# The Impacts on the U.S. Grapefruit Industry from Banning the Pesticide Sodium Ōrtho-Phenylphenate

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Sodium ōrtho-phenylphenate (SOPP) is a postharvest pesticide commonly used on citrus. SOPP poses some food safety risks and is currently in the Environmental Protection Agency's Stage IV of the pesticide re-registration process. Costs to the fresh grapefruit industry are estimated for increases in the postharvest loss rates of fresh grapefruit following an SOPP ban. The ban's effects on domestic and export sales of fresh and processed grapefruit are estimated.

In the agricultural policy arena, pesticide issues are a top food safety concern. Currently, the Environmental Protection Agency (EPA) is involved with the mandatory re-registration program of all registered pesticides. This comprehensive re-registration of pesticides will likely cause the cancellation, suspension, and voluntary withdrawal of some agricultural pesticides. This process uses modern standards to protect human health and the environment while preserving the public's confidence in the food supply (EPA 1991). When reviewing a pesticide, the EPA's policy agenda and accounting of costs and benefits of reducing a selected pesticide involves a heavy emphasis on the biological effects on human health; the main focus is toxicity.

This study focuses on estimating the cost of increases in postharvest losses of grapefruit resulting from a ban of the postharvest pesticide, sodium ōrtho-phenylphenate (SOPP), from use in grapefruit packinghouses. On citrus, SOPP has been used extensively in controlling postharvest diseases for over 25 years (Eckert and Ogawa, p. 431) and is used exclusively in postharvest stages. SOPP is considered essential to postharvest regimes for citrus (Lindsey and others, p. 27). A United States Department of Agriculture (USDA) 1992 survey of 103 Florida grapefruit packinghouses revealed that in the 1990-91 season, 51 percent of all fresh grapefruit received by the packinghouses were treated with SOPP (Love and Buzby). However, SOPP has been found carcinogenic and oncogenic in laboratory animals and promotes benign and cancerous tumors (Hiraga and Fujii, Fukushima and others). SOPP is currently in Phase IV of the EPA's re-registration program which means that all past chronic toxicology studies are being reviewed and additional research needs are being identified and requested.

In this study, the Florida grapefruit industry is used as a proxy for the U.S. grapefruit industry. Florida grapefruit production is reasonable proxy of U.S. grapefruit production because in 1990-91, Florida produced 85 percent of total U.S. output of grapefruit (Fl. Ag. Stat. Serv.). Also Florida produces the dominant share (99+%) of all grapefruit exports. In the 1992-93 season, 17.2 million cartons of grapefruit were exported out of the U.S. and all but 9 thousand of these cartons were produced in Florida (Fl. Ag. Stat. Serv.).

In general, if an important postharvest pesticide is banned from use on fresh grapefruit, in the short run there would potentially be three main costs to the grapefruit industry. The three industry costs are: (1) new fixed costs for packinghouses to switch to an alternative technology, (2) higher variable costs for more expensive pesticides, and (3) lost producer surplus because of increased postharvest losses (following increased pathogen resistance).[1]

New fixed costs might include costs of purchasing equipment to apply a new non-chemical

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[1] Cappellini and Ceponis define *postharvest losses* as the difference between the product harvested and the product consumed (p. 24).

technology (*e.g.*, cold treatments) or to apply alternative pesticides. Yet, often different pesticides can use the same equipment, *i.e.*, fixed costs may not change if the replacement pesticide uses the same application technology as the banned pesticide. Irradiation is not a feasible technology for citrus fruits because doses high enough to kill pathogens are damaging to the fruit.

Whether total variable costs increase following a pesticide ban depends on which pesticide is banned and on the annual variable costs of the replacement technology. For profit maximizing grapefruit packinghouses, the ban will lead to higher variable costs of more expensive pesticides until they have access to alternatives that are less expensive and are equally effective. The difference in variable costs between using a banned pesticide and its alternative may be small relative to the other costs of the ban.[2]

Beyond the typical fixed and variable cost increases resulting from a ban of a major postharvest pesticide, postharvest losses would most likely increase due to the build-up of pathogen resistance. Kader and Arpaia state that for citrus fruits, pathogen resistance to fungicides can quickly develop and this resistance limits the postharvest life of the fruit. Grapefruit packinghouses currently have a limited selection of postharvest pesticides available for use and often rotate pesticides to deter pathogen resistance.[3] Banning an important postharvest pesticide like SOPP would mean that there are fewer pesticides to rotate.

A ban of an important postharvest pesticide for grapefruit would not only affect the grapefruit industry, but would also impose costs to society: (1) regulatory/enforcement costs, and (2) the loss of consumer surplus. Although, it would be theoretically sound to include the costs of the regulatory action and enforcement in a cost benefit analysis of the pesticide ban, to date, there have not been any bans of postharvest pesticides used on fresh grapefruit for use as a proxy.[4] The EPA's Freedom of Information Office can provide cost figures for regulatory actions when given the names of banned pesticides.

An SOPP ban will not only affect the shelf life of grapefruit sold domestically but will also affect exports. U.S. grapefruit producers rely heavily on export demand. Forty percent of fresh U.S. grapefruit was exported for the 1991-92 crop year while imports were insignificant (Econ. Res. Serv., p. 37). Japan is the main importer of U.S. fresh grapefruit. Other important destinations include France, Canada, and Great Britain. Grapefruit exports to more distant grapefruit importing countries will be especially affected because of the increased difficulty of maintaining quality during transit.

**Previous Literature**

Babcock states that there is a hierarchy of cost estimation methods with different levels of time and data requirements that yield different levels of accuracy and applicability. Selection of a cost estimation method hinges on the purpose of the study and on resource availability. Methods range from simplistic extrapolations of existing cost data to definitive cost estimates that are time-consuming, detailed, and expensive (Babcock). The most basic cost estimation method is an extrapolation of existing cost data to the appropriate level. Babcock identifies some of the more advanced cost estimation approaches as combined multi-variable regressions, discrete multi-variable regressions, and the conceptual factoring of discrete equipment.

Buzby performed a formal cost-benefit analysis of an SOPP ban from use on Florida grapefruit designated for fresh markets. The cost-benefit analysis considered the previously mentioned costs to the U.S. grapefruit industry and found that the cost of postharvest losses would be

[2] For example, in August, 1992, Tom Tsun of FMC Corporation provided variable cost estimates for treating grapefruit with SOPP and an alternative pesticide, TBZ. When the higher variable costs are applied to the number of fresh Florida grapefruit treated with SOPP and not with TBZ in the 1991-92 season, annual variable costs increase by $7,000 for all of Florida's grapefruit industry. Hence in this case, variable costs would be a relatively minor cost if SOPP was banned and TBZ was the alternative technology.

[3] The major postharvest pathogens affecting grapefruit are the stem-end rots and wound pathogens such as blue and green molds (Wardowski and Brown, Eckert and Ogawa, p. 430.)

[4] Yet, some post-harvest pesticides used on grapefruit have been withdrawn by their manufacturers (e.g., benomyl).

the main cost affecting grapefruit packinghouses if SOPP is banned, assuming a 10 percent increase in postharvest losses. Benefits were quantified using a contingent valuation survey that elicited consumers' willingness to pay for grapefruit that was not treated with SOPP (i.e., a food safety risk reduction). Under this scenario, the benefits of the ban outweighed costs.

However, the actual loss rate following an SOPP ban is not known because SOPP has been used continuously on citrus in the United States since its development. The extent of the increase in postharvest grapefruit losses would depend upon the efficacy of the remaining registered pesticides in killing target pests and in combating the build-up of pathogen resistance. Comments of grapefruit packinghouse operators were recorded during the pretesting of USDA's 1992 postharvest handlers survey. These comments indicated that if SOPP was banned, packinghouse operators would be concerned about increased pathogen resistance and postharvest losses because they felt that there were no good substitutes for SOPP. As an approximation for loss rates following an SOPP ban, estimated losses with and without other pesticides can be used as a proxy. For example, in the early 1980's, a study in California estimated that adding the postharvest pesticide, Imazalil, to the list of permissible pesticides for use in packinghouses could potentially decrease fresh grapefruit losses up to five percent. The assumption of a 10 percent loss rate was selected as a reasonable high-end estimate.

## Objectives

The current report extends the work by Buzby and contributes to the literature by revealing the importance of postharvest losses to the U.S. grapefruit industry and the sensitivity of the increased cost to various levels of postharvest losses. This report also extends Buzby's study in that it includes domestic and export markets for processed grapefruit. Although this study focuses on the cost of postharvest losses following an SOPP ban, the results are not specific to SOPP. The results can represent the cost of any pesticide ban that has the loss rates used here. Specifically, this report has two objectives:

(1) to determine the sensitivity of the cost of postharvest losses to the grapefruit industry to two, five, and ten percent increases in postharvest loss rates following an SOPP ban,

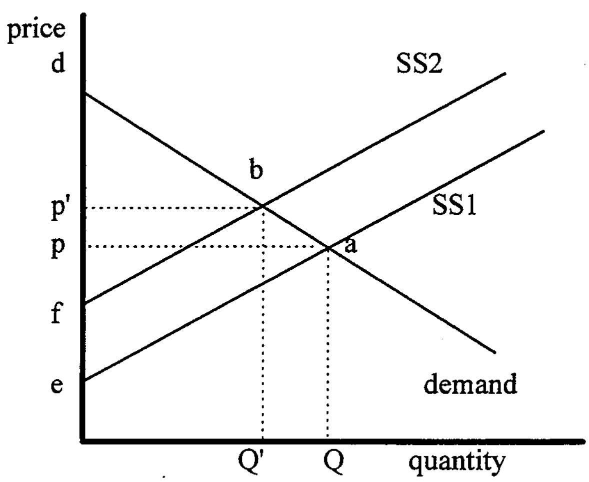
(2) to determine the effect of the postharvest losses on domestic and export sales of fresh and processed grapefruit resulting from the different levels of postharvest losses.

## Theoretical Foundation

Theoretically, the net national benefits (or costs) for all relevant markets are found via consumer surplus (CS) and producer surplus (PS). Changes in CS and PS are estimated to provide a net welfare measure. The underlying rationale for estimating a monetary measure of the costs of an SOPP ban is to provide a check on the economic rationality of the policy change.

An SOPP ban would affect both consumers' and producers' surplus. Because use of a postharvest grapefruit pesticide extends shelf life and reduces losses due to spoilage, a ban would result in a leftward (upward) shift of the supply function for fresh grapefruit as depicted in Figure 1. The supply function would shift from SS1 to SS2. Prior to implementation of the ban, CS is depicted as the area pda while CS after the ban is represented by p'db. The decrease in CS is defined by

**Figure 1. Consumer Surplus and Producer Surplus Changes Following an Increase in Postharvest Losses.**



the area pp'ba. Similarly, PS before the ban is the area pae, and PS after the ban is the area p'bf. The change in PS may be positive or negative, depending upon the elasticity of the demand and supply curves, the time horizon, and the magnitude of the supply shift.

Whether costs rise for individual packinghouses depends on if the firm was using SOPP at the time of the ban and on the adaptability of the existing capital equipment to incorporate the new substitute postharvest technology. Packinghouses currently not using SOPP do not face costs of switching to alternative technology and may benefit from the ban if retail prices for grapefruit increase or if farm-level prices for grapefruit decrease. Though, non-users of SOPP may be negatively affected if farm-level prices increase.

## Estimation of the Cost of Postharvest Losses

Data from the 1992 postharvest handlers survey of Florida grapefruit packinghouses (Love and Buzby) and data from a grapefruit model (Pana) were used to evaluate the costs of increased postharvest losses due to an SOPP ban from use on fresh Florida grapefruit. The survey found that SOPP was widely used and that if SOPP was banned, 29 out of the 40 SOPP users surveyed would switch to or rely more heavily on alternative pesticides such as thiabendazole (TBZ), chlorine, imazalil, and assorted detergents (Buzby, p. 41). Therefore, the scenario assumed in this study is that grapefruit packinghouses switch to alternative pesticides following an SOPP ban. Switching to another pesticide seems rational because non-chemical technologies used without fungicides are not as economical or effective in prolonging grapefruit storage life as when combined with pesticides. For example, grapefruit are chill sensitive which means that the use of refrigeration and other cold treatments are limited (Hardenburg *et al.*).

This study uses a mathematical programming model developed by Pana to project grapefruit production levels and prices following an SOPP ban. The study does not sum all the costs and benefits of the ban but rather focuses on one crucial aspect, postharvest losses. The mathematical programming model developed by Pana was used to project production levels and prices. In particular, Pana developed a spatial equilibrium model for the Florida grapefruit industry. The model maximizes the sum of producer and consumer surpluses subject to a demand and supply balance.

Pana augmented the standard spatial equilibrium model with a cohort population model. Essentially, the cohort model calculates annual grapefruit production by multiplying the stock of trees for each age group by each age group's average yield per tree and then sums the production in each category. Once total grapefruit production is determined, the spatial equilibrium model allocates grapefruit among fresh and processed demands in both domestic and foreign markets. The model has several features that are important in understanding the results: (1) grapefruit supply originates in Florida; (2) each season, supply is determined by the age distribution of trees, survival rates, and yields by age class; (3) there are six markets: fresh white domestic, fresh pink domestic, fresh white exports, fresh pink exports, processed exports, and domestic processed; (4) the model allocates Florida's annual grapefruit production among these six markets and obtains market clearing prices for each market and time period and; (5) there is no substitution between white and pink grapefruit in the fresh market, and both are equally suitable for processing.[5]

The model provides wholesale level prices and quantities for the six markets as well as on-tree prices and quantities for white and pink grapefruit. Marketing margins can be calculated using the on-tree and wholesale prices from a baseline scenario and an alternative scenario.

The model was modified to provide data for this study. The model was adjusted to reflect increases in postharvest losses to the grapefruit industry following an SOPP ban. In order to sell the same quantity of fresh grapefruit, more grapefruit was packed to reflect the loss. In the model, total quantities of both pink and white fresh grapefruit faced the same loss rates because a change in fungicide regime would affect both varieties similarly.

[5] The validity of this assumption is questionable. White grapefruit is generally preferred for processing; there has been expanded use of pink grapefruit for processing in recent years as the production of pink grapefruit has grown.

A one year time horizon was used to determine the short run effects of the policy change on the grapefruit industry. The one year time horizon represents a short-run price and quantity solution where some resources such as grove size are fixed. It is unlikely that a short-run solution will be stable over time (Kohls and Uhl, p. 104). Longer time horizons were not used in this study because it would require information on too many unknowns, such as whether a good alternative to SOPP will be developed in the future. The perennial nature of grapefruit complicates understanding the long run impacts of a postharvest pesticide ban.[6]

Conceptually, the cost of postharvest losses to the industry is represented by the loss of profits to the grapefruit industry. In this study, it is assumed that changes in total revenue (TR) to the industry serve as a good proxy for changes in industry profits.

The calculations were done at the wholesale level. Thus the analysis assumes that the fresh grapefruit industry is comprised of both grapefruit producers and packinghouses. The demand equations in the spatial equilibrium model are estimated for the wholesale level. Changes in revenue were computed for each of the six markets in the spatial equilibrium model and summed to obtain the total change in revenues for the U.S. grapefruit industry. Total revenue changes as quantities of grapefruit are redistributed among the six markets. A ban of SOPP would not directly affect production costs at the grove nor the costs of picking and hauling the fruit to the packinghouse. A ban of SOPP would likely increase the losses incurred between the packinghouse and the consumer. It is likely that more grapefruit would spoil as it is moved from Florida through terminal markets and supermarkets. By increasing the quantity of fresh fruit required to sell in the fresh market, the model is directly accounting for the cost of increased losses due to spoilage in the marketing system.

Table 1 presents the baseline prices, quantities, and total revenue for the six grapefruit markets. Baseline solutions for prices and quantities allocated to each of the six markets were validated against data from the 1990-91 production year and were found to be fairly accurate. When looking at the baseline quantities of grapefruit, fresh pink domestic grapefruit dominated the market for fresh U.S. grapefruit. Substantial quantities for both fresh white and pink grapefruit are exported. Of the six markets included in the model, the domestic processed market accounts for the largest utilization of Florida grapefruit. The majority of Florida grapefruit juice goes to the domestic market with a modest share allocated to exports.

**Table 1. Baseline Grapefruit Prices, Quantities and Total Revenue.[a]**

| Grapefruit Type | Quantity | Price | Total Revenue |
|---|---|---|---|
| | 1,000, 4/5 bu cartons | $/carton | $1,000 |
| Total | | | 864,415 |
| Fresh white domestic | 2,187 | 6.67 | 14,590 |
| Fresh white export | 10,418 | 10.77 | 112,205 |
| Fresh pink domestic | 20,501 | 7.26 | 148,841 |
| Fresh pink export | 11,765 | 10.06 | 118,351 |
| Processed domestic | 94,228[b] | 4.39[c] | 413,662 |
| Processed export | 23,361[b] | 2.43[c] | 56,766 |

[a] Price and quantity in each market were validated against the 1990-91 season data.
[b] Thousands of single strength equivalent (SSE) gallons for processed grapefruit.
[c] Dollars per SSE gallon. Domestic price is retail and processed price is FOB.

The change in total revenue for the grapefruit industry for each of the six grapefruit markets and three postharvest loss scenarios is shown in Table 2. For the four fresh grapefruit categories, prices increased and the quantities sold decreased after each loss scenario. In all three scenarios, total revenue decreased for three of the four fresh grapefruit categories because the increased price could not compensate for lost revenue due to decreased quantity. The exception was for fresh pink domestic grapefruit that had an increase in total revenue in all three scenarios. For the range of simulated prices and quantities of fresh pink domestic grapefruit, demand is inelastic. Thus as the quantity of fresh pink grapefruit to the domestic market is reduced, total revenues increase.

[6] Florida Agricultural Statistics Service records grapefruit tree production for trees three years old and older with the oldest category of trees being 24 years old and older. Generally, as trees age, their annual average yield increases.

**Table 2. Total Revenue Changes under Different Postharvest Loss Rate Scenarios (in dollars).[a]**

| Grapefruit Type | 2 Percent Loss Scenario | 5 Percent Loss Scenario | 10 Percent Loss Scenario |
|---|---|---|---|
| Total | -2,077,050 | -5,521,280 | -12,119,820 |
| Fresh white domestic | -1,009,610 | -2,531,020 | -5,105,040 |
| Fresh white export | -798,900 | -1,970,170 | -4,038,050 |
| Fresh pink domestic | 1,382,300 | 3,529,680 | 6,208,140 |
| Fresh pink export | -1,576,740 | -3,848,310 | -7,989,670 |
| Processed domestic | -163,260 | -826,480 | -1,499,060 |
| Processed export | 89,200 | 125,020 | 303,860 |

[a]The change in total revenue represents the change in dollars (rounded) between the baseline and the given loss scenario.

**Table 3. Potential Impacts on Domestic and Export Total Revenue (TR) Following a Postharvest Pesticide Ban from Use on Fresh Grapefruit (in dollars, rounded).**

| | Baseline Total Revenue | Change in TR after 2% Loss | Change in TR after 5% Loss | Change in TR after 10% Loss |
|---|---|---|---|---|
| Total | 864,415,050 | -2,077,050 | -5,521,280 | -12,119,820 |
| Domestic | 577,092,840 | 209,400 | 172,170 | -395,970 |
| Exports | 287,322,210 | -2,286,450 | -5,693,450 | -11,723,850 |

For both the processed domestic and processed export grapefruit markets, prices decreased and quantities sold increased. Total revenue (TR) for processed domestic grapefruit decreased while total revenue for processed exports increased. This result can be explained by the fact that demand is elastic in the domestic market and inelastic in the export market.

The total cost of the postharvest losses to the grapefruit industry ranged from two to twelve million dollars depending on the loss scenario. The twelve million dollar loss represents over an one percent decrease in total revenue to the grapefruit industry suggesting that the grapefruit industry has a vested interest in whether SOPP is banned.

Table 3 presents the projected impact of the ban on total revenue for the domestic and export components of the grapefruit industry. Those packinghouses geared more toward exports are more likely to be negatively affected by the ban than those that focus on domestic sales. For the three loss scenarios, total revenue from grapefruit exports decreased from the baseline by 2.3 to 11.7 million dollars. Total revenue from domestic sales increased for the two and five percent loss scenarios and decreased by approximately $400,000 for the ten percent loss scenario.

The change in total revenue for each of the four fresh grapefruit categories depended on the relative change in prices and quantities sold. Results show that of the four fresh grapefruit categories, pink grapefruit exports were the most affected category in terms of lost total revenue. For each scenario, there was also a loss in total revenue for white grapefruit sold in both the fresh domestic and export markets. However, the pink domestic category showed an increase in total revenue for all three scenarios.

A long run analysis is complicated by: (1) the eventual rate of pathogen resistance, (2) the possibility of developing an alternative pesticide to replace the banned pesticide in terms of effectiveness and cost, and (3) the perennial nature of grapefruit. The results here could be used as a proxy for the annual costs if there were three main assumptions: (1) the increase in postharvest losses to the fresh grapefruit industry was assumed to reach a certain level and then stabilize, (2) if no new substitute pesticide was developed, and (3) if production is assumed to be constant. The third assumption is particularly questionable because the model predicted that there may be an oversupply of fresh grapefruit in the future, when considering the number and age distribution of planted grapefruit trees. This potential oversupply of fresh grapefruit may suggest that the predicted long run increase in grapefruit production can, to some extent, offset the impacts of the loss scenarios. It is possible that in the long run, the annual costs of the ban to the grapefruit industry may actually be smaller than in the short run.

## Conclusion

The importance of export markets for U.S. grapefruit suggested that a simple supply equation for domestic grapefruit would not fulfill the needs of this study. To the authors' knowledge, Pana's model is the most thorough representation of the U.S. grapefruit market. The model found that the cost of postharvest losses to the U.S. grapefruit industry was sensitive to the loss rate following a ban of a postharvest pesticide used in fresh grapefruit packinghouses. The study found that those grapefruit packinghouses focusing primarily on export sales will likely be more affected than those focusing on domestic sales.

The model's results showed that: (1) the on-tree prices for white grapefruit decreased in all three scenarios, (2) the on-tree price for pink grapefruit remained fairly stable for all three scenarios, and (3) the wholesale prices increased in all four fresh grapefruit markets. Therefore, the marketing margin increases for fresh grapefruit because of both a decrease in the farm price and an increase in wholesale prices. Hence, some grapefruit growers may be negatively affected by the ban. Quantities sold of fresh pink and white grapefruit in both domestic and export markets decreased. Despite the fact that grapefruit consumers would likely pay higher prices for fresh grapefruit (*i.e.*, loss in CS), they may be relatively better off if their food safety risks were significantly reduced. Although the focus here was on an SOPP ban, the results could be applied to any ban of a postharvest grapefruit pesticide that led to two, five, and ten percent postharvest losses to the grapefruit industry. The model could be used to analyze the impacts of other levels of postharvest losses.

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