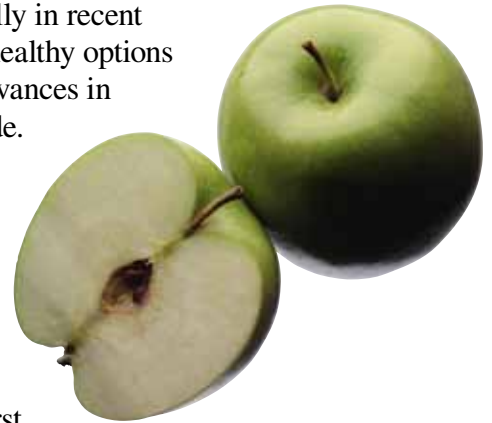


## Extending the Service Life of Anti-browning Solutions in Fresh-cut Fruit Processing

### Introduction

Consumer demand for fresh-cut fruits and vegetables has grown exponentially in recent years. Consumers appreciate the convenience of fresh-cut produce and the healthy options they provide. This market innovation was made possible by a number of advances in growing, processing, packaging and distribution of produce of the last decade.

One such innovation, the development of anti-browning solutions, has led to the marketing of fresh-cut fruits, such as apples, that do not brown for up to 20 days. The solutions, typically containing vitamins, minerals and other ingredients, are sprayed on the apples or contained in a bath in which the apples are soaked after the slicing process, delaying the normal oxidation that would occur.



There are, however, some drawbacks associated with these solutions. The first is that they are relatively expensive to use. Depending on volume and brand they can cost up to \$7 to \$10 per gallon of solution. A second drawback is that the anti-browning solutions have no anti-microbial properties and can become easily contaminated with microorganisms during the apple slicing process. Because of this, processors will typically not re-use the solution and simply discard it daily. Alternative means of controlling microbial growth in the solution either diminish the effectiveness of the solution (chemical sanitizers, ozonation) or add heat and cost to the process (pasteurization).

This 3M Purification Application Brief documents an easy-to-use and effective means of controlling turbidity and bioburden in the solution by means of a staged filtration system. The 3M Purification filtration system allows for re-use of the solution for multiple days, and thereby lowers the operating cost.

### Fresh-cut Fruit Processing

Since fresh-cut fruit processing methods can vary according to the type of fruit and other factors, the schematic in Figure 1 is intended to serve as a guide only.



Figure 1. Fresh Cut Fruit Processing Schematic

## Problems Associated with Anti-Browning Solutions

### *Cost of the Solution*

Commercially available anti-browning solutions typically cost between \$7 to \$10 per gallon of solution. For a small processor with a contact tank of 40 gallons, this represents a cost of \$280 to \$400 to fill the tank. For a large processor with a contact tank of 250 gallons, this represents a cost of \$1750 to \$2500 to fill the tank. For many processors, the solution can only be used for one or two days at the most before the solution becomes very turbid and too contaminated, so therefore must be discarded. This represents a significant operating cost for many processors.

### *Turbidity*

During processing, the anti-browning solution will accumulate bits of fruit, peel, undissolved solids and other debris. These contaminants in the solution come mainly from the cutting process, the conveyor system and from the exposed surfaces of the fruit. They result in a general increase in turbidity during processing runs until the solution is milky or opaque in appearance. Since the solution is re-circulated, these materials to some extent will remain on the fruit surfaces if not removed from the solution. The turbid solution can also accumulate in the bottom of packaging, resulting in a unsightly product.

### *Microorganism Contamination*

Anti-browning solutions can become contaminated with bacteria and other microorganisms during production. Microorganisms can enter the process from many points, but most commonly via the fruit being processed, or via environmental vectors (workers, air-borne contamination, improperly cleaned and sanitized surfaces).

Process operations conducted in a cold environment can help to limit microbial growth, but not prevent it. Other anti-microbial solutions have been attempted, but with mixed results.

Pasteurization (applying a measured amount of heat to a solution for a measured amount of time) is considered a costly solution, and the heat of the equipment raises the temperature of the processing room - the opposite of what most processors want. The cost of purchasing, installing and operating a pasteurizer can also be substantial.

Another alternative, the use of an anti-microbial chemical solution, is considered undesirable since many chemicals either leave trace-residues on the fruit, or counter-act the action of the anti-browning solution itself.

## **The 3M Purification Solution**

3M Purification developed the anti-browning solution filtration system to reduce the turbidity and bacterial contamination in anti-browning solutions and allow multiple re-use of the solution. The 3M Purification system is easy to use and is composed of disposable filter cartridges that are easily replaced when they become fouled. Designed in conjunction with sliced apple producers, a typical system contains three to four stages of filtration in series. The first stages act primarily as prefilters, removing particles and colloidal material to reduce turbidity, while the final stage, a microporous membrane filter, helps remove bacteria present in the solution.

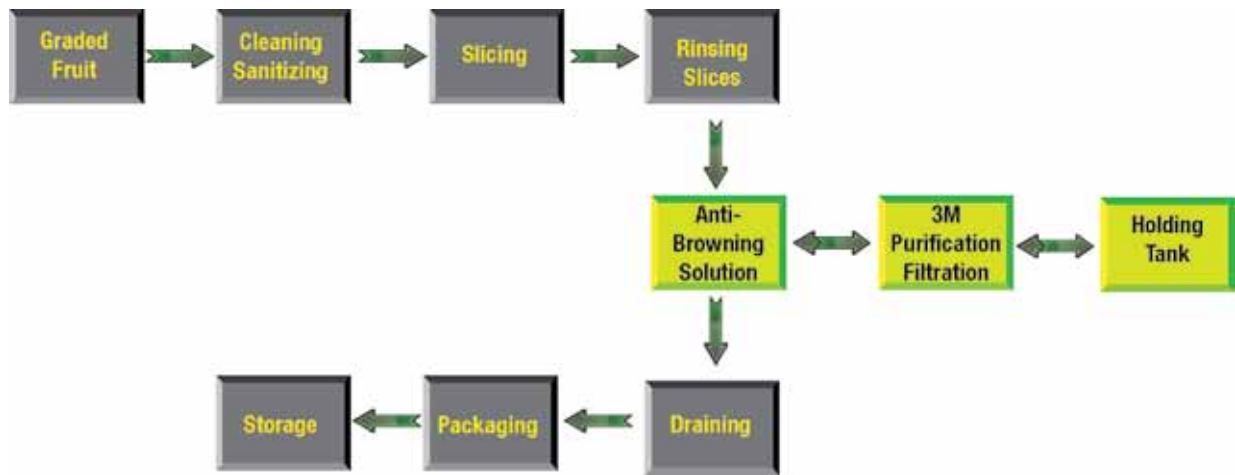


Figure 2. Fresh Cut Fruit Processing Schematic with Anti-browning Solution Filtration System

### System Design - Prefiltration and Turbidity Reduction

Prefiltration of the solution is a critical step that will impact the service life of the final membrane filter, and hence the overall operating cost of the system. The 3M Purification filtration system relies on two or three stages of prefiltration in series. If the solution contains visible fruit particles from the cutting operation, the optional first stage is the 3M Purification NB series bag filter or a cleanable screen filter. Two fruit cutting methods are common: the knife edge cut and the water jet cut. The water jet cut typically results in fewer larger particles as compared to the knife edge cut, although some feel the knife edge cut results in a more appealing surface.

The next filters in the system are the PolyKLEAN™ filter and the Zeta Plus™ filter. The PolyKLEAN filter (Figure 3.) is a rigid, high capacity, fast flowing filter used to remove particles in the solution. A 75 micron nominally rated PolyKLEAN filter is typically employed in this stage. The Zeta Plus filter (Figure 4.) is a cellulose-based depth filter that exhibits excellent control of haze-causing elements in many solutions. The Zeta Plus 10H grade filter is typically employed in the second stage.



Figure 3. PolyKLEAN™ Filter



Figure 4. Zeta Plus™ Filter



Figure 5. Turbidity improvement made with 3M Purification filtration system. Before 3M Purification filtration, left, and after 3M Purification filtration, right

### *System Design - Bacteria Control*

The 3M Purification LifeASSURE™ BLA series filter is employed in the final stage to help reduce the number of microorganisms in the solution significantly. The LifeASSURE BLA series filter contains a pleated layer of microporous nylon membrane that retains microorganisms. The membrane has a unique, multizoned design that retains larger particles and microorganisms in the upstream zone, and smaller particles and microorganisms in downstream zone (see Figure 7.). This patented design combines great retention properties with long service life and high flow rates resulting in lower operating costs when compared to conventional single-zoned membrane filters.



Figure 6. LifeASSURE BLA series final membrane filter

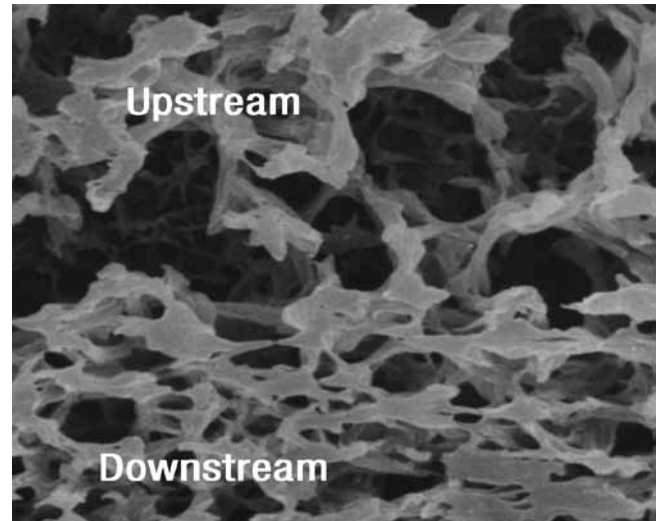


Figure 7. Scanning Electron Micrograph (SEM) showing cross-section of LifeASSURE BLA series membrane

Figure 8 contains microorganism reduction data recorded using a 3M Purification filtration system during pilot testing at an apple processor and is indicative of performance. The 3M Purification filtration system demonstrated significant bioburden control during a six day run.

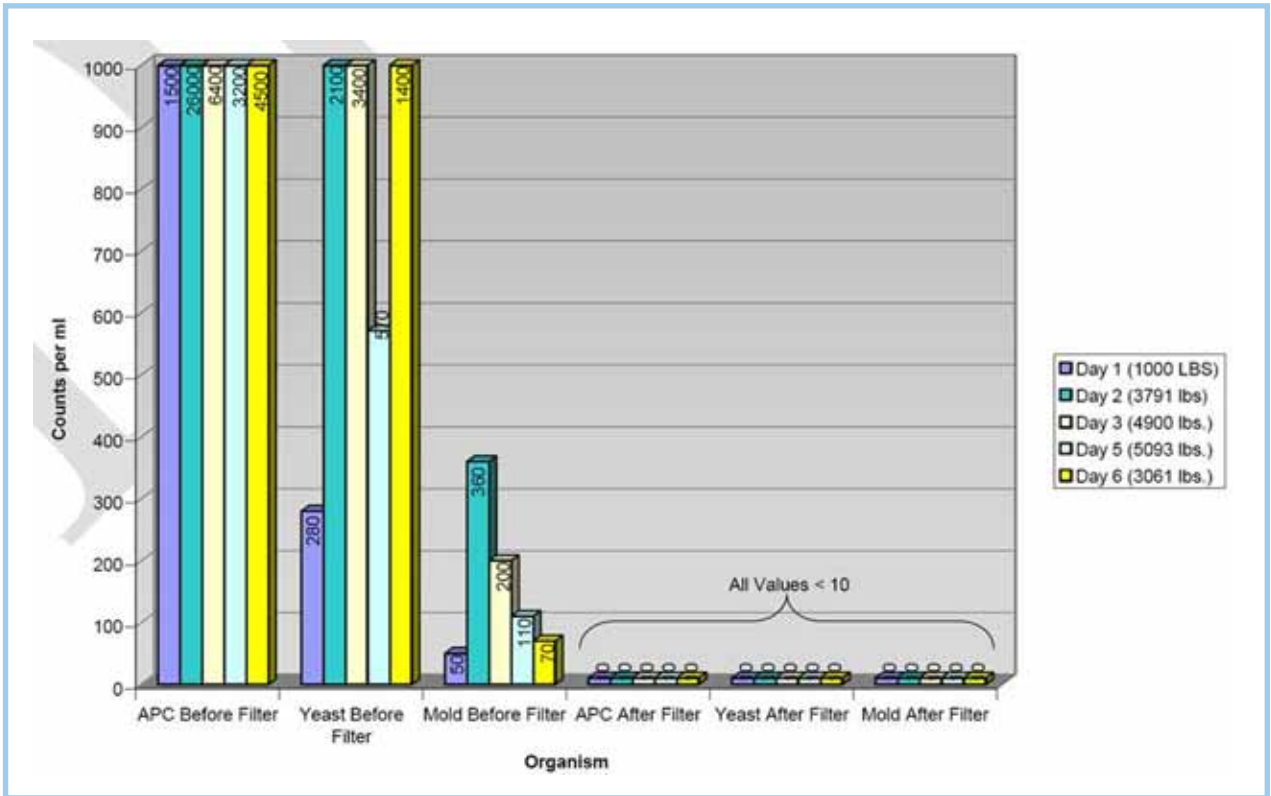


Figure 8. Bioburden Data from Pilot Testing

Table 1: Recommended Filtration Steps

Filtration Stage	Recommended Filter	Rating or Grade	Purpose
1 (optional)	NB Series Bag Filter	100 micron	Large particle reduction
2	PolyKLEAN Filter	75 micron	Small particle reduction
3	Zeta Plus H Series Filter	10H	Haze & micro reduction
4	LifeASSURE BLA Series Filter	0.20 or 0.45 micron	Bacteria reduction

## System Economics

Employing the 3M Purification filtration system and reusing the anti-browning solution can result in significant cost savings. Consider the following example:

The cost of using an anti-browning solution without a filtration system would typically include the cost of the solution itself, along with any costs associated with its preparation and disposal. For instance, a large processor employing a 250 gallon contact tank that is mixed daily with fresh solution might calculate their weekly cost as approximately \$8850 (solution cost = 250 gallons x \$7 per gallon x 5 days; labor costs = \$100 per week to mix daily and dispose daily).

The cost of using an anti-browning solution with a 3M Purification filtration system would typically include the cost of the solution itself and the cost of the filters. For instance, if the same processor filtered the volume of solution described above instead of disposing of it daily, the cost of the solution itself would drop to only \$1,770 per week (250 gallons x \$7 per gallon plus \$20 of labor costs to mix and dispose of the solution at the end of the week). There would also be some additional cost associated with making small amounts of solution during the week to replenish the contact tank as some solution will be lost on the apples as they are processed.

The cost of filtration would include the cost of the primary prefilters, which are typically changed daily, plus the cost of the secondary prefilter, which is usually changed weekly, and the cost of the final membrane filter, which is usually change every two to three weeks. Filter costs can vary according to the grade and quantity used, but the total weekly cost of the filters is typically only a fraction of what the processor was paying to mix a fresh solution tank daily and disposing of it at the end of the shift.

The skid in Figure 9 is a three stage system designed for a 250 gallon contact tank. The skid features a sanitary pump, controls, pressure gauges, sanitary valves and piping and is designed to filter the solution continuously throughout the day. Skids for both smaller and larger volumes are easily configured using smaller or larger filter housings.



Figure 9. Three-stage filtration system for anti-browning solution

## Ease of Use

The filter cartridges installed in the 3M Purification filtration system are of industry standard design and are easy to install and remove. The filters are secured in the filter housings either with a bayonet-locking mechanism (PolyKLEAN and LifeASSURE BLA series filters) or with a spring loaded sealing system (Zeta Plus filters). Filter service life is measured by the pressure drop across each individual filter stage. Once a pressure drop of 35 psid has been achieved, the filter is considered fouled and should be replaced.

## System Operation

There are a number of options in regard to filtration that can be employed. Variables to consider when designing the operation plan would include: typical inlet bioburden, production schedule, hot water sanitation plan, and desired shelf-life. Below are some of the operation plans used by processors:

1. The filtration system is employed only at the end of a production run, when transferring the anti-browning solution to an overnight holding tank. The tank should be sanitized and stored in a cold room.
2. The filtration system is employed throughout the production run in a recirculatory mode, continuously filtering the anti-browning solution in the contact tank through all three stages of filtration.

3. The filtration system is employed throughout the production run in a recirculatory mode, as in Option 2, but the anti-browning solution is only filtered through stages 1 and 2. At the end of the production cycle, the solution is then filtered through the entire filtration train and into a sanitized holding tank.

Some other points to consider for optimal performance include the following:

1. Rinsing the fruit in a separate bath after cutting, but before the anti-browning solution tank, is essential to remove large fruit particulate prior to filtration. The presence of large particles will result in premature blinding of the first stage of filtration and should be avoided.
2. An optional 3M Purification NB series bag filter or a cleanable screen filter can also be installed between to the contact tank and the first stage of filtration to remove any visible particles prior to the filtration system.
3. A low shear pump should always be employed in moving the anti-browning solution. High velocity, impeller-style pumps can create significant small particulate that will foul the filter system and should be avoided.
4. Daily warm water rinsing of the filter system can flush warm-water soluble compounds from the filter pores and reduce the differential pressure across the filters - thereby extending the system service life. Warm water rinsing should follow 3M Purification Technical Brief, 7002025340
5. Regular cleaning and sanitation of the filtration system, especially the solution holding tank, is recommended to keep bioburden in check. The preferred method of sanitation is by using hot, 80°C filtered water for a minimum of 30 minutes.

## Conclusion and Summary

The convenience afforded by packaged fresh cut fruit has led to growing consumer demand. However, one of the processing innovations that sustains this surge in popularity, the use of anti-browning solutions, is relatively expensive if used only once and then disposed. Anti-browning solutions do not have anti-microbial properties and can become contaminated with microorganisms if employed too long. This can result in a diminished quality of the fruit surfaces over time.

Alternative means of controlling microbial growth either reduce the effectiveness of the solution (chemical sanitizers, ozonation) or add heat and cost to the process (pasteurization).

This 3M Purification Customer Application Brief documents an easy-to-use and effective means of controlling turbidity and bioburden in the solution by means of a staged filtration system. The 3M Purification filtration system allows for re-use of the solution, and thereby lowers the operating cost.

For more information regarding the filter components described in this document, please request the literature listed below:

### *Related Reference Literature*

Reference Description	Literature Number
NB Series Bag Filter	70-0201-1136-6
PolyKLEAN Filter Cartridge	70-0201-8723-6
Zeta Plus H Series Filter Cartridges & Capsules	70-0201-8856-4
LifeASSURE BLA Series Filter Cartridges & Capsules	70-0201-8712-9

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