University of Idaho
College of Agricultural and Life Sciences

GENETICALLY MODIFIED (GM) FOODS: CONSUMERS' AND PRODUCERS' PERCEPTIONS AND THE ECONOMIC – ENVIRONMENTAL BENEFITS

Prepared by:
A.A. Araji and J. Guenthner

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Department of Agricultural Economics and Rural Sociology
College of Agricultural and Life Sciences
University of Idaho
Moscow, Idaho 83844-2334

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By

Araji, A.A.
Professor
Department of Agricultural Economics
University of Idaho
Moscow, Idaho 83844-2334
USA
jaraji@uidaho.edu

and

Guenthner, J.F.
Professor
Department of Agricultural Economics
University of Idaho
Moscow, Idaho 83844-2334
USA
jguenthner@uidaho.edu

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ABSTRACT

Globally, there is growing interest in GM food production and consumption. While the technology exists to produce many types of GM foods, mass production and consumption ultimately depend on consumer acceptance. In this paper, international studies of consumers' and producers' attitudes toward GM foods are reviewed. Experimental data on the usage of GM potatoes is used in an ex-ante model with a probability distribution to examine the economic and environmental impacts of GM potato usage in five major regions of the world. Results indicate that worldwide, growers/producers are much more receptive to the use of GM food products. Data analysis demonstrates the economic and environmental benefits of GM potato adoption and how these benefits can affect consumer attitudes. The paper concludes with suggestions for future studies of consumers' attitudes toward GM foods.

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INTRODUCTION

Social scientists have long been intrigued with the study of the attitude – behavior relationship (Allport, 1935; McGuire, 1985; Ajzen and Fishbein, 1980) and the construction of attitudes and attitude change (Petty and Cacioppo, 1986; Petty, Wegener, and Fabrigar, 1997). Most researchers also examine the effects of socio-demographic factors such as sex, age, race, and national origin on attitudinal related issues. While part of this paper focuses on attitudes toward GM food products, relevant studies are not found within the area of social sciences. As a result, social science attitudinal theories are not utilized in the research. We will suggest at the end of this paper that employment of social science based attitudinal theories and research would be beneficial in future studies of consumers' receptivity to GM foods.

Purpose

The purpose of this paper is three-fold. First, studies are reviewed in order to ascertain factors that influence producers' and consumers' attitudes and behaviors related to GM foods. Second, a case study is presented to examine the economic and environmental impacts of GM potato usage in five major regions of the world. The potato was chosen because, along with corn, rice, and wheat, it is one of the four major food crops in the world. Since potatoes produce more calories and more protein per hectare than the other three crops, it is becoming an increasingly important commodity for fighting hunger in developing countries (Niederhauser, 1993). Third, information from the review of research on consumers' and producers' attitudes toward GM foods and findings from the case study of the GM potato are discussed as they relate to diffusion of GM food products worldwide.

RELEVANT LITERATURE

Guenthner (2001) argues that agriculture growers have accepted GM potatoes, and we have now reached a stage where consumer acceptance is important to moving adoption of these products forward. He notes that there are two broad forces that act to influence consumer attitudes toward GM products in general. Citing Naisbett's (1999) book, *High Tech/ High Touch*, he identifies these forces as polar groups who either "hate technology" or "idolize technology". The former is less receptive to GM foods because these foods are a form of technology.

Guenthner (2001) also cites Toffler (1970, 1980, 1990), who has written extensively about the impact of technology on society. In his book, *Future Shock* (1970), Toffler explains that changes in society are not chaotic and unpredictable, but result from driving forces in society that consist of 3 interrelated stages. First, he says a creative, feasible idea emerges. This is followed by a practical application phase, and finally the practical application of the idea is diffused through society. With respect to GM foods, we have entered the third stage--the attempt to diffuse the use of GM foods throughout the world.

In his book, *The Third Wave* (1980), Toffler wrote about techno-rebels or anti-technology activists. According to Guenthner (2001), Toffler says that for 300 years the driving forces for societal acceptance of technology have been economic gain and military power. Today, the techno-rebels want to be the gatekeepers who determine which new technologies pass or fail ecological and social tests. Guenthner (2001) asserts that technologies, which techno-rebels do not oppose, such as electronic technology, will be more quickly accepted by society than those, which these groups oppose, such as food biotechnology.

Issacs (2001) reports that resistance to GM foods and other forms of biotechnology come from both governmental and citizen groups. Further, he notes that acceptance or rejection of products from these new forms of technology are tied to possible effects on human health, the environment, and the welfare and structure of agribusiness. Supporters of biotechnology identify benefits and lack of evidence of negative effects, while detractors focus on the lack of research into the long-term human health or ecosystem-wide effects of introducing new biological forms into widespread usage, i.e., societal diffusion.

Isaacs (2001) designed a study to examine consumers' attitudes toward GM foods and the environment and to determine whether these attitudes would vary by socio demographic characteristics such as sex, age, and race. Returns from a mail-out survey to Louisiana households were divided into two groups, those "willing" or unwilling" to purchase GM foods. As there was a sizable number of findings from this study, we review only those that are most related to the present study.

A number of Isaacs' (2001) findings showed no statistically significant differences between the "Willing" and "Unwilling" groups. Both wanted mandatory labeling for GM foods, appeared to trust the U.S. government to insure food safety in the future, but placed less confidence in global producers' food safety concerns.

There were a number of areas where these two groups did differ significantly. The "Willing" as compared to the "Unwilling" group was more in agreement with the idea that "computer technology is an important factor in the improvement of the quality of life. In contrast, the "Unwilling" group had a more pro-environmental world-view than the "Willing" group. With respect to health concerns, the "Willing" group was significantly more agreeable with a statement about GM foods being safe to eat.

The socioeconomic variables of education, race, age, household size, number of minors in household, and income showed no significant differences between the two groups. With respect to sex, however, women as compared to men were significantly more likely to fall into the "Unwilling" group.

Wolf and Kari (2001) conducted personal interviews with 1137 randomly selected food shoppers in San Luis Obispo County, California over four time periods between 1999--2001. Like Isaacs (2001), they found that respondents who believed that the government had insured food safety in the past were more willing to accept GM foods as compared to those with opposite beliefs. They found that those who placed greater confidence in the government, and were more willing to accept GM foods tended to be single, have lower household incomes and less likely to have dual-income households.

Further, they found that there was a difference in familiarity with GM foods over the four time periods. During the third time period there was an increase in familiarity, but there was also a change in consumers' attitudes toward mandatory labeling and a decline in consumers' positive attitudes toward GM foods. Wolf and Kari (2001) attribute attitudinal changes during this time period to the recall of Star Link corn (a GM product). They assume that consumers became more familiar with GM products due to the media coverage of the recall of 2.5 million boxes of Taco Bell brand taco shells produced by Kraft and a recall of 300 varieties of tacos, tortillas, tostadas and chips made by Mission. This finding appears to represent what ____________( ) calls a "rubber band" effect as attitudinal familiarity and interest in purchasing GM products snapped back, in phase 4, to previous levels. The importance of mandatory labeling for GM foods, however, tended to increase over the four time periods.

Respondents in the third and fourth phases of Wolf and Kari's (2001) study indicated that the most important reason for buying GM products was to improve nutrition. This was followed by modifying food to kill pests, thus allowing farmers to use fewer pesticides. Modifying foods to improve taste and help plants withstand weed killers were of lesser importance to consumers as reasons to purchase GM food products.

Huffman, Shogren, Rousu and Tegene (2001) used a laboratory auction research design to examine consumers' attitudes toward GM foods. Study participants were recruited from several large cities in the Midwest. Results from this study showed that consumers' willingness to pay for a food product decreased when they were certain the product was genetically modified. They also found that socio demographic variables such as sex and income did not significantly influence consumers' attitudes.

The somewhat skeptical view toward GM foods by consumers in the U.S. appears to be even stronger in other countries. Wolf, Donnell and Yount (2001) compared Unites States and Irish consumers' attitudes toward GM foods and found that among those familiar with these products Irish consumers held more negative attitudes.

Similarly, Adele, Teresa, Valeria, and Fabio (2001) found Italians quite opposed to GM food usage.

Bonny (2001) reports that there is a strong anti-GM food movement in Europe and suggests that this influences consumers' attitudes in the negative direction. She notes that this is particularly evident in France.

Worldwide, producers' attitudes and behaviors toward GM foods are almost opposite that of consumers. As Fulponi (2001) points out, there has been widespread adoption of GM products (e.g. seeds) across the globe. The reason for this activity has been tied to higher crop yields and cost reductions (e.g. need for pesticides).

The rate at which producers adopt GM food products, however, is tied to politics and social interest groups as well as consumer acceptance. Governments in countries such as China (see Huang, Hu, Pray, Qiao, and Rozelle, 2001), Brazil (see Portugal, Sampaio, Contini, and Avila 2001), and the Unites States have generally been supportive of GM foods. This facilitates growers/producers use. In contrast, governments in countries such as Canada and France have been opposed to many GM food products, hence slowing the rate of its use by growers/producers.

With respect to special interest groups, Greenpeace, Friends of Earth, organic food growers and chemical producers have been strongly opposed to GM food products. These groups have launched vigorous media campaigns aimed at scaring consumers about GM products. Avery, Forrer, Carlisle and Forrer (2001), for example, note that polling and market data suggest that food scares tend to be the most important factor in organic food sales growth in the United States and Europe.

As previously noted, Guenthner (2001) asserts that anti-GM food techno-rebels (such as those described above) will lengthen the time period for consumer acceptance of GM food products. Guenthner's (2001) assertion seems especially probable if, as some speculate, strange bedfellows begin to forge alliances in opposition to GM foods. For example, it is known that chemical producers have a vested interest in the non-production of GM foods because these foods reduce the need for chemicals such as pesticides. Greenpeace is also against GM products, citing environmental concerns. It is interesting that Greenpeace has accepted money from chemical producers, a group one would expect them (Greenpeace) to oppose for environmental reasons. The motives for this particular alliance become even more questionable considering that most research indicates GM foods are friendly rather than harmful to the environment. In contrast, there is much evidence to demonstrate harm to human health and the environment by chemicals such as pesticides.

As most consumers around the world tend to be unfamiliar with GM foods and the short and long term effects of their usage, many will be fearful of these products as they get mixed messages from supporters and opponents of GM products. Of course, if there is no demand by consumers for GM products, the incentives to use/grow products are reduced. As an example, Guenther (2001) notes that during the 1990s NatureMark, a Monsanto subsidiary began marketing GM potatoes that protected plants from Colorado Potato Beetle. Potato producers adopted the NatureMark varieties to reduce costs and environmental risks of pesticide use. NatureMark's share of the US/Canada seed potato market increased from one percent in 1995 to three percent in 1999. The next year the bottom dropped out of the GM potato market and NatureMark's share plummeted to 0.1%.

Although growers had accepted GM potatoes, consumer fears and resistance blocked development in the frozen fry sector, the largest part of the North American potato market. When anti-GM organizations expressed concern about GM potatoes, quick service restaurants decided to no longer use the product. The anti-GM message from consumer activists traveled the marketing chain from restaurant to processor to commercial grower to seed grower to NatureMark. During the spring of 2001, Monsanto decided it would no longer market GM seed potatoes and would instead focus its GM efforts on large-acreage crops.

CURRENT STATE OF ATTITUDES TOWARD GM FOODS

A review of lengthy abstracts from papers presented at the 5th *International Biotechnology Science and Modern Agriculture: A New Industry at the Dawn of the Century* meeting in Ravello, Italy (2001), leads to several conclusions about the status of consumers' and producers' attitudes toward GM foods.

1) Worldwide, food growers/producers are more accepting of GM foods than are consumers as evidenced by the large numbers of farmers/producers engaged in planting/producing GM products. Their acceptance or rejection appears tied largely to economic and environmental benefits.

2) Unlike growers/producers, consumers are in general, unfriendly toward GM foods when alternatives are available. The strength of unfriendliness varies from one part of the world to the other.

3) Consumer's willingness to buy/use GM products appears to be influenced by familiarity (information) with products, events involving GM foods (e.g., the Star Link corn recall), strength of influence of proponents and opponents of GM foods, degree of trust in food regulating agencies, and fear of the unknown as this relates to the short and long term effects of GM foods on the environment and health of societal members.

4) The effects of socio-demographic variables on attitudes toward GM foods are presently unclear, as results vary from one study to another. At the present time, females as compared to males seem to be less receptive to the use of GM food products, and those who are single and have lower incomes are friendlier toward these products than are their counterparts.

CASE STUDY OF GM POTATO

In this section of the paper we explore the economic and environmental impacts of development and adoption of the GM potato. As noted in the introduction to the paper, we chose this GM food product because of its increasing importance in the war against hunger in developing countries. Potato, along with maize, rice and wheat, is one of the four major food crops in the world. Since potatoes produce more calories and more protein per hectare than the other three major crops, it is becoming an increasingly important commodity for fighting hunger in developing countries (Niederhauser, 1993). Researchers at the International Potato Center in Peru predict that developing countries consumption of potato use will more than double by 2020. Potatoes are also popular in developed countries, with per capita consumption exceeding 100 kg per year in parts of Europe.

Potato production is risky and input intensive. It is among the highest user of synthetic pesticides in agriculture. An estimated 120 pounds of synthetic pesticides per acre are used annually to control pests on potatoes in the United States (U.S.). Growers and consumers are interested in potato production practices that use fewer pesticides, are environmentally friendly and produce ample supplies of potatoes at low costs. Planting potatoes that have been genetically modified to resist pests is a practice that offers hope to growers and consumers around the world.

The first genetically modified potato that was developed and approved for commercial markets is the variety known as New Leaf Russet Burbank that is resistant to Colorado Potato Beetle and Leafroll virus (PLRV). Public and private researcher institutions are genetically modifying potatoes to control potato late blight. The disease has devastated potato production for the last century and a half. Niederhauser (1993) claims it is the most important potato disease in the world. Because of the variability and virulence of the fungus *(Phytophthora infestans)* that causes late blight, durable resistance to the disease is difficult to incorporate into commercial potato cultivars with traditional breeding practices. In recent years, growers have effectively controlled late blight with fungicides, but at a high cost. Blight control costs in some areas in the U.S. exceed 10 percent of total production costs (Stevenson, 1993).

Limited research has been conducted on the economic impact of potato late blight. Knutson et al. (1993) concluded that Maine potato yields would decline 25 percent if fungicide applications were cut in half and that late blight would wipe out the entire Maine potato industry if fungicides were unavailable. More recently, Guenthner et al, (1999) found that late blight was the most serious disease problem in the US potato industry and that the loss of chlorothalonil, a late blight treatment, would cost the industry $80 million per year.

The economic and environmental impacts of genetically modified potatoes that are immune to late blight are analyzed in the following sections. Although the impacts of late blight go beyond the farm, we did not estimate impacts on other enterprises or consumers.

Data

Data on increase in yield, reduction in storage loss, and reduction in fungicide use, attributed to the development and adoption of the genetically modified potato variety that is resistant to late blight, were obtained from a survey of potato scientists in the U.S. The Delphi technique was used to obtain expert opinion from thirteen University scientists who are knowledgeable about potato late blight (Guenthner, Michael and Nolte, 2001). Delphi surveys consist of two or more rounds. Researchers provide participants with group averages and their own answers to previous-round questions. With this new information they ask respondents to again answer the questions, leading to a group consensus. Rasp (1973) found that anonymous responses were more likely to be objective. By not being in the same room, participants are more confident in contributing their opinion and do not feel pressured by a dominant group leader (Linstone & Turoff, 1975).

Respondents were chosen based on their knowledge of potato late blight, the fungicides used to control it and their willingness to participate. Electronic mail was selected as the method of questionnaire distribution for the participants' and facilitators' convenience. The questionnaire asked participants to estimate changes in yield, storage loss, and fungicide use if the late blight's potato resistance variety is adopted. The experts were asked to answer the questions from the perspective of the impact on the entire potato industry rather than the geographical area in which they work.

Average responses for second-round responses were quite close to first round responses. For yield loss and metiram use the average responses were identical. The range of answers narrowed for all questions between the two rounds. Relatively wider ranges persisted for some fungicides, suggesting differences in local conditions. Although respondents were asked to consider the entire US potato industry, some indicated that their answers were influenced by local conditions. Since the average answers remained stable, the survey was concluded after two rounds.

Results of the Delphi survey show that adoption of the genetically modified late-blight-resistant potato variety would increase yield by an estimated 5 percent and reduce present storage loss of the potatoes requiring storage by 17 percent. Wiese et al. (1999) shows that blight control improves quality by reducing the percent of potato rejection and price discount. The quality improvement will reflect in a 3.2 percent increase in the value of sale.

The Delphi survey results show that adoption of the genetically modified potato variety will significantly reduce fungicide application resulting in 3.98 percent reduction in the baseline line active toxic ingredients, depending on the type of fungicides (Table 1). Estimated fungicides cost to control late blight in the U.S. is $77.1 million annually. It is based on survey results and United States Department of Agriculture (USDA) data. For the first eight fungicides shown in Table 1, USDA chemical use surveys (1990-98) and USDA annual price summaries (1990-98) were used to calculate baseline values. Since the last three fungicides were not included in the USDA sources, use data came from the Delphi survey and price data from the University of Idaho (Patterson, 1998). USDA chemical use surveys after 1998 were deemed too limited in scope regarding potatoes to provide updated data for this study.

Data on area planted, yield, production, and storage by potato producing regions of the world is shown in Table 2. Critical assumptions regarding the timetable of late-blight resistant potato development and adoption rates were based on a technology adoption rate paper by Guenthner (2001). The pattern of adoption is typical of a product life cycle consisting of four stages: introduction, growth, maturity and decline. The time horizon used in this analysis is to year 2025 when the market has reached maturity but not decline (Table 3).

Evaluation Methods

The contribution of research to productivity growth in agriculture is well documented for the U.S. and other countries. Returns to investments in agricultural research have been estimated for most major commodities with the exception of the potato. The estimated rate of return ranges from –47.5 percent to investment in wheat research in Bolivia, to 700 percent to investment in hybrid corn research in the U.S. (Arndt, Dalymple, and Ruttan, 1977; Araji, 1980; Norton and Davis, 1981; and Echeverria, 1990). The two approaches used to evaluate the benefit of investment in agricultural research are: (1) *ex-post* and (2) *ex-ante*. Several different methods are used within each approach. No one method is superior or considered standard in all situations (Araji, 1980; Norton and Davis, 1981; Alston, Norton and Pardey, 1995).

The *ex-post* approach evaluates past research performance. The two principle methods used in *ex-post* research evaluation are: (1) production function, and (2) index-number. The production function method estimates the contribution of research in term of its impact on improved production efficiency, and it estimates marginal rates of return. The production function method requires time series data, cross sectional data, or a combination of the two. Several mathematical models are used to estimate the production function, depending on the nature of the problem and the data. Sim and Araji (1981) used a Hybrid Production function to evaluate return to investments in wheat variatal development and management practice research in the U.S. Araji (1989) used the Cobb-Douglas production function to evaluate the benefit of investments to wheat research in the western United States. Araji, White, and Guenthner (1995) used the supply response model to analyze the spillover effects of potato research in six U.S. potato-producing regions. Araji and White (1996) used Vector Autoregressions model, with time series and cross sectional data, to evaluate the impact of agricultural research on U.S. exports of agricultural products.

The index-number method estimates consumer and producer surpluses; it requires a supply shifter, price and quantity data before and after the supply shift, an elasticity of demand coefficient, and an elasticity of supply coefficient. This method estimates average rates of return. Araji and Gardner (1981) used the index-number method to estimate the benefit of investment in the Dairy Herd Improvement Extension Program to producers and consumers of milk and milk products. Araji and White (1990) used the index-number method to estimate the benefit of research to U.S. wheat producers and domestic and international consumers of U.S.

wheat. Also, Araji and White (1991) used the index-number method to assess the multi-market effects of technological changes and benefit of research to consumers and producers of beef and pork in the U.S.

The *ex-ante* approach evaluates future research performance, and projects flow of future benefits and cost expected from the development and adoption of research results. The four principle methods used in the *ex-ante* approach are: (1) benefit-cost method, which estimates rate of return, (2) scoring method, ranks research activities, (3) simulation method, and (4) mathematical programming method, to select an optimal mix of research activities. The benefit-cost method is based on probability distribution of research success and research adoption. The three other methods are based on a preference function.

The benefit-cost is the most widely used *ex-ante* method. Fishel (1971), based on a survey of scientists at the Minnesota agricultural experiment station, estimated probability distributions of costs and values of proposed research projects and projected rate of return to investment in agricultural research. Easter and Norton (1977) used scientist's estimates of yield, expected adoption rates, and costs of various research projects to estimate rate of return to proposed research investments in soybeans and corn production. Araji, Sim, and Gardner (1978) developed probability distribution for research success and rate of adoption and estimated rates of return to research and extension investments in nine major commodities in the western United States. Araji (1981) used a similar *ex-ante* approach to estimate return to investment in integrated pest management for 20 major agricultural commodities in the U.S. Araji (1988) developed probability distribution for research success and rate of adoption and estimated rates of return to investments in maintenance, applied, and basic research in the Idaho Agricultural

Experiment Station. Araji (1990) applied an *ex-ante* benefit-cost approach to analyze the focus, function, and the productivity of the state agricultural experiment station system.

The Economic Model

Given the nature of the problem and the projected flow of future benefits in this study, *ex-ante* approach, is the only appropriate evaluation procedure. An *ex-ante* benefit-cost model with probability distribution was developed to estimate annual gross benefits and project present value of future flow of annual gross benefits resulting from the development and adoption of the genetically modified potato variety. The model is outlined in a set of equations in this section.

The annual gross benefit is estimated using Equation 1.

$$\sum_{j=1}^{N} \beta_{jt} = \sum_{j=1}^{N} A_{jo} \left\{ \Delta P_{jt} V_{jt} + \left(V_{jt} - V_{jo} \right) \right\} \qquad (1)$$

Where:

β_{jt} = the benefit accruing to the genetically modified potato variety in the j^{th} region in year t

A_{jo} = the expected total production or acreage affected by the adoption of the genetically modified potato variety in the j^{th} region in the base year

j = 1-N regions in the world

ΔP_{jt} = the expected percentage change in net productivity, quality, production cost and/or loss of potatoes due to the adoption of the genetically modified variety in the j^{th} region in year t. Net productivity change is defined as net increase in production in tons per hectare; quality change is defined as net reduction in rejection and price discount; production cost is defined as net decrease in pesticide cost, and loss is defined as net decrease in storage loss.

V_{jt} = the expected price received per tons of potato in the j^{th} region in year t, and

$$V_{jt} = \left\{ V_{jo} + V_{jo} \left(f \Delta P_{jt} \right) \right\}$$

where f is the flexibility ration and V_{jo} is the price per unit of potato in the base year. The flexibility ratio is the inverse of price elasticity and it gives the percentage change in price associated with 1 percent change in quantity. Guenthner (1987) calculated a flexibility ratio of 0.83 for potato. Haung (1991) calculated flexibility ratios for several food products and shows a flexibility ratio of -0.7053 for potato.

β_j is the benefit that accrues to producers as a result of adopting the genetically modified potato variety. The outcome β_j is probabilistic because it depends on the probability of successful development and adoption of the variety, $P(A \cap S)$. The expected value of β_j is defined as:

$$\sum_{j=1}^{N} E(\beta_j) = \sum_{j=1}^{N} \sum_{t=0}^{T} \beta_{jt} P(A \cap S) \qquad (2)$$

The present value of the expected flow of future benefits from the adoption of the j[th] variety is calculated by "discounting" the right-hand side of Equation 2 as shown in Equation 3 below.

$$\sum_{j=1}^{N} PE(\beta_j) = \sum_{j=1}^{N} \sum_{t=0}^{T} \frac{\beta_{jt} \{P(A \cap S)\}}{(1+r)^t} \qquad (3)$$

Where:

$PE(\beta_j)$ = present value of the expected flow of benefit in the j[th] region

r = the social discount rate

T = number of years for which the genetically modified potato variety affects production, quality, and/or cost

The probability of research success is estimated at 100 percent. Based on the Delphi survey results and the paper by Guenthner (2001), the probability of adoption of the genetically modified potato variety is projected for 25 years and is shown in Table 3. A 6 percent social discount rate was used to discount the flow of future benefits; this is the risk free rate on government bonds recommended by several federal agencies in the U.S. A 25-year productive life expectancy of the modified variety is estimated in consultation with the potato researchers, extension specialists, and potato farmers. It is assumed that a better technology will likely be available after 25 years. Since the costs of development of the genetically modified potato incurred by public and private research institutions were not made available to the authors, the present value of flow of costs are not analyzed in this study.

Environmental model

The environmental benefit attributed to late blight resistance is the elimination of fungicide sprays. The amount of active toxic materials expected to be eliminated from the environment in each region of the world is estimated by the following equation:

$$ATM_{ji} = \{(AC_j)\ (I_{nj})\ (A_{dj})\ (P_{jt})\ (GL_{ji})\ (Tx_i)\ (P/GL)_i\}\{P(A)\} \qquad (4)$$

Where:

ATM_{ji} = active toxic material in i^{th} late-blight fungicide used in the j^{th} region

AC_j = total hectares of potatoes in the j^{th} region

I_{nj} = percentage of plantings currently susceptible to late-blight in the j^{th} region (100 %)

A_{dj} = percent of I_{nj} plantings that require fungicide spray used to control late blight in the j^{th} region (100%)

P_{ji} = percentage of A_{dj} using the i^{th} late-blight fungicides in the j^{th} region (100%)

GL_{jt} = fungicide application rates per hectare in the j^{th} region in year t

Tx_i = percent of active toxic materials in each fungicide

Gross Benefit

Annual gross benefits attributed to the development and adoptions of the genetically modified potatoes are shown in Table 4 for regions of the world. Annual gross benefits are calculated as the contribution of the genetically modified variety to increase in yield, reduce storage loss, improve quality, and reduce fungicide cost. For all regions of the world, it was estimated that the adoption of the genetically modified potato variety will increase yield by 5 percent, reduce storage loss by 1.241 percent and improve revenue by 3.2 percent due to reduction in potato rejection and price discount.

It is estimated that the adoption of the genetically modified potato variety will reduce fungicides cost by $136 per hectare for Europe, North and Central America, and the Oceania regions of the world. For Africa, Asia, and South America, the reduction in fungicides cost is estimated at $68 per hectare as these regions use less fungicides for late blight control.

The estimated annual gross benefits worldwide attributed to the development and adoption of the genetically modified potato exceeds $4.3 billion. Europe will have the highest annual gross benefit of $1.936 billion, followed by Asia with $1.587 and North and Central America with $0.369 billion. The United States accounts for 90 percent of the annual gross benefit of North and Central America.

Present Value

The present value of future flow of annual gross benefit is projected over 25 years using 6 percent social discount rate and the probability of adoption shown in Table 3. The present value attributed to the development and adoption of the genetically modified potato is estimated at over $27 billion to potato producers in the world at an annual value of $1.082 billion (Table 5). European producers of potato will benefit the most from adopting the genetically modified potato. The present value of annual gross benefit to European producers of potato over 25 years is estimated at over $12.196 billion at an annual value of over $487.84 million. Asian producers of potato will benefit by over $1.225 billion over 25 years of adoption at an annual rate of over $49 million. United States producers of potatoes will benefit by a total $2.117 billion at an annual benefit of over $84.696 million. In general, the development and adoption of the genetically modified potato will benefit all potato producing regions of the world.

Environmental Benefit

The development and adoption of the genetically modified potato will eliminate significant quantities of active toxic ingredients from the environment. An estimated 25,604,958 kg of active toxic ingredients will be eliminated annually from the European environment. North and Central America's environment will have 2,275,268 kg less active toxic ingredients annually. Active toxic synthetic chemicals in the Oceanic environment will be reduced by 150,172 annually. Asian potato producing countries will eliminate 10,276,144 kg of active toxic synthetic ingredients from contaminating their environment annually. South American potato producing countries will eliminate 1,507,767 kg of active toxic ingredients from their environments annually. In general, potato-producing countries of the world are expected to eliminate over 37,520,216 kg of active toxic synthetic ingredients from the world's environment annually by adopting the genetically modified potato variety (Table 6).

Chemical costs of late blight control represent only about one-quarter the total estimated cost of this disease to the grower. In spite of the availability of effective fungicides, late blight still causes serious losses in production, storage and quality. The absence of late blight would reduce, but not eliminate, fungicide use in potato production. Metalaxyl use would decrease by only 3% because growers apply it to control pink rot (*Phytophthera erythroseptica*) and pythium leak (*Pythium spp.*). Growers would also continue to use other fungicides, such as metiram, triphenyltin hydroxide, cholorthalonil and copper hydroxide to control early blight (*Alternaria solani*).

DISCUSSION

The first section of this paper focused largely on consumers' and producers' attitudes toward GM foods. Overall, studies from around the world suggest that producers as compared to consumers are much more receptive toward using and producing GM products.

The case study on GM potatoes shows that adoption of this food will have a significant economic benefit to producers in the areas of yield increase, reduction in storage loss, improved quality, and a reduction in fungicide costs. Additionally, the environmental benefits from a reduction in active toxic ingredients is substantial for all the areas of the world studied – Africa, Asia, Europe, North and Central America, Oceania, and South America. Interestingly, the greatest economic and environmental advantages of producing GM foods will be experienced by Europe, the world region in which according to Bonny (2001), consumers are most resistant. Many of the anti-biotechnology attitudes appear to be fueled by environmentally concerned citizen groups (e.g., Greenpeace and Friends of Earth), some governments (e.g. Canada) and special interest groups (e.g., the organic food industry). Perhaps information such as that presented in our case study of GM potatoes will ease the concerns of some GM food opponents. On the other hand, this information can be used by pro-GM food producers to weaken the attacks of opposition groups.

What is quite clear from the review of literature on producers' and consumers' attitudes on the GM food products is that information, such as that presented in our case study, will do more to increase confidence and support among producers as compared to consumers.

Consumers are not concerned with the economic advantages producers will experience by using GM as compared to non-GM products, whereas this is of great concern to farmers/producers. Consumers are, however, concerned with the reduction in the use of pesticides that can harm people's health as well as the environment. As the literature review suggested, health and environmental issues are two of the factors that have the greatest influence on consumers' receptivity to GM products. Olubobokun, Phillips and Hobbs (2001) report, for example, that the majority of consumers in most markets are not impressed by GM traits that simply change agronomic practices and increase yields. What they are interested in are traits that reduce the use of chemicals, improve nutrition and increase shelf life.

Most consumers across North America, Europe and Australia acknowledge that they have a low awareness and understanding about GM foods (Olubobokun, Phillips & Hobbs). This lack of knowledge fuels GM food scares, which according to Forrer, Carlisle, and Forrer (2001), are among the strongest factors that discourage consumers from considering the use of GM foods.

Given consumers' general lack of knowledge about GM food products as well as their negative attitudes and fears toward usage, it appears that the adoption of these products will depend on well designed educational programs in which consumers have confidence. A starting point for these programs could be a paper by Olubobokun, Phillips, and Hobbs (2001) that reviews discrete choice models used to assess consumers' perceptions of GM products. In this review, they note the advantages and disadvantages of the various choice models currently used to design consumer preference studies.

Further, in our review of the many studies that sought to measure consumers' attitudes toward GM foods, we found none that utilized the extensive body of theoretical literature from the area of social psychology that focuses on the formation of attitudes, attitude change, the attitude-behavior relationship, consumer psychology, and persuasive communication. We believe that utilization of this body of literature could vastly improve the design of future studies of consumers' attitudes toward GM foods.

CONCLUSION

In conclusion, this paper indicates that worldwide, producers, as compared to consumers, are much more receptive to the use of GM products. This is related to a complex interaction of factors that include consumers' lack of knowledge about GM products, fears, and conflicting information disseminated by GM food opponents and proponents. While most scientific information seems to support the use and production of GM foods, particularly for developing countries, it is clear that most consumers are not yet ready to accept these products. This is especially the case if alternative familiar, trusted products are available. The rate of consumers' acceptance will depend on the type of educational programs developed to educate the consumer. Hence, we believe the design of future consumer preference studies related to GM food products could be enhanced by using the extensive body of attitudinal theories and research found in the social sciences, particularly social psychology, and a review of Olubobokun, Philips and Hobbs' (2001) paper on discrete models that assess consumers' perceptions of GM products.

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Table 1: Fungicide baseline use of active toxic ingredient and percent reduction in use due to the adoption of genetically modified potato variety, U.S.

Fungicide:	BaselineUse (1000 kg)	Percent Reduction (percent)	Total Reduction (1000 kg)
Chlorothalonil	1,595	33	526
Copper ammonium	2	54	1
Copper hydroxide	95	51	48
Mancozeb	1046	26	272
Maneb	221	26	57
Metalaxyl	27	3	1
Metiram	125	32	40
Triphenyltin hydroxide	38	44	17
Cymoxanil	327	98	321
Dimethomorph	200	98	196
Propamocarb	114	98	112
Total	3,790	-	1,591
Per hectare	6.7	-	2.8

Source: Guenthner et al., (1999) and Wiese et al., (1999)

Table 2: Area planted, yield, production, and storage by potato producing region of the world

Region	Area Planted (ha)	Yield (ton/ha)	Production (ton)	Price (ton/ha)	Storage Loss (ton)
Africa	893,310	11.32	10,109,857	137.67	1,447,204
Asia	6,850,763	16.53	113,256,129	104.88	8,333,445
Europe	9,144,628	15.39	140,768,746	98.90	15,579,903
N & C America	812,596	37.14	30,178,515	110.34	3,149,277
Oceania	53,633	34.12	1,829,781	133.67	37,013
South America	1,005,178	15.07	15,144,313	84.61	1,446,685
World total	18,760,108	16.59	311,287,579	102.66	31,074,122
USA	546,980	42.79	23,404,000	115.34	1,870,000

Source: Food and Agricultural Organization of the United Nations, 2000.

Table 3: Projected adoption profile for genetically modified potato

Year	Probability of adoption (percent)
2004	4
2005	8
2006	12
2007	16
2008	20
2009	25
2010	34
2011	46
2012	57
2013	65
2014	74
2015	76
2016	78
2017	79
2018	80
2019	81
2020	82
2021	83
2022	83
2023	83
2024	83
2025	83
2026	83
2027	83
2028	83

Source: Delphi Survey and Guenthner (2001)

Table 4: Potato value and annual gross benefit attributed to the development and adoption of the genetically modified potato variety by region of the world, 2000.

Region	Total Annual Value (m.$)	Annual Gross Benefits in Million $				Total
		Yield Increase	Reduce Storage Loss	Improve Quality	Reduce Fungicides Cost	
Africa	1,391.9	69.6	17.3	44.5	60.7	192.2
Asia	11,878.2	593.9	147.4	380.1	465.9	1,587.3
Europe	13,921.8	696.1	172.8	445.5	621.8	1,936.2
North & Central America	3,330.00	166.5	41.3	106.6	55.3	369.6
Oceania	244.6	12.2	3.0	7.8	3.6	26.7
South America	1,281.4	64.1	15.9	41.0	68.4	189.3
World Total	32,047.8	1,602.4	397.7	1,025.5	1,275.7	4,301.3
U.S.	2,721.3	136.1	33.8	87.1	77.1	334.0

Source: Food and Agricultural Organization of the United Nations and Guenthner, et al., 2001

Table 5: Present Value of the flow of future annual gross benefit attributed to the development and adoption of the genetically modified potato variety

Region	Present Value over 25 Years ($)	Annual Present Value ($)
Africa	1,225,298,079	49,011,923
Asia	10,001,285,145	400,051,406
Europe	12,196,068,234	487,842,729
North & Central America	2,341,246,832	93,649,873
Oceania	184,207,218	7,368,288
South America	1,207,055,399	84,696,438
World Total	27,073,917,142	1,082,956,685
U.S.	2,117,440,957	84,696,438

Table 6: Annual reduction in active toxic ingredients attributed to the development and adoption of the genetically modified potato

Region	Reduction in active toxic ingredients (kg)
Africa	1,339,965
Asia	10,276,144
Europe	25,604,958
North and Central America	2,275,268
Oceania	150,172
South America	1,507,767
World Total	41,154,274
U.S.	1,531,544