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Process versus product: which determines consumer demand for genetically modified apples?*

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One debate in the literature regarding consumers' reactions to genetically modified food (GMF) centres on whether consumers react to the process of gene technology or to the specific GMF products. Results from a choice experiment survey in New Zealand indicate that consumers are heterogeneous with regard to GMF and that some modifications are viewed more positively than others. These findings suggest that for some consumers the process of gene technology is the decisive factor in evaluating GMF, while for others the different potential GMF products are valued according to their enhanced attributes.

Key words: choice modelling, consumer surveys, food, genetic modification, preferences.

1. Introduction

The research reported in this paper addresses whether consumers consider the specific attributes of genetically modified food (GMF) products, or instead react generally to the process of genetic modification (GM) in food. Some research has found that consumers make judgements about specific GM products offered (Frewer *et al.* 1997; Burton and Pearse 2002). Other research has found a strong correlation between general attitudes to GM and product-specific reactions, concluding that consumer reactions are driven by these general attitudes (Bredahl 2001). For GM in apple production, different applications of gene technology all elicited similar reactions from consumers (Richardson-Harman *et al.* 1998), again suggesting that reactions to specific products may be determined by general attitudes to GM.

This debate on process-centred versus product-centred reactions has not been resolved, but its resolution could be useful for projecting future GMF demand. If consumers find some products more acceptable than others, agri-food companies could focus research and development spending on more acceptable products. If consumers'

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concern is with the process of GM per se, then the percentage of consumers likely to buy a product will remain stable regardless of the specific enhancement that it provides. It is therefore important to determine the intrinsic acceptability of GMF and the modifications that are more acceptable.

In this paper, results of a survey conducted in Christchurch, New Zealand, are presented. The survey was designed to assess whether consumers react differently to GM apples that offer different benefits. Information that could identify different consumer groups was also collected and analysed. Results generally show that some consumers evaluate GM apples based on the enhancements offered, while other consumers reject all GM apples. The following discussion begins with a review of the theory of consumer choice and its application to research on willingness to pay for GMF. The model and survey design for the present research is then presented in some detail. The final sections contain a presentation of the modelling results and a discussion of the research findings.

2. Theory

This research is based on the neoclassical model of consumer choice. Individuals are held to consume goods, in this case food, because the goods provide satisfaction or enjoyment, that is, utility. The goods they choose to consume out of all possible goods are the ones that provide the most utility, subject to constraints such as budgets and time.

When consumers make their choices with respect to GMF, the fact that a product is GM could affect their utility calculations in two ways. First, the process of GM could be a discrete product attribute, evaluated separately from other attributes. For some consumers, GM may make no difference to a food's utility. For others, it may decrease a food's utility, even to the point that they will not choose to consume GMF. Either way, the value of GM does not vary according to the product offered. This is a process-based judgement.

The second possibility is that GM could affect utility in more complex ways. For example, GM has been found more acceptable when it is used to reduce pesticides than when it is used to reduce prices (Pew Initiative 2003). It is commonly asserted that second-generation GMF, that will have consumer-oriented benefits as opposed to production-oriented benefits, will be more positively viewed by consumers (e.g., Rousu *et al.* 2003). This assertion suggests that the specific benefit produced through GM affects the perception of the technology, that the net value of GM is not discrete but the result of an interaction with the offered benefit. To understand the importance of an interaction, consider that falling asleep in bed is generally pleasant, that falling asleep in a meeting may be professionally damaging, and that falling asleep behind the wheel may be physically dangerous. If consumers' evaluations are affected by such an interaction, then their assessments of GMF are product-based.

The neoclassical model that individuals choose goods with the greatest utility is the starting point for Random Utility Maximisation (RUM) models. RUM models were developed to analyse actual choices that people make and map these choices to the underlying preferences (McFadden 2001). To an outside observer, the utility (U)

that people derive from their choices, whether in the transport mode they choose, the food they eat, or the survey responses they select, may be divided into observed (V) and latent (ε) components. It is thus possible to model the choices made as functions of observed attributes of the choice alternatives and their relative weights. The observed component of utility can be expressed as a weighted sum of the attributes:

$$V_j = \beta \mathrm{X}_j,$$

where X is a vector of the attributes of alternative j and β is a vector of weights, which are parameters to be estimated.

If a respondent chooses alternative a from a choice set A with j alternatives, this implies:

$$U_a > U_j \quad \text{for all } j \in A, j \neq a, \text{ or}$$

$$V_a + \varepsilon_a > V_j + \varepsilon_j, \text{ and finally}$$

$$\beta \mathrm{X}_a + \varepsilon_a > \beta \mathrm{X}_j + \varepsilon_j.$$

A common RUM model for estimating parameters from choice data is the multinomial logit (MNL) (Maddala 1983; McFadden 2001). It assumes that the unobserved latent term is identically and independently distributed with a Weibull distribution. The probability that option a will be chosen from among j options is given as:

$$\Pr(a) = \exp(V_a)/\Sigma \exp(V_j).$$

The observed utility, V, can include both product attributes and personal characteristics of consumers interacted with product attributes (Louviere 2001):

$$V = \Sigma \beta \mathrm{X} + \Sigma \phi \mathrm{XZ},$$

where Z is a vector of personal characteristics, and ϕ is a matrix to be estimated that represents the weights attached to different product attributes by people with different characteristics.

One limitation of MNL is the Independence from Irrelevant Alternatives (IIA) axiom, which holds that the ratio of choice probabilities between two alternatives is unaffected by the other alternatives in the choice set (McFadden 2001). Although this is in theory a potential issue, in practice it is unclear how much bias this property introduces into MNL results. There are many possible approaches to addressing IIA. One option is to test for violation of IIA, either by using a Hausman–McFadden test statistic or by estimating a nested model and testing whether it is an improvement over the non-nested model (Hausman and McFadden 1984).

A second option is to estimate a model that relaxes IIA; several such models are available. The nested model is well established, but requires that the different alternatives can be nested into mutually exclusive nests. The cross-nested logit relaxes the requirement of mutual exclusivity, but it is difficult to estimate in research with generic alternatives. An even more powerful model and one that has gained favour is the random parameters logit or mixed logit (Train 2003). It allows estimation of both the mean and the variance of each parameter and allows for correlated error structures. However, because the distribution of parameters must be specified exogenously, the mixed logit raises the question of the appropriate shape of the distributions. The particular choice of distribution could significantly affect willingness-to-pay (WTP) estimates. In particular for GM, whether to use a distribution with a central tendency, a bimodal distribution, or a distribution with specific point masses is an important consideration (Rigby and Burton 2004).

A final option is to do nothing (Kennedy 2003); that is, the researcher can assume that the data are consistent with IIA or that the MNL is robust to misspecification. This course of action is particularly appropriate for choice situations in which there is no a priori case for expecting IIA violations. This is the approach used for the present research.

3. Willingness to pay for genetically modified food

RUM models have been used to analyse data from attribute-based stated choice surveys. These surveys ask respondents to choose one of a set of alternatives or products. Theoretically, the chosen alternative is the one with the greatest utility. In the surveys, the attributes of the products are systematically varied to examine the impact of changes in attribute levels on choices of products. These surveys are useful for assessing consumer responses to GMF because they efficiently gauge reactions to many different combinations of product attributes (Bateman *et al.* 2002). They are also appealing because they highlight the trade-offs that consumers might face between different product attributes, such as between taste and price. A primary theoretical advantage of choice modelling is that it generates data consistent with RUM models, allowing the use of standard discrete choice analysis (Louviere *et al.* 2000). If price is one of the product attributes, the estimated model also allows calculation of implicit prices, or 'partworths' (Bennett and Blamey 2001). For discussions of attribute-based stated choice methods, see Bateman *et al.* (2002), Bennett and Blamey (2001) and Louviere *et al.* (2000).

Choice experiment surveys have been used to determine WTP for GM as a general characteristic of the food system. Results from the UK (Burton *et al.* 2001; Rigby and Burton 2003, 2004) and Australia (James and Burton 2003) have identified different consumer segments with very different WTP. Some consumers are willing to purchase GMF at small discounts compared to non-GMF prices, or even with no discount at all. Other groups, however, are willing to pay large premia for non-GMF. Their willingness to pay is clearly driven by the large negative value they place of GM technology, and no amount of inducements would seem sufficient for them to choose GMF products.

Choice experiments have also been used to assess WTP for specific products rather than the whole food supply. Burton and Pearse (2002) examined preferences for beer made from conventional and GM barley and yeast. Those respondents who were concerned about their cholesterol levels were prepared to pay an additional $A0.83 on average for a GM beer that reduced cholesterol levels. Chern *et al.* (2002) examined

WTP for GM salmon and for GM-fed salmon (which were not themselves GM) in the USA and Norway. Premia for conventional salmon were between 41 and 67 per cent, with GM salmon attracting a larger discount than the GM-fed salmon. These choice experiment results suggest that respondents are evaluating the specific products offered them.

The above research used 'main effects' designs to create the sets of choices presented to respondents. This is the smallest possible design that can be used to estimate how each separate food attribute affects WTP (Louviere *et al.* 2000). A main effects design does not, however, allow the estimation of any interaction effects (John 1998). Any complex effects described in the above research, such as the difference between GM with and without cholesterol-reducing effects, result from the way the levels of the attributes were specified. As a result, Burton and Pearse (2002) were able to estimate WTP for GM beer and for GM beer that reduced cholesterol, but could not estimate a separate effect for the cholesterol reduction.

4. Methodology

The estimated model for the research reported in this paper was a standard MNL, including terms for individuals' characteristics. The research focused on a specific product, apples, to add realism to the survey. Apples are a good example because they are widely consumed and can be modified to achieve changes in eating qualities, nutrition and use of agricultural chemicals. They also contain DNA and protein, which highly processed foods such as oils and sugars do not (Rousu *et al.* 2004). Eating a GM apple would therefore mean eating modified DNA. The five product attributes included in the model were: price (*Price*), genetic modification (*GM*), level of chemical insecticide use (*Chem*), level of antioxidants (*Health*) and flavour (*Flavr*). There were two personal characteristics used to identify different types of consumers: gender and attitude towards GM technology, which was specified with five dummy variables as explained later. Finally, to examine the possibility that respondents' evaluations could be process-based or product-based, four interactions were included: *GM–Price*, *GM–Chem*, *GM–Health* and *GM–Flavr*. In the final model to be estimated, the deterministic portion of utility was:

$$\begin{aligned} V = {} & \beta_0 + \beta_1(Price) + \beta_2(GM) + \beta_3(Chem) + \beta_4(Health) + \beta_5(Flavr) \\ & + \beta_6(GM\text{-}Price) + \beta_7(GM-Chem) + \beta_8(GM-Health) \\ & + \beta_9(GM-Flavr) + \phi_1(GM)(\text{gender}) + \phi_{2\text{–}5}(GM)(\text{attitudes}). \end{aligned}$$

In the end, the MNL was preferred over other possible RUM models for two reasons. First, the research used generic alternatives (Apple A, Apple B, Apple C) rather than labelled alternatives (GM Apple, Non-GM Apple) to avoid sensitising respondents to the specific issue of GM. This choice essentially ruled out nested and cross-nested logits as possible models. Estimating a mixed logit was still a possibility, but raised the question of the correct parameter distributions. It would be instructive to know more about WTP within a less complex modelling framework such as MNL in order to select the correct distributions.

4.1 Survey design

Appropriate survey design requires finding an equilibrium among the competing demands of realism, orthogonality and balance. Realism is an important consideration in all stated choices research in order to obtain valid statements regarding respondents' preferences (Bateman *et al*. 2002). Orthogonality in survey design allows researchers to separate the effects of one product attribute from the effects of another, and balance in attribute levels is desirable (Louviere *et al.* 2000). The following discussion of survey design for the present research describes the compromise reached regarding realism, orthogonality and balance.

An expanded choice set design was used to capture the data necessary to estimate the interactions in the above model. Only interactions between GM and other attributes were estimated, as increasing the number of estimable interactions greatly increases the size of the choice set. This research was focused specifically on the issue of GM. The five attributes and their levels are listed in Table 1.

To design the choice sets, the attribute *GM* was initially set aside and a main effects design for a 3^4 factorial was created for the remaining attributes (Hahn and Shapiro 1966). This fractional factorial was then modified in several ways to include all the attributes and levels in Table 1. One change concerned the attribute *Flavr*, which was collapsed from three levels to two: Current and Improved. Second, to observe the main effect of GM and its interaction effects, the alternatives were doubled so that each profile occurred both as genetically modified and non-genetically modified (Hahn and Shapiro 1966; Louviere *et al.* 2000). Third, each *Price* level was split into two dollar values. Here the design sacrificed some orthogonality in order to collect richer data. Correlation between attributes was zero, except for correlations between *Price* and other attributes. The correlations between *Price* and *Health*, *Flavr*, *Chem* and *GM* were 2.22×10^{-17}, 0.0929, 0.0537 and -0.0730, respectively. The design was thus nearly but not fully orthogonal.

Design efficiency was assessed by a D-efficiency calculation (Kuhfeld *et al.* 1994; Chrzan and Orme 2000). The result was a relatively low 45.4, which is likely the result of an unbalanced design. However, concern with realism outweighed concerns about balance. GM was kept as a binary attribute, because this is how food labels in New Zealand present GM to consumers: food either is or is not GM. There is currently no provision for proportional content of GM (James and Burton 2003) or indications that GM is plant-only (Burton *et al.* 2001). Flavour was also presented as binary – either Current or Improved – because experience of apple flavour is complex and highly

Table 1 Attributes and levels for choice experiment

Apple attribute	Attribute levels
Price (% change) (*Price*)	−50, −20, −10, 0, +20, +50
Genetic modification (*GM*)	Conventional, GM
Level of chemical insecticide use (*Chem*)	−30%, no change, +10%
Level of antioxidants (*Health*)	Current, improved 1, improved 2
Flavour (*Flavr*)	Current, improved

Table 2 List of profiles – first choice alternative

Option	Chem	Health	Flavr	Price	GM
1	−30%	Current	Current	−50	GM
2	−30%	50% more	Improved	50	GM
3	−30%	100% more	Current	−10	GM
4	Current	Current	Improved	0	GM
5	Current	50% more	Current	−50	GM
6	Current	100% more	Current	20	GM
7	10%	Current	Current	50	GM
8	10%	50% more	Current	0	GM
9	10%	100% more	Improved	−50	GM
10	−30%	Current	Current	−50	Non-GM
11	−30%	50% more	Improved	50	Non-GM
12	−30%	100% more	Current	0	Non-GM
13	Current	Current	Improved	−10	Non-GM
14	Current	50% more	Current	−50	Non-GM
15	Current	100% more	Current	50	Non-GM
16	10%	Current	Current	50	Non-GM
17	10%	50% more	Current	−10	Non-GM
18	10%	100% more	Improved	−20	Non-GM

Chem, level of chemical insecticide use; Health, level of antioxidants; Flavr, flavour; GM, genetic modification.

personal (Harker *et al*. 2003). Alternatives would have been descriptors, such as sweet, tart, crunchy, juicy etc., which would become complicated, or graduated improvements, such as Somewhat Improved and Very Improved.

Substituting actual attribute values for the codes, the final list of profiles for the first choice alternative is shown in Table 2.

A list of the second choice alternatives was produced by 'shifting' (Chrzan and Orme 2000; Louviere *et al.* 2000).

The choice sets were created by pairing one profile randomly chosen from the first set with another randomly chosen from the shifted set to create 18 sets, and then including a status quo alternative with each set. The choice sets were randomly assigned to two different versions of the survey, so that each respondent was asked nine questions. The full set of choice questions is available from the authors upon request. A sample choice set is shown in Figure 1.

Although prior research suggests that demographic variables are not always statistically significant predictors of GM demand, this information was collected in the survey because it can help identify and describe consumer segments. Personal information that has proven useful in determining a respondent's willingness to pay for GMF is gender and levels of purchases of organically grown food, so data on these characteristics were collected.

Attitudes towards genetic modification, GMF and nature have all been shown to correlate with WTP for GMF. A set of attitudinal questions was therefore included in the survey. Respondents were asked if they agreed with several statements, using a 5-point Likert scale from 'strongly agree' to 'strongly disagree'. The attitudinal statements were of three types. The first type was general statements about food and

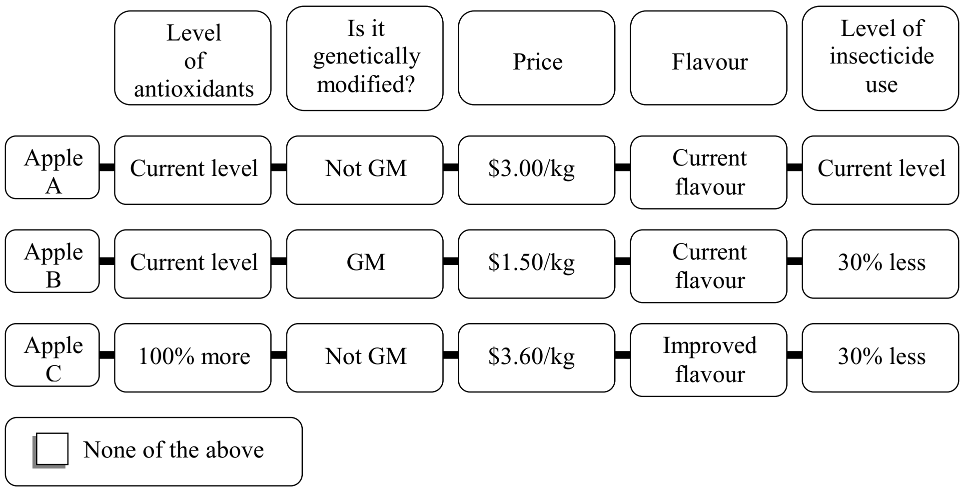

Figure 1 A sample choice set.

preferences, specifically on the apple attributes included in the survey. The second type of statement was intended to capture attitudes towards GM and GMF; these were drawn from research on attitudes to GM (Small *et al.* 2001; Verdurme *et al.* 2003). The third type was statements useful in distinguishing respondents with preferences for environmental goods (Rosenberger *et al.* 2003).

The survey was administered as personal interviews at five supermarkets in Christchurch, New Zealand in November 2003. Shoppers were approached at random as they entered the supermarkets, and information on non-participation was not gathered. The different locations meant that a range of shoppers could be contacted. Surveys were also conducted at different times of the day. Descriptive statistics were computed with SPSS version 10. MNL models were estimated with BIOGEME version 0.6, software from Michel Bierlaire for estimating Generalised Extreme Value models (Bierlaire 2003), using the algorithm donlp2.

5. Results

A total of 374 interviews were completed, of which 21 were excluded from analysis because of incomplete responses. Nearly four-fifths of the respondents were female and the same fraction were the main food shoppers for their household. This was expected, as the interviews occurred at supermarkets. These results are consistent with Johnson (2004), who found that men are 14 per cent of household shoppers in New Zealand's South Island. For ethnic identification, age, and household income, the sample is not statistically different from New Zealand national figures at a probability of 0.10, as confirmed by χ^2 tests. The sample is significantly different from national educational attainment statistics, with the sample being more highly educated than average. The sample is thus reasonably consistent with a random sample of New Zealand households. However, by targeting shoppers specifically, the research collected

Table 3 Responses to attitudinal statement

	Strongly agree (%)	Agree (%)	Neutral (%)	Disagree (%)	Strongly disagree (%)
Producing genetically modified food is too risky to be acceptable to me	18.7	22.4	25.5	26.3	7.1

information on potential market performance of GM apples rather than the economic value of GM apples to the whole population.

Respondents' attitudes towards GMF were captured by the responses to the statement 'Producing genetically modified food is too risky to be acceptable to me' (Table 3). Only those respondents who used the 5-point Likert scale were included in the modelling; those who did not answer or responded 'Don't know' were excluded.

The models were estimated using 2378 choice observations, three-quarters of the dataset. An additional 782 observations were excluded as a holdout sample in order to assess how well the estimated model performed on data not used to estimate the model.

Parameter estimates for the model are presented in Table 4. The one change from the above model is that two parameters were estimated for insecticide use, corresponding to either an increase or decrease from current levels. This specification is consistent with Burton *et al.* (2001) and was used because the data exhibited strong non-linearity. Overall, the model performs well, with a pseudo-R^2 of 0.208. Although the results are not presented here, the model performed nearly as well on the holdout sample as on the estimation sample. The parameters generally have the expected signs and levels of significance. There is a bias towards the status quo, or the apples currently available. Among the product attributes, increases in antioxidants, improvement in flavour, and decreases in insecticide use all increase choice probability, indicating that respondents value these improvements. By contrast, increased insecticide use and increased price both decrease choice probability. The signs of these parameters are all as expected. Finally, although GM apples are less likely to be selected, the parameter is not significant at the 5 per cent level.

The impact of the GM attribute on choice probability is complex. The GM attribute by itself, estimated by the parameter *GM*, is not significant. Instead, the impact of the GM attribute depends on respondents' attitudes. All of the parameters estimating the impact for attitudinal groups are significant at the 10 per cent level, and three are significant at the 1 per cent level. They all have the expected magnitudes and signs. Those who strongly disagreed that GMF was too risky (i.e., those who find the risk acceptable) were the base case. All other respondents were less likely to choose a GM apple. The more they agreed with the statement, the less likely they were to choose such an apple.

The results of the interactions are mixed. GM technology does not seem to interact with two of the four other product characteristics: the parameters for *GM–Flavr* and the two insecticide variables are not significant. The parameter for *GM–Health* is significant at the 10 per cent level (and very nearly at the 5% level) and negative. The parameter for the interaction of GM with price is highly significant and positive.

Table 4 Estimation results for interactions multinomial logit (MNL) model

Variables	Estimated parameters (standard errors)
Status quo constant	0.258 (0.111)**
Product attributes	
Antioxidants	0.428 (0.114)***
Flavour	0.389 (0.102)***
GM	−0.566 (0.414)
30% less insecticide	0.495 (0.113)***
10% more insecticide	−0.766 (0.131)***
Price	−0.755 (0.053)***
'GM food is risky'	
Strongly agree	−3.055 (0.342)***
Agree	−1.882 (0.243)***
Neutral	−0.872 (0.216)***
Disagree	−0.358 (0.211)*
Strongly disagree	(base)
Gender – respondent male	0.001 (0.144)
Interaction terms	
GM–antioxidants	−0.363 (0.189)*
GM–flavour	0.135 (0.169)
GM–30% less insecticide	0.089 (0.185)
GM–10% more insecticide	0.262 (0.210)
GM–price	0.263 (0.085)***
Log-likelihood at convergence	−2070.07
Likelihood ratio test	1084.86
R^2	0.208

*Significant at the 10 per cent level; **significant at the 5 per cent level; ***significant at the 1 per cent level. GM, genetic modification.

One unexpected result is that the estimated parameter for gender was essentially zero. In most research on attitudes towards GM, men and women are found to react differently; an exception is Rigby and Burton (2003). One possible reason for this lack of significance is that over half (55.3%) of the male respondents were main household shoppers. These respondents are thus a non-random sample of the male population.

Calculations of the partworths or WTP for product attributes are presented in Table 5. Partworths for non-GM and GM alternatives are calculated separately. The significance of the GM–price parameter signals that the partworths for the two types of apples must be calculated with different denominators. The denominator for non-GM alternatives is the parameter for price; the denominator for GM alternatives is the sum of the parameters for price and the GM–price interaction. The WTP for non-GM apple attributes is straightforward: respondents would pay a premium for more antioxidants, better flavour or less insecticide use. The WTP for GM apples is not so straightforward. The main effects follow the same pattern as the non-GM apples (they are calculated with the same numerators but a different denominator). The interaction terms show different effects, however. The GM–antioxidant interaction nullifies nearly the entire WTP for more antioxidants. The WTP for that attribute is $NZ0.567 for non-GM apples, but only $NZ0.132 when the antioxidants are in a GM apple. The interaction

Table 5 Calculations of partworths

	non-GM alternative	GM alternative		
		Main effects	Interaction effect	Total
Status quo constant	0.342			
Product attributes				
Antioxidants	0.567	0.869	−0.737	0.132
Flavour	0.516	0.792	0.275	1.066
30% less insecticide	0.656	1.006	0.181	1.187
10% more insecticide	−1.015	−1.557	0.532	−1.025
'GM food is risky'				
GM + strongly agree		−7.360		−7.360
GM + agree		−4.975		−4.975
GM + neutral		−2.922		−2.922
GM + disagree		−1.877		−1.877
GM + strongly disagree		−1.150		−1.150

GM, genetic modification.

between the two attributes suggests that greater antioxidants are not viewed as positive when achieved through GM. The WTP for greater flavour and less insecticide are, on the other hand, increased by the interaction effects. That is, respondents prefer apples with greater flavour and have negative WTP for GM apples. Adding just the main effects together, however, overstates respondents' reluctance to purchase these GM apples. The positive interaction suggests that respondents are willing to set aside some of their aversion to GM apples when presented with apples with better flavour or less insecticide.

As an example, a respondent who strongly disagreed that GMF was risky would be willing to pay $NZ2.57 per kilo for an apple genetically modified to have better flavour.

Base price	$NZ3.00
Status quo effect	−0.342
Flavour (main + interaction)	1.066
GM + strongly disagree	−1.150
Price for GM apple	$NZ2.574

Table 5 also contains partworths for respondents' attitudes. For these calculations, the parameter for GM and the parameter for the attitudinal category are summed, then divided by the sum of the price and GM–price parameters. Their magnitudes relative to apple attributes indicate that respondents who view GM food as risky would on average not purchase GM apples. Other respondents, however, are less negatively disposed and would choose GM apples given the right incentives. Respondents who agreed or strongly agreed that GM food is risky apply total discounts to the GM apples greater than the base price for status quo apples, which was $NZ3.00. The partworths associated with other attitudinal groups are not so large, and suggest that GM apples would have a market, given the right prices and product enhancements.

6. Discussion

These results support both sides of the process-versus-product debate. The estimated parameters for different attitudes towards the riskiness of GMF show an order-of-magnitude difference between respondents who are comfortable with the technology and those who are not. A sizeable minority does not react categorically to GM as a food attribute. For them, the value of GM apples is determined by the specific benefits that can be provided. The value that they attach to the attribute *GM* is a function of the specific benefits that GMF offers. On the other hand, a large minority might not consume GMF even if it were free: the total discount demanded exceeded the original cost of the conventional apples. For these respondents, the process of GM in food production is decisive in their assessments of the apples offered.

The model produced useful information about the attributes that respondents value in the GM apples. Two attributes, insecticide use and flavour, did not interact significantly with GM. This result implies that the value of these attributes to respondents is essentially independent of the use of gene technology. If anything, the simple sum of the GM discount and the main effects premium for either of these attributes understates respondents' WTP for such apples. The interaction terms, although not significant, increase the total WTP for the GM apples with either improved flavour or less insecticides.

The opposite is true for antioxidants, which react negatively and marginally significantly with the GM attribute. Respondents value apples with greater antioxidants, but the use of GM negates nearly all the increased value; the apples then still receive the standard GM discount. These results suggest that greater antioxidant content in apples is perceived as valuable, but not if it is achieved with GM technology. One possible explanation is that antioxidants are perceived as a natural health benefit, and that GM somehow 'corrupts' its naturalness (Coyle *et al.* 2003). Another explanation is that those respondents who value increased antioxidants also are reluctant to consume GMF. If their WTP is driving the parameter estimate for antioxidants, then positive values for antioxidants would correlate with highly negative values for GM, leading to the observed findings. Of course, both explanations could be correct.

A final result that could be interesting to the agri-food sector was the non-significance of gender. Prior research has suggested that men and women have different reactions to GMF. Nevertheless, it seems that when they act in the role of main household food shopper their choices are similar.

An issue in the analysis of the data was the IIA assumption. Although alternatives to MNL were rejected as inappropriate, a Hausman–McFadden test (Hausman and McFadden 1984) was attempted. Unfortunately, the test could not be performed for this model. The strong correlation between respondents' attitudes and their choices made the restricted models unsolvable. As there is no compelling case that offering respondents three apples instead of two apples would alter relative choice probabilities, the MNL is likely to be a correct model.

7. Conclusion

This research was designed to assess whether consumers' choices of GMF were process-based or product-based. The results suggest that for some consumers, it is the process that is decisive. These consumers, who make up 41.1 per cent of the sample, do not seem willing to consume GM apples even when they cost nothing. By contrast, product attributes do affect the choices of consumers who view GM most favourably (33% of the sample). Respondents in this category valued increases in antioxidants, improved flavour, reductions in pesticide use and lower prices. Furthermore, the value that these respondents placed on GM technology was a function of the specific benefits the technology could provide. The choices of the remaining consumers (25.5% of the sample) would be affected by the estimated attribute interactions, but the base GM discount is also relatively sizeable; the net impact on their choices is difficult to categorise.

There are opportunities for the research to be extended. First, respondents' knowledge or awareness of antioxidants was not tested. It is therefore not clear that respondents were fully informed about the health benefits associated with higher levels of antioxidants. Reactions to antioxidants might have been affected by ignorance and would therefore not be representative of demand for healthier food.

Second, this research did not address the issue of the type of genetic modification. Other research has shown that consumers react differently to plant-only GM versus inter-kingdom transgenic GM (Burton *et al.* 2001). The generic designation 'GM' in this survey could be masking such a differential response.

This research contributes to existing literature and knowledge regarding GM food by demonstrating that the specific food attribute to be modified is important. The main effects in the model showed that increased antioxidants, improved flavour and less insecticide use are valuable to consumers. The interaction terms in the model further show that the implied price for these attributes cannot simply be added to the discount on GM food; they in fact interact quite differently. As a result, this research also demonstrates the value of considering the impact of likely attribute interactions when designing choice surveys.

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