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Public Perceptions of Tobacco Biopharming

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A telephone survey of United States consumers' views on tobacco biopharming indicates widespread support for developing the technology when it generates a socially beneficial application. Perceptions of risks associated with the technology, however, are split: Most respondents either hold concerns in every risk area presented or in none of them. Willingness to purchase a bio-tobacco-based medicine is bimodal as well. These polarized perceptions point to the challenges faced by policy makers who attempt to implement regulatory oversight of biopharming by balancing the broad-based concerns of the public against the potentially significant benefits of the technology.

Key words: agricultural biotechnology, biopharming, consumer surveys, genetically modified (GM) crops, plant-made pharmaceuticals, risk perception, technology acceptance, transgenic tobacco, willingness to purchase.

Introduction

Agricultural biotechnology has had a significant impact on crop production in the United States and increasingly in other countries as well. First-generation genetically modified (GM) crops improved farming efficiency with technologies that focused primarily on herbicide and insect resistance. More recent applications of agricultural biotechnology have included GM field crops with output traits that create new markets. *Biopharming*—synthesizing plant-made pharmaceuticals (PMPs) out of transgenic field crops—is a case in point.

Large-molecule drugs based on proteins have captured the interest of the medical community for their ability to treat and detect cancer and cardiovascular and infectious diseases. Demand for affordable protein-based therapies has already outpaced production capacity, and as new therapies are developed and approved for use, pressure on protein production systems is expected to increase. In response to production constraints, niche biotech companies are designing transgenic field crops such as corn, rice, and tobacco to serve as bioproduction platforms for therapeutic proteins. Elbehri (2005) offers a comprehensive review of the social and production issues surrounding PMPs as well as a summary of the companies, crops, and target products utilizing this emerging technology.

One challenge for the PMP industry is to develop a cost-effective means for maintaining identity preservation and segregation of drug-producing crops. In fact, members of the food processing sector and public advocacy groups have called for zero tolerance regarding contamination of the food/feed supply by PMP crops (Fernandez, Crawford, & Hefferan, 2002). The United States Department of Agriculture (USDA) and the Food and Drug Administration (FDA) have responded by tightening protocols for biopharming field trials (USDA, 2005) and integrating Good Manufacturing Practices into the field culture of PMP crops (FDA, 2002). Public policy on biopharming is evolving with the technology itself and must be responsive to public participation and transparency. As such, understanding how the public feels about PMPs is crucial to developing appropriate regulation of the technology.

Little is known about public attitudes toward biopharming and PMPs. Annual US consumer surveys covering broad issues in agricultural biotechnology (Hoban, 1999; International Food Information Council, 2005; Pew Initiative on Food and Biotechnology, 2004) have included isolated questions on PMPs and reported that (a) most Americans are unaware of biopharming, and (b) US consumers are generally favorable toward using biotechnology to produce medicines (albeit less enthusiastic about using transgenic animals to produce medicines than GM plants). Other studies have examined the roles of risk and benefit perceptions, trust in federal regulators and the media, and personal characteristics as potential indicators of consumer attitudes toward first-generation GM crop technologies and related products. Harrison, Boccaletti, and House (2004) pointed to risk perception as an important marker of willingness to buy GM foods, while Frewer (2003) noted that perceptions of risk and ethical concerns may be offset by perceptions of need or benefit, especially in the context of medical applications. Demographic characteristics have only weakly and inconsistently been useful predictors for modeling public support, although there is some evi-

dence of a gender gap, as men have consistently been more favorable toward agricultural biotechnology and more willing to buy GM foods than have women (Blaine, Kamaldeen, & Powell, 2002). Moon and Balasubramanian (2004) reported that social characteristics can impact risk perception, which in turn plays a role in forming attitudes toward agricultural biotechnology.

Although knowledge about public perceptions of first-generation GM crops and foods has steadily accumulated over the last decade, few studies have focused exclusively on biopharming. Einsiedel and Medlock (2005) reported results on a qualitative investigation in Canada in which 48 participants discussed issues and concerns associated with specific applications of plant molecular farming. Participants in their study differentially weighted products produced through biopharming based on the *purpose* of the application. The authors concluded from their focus group discussions that the purpose (i.e., the benefit) of the application was the most important determinant of acceptability.

In 2003, we conducted a large telephone survey in the United States to gauge consumer reactions to PMPs produced from transgenic tobacco. This study adds to this accumulating body of research by exploring public perceptions of emerging tobacco biopharming technologies in three areas. First, it explores the frequency of concerns about four areas of risk associated with the technology. Second, it documents acceptability in the face of variable levels of social benefits. Third, it documents the willingness to purchase a GM tobacco-based medicine under alternative discounts. The survey showed strong public support for developing a socially beneficial application of the technology, although perceptions of the associated risks were split. In terms of purchase intentions, respondents were insensitive to price discounts, with most respondents either willing to purchase a product without discount incentive or rejecting the product regardless of the discount they were offered.

Survey Data Collection and Sample

The primary data collected in a nationally representative survey[1] consisted of:

1. support for developing a tobacco-based biopharming application in the face of a hypothetical benefit level;
2. binary indicators of concern in four risk areas (corporate ownership of genetic code, impacts on human health, environmental consequences, and general moral/ethical concerns);
3. willingness to purchase a pharmaceutical product made from GM medicine-producing tobacco; and
4. respondent personal characteristics such as sex, age, education level, and other demographic variables.

Table 1. Characteristics of survey respondents.

Attribute	% of responders
Female	60.3
Age > 39 years	68.5 *M* = 48.4; *SD* = 17.1
White	80.8
Married	59.8
Children in household	38.2
Income >= $60k	39.8
Four-year college degree	38.6
Exposure to information on PMPs	
Nothing at all	54.5
Not much	23.9
Some	15.4
A lot	6.3

Note. Summary percentages are based on subsets of subjects responding to each item. There were 14.7% nonresponders to the income item; refusals for all other socioeconomic items were 3% or less. Attributes listed in the table were assigned a value of 1 when dummy coding variables for logit models except for exposure to information which was coded as 0 = nothing/not much, 1 = some/a lot.

Table 1 summarizes the socioeconomic characteristics of the survey respondents. Slightly more than half of the respondents were women, most were white, and nearly 40% held a four-year college degree. Respondents were asked how much they had seen, read, or heard about using genetically engineered plants to make medicines. A majority of the sample (55%) reported having had no exposure to information about the topic. Findings reported here are qualified against the public's general lack of exposure to the topic and the limited information offered to respondents during the interviews. Furthermore, because tobacco is a nonfood crop, the survey did not specifically mention risks of biopharmed crops entering the food supply.

1. *Telephone numbers were computer generated to include area codes for the contiguous states within the United States. Only adults were interviewed, with interview length averaging nine minutes. A total of 672 completed surveys were obtained, yielding a survey sampling error of ±4.1%.*

Table 2. Logit models for risk area concerns.

	Ownership	Health	Environmental	Moral/ethical	Summed index
LR	185.34***	251.01***	247.49***	200.17***	24.40***
Pseudo R^2	0.355	0.448	0.448	0.432	0.02
Female	1.40	1.10	1.60	1.00	1.92***
Age > 39	1.46	0.54*	0.81	1.16	0.71
Children	1.57	1.38	0.74	0.91	1.22
Four-year degree	0.91	1.07	1.04	0.93	0.93
Married	1.26	0.62	1.05	1.22	0.93
White	1.44	1.12	0.73	0.45*	0.63*
Exposure to information	1.29	0.56	1.19	1.61	1.17
Ownership		4.59***	2.27*	6.27***	
Health	4.87***		11.86***	4.14**	
Environmental	2.30*	11.91***		6.80***	
Moral/ethical	6.12***	4.10**	6.58***		

*Note. Models are based on n = 404 observations. LR is likelihood ratio. Values associated with independent variables are estimated odds ratios. *p < .05. **p < .01. ***p < .001.*

Results

Risk Areas

Survey respondents were presented the following statement:

> Currently scientists are using genetic engineering to develop tobacco that has new properties allowing it to be used in cancer treatments, blood products, and medicines. Some people say this is useful because it will provide much-needed medicines, while others say this approach might lead to unexpected effects on humans or the environment. Some people also have concerns over private companies owning genetic code.

Respondents were then asked to indicate if they held concerns in each of the following four risk areas: (a) companies owning the rights to genetically engineered tobacco, (b) negative effects on human health, (c) impacts on the environment, and (d) moral/ethical considerations.

For participants in the survey who offered a response,[2] 36% indicated they held concerns about corporate ownership of genetic code, while 56% expressed concern about adverse health effects, 47% were concerned that pharmaceutical-producing tobacco might negatively impact the environment, and 28% indicated that moral issues concerned them. A logit model for each risk area was estimated in which concern for that type of risk was predicted by demographic variables, exposure to information, and concerns in the other three risk areas (Table 2).[3] Overall, socioeconomic characteristics and exposure to information had little or no association with respondent concern over the technology. However, in the model for each risk area, concerns held in the other three risk areas were always statistically significant predictors, suggesting that concerns were strongly associated across risk areas. Given this significant association across risk types, a summed index of responses to the four risk areas was also estimated as a function of demographics and exposure to information using an ordered logit. Results suggest that women are more likely to express concerns, and whites are less likely to express concerns.

The joint distribution of responses among concerns in the four risk areas is also examined. Across four dichotomous questions, each survey respondent falls into one of 16 response strings. The distribution of the sample across these response patterns is shown in Table 3. Rows with a single letter indicate respondents who held only one concern; two letters indicate those subjects who expressed concern in two of the risk areas, and so forth. Note in the table that the distribution is strongly

2. *"Don't know" responses were treated as nonresponses for all summaries and models in this report. Analyses on missing data showed no evidence linking nonresponse to other data collected in the survey.*

3. *Due to high rates of refusal, income was not used in any of the models reported in this study.*

Table 3. Distribution of concerns across risk areas.

Risk pattern	% of responders
None	40.8
O	3.8
H	7.0
E	3.8
M	0.5
O,H	2.1
O,E	0.9
O,M	0.5
H,E	7.7
H,M	0.5
E,M	0.9
O,H,E	7.0
O,H,M	1.2
O,E,M	0.5
H,E,M	3.5
All	19.4

Note. Summaries are based on n = 427 observations with complete response strings. O = ownership of genetic code; H = health impacts; E = environmental consequences; M = moral/ethical considerations. Multiple codes indicate that respondents expressed multiple concerns. Due to rounding, percentages may not sum to 100%.

bimodal, with a plurality of respondents (41%) indicating they held no concerns, and another prominent class (nearly 20%) expressing concern in all four risk areas. This finding is consistent with previous studies that report a split in public opinion toward agricultural biotechnology (Pew, 2004; Priest, 2000). There are, however, some spikes in response patterns in between the polar ends. Response strings that included concern over health impacts of tobacco biopharming showed relative larger frequency—note the block of respondents (about 8%) who held both human health and environmental impact concerns.

Support for Developing Tobacco Biopharming Technology

Public support for an application of tobacco biopharming was then explored by presenting survey respondents with a randomized level of social benefit in the following short description:

> Biomedical companies are using genetic engineering to develop tobacco that can be used as an essential blood replacement product that is in short supply. The product is used in surgeries, and to treat shock and serious burns. If making this blood product from tobacco could save [insert randomized number] lives each year, which is [insert randomized percent] percent of Americans who receive donated blood yearly, would you support efforts to develop such products, [insert if respondent expressed concerns:] even though you mentioned you had a concern/some concerns?

Each respondent was presented a hypothetical number of lives that could be saved should the technology be implemented (called the social benefit here). The social benefit level was monotonically increased across 50 cells in the design, ranging from one life to one million lives (see Table 4). [4] Respondents were asked to make a

Table 4. Rates of support for a tobacco biopharming application.

Benefit level	Benchmark	Rate	Benefit level	Benchmark	Rate
1	<0.1	75.0	**30,000**	1	83.3
10	<0.1	88.9	**35,000**	1	91.7
25	<0.1	78.6	**40,000**	1	75.0
50	<0.1	72.7	**45,000**	1	83.3
75	<0.1	83.3	**50,000**	1	70.0
100	<0.1	90.9	**60,000**	1	92.9
150	<0.1	75.0	**70,000**	1	91.7
250	<0.1	81.8	**80,000**	2	80.0
300	<0.1	83.3	**90,000**	2	77.8
400	<0.1	72.7	**100,000**	2	81.8
500	<0.1	81.8	**125,000**	3	88.9
750	<0.1	76.9	**150,000**	3	88.9
1,000	<0.1	83.3	**175,000**	4	92.3
1,500	<0.1	78.6	**200,000**	4	66.7
2,000	<0.1	91.7	**250,000**	5	88.9
2,500	0.1	75.0	**300,000**	6	82.4
3,000	0.1	88.9	**350,000**	7	92.3
4,000	0.1	66.7	**400,000**	8	100.0
5,000	0.1	50.0	**450,000**	9	80.0
6,000	0.1	64.3	**500,000**	10	83.3
8,000	0.2	83.3	**600,000**	12	91.7
10,000	0.2	80.0	**700,000**	14	100.0
15,000	0.3	75.0	**800,000**	16	100.0
20,000	0.4	66.7	**900,000**	18	100.0
25,000	1	88.9	**1,000,000**	20	100.0

Note. Summaries are based on n = 570 responses. Benefit level is in number of lives saved. Benchmark is the percentage of lives saved relative to the annual number of blood recipients (5,000,000). Rate is the cell percentage of survey respondents supporting the technology.

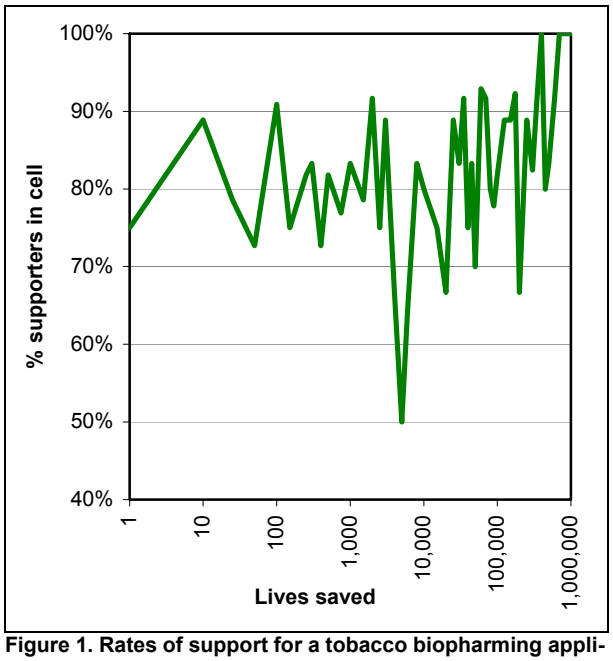

Figure 1. Rates of support for a tobacco biopharming application.

Note. Chart data are given in Table 4.

dichotomous choice on their support for developing the GM tobacco-based medical product.

Across benefit levels, 83% of the respondents supported efforts to develop the transgenic tobacco-based medical product. Further, support rates appear to be relatively constant across the spectrum of social benefits (Figure 1). A logit model was used to screen for the effects of social benefit, risk perception, and demographic characteristics on support for the technology. Predictors in the model included the (log 10) number of lives saved, and (dummy coded) demographics, exposure to information, and concerns in the four risk areas (Table 5). Only the social benefit variable and concern over morals/ethics show significant associations with support for the technology. Despite its statistical significance, social benefit had a weak effect: For each unit increase in log lives (reflecting a tenfold increase in the raw lives saved) the odds favoring support for the technology are expected to increase by a factor of 1.25, a modest upturn of support for the technology with increasing social benefit. Apparently the larger purpose

Table 5. Support for technology and purchase intention logit models.

	Support for technology	Purchase—full price	Purchase—discount
n	366	325	109
LR	65.05***	190.05***	31.62**
Pseudo R^2	0.201	0.480	0.281
Female	1.27	0.39*	0.40
Age > 39	1.03	0.91	1.25
Children	1.24	1.48	0.61
Four-year degree	0.76	0.65	1.79
Married	0.82	1.58	0.72
White	1.56	2.33*	1.30
Exposure to information	1.23	1.26	0.66
Ownership	0.51	0.42*	0.50
Health	0.70	1.07	1.71
Environmental	0.56	0.41	0.32
Moral/ethical	0.29**	0.17***	0.40
Support for technology		21.73***	7.52**
(log) Lives	1.25*		
Discount			0.99

*Note. n is sample size with complete data available for analysis; LR is likelihood ratio. Values associated with independent variables are estimated odds ratios. *p < .05. **p < .01. ***p < .001.*

of the application—a product used in emergency medical situations and surgeries—was enough to drive respondent support of the technology, regardless of the specification of social benefit. Note that even at the lowest (and for all intents and purposes trivial) values of social benefit, respondents solidly supported development of the technology. The odds ratio associated with concern in the moral/ethical risk area (0.29) reflects a stronger effect; respondents who held this concern were 3.4 times less likely to support developing the GM tobacco-based medical product.

Purchase Intentions

The distinction and overlap between support for an application of tobacco biopharming as a societal abstraction and willingness on the part of respondents to actually purchase a medicine produced with the technology is also explored through the following question:

> If you or a member of your family wanted to buy medicine at your local store, would you be willing to buy a product made from genetically engi-

4. *To minimize potential impact of a "large number effect" in the upper cells of the design, social benefit level was also presented as the percentage of the total population of yearly blood recipients (a benchmark value of five million; American Association of Blood Banks, 2005).*

neered tobacco if it were the same price as medicine that had not been made this way?

Of those who responded to the question, 63% indicated they would be willing to purchase the GM tobacco-based medicine—a notable decline compared to the 83% who supported developing the technology in the face of societal benefits.

Response to the full-price-purchase question was modeled as a function of support for the technology, demographics, exposure to information, and risk perception (Table 5). Support for the technology was an overwhelming predictor of willingness to purchase—supporters of the technology were nearly 22 times more likely to agree to purchase the product as compared to nonsupporters. Purchase intentions differed by gender, with women 2.6 times less likely as men to be willing to purchase the product. Nonwhite respondents, respondents who held concerns over rights to ownership of genetic code, and respondents who held moral/ethical concerns over the technology were also less likely to be willing to purchase the product.

Respondents who either declined to purchase the product or withheld opinion were asked in a follow-up question if they would be willing to purchase the product at a discount. To screen for discount incentive effects, respondents offered the follow-up question were randomized into one of five discount price percentages: 5, 10, 25, 40, and 50%. Generally speaking, respondents who were not willing to purchase the product at full price were not swayed by the price discount; 81% of the respondents who were offered the follow-up (and who responded to the question) declined to purchase at a discount. Among those declining to purchase at equivalent full price, the model for purchase-at-discount (Table 5) shows no statistical evidence that increasing the discount percentage impacted rates of willingness to purchase at a discount.

Based on responses to the two purchase items, survey respondents were classified into three categories (Table 6): those who were *willing to purchase* (67% of the responding sample, indicating they would purchase the product with no discount incentive), *reluctant to purchase* (7%, respondents swayed to purchase by discount incentive), and *unwilling to purchase* (27%, respondents not swayed by discount). As with the distribution of risk assessment, the distribution of the sample across this willingness to purchase spectrum is bimodal, again indicative of a split in public reaction to tobacco biopharming.

Table 6. Joint distribution of support for technology and willingness to purchase.

	Support for technology		
Purchase group	**Yes**	**No**	**Total**
Willing	64.3	2.2	66.5
Reluctant	5.7	1.0	6.7
Unwilling	11.6	15.3	26.9
Total	81.6	18.5	

Note. Summary percentages are based on n = 510 observations with complete response strings. Due to rounding, totals may not sum to 100%.

The joint distribution of the purchase groups and the binary support for technology variable is also examined (Table 6). There again appear to be two groups: consumers who have no reservations about tobacco biopharming (64% of the responding sample, those who supported developing the technology and would purchase a GM tobacco-based product), and consumers who seem to be fundamentally opposed to the technology (15%, respondents not supporting the technology and who would not purchase the product). This finding demonstrates the polarization of attitudes with respect to biopharming. There were some respondents, however, who are supportive of the development of the technology but do not wish to personally use it. For example, roughly 18% of the survey respondents supported developing the technology but were either reluctant (6%) or unwilling (12%) to purchase the GM tobacco-based medicine. The motives are unclear for the small block of survey respondents (2%) who would not support development of the technology but who were willing to purchase the product.

Concluding Remarks

Findings from the survey highlight significant challenges to policy makers and to social science investigators with respect to biopharming. For policy makers, although it appears that a majority of US consumers are comfortable with transgenic plant biopharming and PMPs, the bimodal distributions here point to a significant class of consumers who are resolutely opposed to this technology. Policy makers are challenged to implement regulatory oversight in a manner that balances the broad-based concerns of the opposing public against hindering the advancement of this potentially beneficial technology. Maintaining transparency and keeping the public informed on oversight measures should help promote public confidence in the safety of biopharming and PMPs.

This investigation also illustrates the difficulties in gauging the public mind toward biopharming. It is a topic with which few consumers are familiar. On the one hand, small-sample qualitative studies provide the opportunity to richly inform participants prior to gathering their thoughts (Einsiedel & Medlock, 2005). However, the reflections of a small handful of purposely informed subjects may not adequately reflect broader public sentiment. The present investigation, on the other hand, permitted inference of US consumer attitudes, but given relatively little prior information, the findings are strongly predicated on the information offered to respondents during the interview.

Consumer perceptions of GM crops have influenced public policy governing them; PMP technology is no exception. Information exchange is critical to shaping those perceptions, and as biopharming technology matures from the research and development stage into full-scale PMP production, new debates and questions will emerge as new issues come to light. Policy makers and social scientists must remain knowledgeable about this technology to ensure that important issues are addressed. Providing the public with balanced and accurate information, allowing stakeholders to fairly evaluate benefits against risks, should foster greater public participation and effective policy regulating PMPs.

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