests (Mean over all test samples)

Verities	Canopy Structure	Harvesting Efficiency			Harvested fruit quality			Orchard Picture
		Removal Eff. (%)	Collection Eff. (%)	Recovery Eff. (%)	Extra-Fancy (%)	Fresh Market (%)	Downgrade (%)	
Gala*	Vertical	68%	100%	68%	-	-	-	Fig. 5a
Fuji	V-trellis	85%	98%	83%	70%	86%	14%	Fig. 5b
Jazz	Vertical	86%	98%	84%	80%	94%	6%	Fig. 5c
Envy	V-trellis	66%	91%	61%	71%	82%	18%	Fig. 5d
Pacific Rose#	Vertical	85%	95%	81%	74%	87%	13%	Fig. 5e
Pink Lady#	Vertical	88%	96%	85%	89%	94%	6%	Fig. 5f
WA 38	Bi-axis	92%	-	-	-	-	-	Fig. 5g
Honey Crisp#	V-trellis	95%	-	-	57%	78%	22%	Fig. 5h

*for Gala, another similar shaker was used (20 Hz with 30 mm amplitude), and the harvested fruit was collected by a catching surface right below the fruits without any tilt angle; for the rest of tests, the shake and catch system as shown in Figure 1 was used;

for these three varieties, “Ethephon” was applied to those orchards approximately 2 weeks before the harvesting test.

It was found that the fruit removal efficiency and fruit quality were depended on the cultivars. For the varieties and architectures tested, fruit removal efficiency varied from 66% to 95% under the shaking frequency of 20 Hz. “Gala” and “Envy” varieties were the most difficult to detach from branches. For other tested varieties, removal efficiency was 80% or higher from the targeted area. Developed catching device collected a large percentage of the harvested fruit ranging from 91% to 100%. In these experiments, percentage of fruit with US Extra Fancy quality (bruise area diameter less than 12.7 mm) varied from 57% to 89%. With some varieties, the harvesting system achieved both good fruit removal efficiency and good fruit quality. For example, a fruit removal efficiency of 86% and US Extra Fancy grade of 80% was achieved for 'Jazz' cultivar. Compared to "Jazz", "Fuji" had much bigger fruit size in our study, which might have resulted in higher fruit damage during the fruit catching process. For "Pacific Rose", "Pink Lady" and "Honey Crisp", hail damage occurred in those orchards during the early fruiting stage and ethephon was applied before harvesting. For "Honey Crisp", we started harvesting a little bit later than usual harvesting window, which might have partially influenced fruit removal efficiency and fruit quality. For WA 38 variety (not a commercial variety yet), the tree architecture was bi-axis, with fruits mainly located in one of the big limbs, which contributed to high fruit removal efficiency of 92%. However, it was difficult to catch all the fruit using the catching device primarily developed for planner architectures. In summary, the results indicated that 'Jazz', 'Pink Lady', and 'Pacific Rose' varieties performed better in terms of fruit removal efficiency and fruit quality, and in contrast, 'Gala', 'Envy', and 'Honeycrisp' cultivars were found to be difficult to remove or maintain good quality during targeted shake-and-catch harvesting.

4. Conclusions

In this study, a set of tests were conducted to investigate several fundamental parameters of shake and catch fruit harvesting operations. A system level field harvesting test was then conducted to validate the developed shake and catch system. The following specific conclusions could be drawn from this work: 1) Fruit detachment was strongly related to fruit location in the limb, and fruit acceleration was generally higher when the fruit location index was small; 2) Catching material had big influence on the impact force between fruit and catching surface; catching device with appropriate cushion materials could significantly reduce the strength of impact during fruit collection process; 3) Fruit removal efficiency and fruit quality were depended on the cultivars, some varieties such as Jazz, and Pink Lady were found to be promising for mechanical harvesting. For example, a removal efficiency of 86% was achieved with "Jazz" cultivar with a minimal fruit downgrade of 6%.

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References

Crooke, J. R. and R. H. Rand. 1969. Vibratory fruit harvesting: a linear theory of fruit-stem dynamics. Journal of Agricultural Engineering Research. 14(3), 195-209.

De Kleine, M. E. and M. Karkee. 2015. A Semi-Automated Harvesting Prototype for Shaking Fruit Tree Limbs. Transactions of the ASABE. 58(6), 1461-1470.

Erdoğan, D., M. Güner, E. Dursun, and İ. Gezer. 2003. Mechanical harvesting of apricots. Biosystems Engineering. 85(1), 19-28.

Diener, R.G., Mohsenin, N.N., and Jenks, B.L. 1965. Vibration characteristics of trellis-trained apple trees with reference to fruit detachment. Transactions of the ASAE. 8(1), 20-24.

Fu, H., L. He, S. Ma, M. Karkee, Q. Zhang, and S. Wang. 2016. 'Jazz' apple impact bruise response to different cushioning materials. (Submitted to the ASABE annual meeting)

Johnson, J. C., R. G. Diener, K. C. Elliott, P. E. Nesselroad, S. Singha, S. H. Blizzard, and M. Ingle. 1983. Two experimental bruise reduction methods for mechanically harvested apples. Transactions of the ASAE. 26(4), 1037-1040.

Markwardt, E. D., R. W. Guest, J. C. Cain, and R. L. Labelle. 1964. Mechanical cherry harvesting. Transactions of the ASAE. 7(1), 70-74, 82.

Norton, R.A., Claypool, L.L., Leonard, S.J., Adrian, P.A., Fridley, R.B., and Charles, F.M. 1962. Mechanical harvest of sweet cherries. California Agriculture. 16(5), 8-10.

Peterson, D. L., B. S. Bennedsen, W. C. Anger, and S. D. Wolford. 1999. A systems approach to robotic bulk harvesting of apples. Transactions of the ASAE. 42(4), 871-876.

Peterson, D. L. and S. D. Wolford. 2003. Fresh–Market Quality Tree Fruit Harvester Part II: Apples. Applied engineering in agriculture. 19(5), 545-548.

Peterson, D. L., A. L. Tabb, T. A. Baugher, K. Lewis, and D. M. Glenn. 2010. Dry bin filler for apples. Applied engineering in agriculture. 26(4), 541-549.

Pitt, R. E. 1982. Models for the rheology and statistical strength of uniformly stressed vegetative tissue. Transactions of the ASAE. 25(6), 1776-1784.

Robinson, T. L., W. F. Millier, J. A. Throop, S. G. Carpenter, and A. N. Lakso. 1990. Mechanical Harvest ability of Y-shaped and Pyramid-shaped Empire' and Delicious' Apple Trees. Journal of the American Society for Horticultural Science. 115(3), 368-374.

Tennes, B. R. and G. K. Brown. 1985. A sway-bar shaker for apples. Transactions of the ASAE. 29(1), 60-64.

USDA-NASS. 2015. Noncitrus fruits and nuts: 2014 summary. Available on: http://usda.mannlib.cornell.edu/usda/nass/NoncFruiNu//2010s/2015/NoncFruiNu-07-17-2015.pdf. Access on: 2/20/2016.