

Adequacy of Hand Washing Apples: An ATP Analysis

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Abstract

Background: Foodborne illnesses linked to fresh produce has been on the rise in recent years. This increase in illnesses pose a massive burden to the healthcare system. One way to prevent this is through educating the public the importance of handwashing produce. There are many studies that have tested ways of washing and sanitizing fresh produce to reduce surface pathogens. However the average consumer mainly hand washes produce before consuming it. Thus this study intends to test the efficacy of hand washing by testing surface ATP on apples before and after they have been washed.

Methods: Apples were purchased from the bulk section of a super market. ATP swabs were used to test the concentration of ATP on the surface of the apples. The values were recorded. All the apples were hand washed under running tap water for 15 seconds and the surface ATP concentration were obtained and recorded. The values were then compared to draw a conclusion.

Results: The results show that there is statistically significant reduction in surface ATP values on apples after washing them (mean ATP value of 33.2) compared to before washing them (mean ATP value of 116.67). The p-value obtained was 0.00033 when $\alpha = 0.05$.

Conclusion: This study was able to conclude that there was a significant reduction in surface ATP values following handwashing of the apples. There was an observed 60% reduction in the mean values of ATP of before and after hand washing. In conclusion, hand washing apples do provide an adequate reduction of surface ATP values thus attaining surface cleanliness.

Keywords: ATP, cross contamination, apples, sanitization, foodborne illness, cleaning methods, UltraSnap swabs, luminometer, pathogens, fresh produce, outbreaks

Introduction

In our current society, where everyone is always on the move, it can be hard to get the necessary servings of fruits and vegetables. Fresh produce like fruits are natural pre-packaged foods, which is healthy and nutritious. Fruits go through various stages of handling during processing and packaging before they reach the end consumers. The various stages of

handling increase the probability of them being tainted with chemicals and microbes. Furthermore, at a retail store, they are handled by various employees and shoppers which can heighten the risk of transferring disease-causing microbes onto the fruit. The only precaution that is taken against contracting these transferred microbes, is to wash the produce before it being consumed. The researcher intends to find out through ATP analysis, before

and after washing some fruits, if humans are indeed taking enough care to protect themselves. The scientists at University of Massachusetts in an experiment found that baking soda was a better cleaning agent for apples than bleach (16). In reality humans do not use bleach nor baking when washing apples before consumption. In the event where significant results are found, it could lead to a health promotion campaign that can mitigate the recent increase in foodborne illness outbreaks that are related to fresh produce.

day (2). British Columbians, in general, consumed more fruits and vegetables compared to the national average. Yet, more than 55% of the BC population groups are not getting more than 5 servings of fruits and vegetables per day. Furthermore, Canada has one of the highest per capita consumption of fruits and vegetables worldwide (17). Thus it is essential to prevent any health complications that may arise due to improper preparation of fruits and veggies prior to consumption. While BC was relatively shielded from produce related outbreaks compared to the rest of Canada there have been frequent Cyclospora outbreaks detected (22).

Literature Review

Canada’s Food Guide recommends that adults should eat between 7-10 servings of food and vegetables every day (1). It is essential that humans consume enough fruits and vegetables to lead a healthy lifestyle. But fruits and vegetables can house many pathogens and chemicals that can cause harm to human health, thus pose a health hazard.

Various studies have been conducted to demonstrate that Canadians are not getting enough fruits and vegetables in their diets.

Rationale

While it is essential to incorporate more fruits and vegetables into the diet, it is also essential to not get into harm doing so. Foodborne disease outbreaks have been an increasing occurrence worldwide (17). It is important to note that foodborne illnesses caused by pathogens is the largest class of emerging infectious disease in Canada (3, 21).

Every year there are about 4 million Canadian affected by foodborne illnesses which

Percent		Canada (excluding territories)		British Columbia	
		2015	2016	2015	2016
Males	18 to 34 years	25.8	24.4	22.8	31.9
	35 to 49 years	25.2	23.5	21.7	23.0
	50 to 64 years	21.7	20.3	20.5	22.5
	65 years and over	24.9	21.3	23.1	24.1
Females	18 to 34 years	36.8	36.4	35.5	40.5
	35 to 49 years	40.3	40.4	40.4	37.9
	50 to 64 years	39.4	36.3	38.6	37.9
	65 years and over	36.9	36.3	35.4	35.9

Table 1: Males and females who get more than 5 servings of fruits and vegetables/ day in Canada and BC

The above table from the Public Health Agency of Canada (PHAC) depicts the data of the percentage of Canadians who consume more than 5 servings of fruits & vegetables per

result in 11,600 hospitalization and 238 deaths (21). In 2003, there was a Hepatitis A outbreak from Mexican scallions, which consisted of 650 cases (3). In 2006, there was a Salmonella

outbreak (600 cases) which was related to the consumption of mung bean sprouts in Ontario (3). Overall the number of human infection cases associated with consumption of raw produce has increased in recent years (4). In the US, between 1995 & 1998 there were nine reported large-scale outbreaks that were associated with eating fresh raw vegetables or fruits (4). Salmonella and E.coli O157: H7 was determined to be the root cause of all these outbreaks, but researchers were unable to find where these pathogens originated from (4). The reason for the recent increase in foodborne illnesses can be attributed to the increase in consumption of fresh fruits and vegetables by North Americans (4). Furthermore, the methods associated with testing for pathogens in fresh produce is less advanced which limits the effectiveness of the testing (4). With the recent increase in awareness of health benefits associated with eating raw vegetables, there has been an increase in commercial salad bars and meals eaten outside of the home (4, 5). Yearly consumption of fresh produce by an average person has increased by 20 pounds between 1988 and 1996 in North America (4). This trend is only forecasted to increase.

The desire for fresh produce year-round has resulted in vegetables being brought in from non-seasonal to seasonal countries (5). This means there are increased number of steps associated with the preservation and handling of fresh produce (5).

“In addition, changes in production and processing methods, sources of produce and the emergence of pathogens not previously associated with raw produce have enhanced the potential for foodborne illness outbreaks associated with raw fruits and vegetables” (4)

Pathogens are not the only foreign matter found on raw fruits and vegetables that pose a health hazard. A recently released study by the Environmental Working Group states that nearly 70% of the conventionally grown

produce have pesticide residues on them (6). The USDA found over 230 different pesticides or pesticide by-products that can prove hazardous to human health on the thousands of samples that were collected and analyzed (6). A previous study conducted by Harvard University EARTH study found fertility issues among individuals who were exposed to pesticides in raw foods (6).

Food has been identified as the main route of exposures to contaminants of multiple chemicals classes (7). The authors suggest that even though a plant-based diet results in lower exposure to chemicals, compared to a meat and seafood diet, there is still a risk of exposure to chemicals such as endosulfans and permethrin which are found in pesticides (7). These chemicals, while harmless in smaller quantities, can bio-accumulate in the fatty tissue of the human body and can cause long-term health effects. As with many chemicals, chronic exposure can result in unwanted side effects in pregnant women and children. For pregnant women, there is a chance that the chemicals can pass onto the fetus through the placenta. Furthermore, Children are most vulnerable due to their physically smaller size and the developmental stages of their organs (7, 8). Exposure to such chemicals by either parent before conception can result in unwanted effects on the child many years after birth (8). Not enough studies have been done to quantify all of the effects that can occur in children throughout their development (8).

Due to the similarities in the mammalian and insect neuro-systems, the insecticides used on plants can affect humans. Usually they result in inhibition of the hormonal pathway (8). Hormones are the human body’s messengers that relay information to various parts of the body. They turn genes on and off and also influence the responses to environmental stimuli (8). Thus, the presence of the pesticides on the produce can result in the unwanted responses from the hormonal systems. This gives more reason to clean fruits and vegetables

properly and effectively before consumption to minimize the harm.

Very little is known about the microbial ecosystem present on the surface of the fruits and vegetables (4, 23). Fresh produce, including apples, grapes, lettuce, peaches, peppers, spinach, sprouts, and tomatoes, are known to harbor large bacterial populations (23). While certain micro-organisms are harmless or even beneficial, there are certain microbes that can create a biofilm on the surface of the produce (4, 23). Due to the formation of the biofilm, industrial sanitization techniques may not be able to avert the health hazard (23). There is a need for more studies to be done to further advance the understanding of proper cleaning and packaging of produce. Until then, it is important that we take the necessary precaution at home; properly cleaning the fruits and vegetables before consumption.

Microbes

For the purposes of this study, the researcher intends to test for the presence of Adenosine Triphosphate (ATP) on the surface of apples. The presence of ATP is indicative of biological organisms such as E.coli, Listeria or Salmonella (9). E.coli is part of a diverse group of organisms that are present in both animal and human intestines (9). While most strains don't cause any infection or side effects there are some strains that can cause diarrhea or urinary tract infections. The more adverse strains can cause Hemolytic Uremic Syndrome (HUS) which can cause the kidneys to stop working and can alter the course of an individual's life (9). E.coli can be transmitted through contaminated water, food or through contact with humans or animals.

E.coli is often present in both human and animal stools. They can also be spread by improper hand washing after using the washroom. An individual who may have not washed their hands properly can handle fresh produce at a store and transfer the pathogens on to the produce (9). There are many other

pathogens such as Staphylococcus aureus and Salmonella typhi that can be transferred onto the fresh produce via this method. In addition, when contaminated water is used to irrigate crops, the crops can get tainted with various other microbes. While it is not common for vegetables and fruits produced in developed countries to come in contact with E.coli, it is a common issue in the developing world (8). However, with demand for year-long demand for fresh produce, and the increasing trend observed above, there will be increased amounts of imported fruits and vegetables in the market.

Listeria is a pathogenic bacteria that is commonly found in agricultural environments. It can cause a wide range of illnesses from a mild gastroenteritis to an abortion or stillbirth in pregnant women (10, 11). While listeria is commonly associated with meat products and processed food products such as soft cheese and processed meat, lately it has been associated with outbreaks related to fresh produce as well (10). It has been detected in fresh produce including parsley, lettuce, cabbage, melons and apples (11, 19). In 2015 there was a multistate Listeria outbreak in the US that resulted in 34 hospitalizations and 12 deaths (19). This specific outbreak caused two hospitalizations in Canada as the apples were exported out of the US as well (20). While foodborne Listeriosis cases are rare, they have a very high fatality rate of 30% compared to other foodborne illnesses (25). Listeria infections and outbreaks have been commonly reported in the USA, Canada, Australia and Europe (11).

Introduction to Adenosine Triphosphate (ATP)

All living organisms have ATP in them. Thus the presence of ATP indicates the presence of microbes as well. Bioluminescence testing can be used as an indicator for surface cleanliness (12). However, ATP does not directly measure the presence or the absence of an organism of interest (13). ATP is routinely used in large food processing facilities and hospitals to test cleanliness of surfaces after sterilization

(13). A study among employees and their handwashing was conducted in a hospital. A bioluminescence test was conducted on participants' hands prior to and after handwashing. On live or once living surfaces an RLU unit of less than 100 was considered safe and an average reduction 80% reduction in RLUs were detected by proper handwashing (14). As a living organ, the skin has naturally occurring ATP present on the surface so it is virtually impossible to obtain an absolute zero value. In the study that was conducted on the handwashing adequacy of hospital staff, most of the participants had an RLU value of less than 60 (14). This was far below the acceptable limit that was proposed earlier.

Opportunity for Knowledge Translation

It is an EHO's duty to educate the general public on proper techniques of adequate sanitation. The results of this study could potentially lead

to an awareness campaign of adequate washing of the fruits and vegetables before consumption. This study could be the tool that is necessary to mitigate the increasing rates of foodborne outbreaks related to fresh produce. The campaign can potentially reduce the health care dollars that are spent on foodborne illness outbreaks and investigations.

Research Question

The purpose of this study is to find out if normal washing of fresh produce is enough to mitigate the harm potentially posed by contact with pathogens. The researcher intends to conduct ATP analysis on apples before and after they are washed and collect the RLU values before and after. The quantified RLU values will be used to measure the adequacy of washing the apples which could, in turn, be used for other fruits as well.

H₀ = There is no significant difference in ATP levels in apple skins when compared to before and after washing

H_a = There is a significant difference in ATP levels in apples skins when compared to before and after washing

Materials

A complete list of the materials and their descriptions are outlined in the table below.

Materials	Description
Nitrile Gloves	To maintain an aseptic environment and to reduce any transfer ATP from hands onto the fruits
15 apples	Non-organic Ambrosia apples purchased from Superstore bulk section. To test for the presence and the reduction of ATP on their surface following a washing procedure

30 Hygiena UltraSnap ATP surface test swabs	A pre-moistened swab equipped with a liquid-stable reagent that is used to perform an ATP surface sample test
SystemSURE Plus™ Luminometer	Detects the light emitted from the Hygiena UltraSnap – ATP Surface Test and generates a numerical reading in relative light units (RLUs)
Calibration Kit for SytemSURE Plus™	To further verify that the SystemSURE Plus™ is within calibration. Contains a reusable negative control rod for specification confirmation
Plastic film with rectangular cut-out	To ensure that the same surface area was swabbed regardless of size of the apple
Timer / Clock	To measure the washing period for each apple
Microfiber Cloth	To dry apples after being washed and before swabbing to measure ATP reduction
Pen, Ruler, Clipboard, Paper	To record RLU vales from the Luminometer
NCSS Software	For statistical manipulation

Method

In order to collect the samples, 15 Ambrosia apples were purchased from The Real Canadian Superstore in the Metropolis Mall located in the city of Burnaby, BC. Non-organic apples were chosen to be representative of the larger population. For simplicity, this location will be referred to as Superstore in the text from here onwards. This particular location was chosen due to the high human traffic in the mall. This mall is also in close proximity to the researcher's worksite which offers convenience. A location with high human-traffic was chosen to make the data more relevant to the general population. It was deduced that a higher number of people buy produce from Superstore compared to a smaller store that may be independently owned and operated. Thus the study findings would be representative of a wider population. The apples were chosen from the loose non-packaged section to maximise the

exposure to external factors like hands of the customers and employees who handle the produce and air. Research has shown that

“retail-handling” of non-packaged apples and other produce contributes to the



continuum of farm to plate increased risk of harbouring pathogens (23, 26). The bulk pre-packaged apples will not have to same exposure due to their packaging because they are shielded from external factors (26). As the apples were purchased outright from the store there was no ethics approval necessary.

The apples were brought to the lab at BCIT where the Luminometer and ATP test swabs were kept. The SystemSURE Plus™ Luminometer was used because of its ease of use and the fact that it produced instant results. The Hygiena Luminometer has been used in various other studies to test for surface cleanliness (24). Also the unit was readily available in the BCIT Health Sciences Lab. The test swabs were also inexpensive and contributed to the financial viability of the study.



A plastic film was used on apples to keep the surface

The Hygiena Luminometer was used because of its ease of use and the fact that it produced instant results. The Hygiena Luminometer has been used in various other studies to test for surface cleanliness (24). Also the unit was readily available in the BCIT Health Sciences Lab. The test swabs were also inexpensive and contributed to the financial viability of the study.

The SystemSURE Plus™ Luminometer was calibrated before each individual reading using the blank cartridge calibration kit to reduce error. The manufacturer’s instructions were followed as outlined in the user manual (15). In



order to keep the surface area of swabbing constant regardless of the size of the apple, a piece of soft plastic was applied to each apple as demonstrated in the picture above. Area within the plastic film was covered twice to ensure all the available ATP found on the surface was absorbed by the swab.

This method was repeated after the wash to keep the results constant. Once swabbed, the kit was activated by snapping the test tube, which releases the solution that luminesces in the presence of ATP. Once all of the solution was released after inserting the swab inside the

test tube it was shaken gently for 10 seconds. Then the Luminometer was held upright and the swabs were inserted and the lid of the unit closed (15). The same unit was used to conduct each reading to reduce any confounding factors. Each reading took 15 seconds and RLU values were obtained instantly. These values were recorded for each fruit. It was essential to record these values right away as the RLU values will change over time as the ATP gets consumed by the enzyme in the solution. This procedure was repeated for all of 15 apples. Later all the apples were hand-washed for 15 seconds under running water in a sink. Each apple was dried using the microfiber cloth. The above procedure was repeated on every apple and the values were recorded.

The Reliability and Validity of Measures

Reliability.

This measures the degree to which the equipment produces the same results when the method or procedures are repeated. The UltraSnap received a Performance Tested Method



Validation from the AOAC Research Institute (15). The sampling of the apple’s surfaces were all administered in the exact same order of the procedure using the same instruments and equipment. The variation of the size and the surface area of the apples were taken into consideration with implementation of the plastic film method. In addition, the sampling of apples was all done by the researcher from the bulk bins in the produce section of Superstore. Furthermore, the same researcher did the testing for surface ATP on the apples.

Validity. The Hygiena SystemSURE Plus™ Luminometer has a field calibration process pre-

installed as per the specifications of the device (15). Furthermore, the detection device can be used for other systems such as the Surface ATP, Water ATP, Allergen Prevention, Alkaline Phosphatase, and Acid Phosphatase (15). In terms of external validity of the study, the apples were chosen from the open bins in Superstore. There was no known selection bias in the apple selection. In general, the method of this research and the result can be generalized to contamination found in apples in grocery stores.

As mentioned in the statistical analysis section, even though there was a small sample size chosen, the researcher was able to get significant results negating the chance of beta error. The smaller sample size was due to limited financial resources that was available. Based on the statistical analysis the reliability of this study was not compromised by the limited sample size.

Inclusion & Exclusion Criteria

For this study only non-organic apples were chosen. As explained previously, a larger number of people buy non-organic produce, thus keeping the results relevant to the wider population. In addition, to keep the results homogenous the same brand of apples were chosen. In this study the researcher chose to use Ambrosia apples due to their year round availability. This was also to keep the results relevant to a wider population. These apples were also sourced from Canada. As mentioned in the paper previously fresh fruits and vegetables that are imported do not follow strict laws and regulations for sanitation.

The apples were chosen to have no bruises or cuts as they provide a greater surface area for pathogens to harbour in. Bruises and cuts also allow for the apple juice to surface.

This could show inflated ATP rates present on the surface.

Statistical Analysis

In this research we evaluated the presence of ATP on surfaces of apples pre and post washing. ATP presence was measured by bioluminescence rating measured using UltraSnap Swabs and the Hygiene SystemSURE Plus™ Luminometer. The Validity and the Reliability of this instrument has been demonstrated above. The Luminometer

	Before Washing	After Washing
Count	15	15
Mean	116.67	33.2
Median	102	32
Standard Deviation	44.32	15.5
Range	131	58
Minimum	50	14
Maximum	181	72

provides readings in relative light unit (RLU) values. Previous studies have shown a highly significant correlation ($r = 0.99$) between the means of ATP bioluminescence readings and the viable counts of total microbes on any surface (18).

The RLU values are presented as a numerical values by the Luminometer. The RLU values were recorded on paper after every test later transferred to a NCSS spreadsheet. The NCSS software was used to conduct statistical analysis on the data that was collected. With the help of the software there was a paired t-test conducted to obtain the results presented below. A paired t-test was chosen because of the analysis was done on before and after conditions of the same apple.

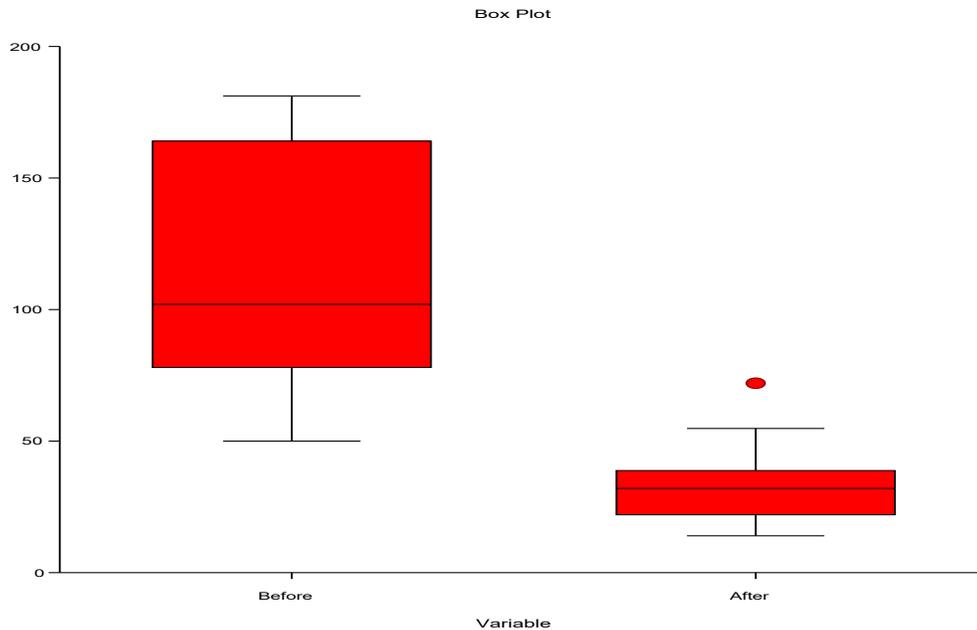
Based on the box plot presented below, ATP levels tested on the apples before washing was varied compared to the ATP levels present after washing the apples.

Washing the apples made a significant difference in the ATP levels and washing the apples brought the levels down to a smaller margin. This suggests that there is a direct correlation between washing and reduction in ATP on the surface on the apples. As it was mentioned earlier an ATP level of less than 100 RLUs as safe on the hands of hospital staff (14). Apples, like skin, was a once living surface. With the exception of one instance all the values observed after washing were under 55 RLUs with a median 32.

As observed in the table above the mean differences in ATP levels before and after

washing was greater than 0. The data was normally distributed as well hence a paired t-test was used. The p-value as calculated in by NCCSS software was 0.00033. Therefore, one must reject H_0 and correlate that there is a statistically significant reduction in ATP levels on apple skins after washing

It is unlikely that the statistically significant found in the test result is caused by alpha error as the p-value is 0.00033. Looking at the "Power for the Paired-Sample T-Test" (27) results, it is seen that when alpha is 0.05, the power is 1.000 which is greater than 0.8, which is considered the cut-off. Since the beta error is equal to 1- power, when the power is equal to 1.000, the beta error is 0.



Discussion

The purpose of this study was to determine adequacy of handwashing apples in terms of reducing surface microbes and contamination. Experts around the world have recommended several ways the fresh produce can be cleaned

to reach adequate surface decontamination. Researchers from the University of Massachusetts recommend washing apples with baking soda (Sodium Bicarbonate solution) is the most effective in removing surface contaminants (16). The average consumer, however, does not go to such extents to clean an apple. The presence of ATP was tested before and after basic handwashing of an apple under running tap water.

When comparing the means the findings revealed that that there was a 61% average reduction in ATP values compared to the before and after washing the apples. This highlights that washing the apple made a significant difference in removing potential contaminants from the surface of the apples. As mentioned in earlier in the paper, various contaminants can get onto the surface of the apples throughout the different stages of handling and merchandising in the stores (9). Pathogens, in addition to pesticides, can pose a harm to the consumers without even their knowledge. While there are many ways the consumer can avert the risk of surface contaminants the easiest way to mitigate this will be washing the apples thoroughly under running water. As outlined in the methods section washing the apples for a mere 15 seconds was found to be adequate in the reducing the surface contaminants. This simple and effective way has the potential to reduce health care costs in the long term by protecting the public.

More and more restaurants are serving fresh ingredients in their dishes such as salads, freshly made juices and cocktails. In addition to restaurants, there are many salad bars that are offering healthier meals as well. It is important to educate the operators of the importance of washing produce. In a restaurant or food facility, depending on the volume of the customers served, the staff, including the kitchen staff, can be very busy. The limited time that is available can result in staff not following protocol that can expose the customers to various hazards. Education plays a key role in averting the hazards to the customer. The fact

that washing produce is not too time consuming and can reduce the risk to the customers should encourage them to implement this into their preparation steps even during busy hours.

Traditional FoodSafe courses, while they offer training on proper handwashing and proper storage of the fresh produce, they do not emphasize the importance of washing produce. The findings of this study can be incorporated into FoodSafe courses and education that is provided to operators by health inspectors. This education provided can potentially reduce health care costs and hazards to the public. Furthermore, when a customer does not get sick they are more likely to return to restaurant and recommend it to others.

Limitations

While the findings were significant from the study there were some limitations as well. The most significant one was the limited sample size. This was mainly due to the limited budget that was available. Each student experiment had limited funding which played a role in the sample size. For example the UltraSnap swabs used to sample the apples utilized most of the funding available.

Another limitation was the limited time available to conduct the research. Being a student and attending schooling full-time resulted in inadequate time to do multiple experiments. Hence, only 15 replicates for the cleaning method were completed. With adequate time, money and a larger sample size, a more robust study could have been conducted.

Another limitation was that there were insufficient resources to conduct microbiological assessments for the presence of various pathogens. This would have allowed the researcher to deduce how much of the reduced ATP was from pathogens and how much was from naturally occurring ATP in organic produce. Furthermore, not all organisms can

cause adverse health effects in humans. The UltraSnap swabs are not indicative of the number of organisms that are present. Thus, the number pathogens that were removed through cleaning is unknown. With adequate time and funding a comprehensive study could have been.

Knowledge Translation

The findings of this study can be incorporated into FoodSafe classes and can benefit food handlers in maintaining adequate hygiene. This would ensure food handlers will take necessary steps in handling produce and are aware of the need to wash produce. In addition this would also enable the food handlers to bring the knowledge home and spread the word in the community.

Health Authorities can use the findings to create a public awareness campaign that will educate the public. The findings can be also used to promote alongside other campaigns already under way. Education pamphlets can be made to spread the word and knowledge. The various social media platforms available could be utilized to reach a wide range of audience.

Guidelines can be created that would give food facilities operators some guidance in the workplace. Guidelines are created in addition to legislation, and used to interpret and follow the legislation and regulation. The guidelines can also serve as guide for Health Inspectors promoting the practice and as an education tool.

Future Research

References

Some interesting future student projects that can be conducted based on this research study includes:

- Microbiological analysis of type of pathogens that might present on the surface of the produce
- Try ATP analysis on different types of apples (Fuji vs. Ambrosia) or organic vs. inorganic apples to see if any particular apple was to have fewer ATP levels.
- Try other cleaning methods with shorter or longer duration of time
- Test other means of efficiently cleaning the apples

Conclusion

Fresh produce is essential to maintain a healthy lifestyle. Fruits and vegetables are rich in nutrients that ensure the health and wellbeing of an individual. Washing the produce is the most important step in removing surface contamination. Washing the produce can ensure that the produce will have no microbes that can cause disease and adverse health effects.

Food borne illnesses are not only detrimental to an individual's health but also causes preventable expenses to the health care system. The study showed that washing the apples provided significant reduction in surface contaminants. The average 61% reduction as observed was indicative of cleaning the apples. As adequate washing can be incorporated into the general procedures it should not cause great difficulty to an operator or general public. The information obtained in this study can be utilized [1] to continue educating the public, especially food handlers, about the importance of proper cleaning and [2] to further develop studies which investigate the efficacy of different cleaning methods.

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