Acceptance of GM food—an experiment in six countries

To the editor:

Genetically modified (GM) foods have generated intensely negative consumer attitudes in many countries, particularly in Europe[1,2]. Several expert reviews indicate that safety concerns regarding GM foods appear largely unfounded[3,4], but expert opinions have been insufficient to greatly change public sentiment[1,5]. Even so, antipathy toward the concept of genetic modification will not necessarily translate into consumer resistance to such foods once introduced into the market.

The experiments reported here were undertaken to determine how consumers in a range of countries with highly negative public perceptions of GM technology might react toward GM food products that offer clearly stated consumer benefits if introduced into their markets. Classic economic theory postulates that consumers seek to maximize self-interest in the presence of pecuniary or other advantages[6]. Ample evidence exists that consumer attitudes, and even stated behavioral intentions, may not translate into purchase behavior[7,8].

We set up real roadside fruit stalls based on a choice modeling experimental design. Experimental choice modeling has been widely used as a method for determining behavior based on subjects making choices from sets of product options put before them[9]. What makes our study highly novel is that the choices were real in a genuine shopping situation, rather than being made under circumstances where the subjects knew that their choices were being observed. Our intention was to minimize the possibility of social desirability bias[10] influencing the results.

We placed on sale conventional fruit labeled as 'organic', 'spray-free genetically modified', or 'conventional', or appropriate translations of same in the prevalent local language at each site, at varying price levels. The price for each fruit category was set at one of three levels: the median market price in that locality, median plus 15% or median minus 15%. A parsimonious main effects balanced fractional factorial design was used to generate nine price and fruit offerings (**Table 1**). Research assistants fluent in the local language operated the stalls, which were set up on the outskirts of urban areas in New Zealand (Queenstown), Sweden (Ystad, Skåne), Belgium (near Brussels), France (Paris), Germany (Koblenz, Rheinland-Pfalz) and the UK (Berwick-upon-Tweed). We avoided locating adjacent to farms or orchards to minimize the risk of upsetting local producers. If customers asked about the spray status of different fruit types, verbal explanation was provided that the organic fruit could have been sprayed with "*Bacillus thuringiensis* (*Bt*) organic spray" and that the spray-free GM fruit was from plants incorporating the *Bt* gene, making spraying unnecessary. (Less than 5% of customers over the six experiments enquired.) In each case, the experimental set of offerings (**Table 1**) changed after ~50 customers, yielding ~450 observations from each country. In accordance with University of Otago Ethics Approval requirements, customers were informed of the experiment (verbally, or by using a display card if other customers were present) after they had made their selection, but before money changed hands. A main reason for using roadside fruit stalls, rather than street market or other walk-in situations, was to minimize the risk of contamination of customer intentions through overhearing reactions from customers newly aware of the 'candid camera'-like stratagem.

A total of 2,736 consumers visited the fruit-stall experiments in the six different countries. Market-share estimations were derived using multinomial logit models, as shown in **Box 1**. Further details of the analysis method are provided elsewhere[11]. The fruit stall findings across the six countries showed the spray-free GM option gained a 21% market share on average (range: 17–27%), when all fruit types were sold at the prevailing market price. Market-share estimates based upon prevailing market prices (**Table 2**), found a similar pattern

Table 1 Balanced fractional factorial design showing varying price levels and fruit types

Run	Organic	Conventional	Spray-free GM
1	Median price –15%	Median price	Median price
2	Median price +15%	Median price	Median price +15%
3	Median price +15%	Median price +15%	Median price –15%
4	Median price –15%	Median price –15%	Median price –15%
5	Median price	Median price +15%	Median price
6	Median price –15%	Median price +15%	Median price +15%
7	Median price +15%	Median price –15%	Median price
8	Median price	Median price	Median price –15%
9	Median price	Median price –15%	Median price +15%

Box 1 Method of analysis

Market share estimations were derived using the multinomial logit equation as follows:

$$\hat{M}s_{jk} = \frac{e^{\hat{\alpha}_j + \hat{\beta}_j x_{jk}}}{\sum_i e^{\hat{\alpha}_i + \hat{\beta}_i x_{ik}}} \quad \text{where}$$

i is the index over all the alternative fruit types, varying from 1 to 3.

j is the index for the jth. alternative for which the market share is to be calculated.

k is the index over the four pricing scenarios varying from 1 to 4.

Each scenario is defined by a vector of 3 given prices for each of the three alternative fruit types.

$\hat{M}s_{jk}$ is the estimated market share for the jth. alternative of fruit type for the kth. scenario.

$\hat{\alpha}_j$ ($\hat{\alpha}_i$) is the fruit type intercept estimate for the jth. (ith.) alternative, or fruit type,

$\hat{\beta}_j$ ($\hat{\beta}_i$) is the price sensitivity parameter estimate for the jth. (ith.) alternative or fruit type,

x_{jk} (x_{ik}) is the level of price, in currency units, for the jth. (ith.) alternative or fruit type, defining part of the kth. scenario.

Table 2 Comparison of market shares in different locations for the three fruit types sold at the prevailing market price, derived from choice modeling estimations

	Percentage market shares		
Location of fruit stall	Organic	Conventional	Spray-free GM
New Zealand	46%	27%	27%
Sweden	39%	39%	21%
France	46%	34%	20%
Belgium	54%	26%	20%
UK	50%	34%	17%
Germany	50%	28%	22%

across the six countries for the three fruit types. This pattern consisted of the organic produce gaining the largest market share, followed by conventionally grown fruit, with the spray free-GM product gaining the smallest market share.

However, the pricing scenario that we consider most likely would be organic produce sold at a premium, with a discount offered for the spray free-GM option, given its lower cost of inputs. Market-share estimates based on this pricing scenario found market shares changing both by product type and by country location of the fruit stall (**Table 3**). Organic produce lost market share in all countries, except Belgium, where it still dominated. By comparison, the spray free-GM fruit gained the highest market share in the New Zealand, Swedish and German stalls, and reached 30% or more in the UK and French stalls (**Table 3**). The gains in market share of the spray-free GM fruit between the first scenario (**Table 2**) and the second scenario (**Table 3**) were significant at the 99% confidence level or more in all stalls, except the Belgian stall, as indicated by the asterisks in **Table 3**.

In conclusion, this research revealed that a significant (and in some markets, surprisingly high) percentage of consumers in European countries appear willing to choose GM food provided there is a price advantage coupled with a consumer benefit (in this case, 'spray-free' status). Our findings are in line with the proposition of classical economic theory that consumers will seek to maximize utility[6]. They are also consistent with data from the latest Eurobarometer report[1]. Although "strong opposition" to the overall concept of GM foods technology was reported, when Eurobarometer respondents were asked whether they would buy GM food "if it contained less pesticide residues than other food," 18% indicated "yes, definitely" and 33% indicated "yes, probably." When asked whether they would buy GM food "if it were cheaper than other foods," 12% indicated "yes, definitely" and 24% indicated "yes, probably"[1]. Our revealed preference findings are broadly consistent with these recent Eurobarometer data.

Caution is needed in interpreting these findings on a country-by-country basis; extrapolating uncritically from behavior observed at a single purchasing location to everywhere within that country is not realistic. Furthermore, not all consumers would be in the habit of stopping at roadside stalls to purchase fruit.

Table 3 Comparison of market shares for the three fruit types in a scenario where organic is priced at a 15% premium and the spray-free GM product is discounted 15%, based on the choice modeling estimations

	Percentage market shares		
Location of fruit stall	Organic	Ordinary	Spray-free GM
New Zealand	20%***	20%*	60%***
Sweden	20%***	38% ns	43%***
France	28%***	39%*	33%**
Belgium	55% ns	29% ns	17% ns
UK	32%***	38%*	30%**
Germany	33%***	31% ns	36%**

Significant differences better than 95% (*), 99% (**) or 99.9%(***) confidence level or otherwise (ns, not significant) between market share in scenario 1 (**Table 2**) and scenario 2 (**Table 3**) for each fruit type/country (data set) combination. These confidence intervals were estimated using the hybrid bootstrap method of Shao & Tu[12], each comparison using 2,000 resamples.

Nevertheless, in aggregate these findings represent a very substantial sample of consumers spread through six countries in which the GM issue has reached high levels of awareness and controversy. The findings are indicative, and it would not be prudent to base either policy or commercial decisions upon them without further research. The results imply that GM food may prove much more acceptable than has been previously widely stated, provided there is full information availability and clear statements of consumer benefits.

ACKNOWLEDGEMENTS

We thank Tim Breitbarth, Amy Coleman, Jean-Baptiste Faucher, Karen Knightbridge, Charlotte McLeod, Miranda Mirosa, Romain Mirosa, Barbara Neve and Anna Wellingham for help in these experiments. We also thank the anonymous reviewer who pointed out the support for our findings in the latest Eurobarometer report. This work was supported by a grant from the Agricultural and Marketing Research and Development Trust of New Zealand.

AUTHOR CONTRIBUTIONS

J.G.K., D.W.M. and D.K.H. contributed equally to this work. J.G.K. oversaw the research program and obtained funding. D.W.M. designed the experiments and conducted the statistical analyses. J.G.K. and D.K.H. wrote the paper. D.F.E. conducted the experiments in New Zealand and Sweden. All authors discussed the results and commented on the manuscript.

COMPETING INTERESTS STATEMENT

The authors declare no competing financial interests.

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