Genetically Modified Organisms (GMOs) and Sustainability in Agriculture

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Contributed paper prepared for presentation at the International Association of Agricultural Economists Conference, Gold Coast, Australia, August 12-18, 2006

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Abstract

Surveys on consumer acceptance of GM foods revealed differences in knowledge, risk perception and acceptance of GM foods in Japan, Norway, Spain, Taiwan and the United States. There were opponents and proponents of GM foods. However, even in the United States, one of the most supportive countries, consumers were willing to pay substantial premiums to avoid GM alternatives. While genetic engineering holds great potential to enhance yield and productivity for many crops, especially those widely cultivated in the developing world, there have been little, if any tangible benefits to the consumer from the first wave of GM crops. Partially due to this lack of consumer benefits, there has been consumer resistance to GM foods in many parts of the world. It would be a great challenge for the biotechnology industry and government policy makers to improve consumer acceptance of GM foods derived from the current and future generations of GM crops. Policy makers also need to find ways to make GM technologies affordable to poor farmers in the developing world to enhance their agricultural sustainability and food security.

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* The author expresses gratitude to Professors Kyrre Rickertsen of Agricultural University of Norway, Nobuhiro Tsuboi of Tsukuba University, Japan, Tsu-Tan Fu of Academia Sinica, Taiwan, Fu-Sung Chiang of National Taiwan Ocean University and Jose M. Gil of Universidad Politécnica de Cataluña, Spain for their helps in conducting the joint surveys in their countries. Appreciation is also extended to Pierre Ganiere and Naoya Kaneko for their able research assistance. This research was supported by the National Research Initiative (NRI) of the Cooperative State Research, Education and Extension Service, USDA, Grant # 2003-35400-12883.

Introduction

Agricultural biotechnology based on genetically modified organisms (GMOs) represents one of the most advanced technological innovations in modern agriculture. The commercialization of genetically modified (GM) varieties such as Roundup Ready soybeans and Bt corn have benefited many grain farmers, especially in the U.S., Canada and Argentina, among others. However, there have been stiff consumer resistances to foods produced with these GM ingredients in many countries in the European Union (EU) and Japan.

The objective of this paper are to analyze the issues surrounding the adoption of GM technologies, to present the results from surveys on the consumer acceptance of GM foods conducted in several countries, and to discuss the factors affecting the consumer attitudes towards GM foods, the results of estimating the willingness to pay (WTP) for GM vs. non-GM foods, and the implications of these survey and estimation results on the future contribution of biotechnology to agricultural sustainability.

First Wave

The first generation of GM crops, mainly GM soybeans, canola (or more commonly known as rapeseeds), corn (maize) and cotton, was approved for commercialization in 1996. These GM crops were primarily aimed at improving pest management such as herbicide tolerance or insect resistance, some yield enhancement, but not profitability. The rapid adoption of these biotechnologies in agriculture attested their benefits to producers in the United States and elsewhere. At the present time, Argentina, Canada, China, South Africa, and the U.S. are among the most important producing countries of GM products in the world. Table 1 showed the adoption rates of GM crops in the United States. The adoption rate of GM soybeans increased from 7.4% in 1996 to more than 87% in 2005 within merely 10 years.

One of the notable characteristics of the GM crops from the first wave is the lack of tangible benefit to the consumer. One motivation of releasing these GM crops has largely lied on the claim of equivalence to the traditional counterparts so that there was no need to label GM foods if they were essentially the same as their non-GM counterparts. Apparently there was fear of labeling GM foods in the marketplace by biotechnology companies such as Monsanto. This fear turned out to be true in recent years as many consumers in many parts of the world have showed resistance to GM foods. However, studies have shown that one reason for the resistance was the lack of benefits to consumers.

Another characteristics of the GM crops from the first wave is that they are not directly used as foods. Corn is mainly used as feeds. Cotton is of course not a food product. Soybeans and canola are used mostly for crushing into meal and oil. Soybean and canola oils are used in cooking, but not directly eaten as foods. Furthermore, these GM vegetable oils are exempted from mandatory labeling regulations in the major importing countries of Japan, South Korea, and Taiwan. Even though soybean products consumed directly as foods like tofu and soy milk are subject to mandatory GM labeling regulations in most of these Asian countries, the quantities are relatively small and the identity preservation (IP) is required to segregate soybeans for direct food uses from those bulk imports for crushing.

The concerns on consumer acceptance forced Monsanto to suspend plans to introduce GM wheat in May 2004 (Wall Street Journal, May 11, 2004). Wheat is a main ingredient to many staple foods such as bread and noodle. No one would risk the possibility of consumer resistance to GM wheat products.

Second Wave

Golden rice contains beta-carotene which our body converts to vitamin A. Since many people in poor countries are deficient in vitamin A, Golden rice is perceived as highly beneficial to

the third world. Yet, there is still fairly uncertain about any success of commercialization of this GM crop (Lusk, 2003).

Scientists have been pursuing many avenues to produce the second generation of GM crops which may provide more benefits to producers and some tangible benefits to consumers. Conway and Toenniessen (1999) listed many of these examples in various stage of development such as modified starch in rice, potato and maize and modified fatty-acid content in field tests and drought and salinity tolerance in cereals in laboratory tests. In addition, pest-resistance GM papaya is being developed in Taiwan and drought-resistance GM rice being developed in China. We note also that there are efforts being made on resistance to viruses and bacterial blight in Cassava, one of the most important food crops in Africa and South East Asia. Cassava is relatively easy to grow. However, its roots are low in protein and deficient in micronutrients like iron and vitamin A. Once the roots are harvested, certain cassava strains can produce potentially toxic level of cyanogens which are harmful to human (Siritunga and Sayre, 2004). A breakthrough in these GMO applications on cassava would either increase its productivity or reduce the harmful toxic substance of this important food crop in many parts of the developing world. These new GM crops would undoubtedly help many farmers and enhance food security in the world.

The examples of the second wave also clearly show that the emphasis in the GMO technology has shifted to the attributes giving direct benefits to the consumer such as reduced or changed composition of fatty acid contents in soybeans. However, it remains to be seen whether the tangible benefits to the consumer of GM foods can clear the way for their embrace in both the developed and developing worlds.

GMO Surveys

The commercialization of GM crops has generated intense debates on the long-term environmental, social, and human health consequences. These debates have resulted in the

legislation of mandatory labeling laws for GM foods. Since consumer acceptance is essential for the success of biotechnology applications in agriculture, there have been growing interests in investigating the level of consumer acceptance and in estimating the consumer's willingness to pay (WTP) premiums for non-GM foods or the willingness to accept (WTA) discounts for GM foods.

We conducted public telephone surveys on GM foods in Norway, Japan, Spain, Taiwan and the United States during 2002 and 2003 (Table 2). Theses surveys were based on the same questionnaire. One of the most important features of our survey was that we did not assume that GM foods were inferior to their non-GM counterparts in the contingent valuation (CV) sections.

For the purpose of comparison, the results from the full surveys conduced in Taiwan and the U.S. and the pilot surveys conducted in Norway, Japan and Spain were summarized. We only selected a few survey questions to highlight the differences across these countries.

Knowledge and Information

In the surveys, we asked respondents about their self-assessed knowledge on GM foods and GMOs. This was subjective knowledge. Figure 1 showed the survey results from the five countries. As showed, more than 10% of respondents in Japan and the U.S. indicated that they were very well informed about the GM foods and GMOs. Overall, 94% of the Japanese respondents expressed very well or somewhat informed about GM foods or GMOs. The comparable figures were 53% for Norway, 39% for Spain, 59% for Taiwan and 45% for the U.S. There were two (in the pilot survey) or three (in the full surveys) questions testing the respondent's objective knowledge on GMOs. The results from such a question were presented in Figure 2. The results showed that 54.8% of the American respondents answered the question correctly, followed by 44.3% by Japanese respondents, 36% by Norwegians, 25.3% by Spaniels,

and 33% by Taiwanese. The respondents from Japan, Spain and Norway had very high percentages of "Don't Know" to this question, i.e., 47.2%, 45.5%, and 36%, respectively.

The survey results indicated that the consumers in these countries tended to lack specific knowledge on GM foods or GMOs. Overall, the consumers from Japan and the U.S. were more informed than those from Norway, Spain and Taiwan.

Risk Perception

Knowledge on GM foods likely affected the consumer's risk perception. Figure 3 compared the perception of risk on human health of GM foods across the five countries. The results showed that Norway had the highest percentage of respondents (33.5%) selecting "extremely risky" for this question on the effects of GM foods on human health. Overall, the percentages expressing "extremely risky" or "somewhat risky" were 60% for Norway, 43% for Japan, 44% for Spain, 36% for Taiwan and 50% for the U.S. Note that there was a very high percentage of Japanese respondents (38%) indicating "don't know". We noted that the Japanese respondents tended to be more conservative and unwilling to offer definite answer to these types of question. On the other hand, 24% of Norwegian respondents, 28% of Americans and 38% of Taiwanese expressed GM foods being somewhat or extremely safe while the comparable figures for Japanese or Spaniels were all less than 10%.

The survey results suggested that there were more people who thought GM foods were risky than those who thought GM foods were safe. Overall, the results showed that American and Taiwanese were the least fearful of GM foods while the Japanese were most fearful.

Willingness to Consume GM Foods

Consumer perception of GM foods should in principle affect the consumer's willingness to purchase or consume them. In the surveys, we had three qualitative questions on the willingness to consume GM foods. Figures 4-6 presented the survey results across the five countries. Figure 4

showed that more than 40% of the respondents in Taiwan and the U.S. expressed at least "somewhat willing" to consume GM foods. The Japanese respondents were least willing to consume while the respondents from Norway and Spain had only 30% or less being either "somewhat willing" or "extremely willing" to consume GM foods.

Results also showed that if GM foods possessed some benefits such as reduced use of pesticide (Figure 5) or more nutritious (Figure 6), the willingness to consume increased. For example, the percentages of "extremely willing" and "somewhat willing" exceeded 60% in Taiwan and the U.S. in the case of reduction in pesticide use. In Japan, the percentage figure increased from 1.8% to 11.8% as either "extremely willing" or "somewhat willing". These percentages were still very low, reflecting strong resistance to GM foods by the Japanese consumers.

Differences between Plant and Animal Products

In the surveys we asked a series of contingent valuation (CV) questions on GM vs. non-GM foods given same or different prices. These were product-specific questions. Since salmon was used in all surveys, we presented survey results on this product in Figure 7. Results showed that given the same price for salmon fed with GM soybean feed (GM-Fed) and salmon fed with non-GM soybean feed (non-GM), more than 80% of the respondents from Norway, Spain, and Japan selected non-GM salmon. On the other hand, only 35% of American respondents and 50% of Taiwanese respondents selected non-GM salmon. A very substantial proportion (34.2% in the U.S. and 16.7% in Taiwan) chose "both GM-fed and non-GM are equally good". These results clearly showed that the consumer resistance to GM foods was much stronger in Japan, Norway and Spain than in Taiwan or the United States.

Figure 8 compared the choices between GM and non-GM vegetable (soybean) oil in four countries. Since soybean oil was not commonly used in Spain, it was not included in the Spanish

survey. Results showed the percentages of selecting the GM alternative for vegetable oil were higher than those for salmon in all countries. Furthermore, the percentages of selecting the non-GM oil were smaller than those for non-GM salmon. Specifically, the percentage of selecting GM-fed salmon was 5.6% compared with 8.5% for GM vegetable oil in the U.S. These results suggested that consumers in all these countries were more concerned about the genetic modification for animal products than for plant products.

Consumer Profile

We conducted a multiple correspondence analysis (MCA) and a classification analysis to construct a consumer profile in terms of the degree of acceptance of GM foods, using the data obtained from Taiwan and the United States. The detailed methodology was available in Geniere et al. (2004).

Table 3 showed the classification results, indicating the percentages of the survey respondents belonging to various classes of GM food acceptance. Results indicated that about 43% of Taiwanese and 34% of Americans were either moderate or extreme opponents of GM foods. In the United States, about 61% of the respondents took the neutral position as non-opponents of GM foods while only 4.7% were clearly proponents. In Taiwan, about 52% of the respondents were proponents of GM foods.

Clearly there were proponents and opponents to GM foods in every country. How to convert those opposing GM foods to become proponents is important to the future of GM technology.

Willingness to Pay for GM Foods

Our survey results were also used to estimate the consumer willingness to pay for GM vs. non-GM foods in the United States. Willingness to pay (WTP) for a non-GM premium to avoid GM alternative was derived from the random utility model and expressed as a function of the

parameters estimated from either the multinomial logit or standard logit models (see Kaneko and Chern , 2005 for details).

Table 4 presented the estimates of the WTP premiums in terms of dollar amounts and the percentages of the base prices used in the U.S. survey. Overall the estimated WTP premiums for non-GM alternatives ranged from 15% for cornflakes to 30% for non-GM salmon as compared to GM salmon. By types of American consumers, results revealed that the non-GM choosers (those who selected non-GM alternative given the same price) were willing to pay substantially higher premiums for non-GM alternatives. For example, they were willing to pay up to 47% premium for non-GM salmon as compared to the GM alternative. On the other hand, the GM choosers (those selected GM alternative given the same price as non-GM alternative) were willing to pay negative premiums for non-GM products, that is, equivalent to positive premiums for GM alternatives. For example, the GM choosers were willing to pay a 20% premium to buy GM vegetable oil over the non-GM oil. Finally, the indifferent respondents were shown to be willing to pay negligible amounts of premiums for either GM or non-GM alternatives as expected. Since Americans tended to be more supportive of GM foods than people in other countries, their estimated WTP premiums for non-GM foods were expected to be smaller than those for Japanese and Europeans.

Implications for Agricultural Sustainability

The first wave of GM crops was not targeted to yield enhancement which would be more important to the developing world than the developed world. Even though the adoption of GM crops has reduced the uses of pesticide and herbicide in some countries, the environmental groups have been the most vocal in opposing the GM crops due to their perceived potential risks to the environment. The lack of tangible benefits to the consumer has caused the growing resistance to GM foods in many countries. Our surveys showed that there were differences in the consumer's knowledge, perception and willingness to consume GM foods. Taiwan and the U.S. were more

supportive to GM foods than Japan, Norway and Spain. However, even in the United States, there were proponents as well as opponents to GM foods. Furthermore, for those who disliked the GM foods, they were willing to pay substantial premiums to the non-GM alternatives.

By all accounts, it is still critical to enhance the yields of main staple food crops such as rice, corn (maize), wheat, and cassava for food security. Biotechnology such as GMOs holds the best promise to deliver the next Green Revolution. However the road to this destination will not be easy and smooth. In fact, it will be bumpy.

This study showed that one of the main reasons for the consumer's resistance to GM foods was the lack of tangible benefits to the consumer. The consumer's acceptance would increase if the GM foods contained tangible benefits such as better nutrition. There are several GM crop varieties in the second wave that possess tangible benefits to the consumer. It is crucial for the biotechnology industry to commercialize a few examples of such GM crops to increase the consumer's confidence on GM products.

With respect to adoption, poor farmers in the developing countries can not afford to purchase GM seeds. Since one important contribution of future biotechnology lies in its ability to increase crop yield and productivity, we need to find ways to make these advanced technologies affordable to poor farmers in developing countries.

Concluding Remarks

Consumer acceptance has become a major obstacle for the continuing development of agricultural biotechnology in genetic engineering. The biotechnology industry and governments need to work on promoting the positive aspects of the GM technologies. Perhaps the best strategy is to commercialize GM crops with tangible benefits to the consumer from the second wave.

In conclusion, GM technology will play an increasingly important role for agricultural sustainability in the future. This technology is likely to produce varieties of crops which can resist

to pest or drought and thus they will increase yield and enhance productivity to combat the food security problems in the developing countries. However, the road to achieve this goal is likely to be bumpy. In addition to the need to increase the consumer's acceptance, we must also find ways to make these advanced technologies affordable to poor farmers in the developing world.

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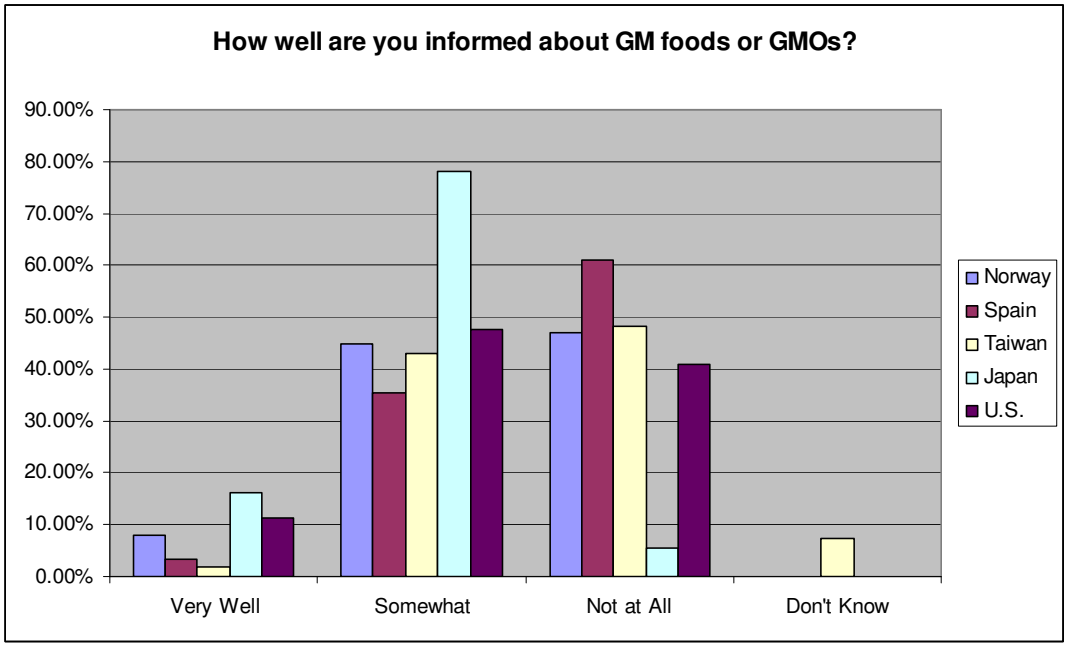

Figure 1. Comparison of Consumer's Subjective Knowledge on GM Foods

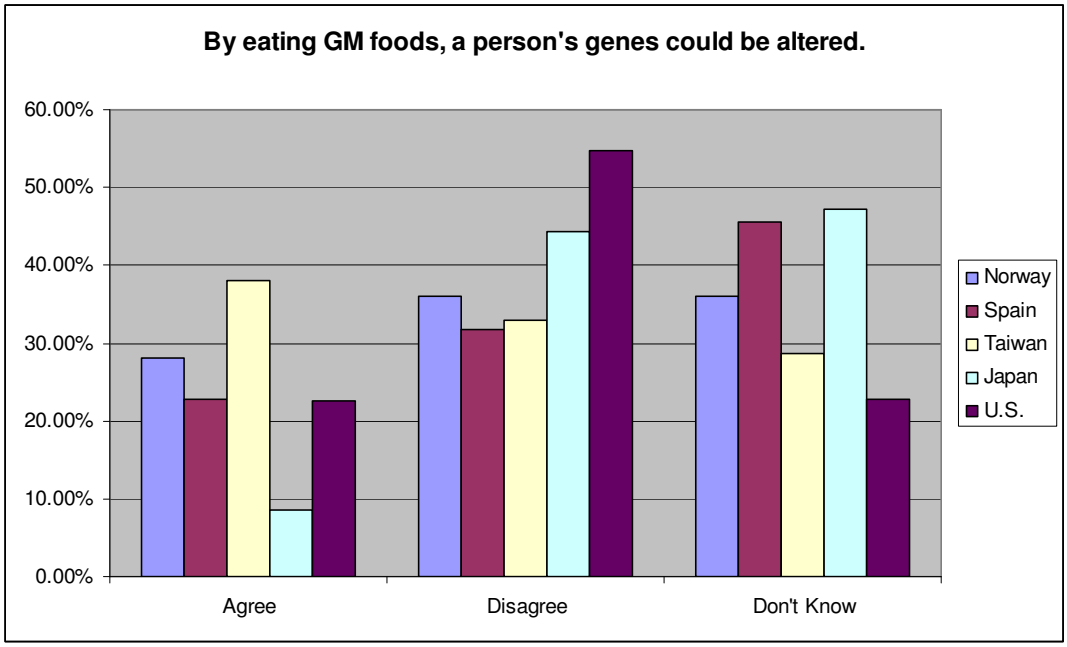

Figure 2. Comparison of Consumer's Objective Knowledge on GM Foods

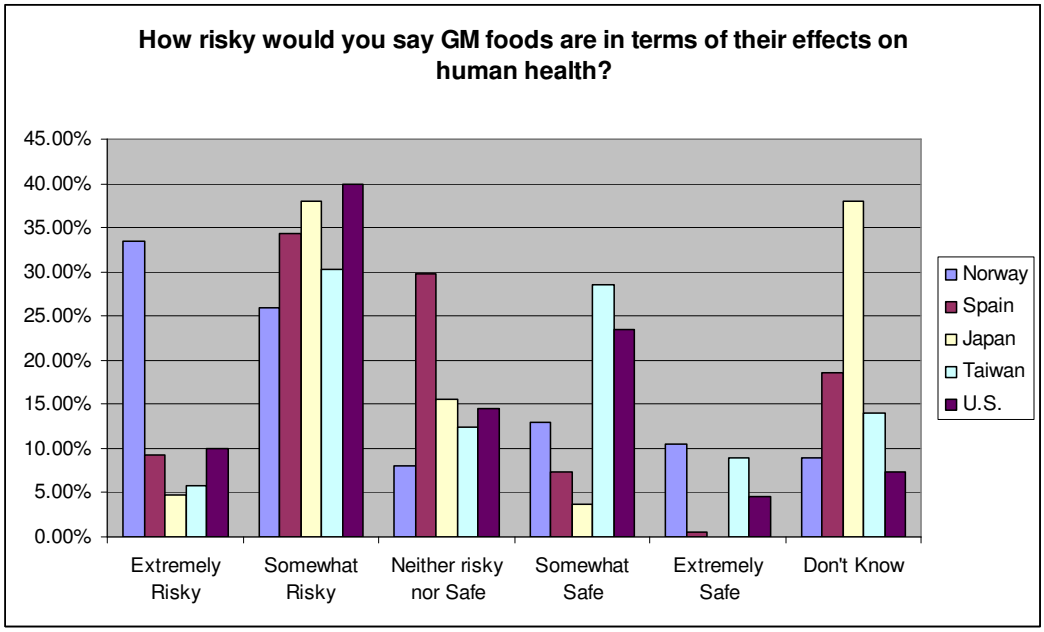

Figure 3. Comparison of Consumer's Risk Perception of GM Foods

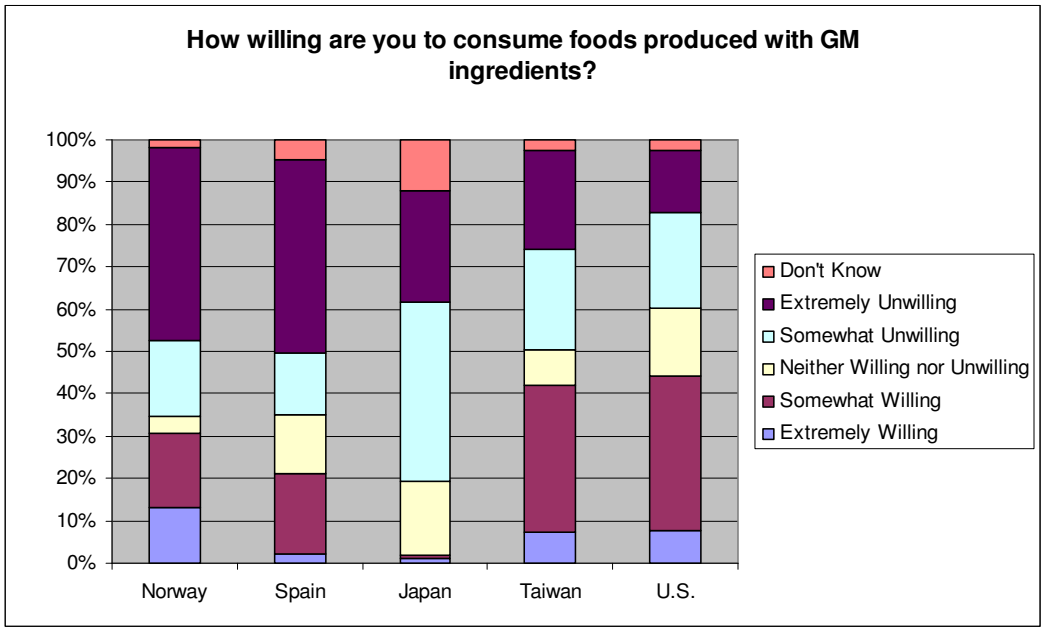

Figure 4. Comparison of Consumer's Willingness to Consume GM Foods

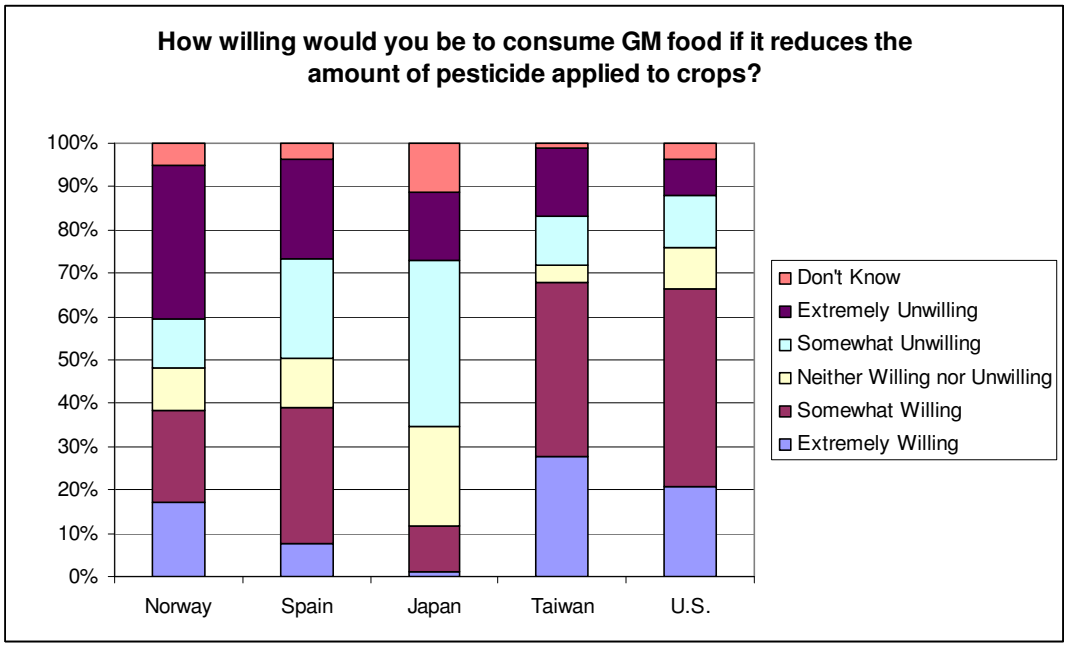

Figure 5. Comparison of Consumer's Willingness to Consume GM Foods if They Reduced Pesticide Use

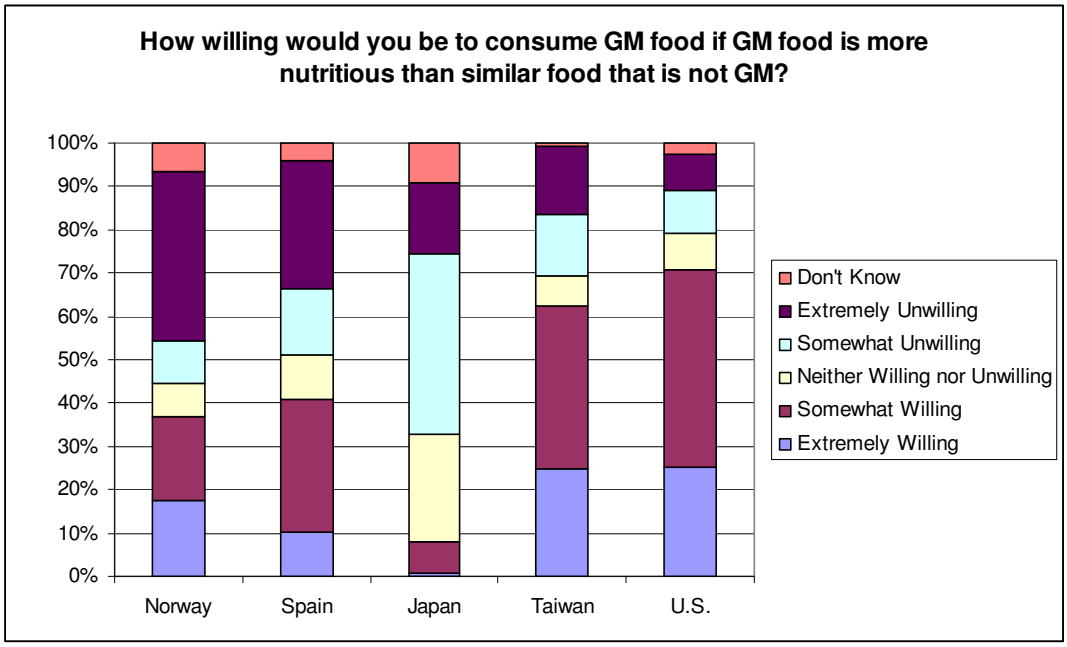

Figure 6. Comparison of Consumer's Willingness to Consume GM Foods if They Were More Nutritious

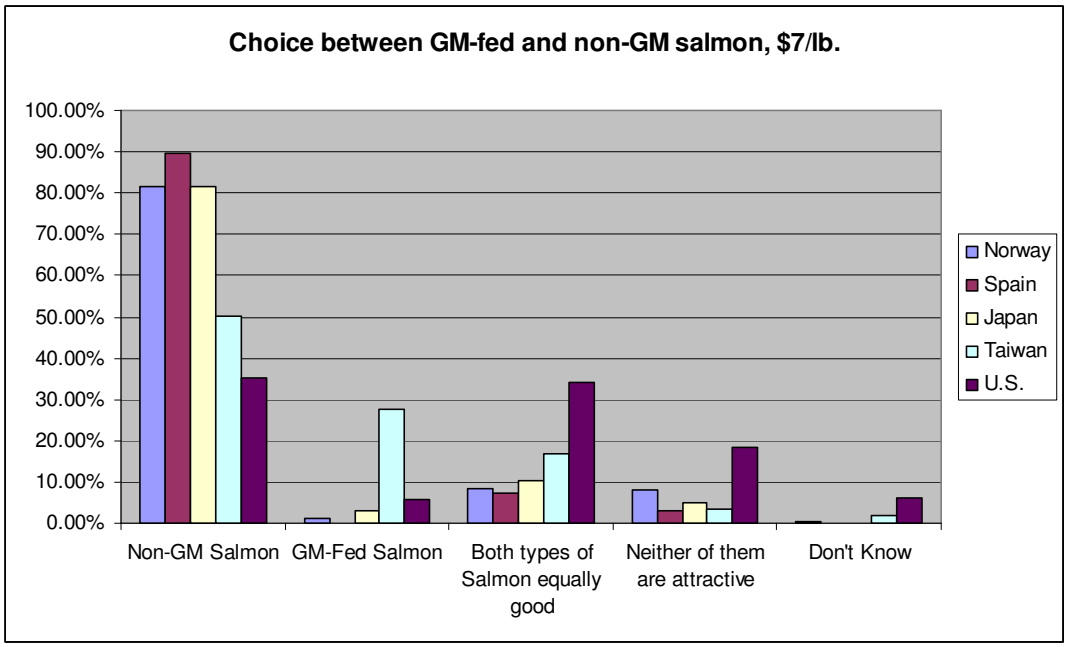

Figure 7. Comparison of Choices between GM-Fed and Non-GM Salmon Given Same Price

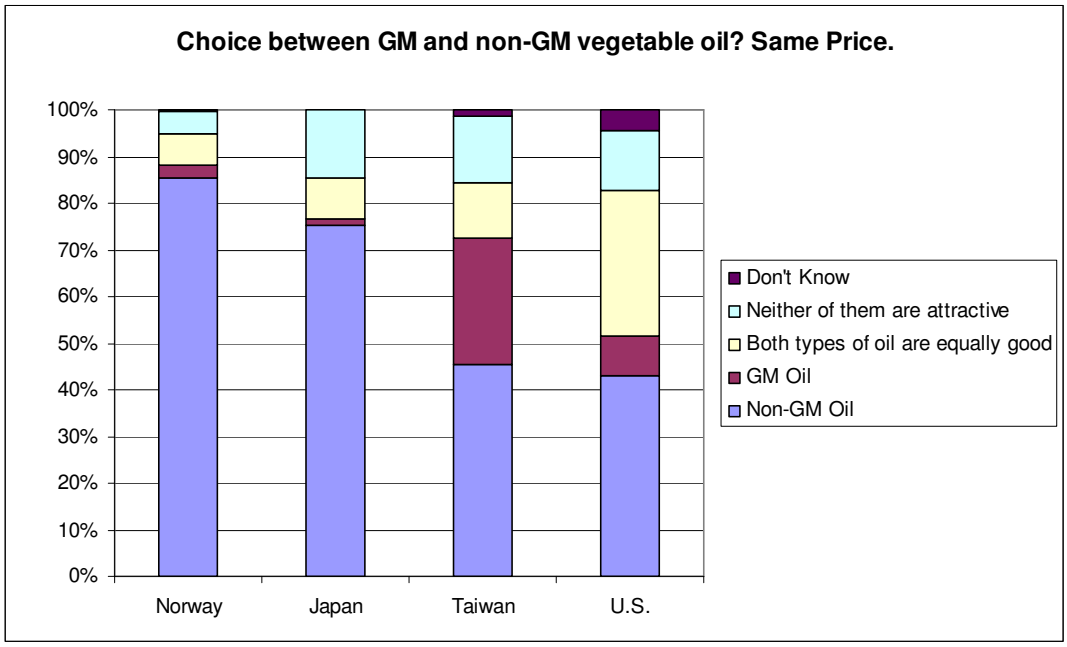

Figure 8. Comparison of Choices between GM-Fed and Non-GM Salmon Given Same Price

Table 1. Adoption Rates of GM Crops in the United States, 1996-2005

Unit: Percent (%) of Planted Acres

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
GM Soybeans (Herbicide-tolerant)	7.4	17.0	44.2	57	54	68	75	81	85	87
Total GM Corn	4.4	11.9	37.5	38	25	26	34	40	45	52
Bt Corn	1.4	7.6	19.1	30	18	18	22	25	27	26
Herbicide-tolerant Corn	3.0	4.3	18.4	8	6	7	9	11	13	17
Total GM Cotton	NA	25.5	43.0	65	61	69	71	73	76	79
Bt Cotton	14.6	15.0	16.8	27	15	13	13	14	16	18
Herbicide-tolerant Cotton	NA	10.5	26.2	38	26	32	36	32	30	27

Source: Agricultural Statistics Board, National Agricultural Statistical Service, U.S. Department of Agriculture, (http://usda.mannlib.cornell.edu//reports/nassr/field/pcp-bb).

Table 2. Comparison of Surveys by Country

Item	Pilot Surveys					Full Surveys	
Country	U.S.	Norway	Taiwan	Japan	Spain	U.S.	Taiwan
Year	2002	2002	2002	2003	2002	2003	2003
Sample Size	256	200	257	271	660	1,014	1,004
Response Rate	28.6%	20%	29.3%	NA	NA	23.9%	27.5%

Table 3. Consumer Profiles in Taiwan and the U.S.

Class	% of Sample	
	Taiwan (N=257)	U.S. (N=256)
Proponents	52%	4.7%
Non-Opponents	*	60.9%
Moderate Opponents	30%	22.7%
Extreme Opponents	12.5%	11.7%
Don't Know	5.5%	*

N : Sample Size

* Does not Apply

Source: Ganiere et al. (2004).

Table 4. Mean Willingness to Pay a Non-GM Premium to Avoid GM Alternative, United States

Item	GM Oil[a]	GM Cornflakes	GM-fed Salmon	GM Salmon
	All Respondents			
Mean ($)	0.397	0.593	1.704	1.779
% [a]	20.9%	14.8%	28.4%	29.7%
	Non-GM Choosers			
Mean ($)	0.737	1.831	2.649	2.797
%	38.8%	45.8%	44.2%	46.6%
	GM Choosers			
Mean ($)	-0.371	-1.733	-1.452	-1.567
%	-19.5%	-43.3%	-24.2%	-26.1%
	Indifferent Respondents			
Mean ($)	0.016	-0.034	-0.006	-0.072
%	0.8%	-0.9%	-0.1%	-1.2%

[a]Percentages were computed by dividing the point estimates of willingness to pay by the appropriate base prices. The base prices are $1.9 per 32 oz for vegetable oil, $4.0 per 18 oz for cornflakes and $6.0 per pound for salmon.

Source: Kaneko and Chern (2005).