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Survival of Eschenichia coli 0157:H7 in Apple Juice As Affected by Addition of Pure Cranberry Juice

Emily Arlene Curtis
University of Tennessee - Knoxville

Survival of *Escherichia coli* O157:H7 in Apple Juice As Affected by Addition of Pure Cranberry Juice

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ABSTRACT

Recent outbreaks involving *Escherichia coli* O157:H7 in fresh apple juice or cider have prompted a whole body of research focusing on devising practical, inexpensive, simple, but effective methods for controlling contamination in unpasteurized juices and ciders. Cranberry juice, known for its intrinsic antimicrobial properties, could serve as an effective antimicrobial against this prominent pathogen. The purpose of the current study was to determine the effect, if any, cranberry juice has on survival of *E. coli* O157:H7 in apple juice. Pasteurized pure cranberry and apple juices were combined to yield mixed juices containing 0 (control), 10, 25, and 50% (v/v) pure cranberry juice. Juices were inoculated to achieve an initial bacterial concentration of approximately 10^7 *E. coli* O157:H7 colony forming units (CFU)/ml of juice. Juices were stored at 25°C, and one ml samples were removed at 30 minutes and 24, 72, and 144 hr. Samples were plated onto trypic soy agar (non-selective), sorbitol MacConkey agar, and modified eosin methylene blue agar (both selective) to determine sublethal injury and lethality to the pathogen. Counts in juice containing 50% pure cranberry juice decreased to below the detectable limit in less than 24 hr. In both the 10 and 25% juice lots, at least a 6-log reduction in *E. coli* O157:H7 occurred by day 6 suggesting, that both of these concentrations of cranberry juice have the possibility of being effective antimicrobial strategies used to combat this pathogen in apple juice. Further research is needed to determine the reliability of these findings and to examine the sensory changes, such as color, flavor, and aroma, caused by adding pure cranberry juice to apple juice.

INTRODUCTION

Fruit juices and other similar beverages were once thought to pose minimal safety risk because of their low pH, which was believed to inhibit the growth of pathogenic microorganisms. However, several outbreaks have been associated with consuming unpasteurized apple juice or cider (Rangel et al., 2004). The pathogen most often indicated as the causative agent of illnesses involved consumption of fresh apple juice or cider is a serotype of the Gram-negative, rod-shaped *Escherichia coli* now identified based on its serological characteristics as *E. coli* O157:H7 (Besser et al., 1993).

More than 73,000 illnesses are associated with *E. coli* O157:H7 in the United States each year (Rangel et al., 2004). The illnesses lead to an estimated 2,170 hospitalizations and 61 fatalities annually (Rangel et al., 2004). Infection with the pathogen has been implicated as an important cause of kidney failure in children (Rangel et al., 2004), and immunocompromised populations such as young children, elderly adults, or pregnant women are especially susceptible (CDC, 2000).

Infection with *E. coli* O157:H7 can cause hemorrhagic colitis and hemolytic uremic syndrome (Besser et al., 1993). According to the Centers for Disease Control and Prevention (CDC), hemolytic uremic syndrome (HUS) is often characterized by kidney failure, after which patients usually require dialysis and/or blood transfusions (CDC, 2000). Some persons with HUS develop chronic kidney failure or neurological impairments such as strokes or seizures (CDC, 2000). Other symptoms of *E. coli* O157:H7 infection, which often subside after 5-10 days (CDC, 2004), include bloody diarrhea, abdominal cramps, and little or no fever (CDC, 2000).

There were 350 outbreaks associated with *E. coli* O157:H7 between 1982 and 2002 (Rangel et al., 2004). Of those 350 outbreaks, 52% were food related and 38 outbreaks (11% of the total) were attributed to produce items such as lettuce, apple cider or juice, salad, coleslaw, melons, alfalfa sprouts, and grapes (Rangel et al., 2004). Surprisingly, food accounted for 61% of the total number of *E. coli* O157:H7 infection cases, and produce accounted for 21% of the total number of outbreak cases (Rangel et al., 2004).

After examining three outbreaks associated with unpasteurized apple cider or juice, all of which occurred in October 1996, the CDC concluded that current practices for producing apple cider may not be adequate to prevent contamination with *E. coli* O157:H7 (CDC, 1997). Cider-making is more of an art than a science, and currently, few small-scale cider producers employ manufacturing practices that reduce the number of pathogenic microorganisms in their cider. Pasteurization is the most effective means of controlling pathogenic microorganisms in juices and other beverages, but most small producers cannot afford such an expensive treatment, nor do they want to utilize the process.

Pasteurization, as with most other food processing treatments, causes changes in the flavor and color characteristics of subjected foods; therefore, most cider producers reject pasteurization because of the undesirable changes it causes in their product. Occasionally, the lack of pasteurization or other effective processes results in cider that is contaminated with pathogenic microorganisms such as *E. coli* O157:H7 and *Salmonella*, which upon consumption, can lead to outbreaks of illnesses. Methods are needed that will reduce the number of pathogenic microorganisms in fresh apple juices and ciders to

safe levels. To be widely used, the techniques need to be simple, inexpensive, and effective.

Zhao et al. (1993) examined the effects of sodium benzoate and potassium sorbate on survival of *E. coli* O157:H7 in unpasteurized apple cider. They reached several important conclusions based on the results of their work. First they found that initial inoculum size influenced the number of days postinoculation survivors were detected in the cider samples. They found that at 25°C with an initial population of 10^5 *E. coli* O157:H7 organisms, survivors were detected at 2 to 3 days but not 6 days after inoculation, and at 8°C levels of *E. coli* O157:H7 remained stable for 7 to 12 days. These two findings illustrate the importance of measures taken to decrease the numbers of *E. coli* O157:H7 in unpasteurized apple cider because at refrigeration temperatures, the bacteria are able to survive beyond the normal shelf life of cider.

The researchers also found that 0.1% potassium sorbate did not significantly affect survival, regardless of incubation temperature, but that 0.1% sodium benzoate was antimicrobial against *E. coli* O157:H7 at 8 and 25°C. A combination of 0.1% potassium sorbate and 0.1% sodium benzoate did increase antimicrobial activity at 8°C but had no significant influence on survival at 25°C. Finally, they concluded that small processors could use 0.1% sodium benzoate as a method to reduce bacterial counts without having to pasteurize their product.

Combinations of simple, inexpensive, and practical intervention treatments such as short term storage at 4, 25, and 35°C, a freeze-thaw cycle (48 hr at -20°C, then 4 hr at 4°C), and addition of common organic acids such as lactic, sorbic, and propionic acids, could reduce the numbers of *E. coli* O157:H7 in apple cider by the FDA required 5-$\log_{10}$

units (Uljas and Ingham, 1999). They found that pH was the determining factor when assessing the effectiveness of a treatment or combination of treatments. They observed that as pH decreased, cell death increased. Uljas and Ingham (1999) also evaluated consumer preference of pasteurized apple cider compared with preference for cider in which the bacterial numbers had been decreased using one or a combination of the simple methods proposed and found that consumers preferred the intervention treatments over pasteurization.

Williams et al. (2004) found that both treatment temperature and ozone affected survival of *E. coli* O157:H7 in apple cider. They found that ozone treatment at 50°C was more effective than treatment at 4°C or ambient temperature but that ozone treatment at 4°C was generally better than treatment at ambient temperature. They also demonstrated the sublethal injury inflicted on target organisms by ozone treatment in apple cider and emphasized the importance of media selection when evaluating the effectiveness of any treatment.

Low-dose irradiation has also been shown to reduce numbers of *E. coli* O157:H7 in fresh apple juice (Buchanan et al., 1998). Reinders et al. (2001) suggested a possible reason why most outbreaks associated with fresh apple juice or cider occur between October and November. They found that caffeic acid in concentrations at or above 0.4mg/ml was effective at reducing the numbers of *E. coli* O157:H7 organisms in a model apple juice medium and that naturally occurring caffeic acid in apples peaks in July and decreases to 0.1 g/kg in October. The concentration of caffeic acid present in apples during most of the year would inhibit survival of *E. coli* O157:H7 even if the

apples became contaminated, but when caffeic acid concentrations drop in October, contaminating bacteria are more likely to survive (Reinders, et al., 2001).

Noma et al. (2004) examined how decompression rate after hydrostatic pressure treatment and subsequent storage temperature would affect survival of *E. coli* O157:H7 in apple juice. They found that storage at 4°C of untreated, inoculated juice did not inactivate *E. coli* O157:H7 during a five-day storage period but that storage of pressure-treated juices at 4°C did reduce the number of surviving organisms. The inactivation was more pronounced in juices that had been subjected to pressure treatment followed by rapid decompression versus juices that had been treated and had the pressure slowly released (Noma et al., 2004).

Fermentation has also been shown to reduce populations of *E. coli* O157:H7 in apple cider when compared to non-fermenting cider populations (Semanchek and Golden, 1996). Semanchek and Golden (1996) also found that fermentation induced more sublethal injury on bacterial cells than non-fermenting cider caused. They hypothesized that a synergistic effect resulting from increased ethanol levels and pH changes, or other by-products of fermentation, caused the reduced recovery of *E. coli* O157:H7 from fermenting cider. From their results, they concluded that alcoholic fermentation of cider is an effective method of eliminating *E. coli* O157:H7.

Counts in untreated apple juice stored at 20°C decreased to very low levels within 14 days of storage (Yuste and Fung, 2004). Yuste and Fung (2004) examined the synergistic effect of nisin and cinnamon, two naturally occurring antimicrobial compounds, on recovery of *E. coli* O157:H7 from apple juice and found that in the low pH conditions of apple juice addition of nisin sped up inactivation and cinnamon

generally contributed to inhibition. Higher doses of nisin caused greater lethality (Yuste and Fung, 2004).

Ingham and Uljas (1998) illustrated the effect of storage of inoculated apple juice and cider at 21°C and inoculated apple juice at 4°C for various times on the thermoresistance of the microorganism once heated. They found that storing inoculated apple juice for 6 hr at 21°C (room temperature) greatly reduced the heating time at 61°C needed to reduce populations below the detectable limit. The lethality of the same storage conditions was not as pronounced in apple cider (Ingham and Uljas, 1998). They also found that prior storage of apple juice at 4°C greatly reducing heating time required to inactivate *E. coli* O157:H7. Oyarzabal et al. (2003) found that pathogens such as *E. coli* O157:H7 and *Salmonella* could be recovered from concentrated frozen apple, orange, pineapple, and white grape juices for up to 12 weeks when stored at -23°C.

This research study proposes another possible alternative treatment be investigated. Cranberry juice has long been used as a preventative measure or even a treatment for certain infections, especially urinary tract infections. The antimicrobial activity of cranberry juice has been evaluated and validated, but the mechanism(s) by which cranberry juice prevents and/or treats bacterial infection is unclear. Two proposed methods include anti-adherence factors that prevent bacteria from colonizing linings of the gastrointestinal and urinary tracts and acidification of bodily excretions (Rhee and Charles, 2004). Rhee and Charles (2004) propose a third potential mechanism. They hypothesized that ascorbic acid, commonly added to cranberry juices, aids in the production of nitric oxide gas from compounds already present in the urine. Nitric oxide is a potent antimicrobial often involved in anti-inflammatory reactions, but the

researchers caution that further research is warranted before determining the efficiency of cranberry juice in treating urinary tract infections (Rhee and Charles, 2004).

Nogueira et al. (2003) demonstrated that cranberry juice concentrates had intrinsic antimicrobial properties capable of eliminating contaminating pathogens. They demonstrated a least a 5-$\log_{10}$ *E. coli* O157:H7 inactivation at -11°C due to the hostile environment (low pH and high acid concentrations) created by cranberry juice. The purpose of the current study is to determine the efficiency of cranberry juice in reducing the number of surviving *E. coli* O157:H7 organisms in apple juice during storage at 25°C. Concentrations of 10, 25, and 50% pure cranberry juice (v/v) will be examined for sublethal injury of and lethality against *E. coli* O157:H7 in apple juice. If found to be effective, cranberry juice may be an additional natural antimicrobial that can be easily and inexpensively added to fresh apple juice and cider to ensure safety.

MATERIALS AND METHODS

Preparation of inoculum

A strain of *Escherichia coli* O157:H7 isolated from apple cider and held in the University of Tennessee Food Microbiology laboratory culture collection was used to inoculate juices. The strain was maintained in Luria-Bertani Broth (LB; Difco Becton Dickinson Microbiology Systems; Sparks, MD) at 37°C and in preparation for inoculation, was cultured in tryptic soy broth (TSB; Difco Becton Dickinson Microbiology Systems; Sparks, MD) for 24 hr at 37°C. The culture was transferred a minimum of three times at 24 hr intervals before use.

Preparation of juices for inoculation

     Pasteurized apple juice (100% apple juice from concentrate, no sugar added, and no preservatives) was purchased from a local supermarket. Pasteurized pure cranberry juice (100% cranberry juice, unsweetened, with added Vitamin C) was purchased from a local health foods specialty store. Both juices were stored at room temperature until opened and then at 4°C after opening. Apple and cranberry juices were combined in sterile 250-ml bottles to yield 100 ml of juice containing 0, 10, 25, and 50% (v/v) pure cranberry juice. The prepared bottles were allowed to reach room temperature before inoculation.

Inoculation, incubation, and sampling of juices

     Juices were inoculated with 1 ml of the 24-hr culture (to yield about 10^7 CFU/ml), shaken briefly to suspend the cells, and placed in a 25°C incubator for the entire sampling period. One milliliter samples were taken from each bottle at 30 minutes and 24 hr, 72 hr, and 144 hr. If necessary, samples were diluted in 0.1% peptone water (PW; Difco Becton Dickinson Microbiology Systems; Sparks, MD). The inoculum was also serially diluted in 0.1% PW for a determination of initial inoculum population.

Plating and analyzing the juice samples

     Samples from the juice, or the diluted samples, and the diluted inoculum were surface plated on trypic soy agar (TSA; Difco Becton Dickinson Microbiology Systems; Sparks, MD), sorbitol MacConkey agar (SMAC; Oxoid Limited; Hampshire, England), and modified eosin methylene blue agar (MEMB; Clavero and Beuchat, 1995) in duplicate using a spiral plater (Don Whitley Scientific Limited; Yorkshire, England). Media were sterilized and poured (~20 ml) into 100 mm diameter Petri dishes 24 hr

before use. Inoculated media were incubated for 48 hr at 37°C before enumeration of *E. coli* O157:H7 using a Protocol automatic plate counter (Synoptics Limited; Cambridge, UK).

Control trials were performed in triplicate, all beginning on the same day. Trials with cranberry juice were also performed in triplicate, beginning on the same day but were performed after the control trial was completed.

RESULTS AND DISCUSSION

Overview

Survival of *E. coli* O157:H7 in apple juice containing 0, 10, 25, and 50% (v/v) pure cranberry juice is illustrated in Figures 1-7. Initial populations of *E. coli* O157:H7 in inoculated juices were approximately 7 log CFU/ml. The number of bacteria recovered on both non-selective (TSA) and selective (SMAC and MEMB) media was inversely proportional to the cranberry juice concentration. As the percentage of cranberry juice increased, recovery of *E. coli* O157:H7 generally decreased. This relationship between cranberry juice concentration and recovery may be due to the decrease in pH caused by adding more pure cranberry juice. Uljas and Ingham (1999) reported pH was a primary determinant affecting survival of *E. coli* O157:H7 in apple cider, and they found that as pH decreased, cell death increased.

According to their research, pH differences of only 0.9 units greatly affected the lethality of the treatments applied. For instance, a freeze-thaw treatment (48 hours at -20°C followed by 4 hours at 4°C) was sufficient to reduce numbers of *E. coli* O157:H7 by 5-$\log_{10}$ units when applied to apple cider with pH of 3.3 (Uljas and Ingham, 1999). At pH 3.7, reducing numbers of *E. coli* O157:H7 by 5-$\log_{10}$ units required an hour of storage

at 35°C in addition to the freeze-thaw cycle (Uljas and Ingham, 1999). However, in cider with pH of 4.1, achieving a similar reduction in the number of *E. coli* O157:H7 required storage at 35°C for 6 hr and subjecting inoculated cider to the freeze-thaw treatment (Uljas and Ingham, 1999).

Another explanation for the observed effect cranberry juice concentration has on survival of *E. coli* O157:H7 in apple juice could be that the organic acids in cranberry juice differ significantly from those in apple juice so that bacterial numbers are reduced. Price et al. (2004) discovered that *E. coli* O157:H7 employs different acid resistance systems to survive in different environments. Their research compared the mechanisms used by bacteria in the bovine gastrointestinal (GI) tract with those used by bacteria in apple cider, two environments with widely different organic acid profiles.

They found that in apple cider, *E. coli* O157:H7 could not survive if the genes needed for acid resistance (AR) system 1 were knocked out; in contrast, the bacteria could not survive without AR systems 2 and 3 in the bovine GI tract. The introduction of increasing amounts of quinic or citric acids, the two main organic acids in cranberry juice (Jensen et al., 2002), into apple juice which contains mostly malic acid might change the environment sufficiently to decrease survival of *E. coli* O157:H7.

Counts in the lots of juice containing 50% pure cranberry juice decreased to below the detectable limit in less than 24 hr. In both the 10 and 25% juice lots, at least a 6-log reduction in *E. coli* O157:H7 occurred by day 6 suggesting, that both of these concentrations of cranberry juice have the possibility of being effective antimicrobial strategies used to combat this pathogen in apple juice.

Sublethal injury of recovered bacteria is illustrated in Figures 4-7 and in Table 1. Sublethal injury was indicated by increased recovery on non-selective media versus selective media (Busta, 1994). For the first three days of incubation, sublethal injury of *E. coli* O157:H7 in control juice (0% cranberry juice) was evident because more bacteria were recovered on TSA than on SMAC and MEMB. At certain sample times (i.e., 0-72 hr for 10% cranberry juice and 0-24 hr for 25% cranberry juice), injury was less apparent because more bacteria were recovered on SMAC than TSA. Limitations in sampling and errors in handling samples may have caused this unexpected result.

Survival of E. coli *O157:H7 recovered on non-selective and selective media*

Survival of *E. coli* O157:H7 recovered on TSA is shown in Figure 1. On non-selective media, populations recovered from the juices decreased over time. The greatest numbers were recovered on TSA from control juices (0% cranberry juice). Recovery decreased as cranberry juice concentration increased. Recovery of *E. coli* O157:H7 from control juices decreased by 1-log_{10} unit after 72 hr (day 3), and an additional 2-log_{10} units by day 6 resulting in an overall 3-log_{10} unit reduction in numbers. Zhao et al. (1993) obtained different results when incubating apple cider at 25°C. In their controls, surviving *E. coli* O157:H7 were detected at 2 to 3 days but not at 6 days after inoculation. The recovery methods used by Zhao et al. were more advanced than those used in this study and could explain the difference between current results and their results.

Where recovery in the present study was examined on SMAC, Zhao et al. (1993) used SMAC plus 4-methylumbelliferyl-β-D-glucuronide (MUG), a more differential medium. For their results, only sorbitol-negative/MUG-negative colonies were counted. They also used more sensitive confirmation techniques such as agglutination with O157

antibody beads, enzyme-linked immunosorbent assay (ELISA) with monoclonal antibodies, and biochemical characterization with API 20E miniature diagnostic test, to conclusively identify *E. coli* O157:H7 as the organism isolated from their samples.

In comparison, numbers decreased by 1.5- and 2-$\log_{10}$ units after 24 hours in 10 and 25% cranberry juice samples, respectively. Recovery from 10% cranberry juice declined another 3-$\log_{10}$ units by day 3 and an additional 1-$\log_{10}$ unit by day 6. From 25% cranberry juice, recovery declined more rapidly, decreasing almost 4-$\log_{10}$ units from day 1-day3; it then remained constant at 1-log CFU/ml plated from day 3-day 6. In contrast, bacterial levels dropped below detectable limits in less than 24 hr in the 50% cranberry juice samples.

Figure 2 illustrates the change in survival of *E. coli* O157:H7 recovered on SMAC over the six day trial. Counts in the control juices decreased more rapidly over the first three days when bacteria were recovered on SMAC versus bacteria recovered on TSA, but decreased less rapidly from day 3-day 6 when recovered on SMAC versus TSA. By day 6, counts from the control juices decreased 3-$\log_{10}$ units from approximately 10^7 CFU/ml plated to 10^4 CFU/ml plated. Counts on SMAC from the 10% cranberry juice samples decreased by 1-$\log_{10}$ unit over the first 24 hr, by 4-$\log_{10}$ units at day 3, and to below detectable limits by day 6. Counts from the 25% cranberry juice samples decreased more quickly, declining more than 3-$\log_{10}$ units in the first 24 hr and to below detectable limits by day 3. Bacteria recovered from the 50% cranberry juice samples declined to below detectable limits in less than 24 hr.

Survival of *E. coli* O157:H7 recovered on MEMB is shown in Figure 3. Survival in control juices was greater than survival in those containing cranberry juice. By day 6,

counts from control juices dropped 4-log_{10} units to 3 log CFU/ml plated. Counts in 10% cranberry juices decreased from an initial population of 10^7 CFU/ml to 10^5 CFU/ml by day 1, to 10^3 CFU/ml by day 3, and below detectable limits by day 6. Counts in 25% cranberry juices decreased by more than 4-log_{10} units in 24 hr and below detectable limits by day 3. Counts in 50% cranberry juices declined to below detectable limits in less than 24 hr as illustrated by recovery on MEMB.

Conclusions

Based on the results of this study, addition of cranberry juice to fresh apple juice could be a method employed to reduce the number of *E. coli* O157:H7. Cranberry juice would be a natural, safe antimicrobial agent if added to apple juice for that purpose. However, the changes caused by adding cranberry juice to apple juice as an antimicrobial might not be acceptable to consumers. To achieve the highest reduction in *E. coli* O157:H7 numbers, 50% (v/v) cranberry juice would need to be added to apple juice. The color change caused by adding that much cranberry juice was obvious but was not recorded for this experiment. In order to more effectively evaluate the use of cranberry juice as an antimicrobial in apple juice, more in-depth research would need to be conducted.

Sensory acceptability of the juice mixture would have to be evaluated to determine whether consumers would rather consume pasteurized apple juice or unpasteurized apple juice with cranberry juice added to control the growth of *E. coli* O157:H7. Pure cranberry juice has been noted for its extremely sour and bitter flavors, and addition of it in a 1:1 ratio with apple juice may result in a beverage that is not acceptable to consumers.

Furthermore, additional research is warranted on the reliability of the antimicrobial properties of cranberry juice. The experiments in this study were performed in triplicate, but limitations of this study could have affected all three replicates. For example, no statistical analysis was performed on the results to determine if the decrease in recovery from apple juices containing cranberry juice was significant. The control juices themselves caused some injury to *E. coli* O157:H7, and it was never determined whether the additional injury caused by cranberry juice was significant enough to even warrant further research.

The possibility of adding cranberry juice to fresh apple juice most definitely exists. Using cranberry juice, a natural and relatively inexpensive alternative to pasteurization, synthetic antimicrobials, and other more technologically advanced treatments, would most likely appeal to the small juice and cider producers that seem to be most plagued by *E. coli* O157:H7 contamination.

Table 1. Percent injury of surviving populations of *E. coli* O157:H7 after incubation in juice.

	% injury[1] of *E. coli* O157:H7 after incubation							
Day	0		1		3		6	
Selective Media	SMAC	MEMB	SMAC	MEMB	SMAC	MEMB	SMAC	MEMB
% Cranberry Juice								
0	33.4	19.4	92.5	52.0	97.3	96.0	0.0	88.5
10	--[2]	--	--	72.2	--	--	CI[3]	65.8
25	--	--	87.9	99.2	CI	32.7	CI	32.4
50	4.4	31.0	CI	CI	CI	CI	CI	CI

[1] %injury = $\dfrac{\text{CFU on non-selective media} - \text{CFU on selective media}}{\text{CFU on non-selective media}}$ x 100%

[2] Calculation of % injury resulted in a negative number because the recovery on selective media was higher than recovery on non-selective media
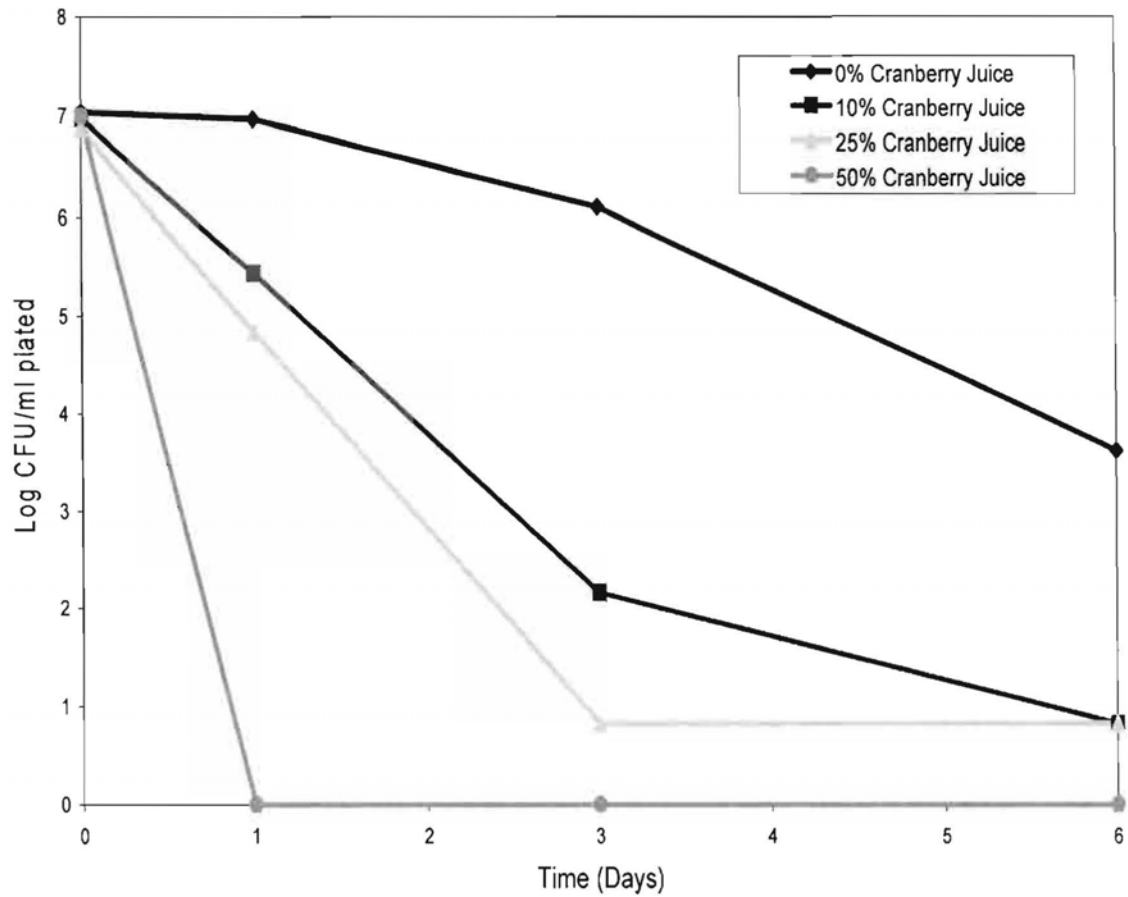
[3] Complete inactivation

Figure 1. Survival of *E. coli* O157:H7 in apple/cranberry juice mixtures and recovered on TSA. Values shown as 0 Log CFU/ml plated represent no detection.
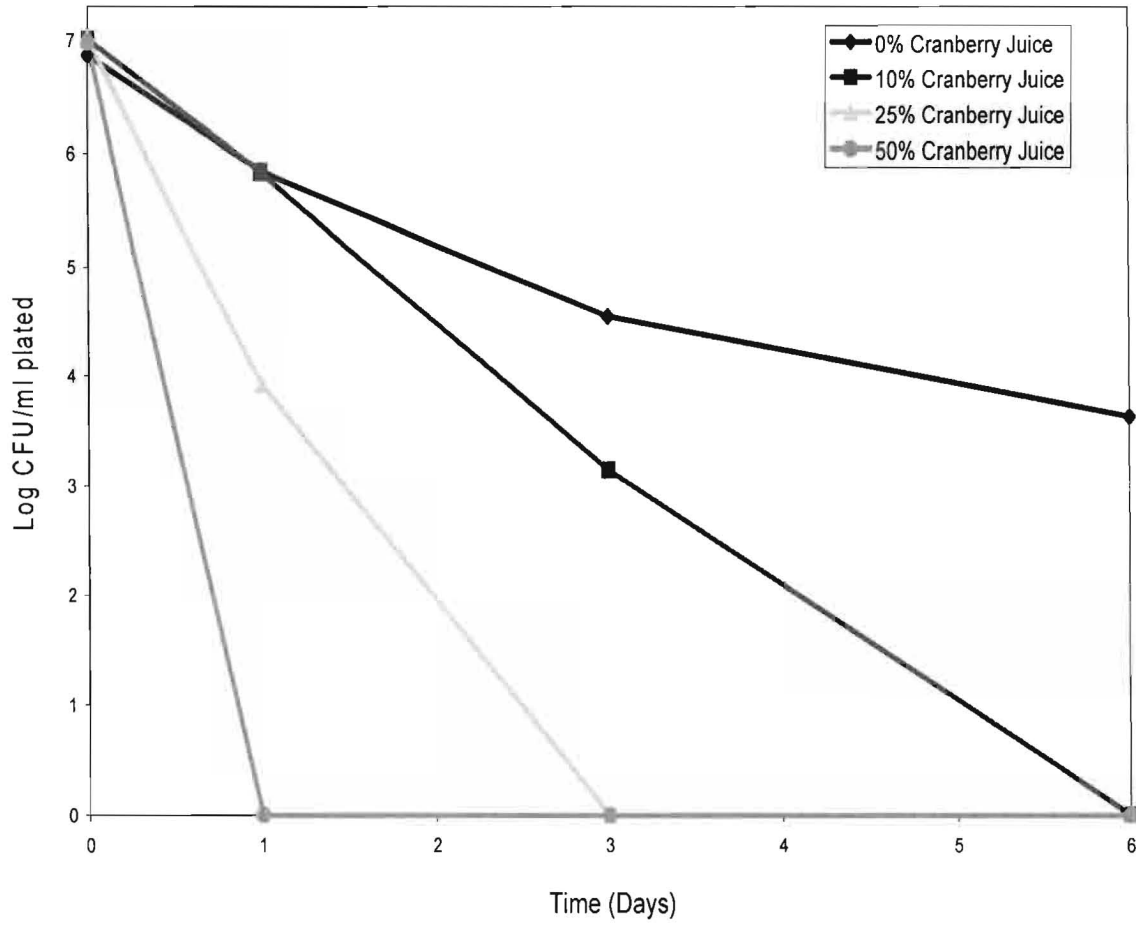
Figure 2. Survival of *E. coli* O157:H7 in apple/cranberry juice mixtures and recovered on SMAC. Values shown as 0 Log CFU/ml plated represent no detection.
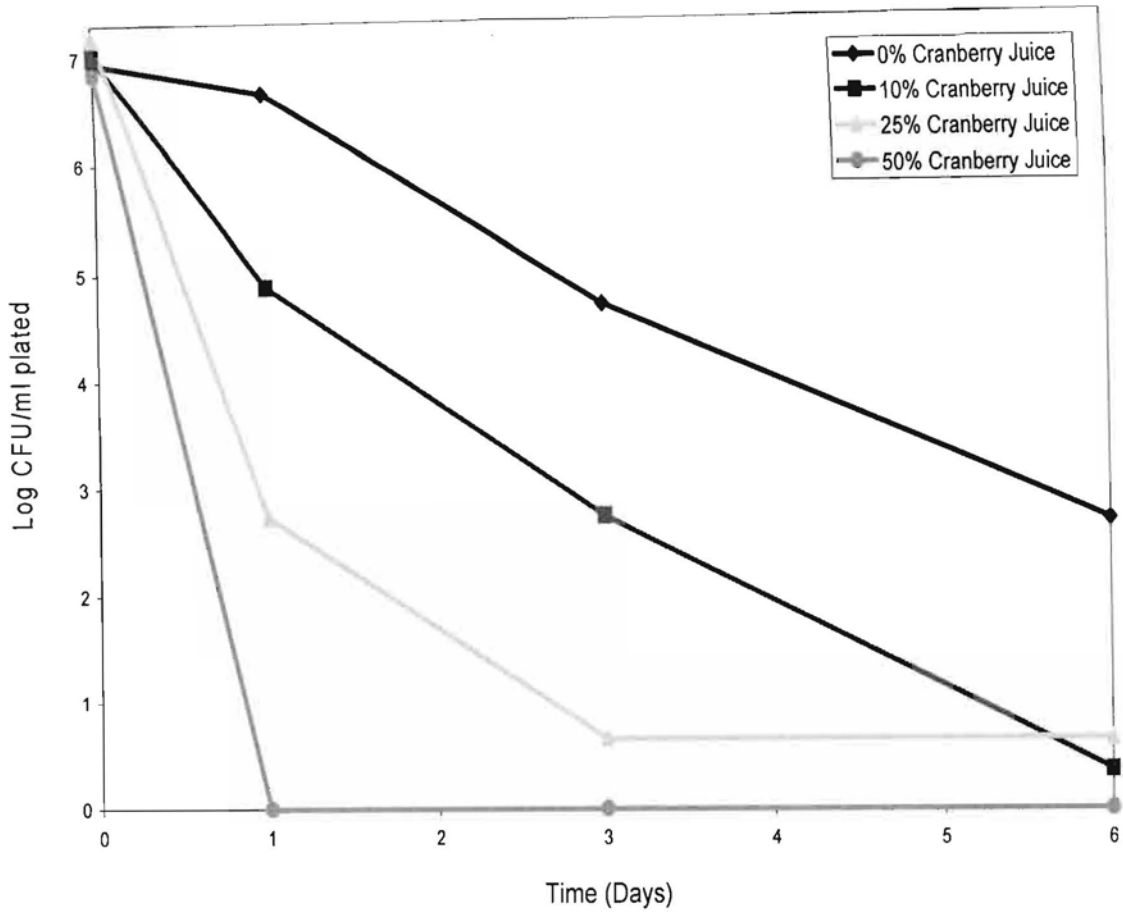
Figure 3. Survival of *E. coli* O157:H7 in apple/cranberry juice mixtures and recovered on MEMB. Values shown as 0 Log CFU/ml plated represent no detection.
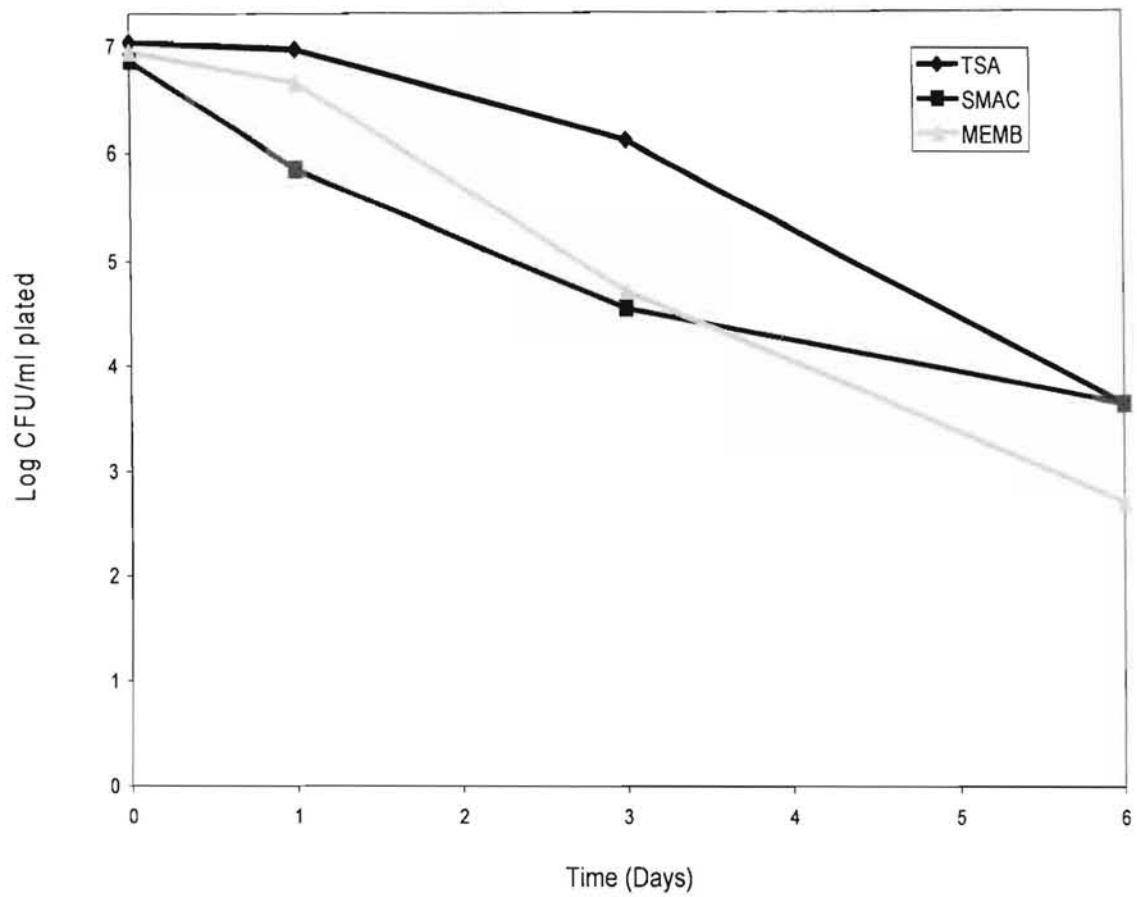
Figure 4. Survival of *E. coli* O157:H7 in pure apple juice (0% cranberry juice) and recovered on TSA, SMAC, and MEMB.
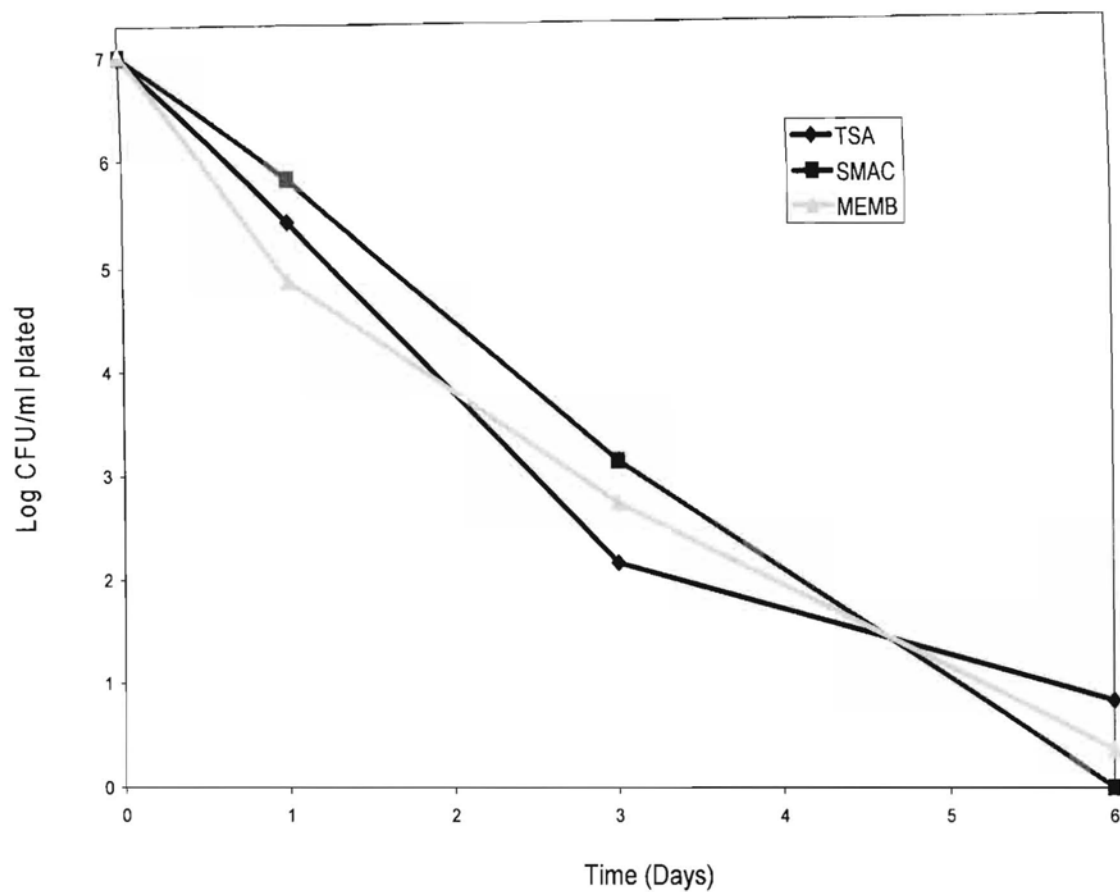
Figure 5. Survival of *E. coli* O157:H7 in 10% cranberry juice and recovered on TSA, SMAC, and MEMB. Values shown as 0 Log CFU/ml plated represent no detection.
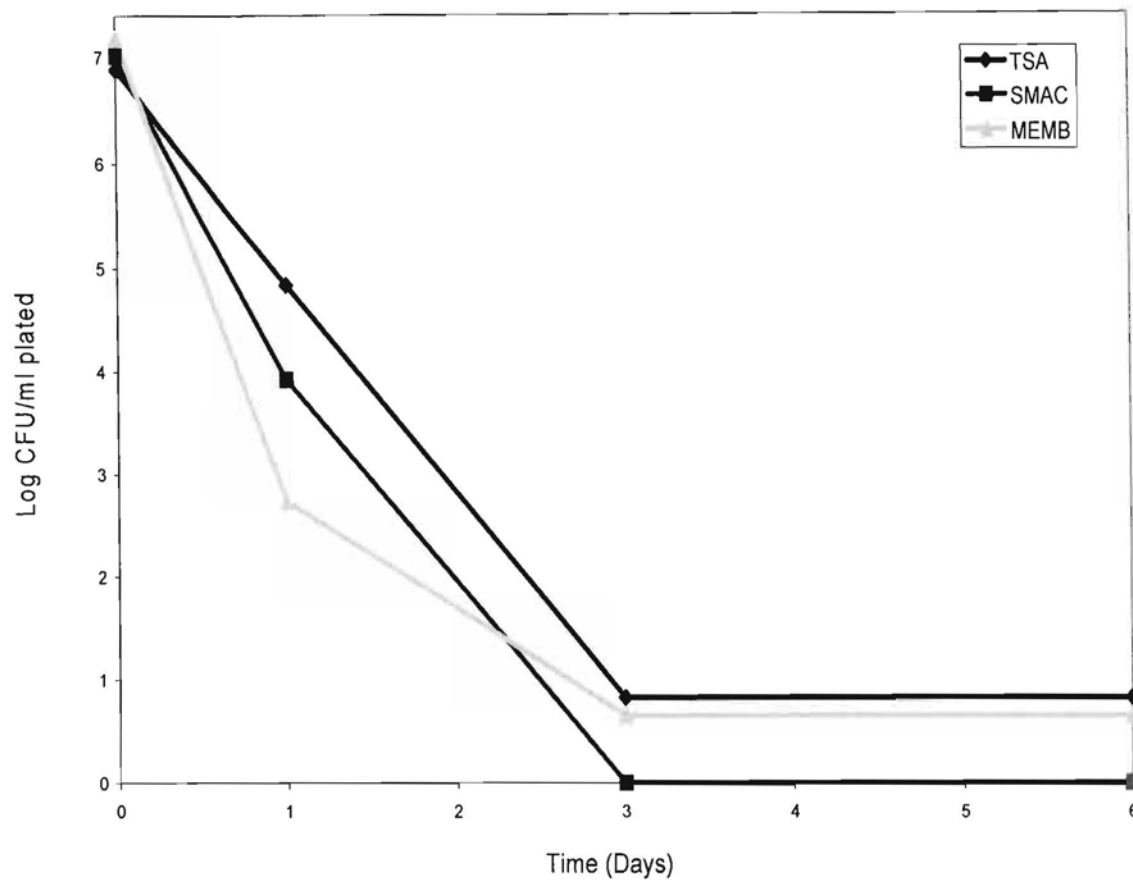
Figure 6. Survival of *E. coli* O157:H7 in 25% cranberry juice and recovered on TSA, SMAC, and MEMB. Values shown as 0 Log CFU/ml plated represent no detection.
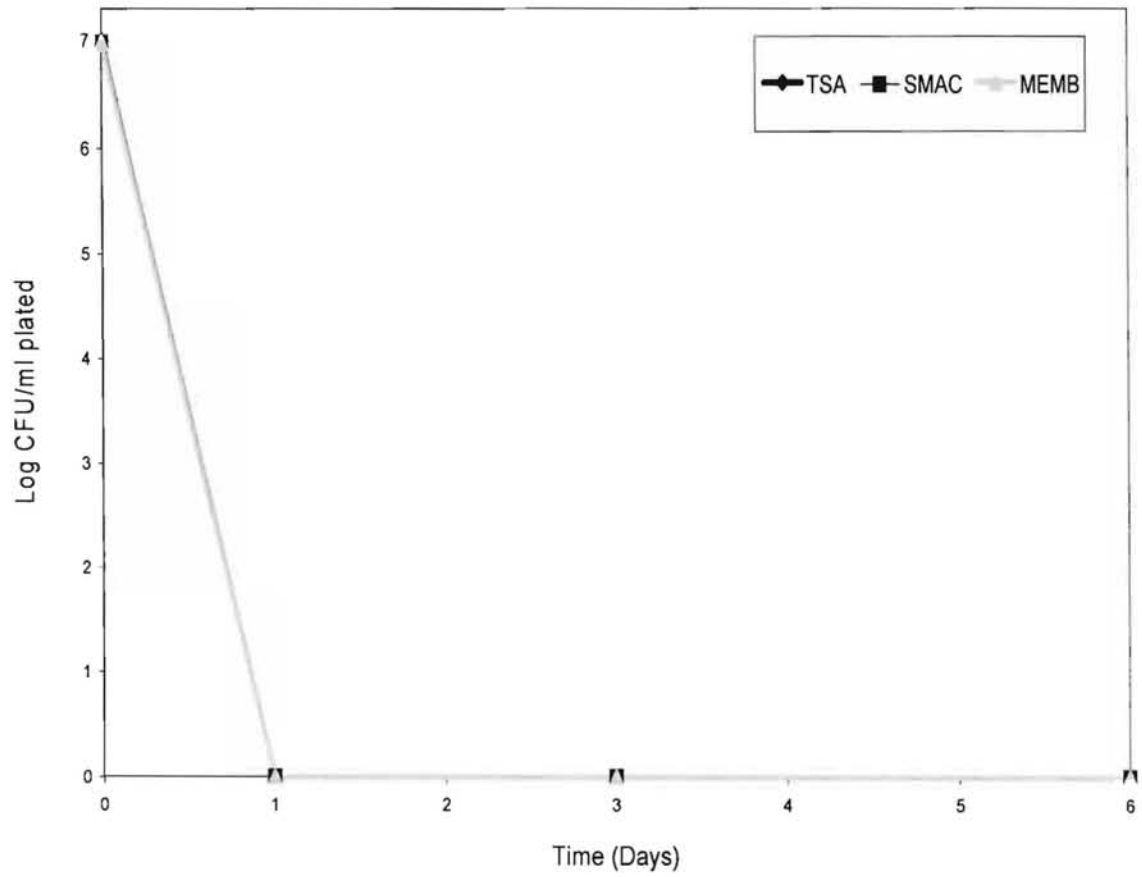
Figure 7. Survival of *E. coli* O157:H7 in 50% cranberry juice and recovered on TSA, SMAC, and MEMB. Values shown as 0 Log CFU/ml plated represent no detection.

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