# PINEAPPLE JUICE PRODUCTION USING ULTRAVIOLET PASTEURISATION: POTENTIAL COST IMPLICATIONS

Noranizan Mohd Adzahan*
Lau Phei Ling
Narimah Hashim
Rosnah Shamsudin
Sew Chang Chew
Babak Sobhi

## ABSTRACT

*Urban lifestyles have contributed to consumers' need for convenient and nutritious food products. This study is aimed at determining the cost implications of pineapple juice production using ultraviolet (UV) as an alternative (non-thermal technology) to the conventional pasteurisation methods used in small-medium scale juice facilities in Malaysia. The financial analysis involved Contribution Margin, Net Present Value, Payback Period, and Profitability Index of the UV and heat treated pineapple juices. Ultraviolet pasteurisation has relatively lower initial capital development cost than heat pasteurisation. Thus, implementation of UV technology can be more profitable than heat treatment when applied in a small-medium scale pineapple juice processing plant.*

**Keywords**: Cost implications, heat treatment, pasteurisation, pineapple juice, ultraviolet.

## INTRODUCTION

Pineapple (Ananas cosmosus) is grown extensively in many countries including Malaysia and has long been one of the most popular non-citrus tropical and subtropical fruit because of its attractive flavour and refreshing sugar-acid balance (Bartolomé, Rupérez, & Fúster, 1995). A survey report mentioned that among pineapple, mango, and passion fruit juices, pineapple juice is most preferred by consumers (Sabbe, Verbeke, & Damme, 2008). Asia is the major supplier of exported pineapple juice in the world with Malaysia contributing 0.7% of the exports; ranked 22nd in the world and 5th in Asia (Parker, 2005).

A non-thermal processing method which is gaining increasing acceptance (Laing, 2003; Schaefer, 2002) and has been approved by the Food and Drug Administration (FDA) is ultraviolet (UV) pasteurisation. This approval is mentioned in the FDA Code of Federal Regulations in Title 2 under Part 179.39 (21 CFR Part 179.39). Interest in ultraviolet (UV) pasteurisation for juice processing has increased consistently in recent years because of growing consumer demands for high quality food products. Ultraviolet irradiation has

*Faculty of Food Science and Technology, Universiti Putra Malaysia*
*E-mail : noraadzahan@food.upm.edu.my*

many advantages over thermal pasteurisation as it does not significantly alter the chemical composition, taste, odour or pH of the fluid being treated (Choi & Nielsen, 2005; Tran & Farid, 2004). Several researchers have studied the efficacy of UV irradiation for microbial load reduction (Basaran, Quintero-Ramos, Moake, Churey, & Worobo, 2004; Guerrero-Beltran & Barbosa-Canovas, 2005; Keyser, Muller, Cilliers, Nel, & Gouws, 2008; Matak, 2004; Matak et al., 2005; Ngadi, Smith, & Cayouette, 2003; Noci et al., 2008; Wright, Sumner, Hackney, Pierson, & Zoecklein, 2000). Extensive research on the application of UV radiation for industrial-scale food processing (Donahue, Canitez, & Bushway, 2004; Geveke, 2005; Ngadi, et al., 2003) has shown that this technology can preserve fresh-like quality attributes of juice with acceptable inactivation level for spoilage and pathogenic microorganisms. UV radiation was successfully applied in single strength fruit juices and nectars without affecting the taste of the product (Keyser, et al., 2008) and with losses of vitamins comparable to those in heat treated juices (Mohd Adzahan, 2006). Limitations of the UV pasteurisation technology are related to factors associated with low transmissivity of UV-C radiation such as initial microbial populations, particles and organic matter (Shama, Peppiatt, & Biguzzi, 1996). Other potentials for the technology include clear and less turbid juices such as pineapple juice, guava, sugarcane and chrysanthemum juice (Mohd. Adzahan & Benchamaporn, 2007).

The use of thermal pasteurisation can cause changes in flavour and nutritional content of the juice and may be cost prohibited for many small processing operations (Koutchma, Keller, Chirtel, & Parisi, 2004). Ultraviolet pasteurisation on the other hand, is a low-cost alternative to heat pasteurisation for small processing operations (Donahue, et al., 2004) especially with regard to the energy required (Tran & Farid, 2004; Worobo, 1998) as well as initial investment (Higgins, 2003; Kozempel, McAloon, & Yee, 1998; Majchrowicz, 1999). The UV unit was designed with the intention to assist farmers or juice manufacturers with limited processing space in producing premium product at minimal cost. Juice could be prepared, UV-treated and bottled on-site (near the orchard) and transported directly to retail stores or consumers. In addition, the unit was designed with a user-friendly touch screen menu (start-run-stop), for non-technical operators. This ultraviolet technology for pasteurisation of juices has yet to be adopted in Malaysia as the equipment is not available in the country except for one unit which is located in Universiti Putra Malaysia. An ultraviolet sterilization unit for water treatment is commonly available, but a UV pasteurisation unit dedicated for juices requires certain design considerations and these are crucial to ensure efficient killing of pertinent microorganisms. Lack of awareness among manufacturers regarding the existence of such technology as well as absence of regulation in the Malaysian Food Act related to juice pasteurisation using UV are other contributing factors for this technology not being adopted.

While most of the published literatures focused on the effects of UV irradiation on the safety and quality aspects of juice, this study was intended to assess the potential cost implications of pineapple juice production using ultraviolet technology as an alternative to the conventional pasteurisation method for small-medium scale juice facilities. This study focuses on two major aspects, (i) product cost estimates and (ii) the financial viability of producing pineapple juices using UV pasteurisation. In the analysis, all costs incurred and estimated returns from the investment were taken into consideration.

## METHODOLOGY

### Data Collection

Structured interviews were used as tools to collect primary data regarding the current practices of producing pineapple juice in Malaysia and its production costs. A pre-determined set of questions on production costs of pineapple juice processing line using thermal processing methods was prepared. Two pineapple juice manufacturers (production managers) in Johor and a technical advisor in a pilot plant located in Selangor were interviewed. Information obtained from the interviews was arranged on task basis, which indentified capital investment costs and operating costs.

### Financial Analysis

The financial analysis was carried out to assess the potential cost implication of producing single strength pineapple juice using ultraviolet (UV) pasteurisation method by taking into account of relevant costs and returns. The discounted cash flow method was used to compare the cost and returns which provided a more realistic and objective basis for evaluating and selecting investment projects. This method takes into consideration both the magnitude and timing of expected cash flows in each period of a project's life. Time value of money is an important concept. As such, the timing of expected future cash flows is extremely important in the investment decision.

#### a) Contribution Margin

Contribution margin allows a company to determine the profitability of individual products, using the difference between the price of a product and the sum of the variable costs of one unit of that product (Hansen & Mowen, 2003). The bigger the contribution margin, the better it is to cover fixed expenses. Any remaining amounts will contribute to the profit of the business. Contribution margin per unit is the difference between product unit price and product unit variable costs.

#### b) Break-even Point

Break-even analysis is based on categorising production costs between variable and fixed costs. Total variable and fixed costs are compared with sales revenue in order to determine the level of sales volume or production at which the business makes neither a profit nor a loss. The Break-even Point (BEP) for a product is the point where total revenue received equals the total costs associated with the sale of the product. It is an important planning technique because it forewarns the business owners the point of sales they must aspire to achieve before any profit can be earned. The BEP is calculated as follows (Hansen & Mowen, 2003):

$$\text{Break-even Point} = \frac{\text{Fixed costs}}{\text{Sales revenue per unit} - \text{Variable costs per unit}}$$

**c) Margin of safety**

Margin of safety is the difference between the expected sales level and the breakeven sales level (Hansen & Mowen, 2003). This measure acts a cushion to remind business owners how fast and how much they can fall before making a loss. It can be expressed as below:

$$\text{Margin of safety} = \frac{\text{Budgeted sales - break-even sales}}{\text{Budgeted sales}} \times 100\%$$

**d) Net Present Value**

The Net Present Value (NPV) is the cumulative discounted cash position at the end of the project, or the worth of project at the end of its life (Turton, Bailie, Whiting, & Shaeiwitz, 2008). All costs and benefits are adjusted to present value by using discount factors to account for the time value of money. NPV is used in capital budgeting to analyze the profitability of an investment or project. If the NPV of a prospective investment is positive, it should be accepted as the project is expected to add value to the firm and will therefore increase the wealth of the owners (Petty, 2006).

**e) Profitability Index**

Profitability index (PI), a ratio of present value and initial cost are more frequently used by firms with smaller capital budgets (Ryan & Ryan, 2002). The value of PI is calculated as below and can be used as a guide whether to reject (PI < 1) or accept (PI > 1) a project (Petty, 2006).

**f) Payback Period**

Payback period (PBP) is the time required, after start-up, to recover the fixed capital investment for the project (Turton, et al., 2008). It is usually assumed that the longer the payback period, the more uncertain are the positive returns. For this reason, payback period is often used as a measure of risk, or a risk-related criterion that must be met before funds are spent and is calculated as the ratio of initial investment and annual cash flow (Amin Nordin, Ali Ahmed, Muhammad, & Md Isa, 2003).

**Assumptions**

Several assumptions were made to allow calculations of certain values:

- The economic life span of the pineapple juice line is 10 years and that most of the costs are constant for a period of 10 years.

- Depreciation expense for all the machinery and processing unit is calculated based on a straight line depreciation method where an equal amount of depreciation is charged each year over the depreciation period allowed (Turton et al., 2008).

- The price of raw material is assumed to be constant throughout the production period. Estimated price for unpasteurized pineapple juice is RM 500.00 per 1,000 kg and high fructose corn syrup is RM 1,500.00 per 1,000 kg.

- Equipment capability is assumed at 1,250 cans/hour, with 6 hours/day operation time for a 25-day month. Targeted production units are 1,875,000 cans per annum.

- All canned pineapple juices are assumed to be sold.

- The discount rate represents the bank and commercial interest rate, it is assumed to be fixed at 10% per annum (Fong, 2002). Given this rate, the present value of the cash flow over the life of production can be determined.

- The company running the business is a small-medium scale food processing company.

## RESULTS AND DISCUSSION

### Financial Viability

Unit costs for raw materials were obtained from in-depth interviews with pineapple juice manufacturers. A pineapple processing plant usually has many product lines. The raw materials are usually obtained from wastes of pineapple canning lines. Pineapple pulp for juice production is usually obtained from wastes of pineapple canning lines. Thus, pineapple juice is a by-product of canned pineapple industry. Pineapple juice producers are those who have an established facility to process pineapples for canning. Most of the equipment necessary for pineapple juice production are similar to canned pineapples. Thus, lower equipment costs are needed when producing pineapple juice.
The estimated power consumption was made based on a production capacity of 400 litres per hour (Table 1). At present, UV pasteurisation is not being used in the Malaysian juice processing industry. Thus, data related to the UV processing line were obtained from the Faculty of Food Science and Technology, Universiti Putra Malaysia, where a UV pasteurisation unit (CiderSure 3500, Macedon, New York) is available. The CiderSure 3500 can operate up to 454 litres per hour.

**Table 1: Estimated Power Consumption and Electricity Cost (Malaysian Ringgit, RM) for Pineapple Juice Processing Line using Ultraviolet and Thermal Sources**

| Equipments | Estimated Power Consumption (kW/h) | |
|---|---|---|
| | Ultraviolet | Thermal |
| Chopper/Mixer | 0.55 | 0.55 |
| Filtering system | - | - |
| Ultraviolet pasteuriser | 1.00 | - |
| Plate heat exchanger | - | - |
| Boiler | - | 10.0 |

*Table 1 (Continued)*

| Equipments | Estimated Power Consumption (kW/h) | |
|---|---|---|
| | Ultraviolet | Thermal |
| Holding tank | - | - |
| Filler | 4.00 | 4.00 |
| Sealer | 1.20 | 1.20 |
| Cooling system | - | 4.00 |
| Pumping and piping system | 2.00 | 3.00 |
| Conveyor systems | 0.40 | 0.40 |
| Total Power Required (kW/h) | 9.15 | 23.15 |
| Power consumption/month (kWh) | 1372.5 | 3472.5 |
| Electricity cost/month (RM) | 398.00 | 1007.00 |

Note: Plant operation time is 6 hours per day in a 25-day month. Tariff rate for low voltage industrial site is 29 cent/kWh for all kWh used.

The essential requirement of all businesses is capital that is invested in assets, which are in turn employed to produce products that are sold in the market place. The profit for each canned pineapple juice sold is the difference between the selling price of the finished product (pineapple juice in cans) and the total cost of producing the juice. When estimating an investment cost, there is always uncertainty as to how precise all items in the estimate would be when the project is executed. These uncertainties are risks to the investment and it is normal to have an additional 15 percent to 20 percent contingency cost taken into consideration when the investment cost is calculated (Atrill & McLaney, 2007). The total costs involved for producing pineapple juices was divided into 2 distinct categories, namely capital development costs and production costs.

**i) Capital Development Costs**

Capital development costs (CDC) are the expenditure on physical assets and initial expenses for setting up a pasteurisation line for producing juices (Hansen & Mowen, 2003). Capital costs for a pineapple juice processing plant takes into account the costs incurred in implementing a new technology in the production line only where incremental cash flow are involved (Amin Nordin, et al., 2003). The estimated capital development costs for a pineapple juice processing plant using UV and thermal treatment as the pasteurisation method are shown in Tables 2 and 3. The cost for a small-medium scale facility with UV technology is estimated at RM 343,200.00 while a facility with a thermal pasteurisation unit is estimated at RM 427,200.00. These results are consistent with the findings of Donahue et al. (2004) that UV pasteurisation is a low-cost alternative to thermal pasteurisation for small processing operations.

**Table 2: Capital Development Costs (Malaysian Ringgit, RM) for Pineapple Juice Processing Line with an Ultraviolet Pasteurisation Unit**

| Equipments | Unit | Cost/Unit (RM) | Investment cost (RM) | Life span (year) | Depreciation expense per annum (RM) |
|---|---|---|---|---|---|
| Chopper/Mixer | 2 | 12,000 | 24,000 | 10 | 2,400 |
| Filtering system | 1 | 25,000 | 25,000 | 10 | 2,500 |
| Ultraviolet pasteuriser | 1 | 110,000 | 110,000 | 10 | 11,000 |
| Holding tank | 1 | 8,000 | 8,000 | 10 | 800 |
| Filler | 1 | 20,000 | 20,000 | 10 | 2,000 |
| Sealer | 1 | 70,000 | 70,000 | 10 | 7,000 |
| Pumping and piping system | 1 | 10,000 | 10,000 | 10 | 1,000 |
| Conveyor systems | 1 | 18,000 | 18,000 | 10 | 1,800 |
| Collecting table | 1 | 1,000 | 1,000 | 10 | 100 |
| **Total** | | | **286,000** | **-** | **28,600** |
| **+ Contingency cost (20%)** | | | **343,200** | **-** | **34,320** |

**Table 3: Capital Development Costs (Malaysian Ringgit, RM) for a Pineapple Juice Processing Line which Uses a Thermal Pasteurisation Unit**

| Equipments | Unit | Cost/Unit (RM) | Investment value (RM) | Life span (year) | Depreciation expense per annum (RM) |
|---|---|---|---|---|---|
| Chopper/Mixer | 2 | 12,000 | 24,000 | 10 | 2,400 |
| Filtering system | 1 | 25,000 | 25,000 | 5 | 2,500 |
| Plate heat exchanger | 1 | 40,000 | 40,000 | 10 | 4,000 |
| Electrode Boiler | 1 | 70,000 | 70,000 | 10 | 7,000 |
| Holding tank | 1 | 8,000 | 8,000 | 10 | 800 |
| Filler | 1 | 20,000 | 20,000 | 10 | 2,000 |
| Sealer | 1 | 70,000 | 70,000 | 10 | 7,000 |
| Cooling tunnel | 1 | 40,000 | 40,000 | 10 | 4,000 |
| Pumping and piping system | 1 | 40,000 | 40,000 | 10 | 4,000 |
| Conveyor systems | 1 | 18,000 | 18,000 | 10 | 1,800 |
| Collecting Table | 1 | 1,000 | 1,000 | 10 | 100 |
| **Total** | | | **356,000** | **-** | **35,600** |
| **+ Contingency cost (20%)** | | | **427,200** | **-** | **42,720** |

### ii) Production costs

Estimated monthly production cost of pineapple juice processing line with UV and thermal pasteurisers are shown in Tables 4 and 5. The production cost of a processing line with a UV pasteuriser is RM 139,867.20 per month and for thermal pasteuriser is RM 140,598.00 per month. Electricity cost for UV pasteurisation (RM 406 per month) is cheaper than thermal pasteurisation (RM 1,015 per month) with the difference amounting to RM 609 per month. Similar observation regarding energy requirement for both technologies has been pointed out by several researchers (Tran & Farid, 2004; Worobo, 1998).

**Table 4: Monthly Production Cost (Malaysian Ringgit, RM) for a Pineapple Juice Processing Line Utilising an Ultraviolet Pasteurisation Unit**

| Items | Amount | Unit | Cost/Unit (RM) | Investment cost (RM) |
|---|---|---|---|---|
| Human capital | 5 | persons | 700.00 | 3,500.00 |
| Unpasteurised pineapple juice | 50,000 | kg | 500.00 | 25,000.00 |
| High fructose corn syrup | 5,000 | kg | 1,500.00 | 7,500.00 |
| Packaging/labelling material | 160,000 | cans | 0.50 | 80,000.00 |
| Electricity | 1,400 | kWh | 0.29 | 406.00 |
| Water | 1 | litres | 150.00 | 150.00 |
| **Total** | | | | **116,556.00** |
| **+ Contingency cost (20%)** | | | | **139,867.20** |

Note: Plant operation time is 6 hours per day in a 25-day month. Tariff rate for low voltage industrial site is 29 cent/kWh for all kWh used.

**Table 5: Monthly Production Cost (Malaysian Ringgit, RM) for a Pineapple Juice Processing Line Utilising a Thermal Pasteurisation Unit**

| Items | Amount | Unit | Cost/Unit (RM) | Investment Value (RM) |
|---|---|---|---|---|
| Human Capital | 5 | persons | 700.00 | 3,500.00 |
| Unpasteurised pineapple Juice | 50,000 | kg | 500.00 | 25,000.00 |
| High fructose corn syrup | 5,000 | kg | 1,500.00 | 7,500.00 |
| Packaging/labelling material | 160,000 | cans | 0.50 | 80,000.00 |
| Electricity | 3,500 | kWh | 0.29 | 1,015.00 |
| Water | 1 | litres | 150.00 | 150.00 |
| **Total** | | | | **117,165.00** |
| **+ Contingency cost (20%)** | | | | **140,598.00** |

Note: Plant operation time is 6 hours per day in a 25-day month. Tariff rate for low voltage industrial site is 29 cent/kWh for all kWh used.

The cost-volume-profit analyses for UV and thermally treated pineapple juice are summarised in Table 6. Variable cost (calculated as monthly variable cost divided by budgeted monthly production units) for UV treated pineapple juice is RM 0.895 per can (320 ml) while thermally treated pineapple juice is RM 0.900 per can (320 ml). These results indicate that UV pasteurisation could produce juice at a lower production cost than thermal pasteurisation. Similar observations were reported for apple cider where UV pasteurisation costs is approximately RM 1.60 per 100 litres (Higgins, 2003) and thermal pasteurisation costs is approximately RM 4.00 per 100 litres (Kozempel, et al., 1998).

When a product produced is of premium quality (better colour and flavour profile, higher nutrient retention, fresh-like characteristics) the selling price could be set at a relatively higher value. Consumers especially those who are health conscious will be willing to spend money for premium products thus better profitability value. Pineapple juice treated with UV when compared with thermally treated juice, has better taste, colour profile and ascorbic acid content, similar to that of the freshly pressed juice (Choi & Nielsen, 2005; Hanisah, 2009). The selling price of canned (320 ml/can) pineapple juice in the Malaysian market is between RM 1.50 per can to RM 1.80 per can. Based on the accounting principle of conservatism which anticipates no profit but provides for all possible losses (Isa, 2006), price of canned pineapple juice is assumed at RM 1.50 per can. For thermally treated canned pineapple juice which sells at RM 1.50, its contribution margin is RM 0.60 (price per unit – variable costs per unit). This enables pineapple juice manufacturers to cover other miscellaneous costs such as factory space, office supplies, advertising, insurance and income taxes).

**Table 6: Comparison of Cost-Volume-Profit Analysis for Canned Pineapple Juices**

| Parameter | Ultraviolet treated pineapple juice | Thermally treated pineapple juice |
|---|---|---|
| Variable cost per can (320 ml) | RM 0.895 | RM 0.900 |
| Contribution margin per unit | RM 0.605 | RM 0.600 |
| Break-even Point | 567,273 cans per year | 712,000 cans per year |
| Margin of safety | 69.7 % | 62.0 % |

The advantage of being able to deduce the break-even point (BEP) is that it makes it possible to compare the planned volume of activity with the BEP, so it assists judgement of the risk. Hence, investment with low BEP and higher margin of safety is preferred. In this case, UV technology has lower BEP (567,273 cans per year) compared to conventional pasteuriser (712,000 can per year). The UV technology also has higher margin of safety (67%) than a normal pasteuriser (62%). Investors are most likely to adopt UV technology instead of thermal pasteuriser in juice processing as UV technology gives higher return with lower risk. The essential feature of investment decision is time. Investment involves making an outlay of something of economic value at one point in time, which is expected to yield economic benefits to the investor at some other point in time (Atrill & McLaney, 2007). Many investments made by business involve laying out a significant proportion of their total resources. If mistakes are made with the decision, the effects on businesses could be significant. Investment decision must be consistent with the objective of maximising shareholder wealth (Amin Nordin, et al., 2003). Research shows that there are three common analytical tools used in practice by businesses throughout the world to evaluate the investment opportunities, namely: NPV, PI, and PBP (Fong, 2002).

Analysis of investment potential for UV technology as compared to thermal treatment is presented in Table 7. The net present value for the UV treated pineapple juice, which is calculated on the adjusted net cash flow, is estimated at RM 7,400,298.00. A profitability index of 21.56 and payback period of 4 months for UV treated pineapple juice can be considered attractive in comparison to thermally treated pineapple juice, where the profitability index is only 17.10 and the payback period is 30 days longer. The profitability index for both investments predicts high profitability, but UV technology offers excellent investment potential and shorter payback period. Investment with the highest rate of net present value and profitability index but shortest payback period will be chosen when considering two mutually exclusive investments (Amin Nordin, et al., 2003). Net present value and profitability index indicated that the operation would be successful under the conditions established in this report.

**Table 7: Investment Potential for Ultraviolet and Thermally Treated Pineapple Juice**

| Indicator | Ultraviolet treated pineapple juice | Thermal treated pineapple juice |
|---|---|---|
| Net Present Value | RM 7,400,298 | RM 7,303,849 |
| Profitability Index | 21.56 | 17.10 |
| Payback Period: | 4 months | 5 months |

**Limitation of the study**

There is only one UV pasteuriser specific for juice pasteurisation available in the country at the time this study was conducted. Information received and used were from one source.

## CONCLUSION

The objective of this study is to determine the potential cost implications of producing pineapple juice using ultraviolet pasteurisation in Malaysia. As such, for a small-medium scale facility, UV technology gives a better value for the money invested as the net present value and profitability index of UV pasteurised pineapple juice is higher than thermal pasteurised pineapple juice. Moreover, investors can recover their cost quickly with UV technology as the payback period for UV technology is faster by one month when compared to the thermal method under the financial assumptions made in this report.

This study is an effort for creating or increasing awareness with regard to the existence and potential of UV pasteurisation of juice. The advantage of UV technology is not known to many juice manufacturers in Malaysia and should be highlighted accordingly.

## ACKNOWLEDGMENT

The authors would like to acknowledge all individuals who have contributed in providing primary data for this study.

**References**

Amin Nordin, B. A., Ali Ahmed, H. J., Muhammad, J., & Md Isa, A. H. (2003). *Guide to financial management: capital budgeting* (2nd ed.). Singapore: Thomson Learning.

Atrill, P., & McLaney, E. (2007). *Management accounting for decision makers* (5th ed.). New York: Prentice Hall.

Bartolomé, A. P., Rupérez, P., & Fúster, C. (1995). Pineapple fruit: Morphological characteristics, chemical composition and sensory analysis of Red Spanish and Smooth Cayenne cultivars. *Food Chemistry*, 53(1), 75-79.

Basaran, N., Quintero-Ramos, A., Moake, M. M., Churey, J. J., & Worobo, R. W. (2004). Influence of apple cultivars on inactivation of different strains of Escherichia coli O157:H7 in apple cider by UV irradiation. *Applied and Environmental Microbiology,* 70(10), 6061-6065.

Choi, L. H., & Nielsen, S. S. (2005). The effects of thermal and nonthermal processing methods on apple cider quality and consumer acceptability. *Journal of Food Quality,* 28(1), 13-29.

Donahue, D. W., Canitez, N., & Bushway, A. A. (2004). UV inactivation of E. Col O157:H7 in apple cider: Quality, sensory and shelf-life analysis. *Journal of Food Processing and Preservation*, 28(5), 368-387.

Fong, L. L. (2002). *Feasibility Study of Processing Cultured Milk in Malaysia*. Bachelor Thesis, Universiti Putra Malaysia, Serdang, Selangor.

Geveke, D. J. (2005). UV inactivation of bacteria in apple cider. *Journal of Food Protection,* 68(8), 1739-1742.

Guerrero-Beltran, J. A., & Barbosa-Canovas, G. V. (2005). Reduction of Saccharomyces cerevisiae, Escherichia coli and Listeria innocua in apple juice by ultraviolet light. *Journal of Food Process Engineering,* 28(5), 437-452.

Hanisah, H. (2009). Effect of Ultraviolet Irradiation on the Quality of Pineapple Juice. Bachelor thesis, Universiti Putra Malaysia, Serdang, Selangor.

Hansen, D. R., & Mowen, M. M. (2003). *Management Accounting* (6th ed.). South-Western Australia: Thomson Learning.

Higgins, K. T. (2003). Fresh Today, Safe Next week. *Food Engineering Magazine.* Retrieved from http://www.foodengineeringmag.com/Archives

Isa, S. (2006). *Acounting Principles* (1st ed.). Petaling Jaya: Pearson Prentice Hall.

Keyser, M., Muller, I. A., Cilliers, F. P., Nel, W., & Gouws, P. A. (2008). Ultraviolet radiation as a non-thermal treatment for the inactivation of microorganisms in fruit juice. *Innovative Food Science and Emerging Technologies*, 9(3), 348-354.

Koutchma, T., Keller, S., Chirtel, S., & Parisi, B. (2004). Ultraviolet disinfection of juice products in laminar and turbulent flow reactors. *Innovative Food Science and Emerging Technologies,* 5(2), 179-189.

Kozempel, M., McAloon, A., & Yee, W. (1998). The cost of pasteurizing apple cider. *Food Technology*, 52(1), 50-52.

Laing, B. (2003). Developments in Ultraviolet Disinfection. *Water Quality Products,* 8(1). Retrieved from http://www.wwdmag.com/Disinfection-Part-1-Developments-in-Ultraviolet-Disinfection-article3474

Majchrowicz, A. (1999). Innovative technologies could improve food safety. *Food Safety,* 22(2), 16-20.

Matak, K. E. (2004). *Effects of UV Irradiation for the Reduction of Bacterial Pathogens and Chemical Indicators in Milk*. Doctoral dissertation. Virginia Tech. Blacksburg.

Matak, K. E., Churey, J. J., Worobo, R. W., Sumner, S. S., Hovingh, E., Hackney, C. R., & Pierson, M. D. (2005). Efficacy of UV light for the reduction of Listeria monocytogenes in goat's milk. *Journal of Food Protection*, 68(10), 2212-2216.

Mohd Adzahan, N. (2006). *Effects of ultraviolet treatment on water soluble vitamin retention in aqueous model solutions and apple juice*. Doctoral dissertation. Cornell University.

Mohd. Adzahan, N., & Benchamaporn, P. (2007). Potential of non-thermal processing for food preservation in southeast asian countries. *ASEAN Food Journal,* 14(3), 141-152.

Ngadi, M., Smith, J. P., & Cayouette, B. (2003). Kinetics of ultraviolet light inactivation of Escherichia coli O157:H7 in liquid foods. *Journal of the Science of Food and Agriculture*, 83(15), 1551-1555.

Noci, F., Riener, J., Walkling-Ribeiro, M., Cronin, D. A., Morgan, D. J., & Lyng, J. G. (2008). Ultraviolet irradiation and pulsed electric fields (PEF) in a hurdle strategy for the preservation of fresh apple Juice. J*ournal of Food Engineering*, 85(1), 141-146.

Parker, P. M. (2005). The World Market for Pineapple Juice: A 2005 Global Trade Perspective. Retrieved from http://www.icongrouponline.com

Petty, J. W. (Ed.). (2006). *Financial management* (4th ed.). Sydney: Prentice Hall.

Ryan, G. P., & Ryan, P. A. (2002). Capital Budgeting Practices of the Fortune 1000: How Have Things Changed? . *Journal of Business and Management*, 8(4), 355-365.

Sabbe, S., Verbeke, W., & Damme, P. V. (2008). Familiarity and purchasing intention of Belgian consumers for fresh and processed tropical fruit products. *British Food Journal,* 110(8), 805-818.

Schaefer, T. (2002). Ultraviolet for Disinfection. *Water Quality Products,* 7(4). Retrieved from http://www.roadsbridges.com/Ultraviolet-for-Disinfection-article3031

Shama, G., Peppiatt, C., & Biguzzi, M. (1996). A novel thin film photoreactor. J*ournal of Chemical Technology and Biotechnology,* 65(1), 56-64.

Tran, M. T. T., & Farid, M. (2004). Ultraviolet treatment of orange juice. *Innovative Food Science and Emerging Technologies*, 5(4), 495-502.

Turton, R., Bailie, R. C., Whiting, W. B., & Shaeiwitz, J. A. (2008). *Analysis, Synthesis, and Design of Chemical Processes* (3rd ed.). New Jersey: Prentice Hall.

Worobo, R. W. (1998). *Efficacy of the CiderSure 3500 Ultraviolet Light Unit in Apple Cider*. Paper presented at the FDA Apple Cider Food Safety Control Workshop.

Wright, J. R., Sumner, S. S., Hackney, C. R., Pierson, M. D., & Zoecklein, B. W. (2000). Efficacy of ultraviolet light for reducing Escherichia coli O157:H7 in unpasteurized apple cider. *Journal of Food Protection*, 63(5), 563-567.