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# Canadian Consumers' Assessments of Potential Risks and Benefits of Plant Molecular Farming and Potential Food Industry Implications

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# PROJECT REPORT

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# Canadian Consumers' Assessments of Potential Risks and Benefits of Plant Molecular Farming and Potential Food Industry Implications

Applications of crop biotechnology extend beyond genetic modifications of input traits of crop plants to research on output traits, including the production of food plants with modified functional components, as well as non-food compounds produced for industrial or medicinal uses. Potential new risks for food safety may arise from these applications. We report the results of two surveys that assess the extent of concern regarding these potential risks, relative to other risks for food safety. These focus, respectively, on risk assessments by members of the Canadian public and by Alberta food processors. Neither group sees genetically modified foods as major issues of food safety, although food processors perceive these to be of potentially more concern to consumers than to food safety. Although their assessments are influenced by socio-economic and demographic factors, Canadians appear to see plant molecular farming applications as only moderate indirect risks. While the use of genetic engineering to produce more nutritious and cheaper food is not seen as highly risky, this does not have as favorable a benefits-to-risks ratio as for medicinal or industrial applications. Yet, the analyses found that, overall, Canadians generally tend to be relatively comfortable with these "plant molecular farming" applications, particularly if they relate to medical and industrial uses, but also if this leads to improvements in nutrition and price of food.

**Keywords:** food safety, risk perceptions, environmental risks, quantitative assessment

**JEL Classification:** C12, D12, I19, Q18.

## Background

Research on plant biotechnology is supported by both public and private sectors in Canada. Some of this is directed to food-based applications of plant biotechnology which include transgenic applications to produce “genetically-modified foods” (GM foods, sometimes referred to as “genetically engineered” (GE) foods). Other research is directed to non-food applications, commonly referred to as “plant molecular farming” (PMF). These applications may lead to benefits of new or cheaper medicines, industrial products and foods, but may also be the source of appreciable risks to food safety from contamination by PMF materials, as well as potential environmental risks and costs (eg, see May, 1990; Veeman, 2009). Research on Canadian consumers’ views of possible impacts of these types of current and prospective applications of modern agricultural biotechnology, applied to crop plants, are one focus of this report. Complementing this, a second focus concerns the views of a sample of Alberta food processors on related impacts, both for food safety, and for the business performance of their firms.

This report consists of three parts. In the first two of these, focus is placed on perceptions of risks and benefits of PMF applications expressed by Canadian consumers. The third part of the report summarizes results from a survey of Alberta food industry representatives regarding their food safety practices and their related views of a number of food safety issues, including genetically modified (GM) inputs and GM-labelling. The rationale for focus in Parts I and II on public perceptions of safety reflects that these are important aspects of social welfare. Scientists’ risk assessments (“quantitative risk” measures), which are necessary components of any effective risk management plan, do not always agree with public perceptions of risk (“qualitative risk”). It is difficult to determine the level of potential risk that is socially acceptable for a given potential PMF benefit because the risks and benefits of these applications are vaguely defined and, although some applications potentially could be widely distributed, some may be specific to narrow groups. These features highlight the prominent roles of ethics, politics and social issues in debates over emerging agricultural biotechnology applications and related public policy. Gaining a better understanding of public views of these risks and benefits should aid in developing PMF policy and regulation (Huot, 2003). The rationale for Part III is the high and increasing level of public interest in food safety and lack of knowledge about how public concerns are accommodated by food processors.

The data for both Parts I and II of this report come from a Canada-wide survey of 1574 respondents, collected in November 2005, in which a number of different questions focused on assessments of risks and benefits from several different types of applications of agricultural biotechnology to plants. These survey data provide opportunities to check the consistency of respondents' assessments of risks and benefits when different question contexts and wordings are used, and to apply different types of statistical tests to this body of data, enabling assessment of the consistency or sensitivity of results drawn from different methods. Specifically, in Part I, non-parametric analysis of risk rankings and benefit rankings that are given to various PMF applications (amongst other food risk issues) by sampled Canadian consumers are outlined. In Part II, a summary of statistical tests based on a narrower econometric application of ordered probit models is reported. These focus on associations between Canadian's assessments of risk in the form of risk ratings, ascribed to four different types of applications of crop biotechnology, and respondents' socio-economic and demographic characteristics.

In Part III of this report, a summary is given of the responses of a sample of Alberta food processors to a survey that queries the food safety practices that they employ and related issues, including GM-foods and GM-labelling, relative to their interest to maintain food safety and business performance. The data on which Part II is based were collected in 2008 as the survey responses of 42 representatives of Alberta firms that process food products, representing 11 % of the total number of Alberta food processors. This component of the project formed the M.Sc. thesis of Lynne Fletcher (Fletcher 2010).

## Significance to Canadian Agriculture and Food Industries

Applications of agricultural biotechnology are becoming of increasing importance in crop-based agriculture; further innovations that are proposed involve the use of genomic technologies for the production of plant-based medicinal drugs and industrial products. However, these cropping innovations involve many unknowns and uncertainties relative to risk-benefit situations that may be involved with different types of products and containment scenarios. Similarly, there is little knowledge of the actions that may be/are being taken by food industry firms in response to public perceptions of genomic technologies and the possibility of food contamination from non-food products. These issues are assessed in the broader context of public concerns and public and private actions to assure food safety. More knowledge of these features should aid in policy development for agricultural and food innovations and help to inform food industry strategies to maintain food safety.

## Contributions to Education Training and Technology Transfer

Funding from this project contributed to the thesis research project of M.Sc. student Lynne Fletcher (Fletcher 2010).

# Part I: Plant Molecular Farming: Nonparametric Analysis of Canadian Consumers' Concerns

In Part I we draw heavily on Veeman, Volinskiy and Adamowicz (2009) in reporting non-parametric analysis of data from the November 2005 Canada-wide survey of 1574 respondents in which assessments of the risks and benefits from several different types of applications of agricultural biotechnology to plants were queried. A series of nonparametric tests are conducted on ordinal survey data on risk and benefit assessments of respondents. Reasons for the choice of nonparametric methods include: these make relatively few assumptions, they tend to be widely applied, and are relatively robust. Consequently, they are often used to study people's attitudes, especially when these are expressed as rankings or ratings. Further, the methods chosen make it possible to reduce the problem of potential heterogeneity in scale use. On the latter point, it has long been known that survey respondents frequently vary in their use of rating scales (Cronbach, 1946; Lentz, 1938). While some individuals tend to use the upper portion of a rating scale, others use lower or middle portions. These ways of responding are referred to as "response styles" (Baumgartner and Steenkamp, 2001) and refer to a tendency to respond to questionnaire items independently of item content. Stylistic responding may inflate or deflate subjects' scores on measurement instruments and/or lead to erroneous conclusions about correlations between rating scores (Bagozzi, 1994). The nonparametric methods used in this analysis replace actual scores with their ranks, which mitigates potential scale usage heterogeneity.

### *The Survey Instrument: Part I*

Responses from 1574 respondents, aged 18 years or older, drawn from a national representative panel with the aid of an international market research company, provide the data for Part I. Based on existing literature on emerging applications of plant biotechnology and preliminary testing in focus groups, respondents were queried on risk, benefit and priority rankings for various types of GM crops and PMF applications. Respondents were initially provided a brief summary of information on plant molecular farming. This provided definitions, together with examples of potential applications and potential risks.

In the first set of questions (Q1) eliciting risk perceptions, opinions on a randomized listing of food risk issues were queried using a four point scale: "high risk," "moderate risk," "slight risk," almost no risk' and "don't know/unsure" for: "bacteria contamination of food; pesticide residuals; use of hormones in food production; use of antibiotics; genetically modified/engineered crops to increase crop production; medicines made from plant molecular farming through genetic modification/engineering; genetically modified/engineered crops to increase nutritional quality of food; genetically modified/engineered crops to produce industrial products like plastics, fuel or industrial enzymes; BSE (mad cow disease); use of food additives; fat and cholesterol content of food." A similar set of random-ordered questions (Q2) on possible environmental safety issues that might result from modern agriculture cited, in addition to the preceding four crop biotechnology applications, the following issues: "water pollution by chemical run-off from agriculture; agricultural waste disposal; soil erosion from agricultural activity; use of herbicides and pesticides; adverse effects of agriculture on biodiversity."

The third set of risk perception questions (Q3) queried riskiness, overall, of three different PMF applications: "PMF to produce better and cheaper medical drugs; to produce better and cheaper industrial products; and to produce more nutritious and cheaper foods." Using four-point attitude rating scales and the "don't know/unsure" option, respondents were also queried on their beliefs concerning the extent to which contamination of food supplies and damage to the environment are major risks posed by PMF.

The fourth set of questions (Q4) queried potential benefits that might result from the preceding three types of PMF applications using a four point rating scale from "high benefit potential" to "almost no benefit potential" and "don't know/unsure." Using the same benefit scale respondents were also asked if they believed in benefits for Canada from the: "Opportunity for Canada to lead and create job opportunities in a new industry;" and "Production of new drugs that may not be produced by conventional methods or increase in quantities of existing medical drugs at less cost." People's opinions on containment restrictions that should be put in place for PMF research were also queried (Q5). A sixth set of questions (Q6) queried views of the relationships between PMF benefits and costs by asking respondents to choose from seven assessments (from "risks probably significantly outweigh benefits" to "benefits probably significantly outweigh risks" plus "don't know/unsure.") A summary question on whether or not PMF should be pursued in Canada was also posed (Q7).

## *Major Statistical Methods for Part I*

The Friedman test, or nonparametric two-way ANOVA, is the main inference instrument used in this part of the report. The test adjusts for scale use heterogeneity. It operates on the standard two-way layout:

$$X_{ij}^{*} = \mu + \beta_i + \tau_j + \varepsilon_{ij}, \qquad (1)$$

where $X_{ij}^{*}$, $i = 1...b,\ j = 1...k$, is the observed response of block (individual) *i* to treatment *j* (a rating item within a block of statements); $\mu$ is the common mean; $\beta_i$ and $\tau_j$ are block and treatment effects, respectively, and $\varepsilon_{ij}$ is an error term. Actual statement intensities $X_{ij}^{*}$ in Equation (1) are not immediately observed; instead, scale rating scores $X_{ij}$ that are observed are hypothesized to be the result of a mapping $f : \mathbf{R} \mapsto \{1,2,...,r\}$. That is, the unobserved $X_{ij}^{*} \in \mathbf{R}$ are mapped in a monotone manner to a set of *r* ordered discrete risk scores.

The Friedman test replaces the actual scores $X_{ij}^{*}$ with their ranks ($R_{ij}$) for the whole set of alternatives (i.e. within blocks), which makes the test applicable for randomized complete block designs as in Equation (1). While using the actual scores can lead to dubious cardinality assumptions and can be vulnerable to scale usage heterogeneity, using ranks preserves only the ordinal nature of the data. Thus the test can be used with non-independent treatments ($\beta_i$, the block effects, are individual-specific). Consequently, it is not necessary to assume that a particular source of risk is independent of assessments of other risk issues. However, perceived risks are not directly observable, thus as applied in this study Friedman's test may have less power than if the underlying $X_{ij}^{*}$ were available. Under the null hypothesis of all treatments having the same effect on respondents, the Friedman test statistic is distributed as a $\chi^2$ variable with the degrees of freedom equal to the number of treatments minus one.

Associations between different measures of attitudes were evaluated using Kendall's concordance coefficient $\tau$, a nonparametric association measure for a pair of variables, conceptually similar to correlation (Conover, 1999). This ranges between -1 and 1. Positive values (concordance) indicate that greater values of one variable correspond to greater values of the other, i.e. that the two change in the same direction. Negative values (discordance) indicate the opposite. Unlike the correlation measure of co-dependence, concordance is not limited to linear dependence and can be used meaningfully with arbitrarily associated variables. Other complementary tests (specifically the post-Friedman test of Dunn (1965), tests of equality of multivariate distributions by Szekely and Rizzo (2004; 2005), and tests of ambivalence/concordance by Gainous and Martinez (2005) and Thompson, Zanna, and Griffin (1995)) were applied.

## *Analysis, Results and Discussion for Part I*

### Risks to food

One major research question is whether GM/GE/PMF applications are viewed by members of the public as more, or less, risky than other potentially risky practices of food production or other food safety threats. Information from 1284 complete scores (Q1) was available to compute the Friedman test statistic. With 11 treatments (i.e. the risk sources summarized in Table 1), there are 10 degrees-of-freedom for the test statistic. The value of the test statistic was 879.86, with associated p-value of nearly zero, indicating that the null hypothesis of differences in risk attitudes was soundly rejected in favor of the alternative hypothesis: at least one source of food risk was seen as more important than others. To assess possible clustering among risk sources, post-test paired comparisons were run using the technique of Dunn (1965). Average ranks ( $\overline{R}_j$ ) and the summary of results from the two tests are presented in Table 1.

The transformed rankings ( $\overline{R}_j$ in Table 1) indicate that PMF medicines/foods/industrial products appear to be the least significant perceived sources of risk among the queried food risk issues. It is also of interest that the use of genetically modified/engineered crops to increase crop production is seen as more risky than these three types of PMF applications, as well as being riskier than some of the other cited food risk issues (specifically BSE and bacteria contamination). From Table 1 it can be seen that PMF medicine and nutritionally improved foods are seen as equally risky (ie, are not significantly different).

**Table 1. Food Risks: Average Ranks and Comparisons**

| Source of risk | $\overline{R}_j$ [a] | (b) | © | (d) | (e) | (f) | (g) | (h) | (i) | (j) | (k) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Bacteria (a) | 0.53 | * | * | * | * | * | * | * | * | | * |
| Pesticides (b) | 0.43 | | * | | * | * | * | * | * | * | |
| Hormones © | 0.40 | | | * | * | * | * | * | * | * | * |
| Antibiotics (d) | 0.43 | | | | * | * | * | * | * | * | |
| | | | | | | | | | | | |
| GM crops (e) | 0.48 | | | | | * | * | * | * | | * |
| PMF medicines (f) | 0.59 | | | | | | | | * | * | * |
| PMF foods (g) | 0.57 | | | | | | | * | | * | * |
| PMF industrial (h) | 0.61 | | | | | | | | * | * | * |
| | | | | | | | | | | | |
| BSE (i) | 0.55 | | | | | | | | | * | * |
| Additives (j) | 0.49 | | | | | | | | | | * |
| Cholesterol (k) | 0.43 | | | | | | | | | | |
| Observations | 1284 | | | | | | | | | | |
| Test statistic | 879 | | | | | | | | | | |
| P-value | $\approx 0$ | | | | | | | | | | |

Notes: [a] $\overline{R}_j$ are risk ranks ( $R_{ij}$ ) averaged across the sample. Values closer to 1 indicate lower risk.

[b] Asterisk ('*') indicates statistically different sources of risk at least at 0.01 significance level from Dunn's post (Friedman) tests. For comparability across similar questions, average ranks were transformed to fall in the interval [0, 1]: $\overline{R}_j \leftarrow \dfrac{\overline{R}_j - R_{\min}}{R_{\max} - R_{\min}}$, where $\overline{R}_j$ is the average rank for item *j* and $R_{\max}, R_{\min}$ are the maximum and minimum possible ranks, respectively. The closer is the transformed value to unity, the lower is the perceived risk.

Overall, PMF for industrial products is seen as the least risky PMF application. The highest food risk was perceived from using hormones in food production (0.40 rank), followed closely by concerns about pesticides, antibiotics, and high cholesterol foods (each ranking 0.43). Replacing actual risk scores with their within-block ranks helps remove block (individual-specific) effects $\beta_i$ . However, Equation (1) does not include possible interactions between treatments and blocks. These may, if present, involve the influence of respondents' demographic characteristics on treatment effects. A convenient way to test for interactions involves testing for identical distributions of ranks in two or more sub-samples of interest into which respondents are grouped. A nonparametric test of equality of two or more multivariate distributions, reported by Szekely and Rizzo (2004; 2005), was applied to assess such possible interactions. The test E-statistic is based on Euclidian distance between sample elements and the test itself is a derivative of the bootstrap permutation test (Efron, 1993). As indicated in Table 2, groupings based on gender and education gave distinctively different distributions of risk score ranks. However, a rural-urban grouping did not show differences. We conclude that respondents' gender and education play a role in their assessments of the Q1 food risk issues.

**Table 2. Food Risks: Respondent Groups.**

| Groups | Composition | E-statistic (p-value) |
|---|---|---|
| Gender | Male (49%) vs. female (51%) | 22.911 (0.009) |
| Residence location | Rural (33%) vs. metro area (67%) | 14.305 (0.177) |
| Education | College+(43%) vs. before college (57%) | 22.742 (0.008) |

The influence of gender and education on food risk assessments is also demonstrated in Table 3 which gives the average ranks for each food risk issue by these two groups. Men and those with more education tended to rate the use of genetically modified/engineered crops to increase crop production and the use of PMF for industrial products as less risky than did other groups of individuals. With some exceptions, there is a tendency for lower levels of risk to be assessed by male and college-educated respondents.

**Table 3. Food Risks: Average Ranks by Group.**

| | $\overline{R}_j$ [a] | | | |
|---|---|---|---|---|
| Source of risk | Gender | | College+ | |
| | M | F | Yes | No |
| Bacteria | 0.52 | 0.54 | 0.53 | 0.53 |
| Pesticides | 0.44 | 0.42 | 0.41 | 0.45 |
| Hormones | 0.40 | 0.40 | 0.39 | 0.41 |
| Antibiotics | 0.43 | 0.43 | 0.41 | 0.44 |
| | | | | |
| GM crops | 0.49 | 0.47 | 0.50 | 0.47 |
| PMF drugs | 0.59 | 0.59 | 0.60 | 0.58 |
| PMF foods | 0.56 | 0.57 | 0.57 | 0.56 |
| PMF industrial | 0.62 | 0.60 | 0.63 | 0.59 |
| | | | | |
| BSE | 0.55 | 0.54 | 0.54 | 0.55 |
| Additives | 0.50 | 0.47 | 0.49 | 0.49 |
| Cholesterol | 0.41 | 0.45 | 0.44 | 0.42 |

**Notes [a] $\overline{R}_j$ are risk ranks ( $R_{ij}$ ) averaged across the sample. Values closer to 1 indicate lower risk.**

Histograms of risk rank distributions for PMF used to produce medicines, industrial products and nutritionally improved foods, assessed for both male and female respondents and for those with and without college education (not shown in this report) also show differences in skewness, reflecting tendencies for lower levels of risk to be assessed by male and college-educated respondents. However, there tend to be higher levels of variation of ranks for these groups. This is also the case for risk assessments of genetically modified/engineered crops to increase crop production.

## Risks to the environment

Respondents were queried in Q2 on perceived risks to the environment from various agricultural practices, including GM/GE/PMF applications. To test the research question: “are applications of crop biotechnology, including PMF applications, seen as more or less risky from respondents’ points of view, as compared to other potential risky agricultural practices?” the Friedman test was applied to the 1304 available responses to Q2. The test statistic was 1690, with a p-value of nearly zero, indicating rejection of the no-difference null hypothesis with almost absolute confidence. These results are summarized in Table 4. PMF applications are seen as less risky than the other cited sources of environmental damage. No PMF treatment differs from the others at the test confidence level (< 0.01). The most prominent sources of perceived environmental risks from agriculture are chemical run-offs and related use of pesticides and herbicides (each ranked as 0.31, in contrast to the PMF applications which range from 0.59 to 0.61). Consistent with the rank-ordering of perceptions of food risks, the environmental riskiness of genetically modified/engineered crops to increase crop production is seen as more risky (in this case with an average rank of 0.53) than any of the three cited PMF applications, and has an average risk rank equivalent to the adverse effects of agriculture on biodiversity.

**Table 4. Risks to the Environment from Agriculture: Average Ranks and Comparisons.**

| Source of risk | $\overline{R}_j$ [a] | (b) | © | (d) | (e) | (f) | (g) | (h) | (i) |
|---|---|---|---|---|---|---|---|---|---|
| Chemical runoff (a) | 0.31 | * | * | * | * | * | * | | * |
| GM crops (b) | 0.53 | | * | * | * | | | * | |
| PMF medicines © | 0.60 | | | | | * | * | * | * |
| PMF foods (d) | 0.59 | | | | | * | * | * | * |
| PMF industrial (e) | 0.61 | | | | | * | * | * | * |
| Waste disposal (f) | 0.51 | | | | | | | * | * |
| Soil erosion (g) | 0.51 | | | | | | | * | * |
| Herbi/pesticides (h) | 0.31 | | | | | | | | * |
| Biodiversity (i) | 0.53 | | | | | | | | |
| Observations | 1304 | | | | | | | | |
| Test statistic | 1690 | | | | | | | | |
| P-value | $\approx 0$ | | | | | | | | |

**Notes** [a] $\overline{R}_j$ are risk ranks ( $R_{ij}$ ) averaged across the sample. Values closer to 1 indicate lower risk.

[b] Asterisk ('*') indicates statistically different sources of risk at least at 0.01 significance level.

## Potential risks of PMF applications considered alone

Question 3 allows consideration of whether, despite differences in context and wording, respondents' perceptions of risks of contamination of food supplies and damage to the environment by PMF are consistent with opinions stated in Q1 and Q2. For the Q3 questions on the extent of risk from PMF for food contamination and environmental damage, the Friedman test statistic was 122.34, with a nearly zero p-value, giving rejection of the null hypothesis of no difference of the cited risk factors with almost absolute confidence. Dunn's post-test revealed that risk perceptions expressed in Q3 for the three cited PMF applications were significantly different (p-value < 0.01). The transformed average ranks (as before, higher ranks indicate less riskier uses) are presented in Table 5.

**Table 5. Potential risks of PMF applications considered alone**

| Type of PMF application | Q1 | Q2 | Q3 |
|---|---|---|---|
| Production of better and cheaper medicines | 0.59 | 0.60 | 0.57 |
| Production of more nutritious and cheaper foods | 0.57 | 0.59 | 0.47 |
| Production of better and cheaper industrial products | 0.61 | 0.61 | 0.62 |

**Notes** [a] $\overline{R}_j$ are risk ranks ( $R_{ij}$ ) averaged across the sample. Values closer to 1 indicate lower risk.

The Q3 response rankings are generally consistent with those from Q1 and Q2. Use of PMF to produce better and cheaper industrial products is seen as relatively safest, followed by improved PMF-derived medicine. Again, the most risky use of the PMF applications is attributed to food production. Considering the three PMF applications queried in Q3 alone (omitting other risky practices) indicates more differentiation in people's risk attitudes toward these applications than is indicated in the responses to the first two sets of questions.

In parallel questions to Q3, Question 4 asked respondents to rank potential benefits from PMF to produce: better and cheaper medical drugs; better and cheaper industrial products; and more nutritious and cheaper foods. The Friedman test statistic is 186.28, rejecting the null hypothesis of no difference between these responses. Dunn's post-test reveals that perceptions of potential benefits significantly differ between the applications to produce medicines versus foods and industrial products (p-value < 0.01). The transformed average ranks (for which higher ranks indicate more beneficial uses) are:

- PMF to produce better and cheaper medicines: 0.60,
- PMF to produce more nutritious and cheaper foods: 0.46,
- PMF to produce better and cheaper industrial products: 0.44.

Thus pharmaceutical uses of PMF are assessed to be much more beneficial than the others cited, although, as seen in responses to Q3, this application is recognized not to be the safest of these types of PMF. Production of PMF food and industrial products is not seen to be as beneficial as PMF applications for medicine, but PMF for industrial products is perceived as the least risky application. The order of ranking of benefits assessed for the three types of applications are not identical to the order of their risk rankings. Rankings of benefits from production of improved and cheaper PMF foods are slightly higher than for production of industrial products. However, the food category has the worst risk rating and the lowest benefit-to-risks ratio (0.46:0.47) of the three PMF applications, while PMF medicines have the best such ratio (0.60:0.57). These results are consistent with previous findings of generally positive attitudes toward medical PMF applications and dislike of GM/GE applications in food production, as observed for European consumers from studies using the Eurobarometer survey (see Costa-Font and Mossialos, 2005; Gaskell et al., 1999).

The additional queries of Q4 included two additional benefit-related questions, specifically whether respondents perceived benefits from “the opportunity for Canada to lead and create job opportunities in a new industry”, and their belief in “benefits from new drugs that might not be produced by conventional methods or increases in quantities of existing medical drugs that might be produced at lower cost.” The Friedman test statistic was 4.72 (p-value about 0.2), so the null hypothesis of no difference in responses to the two questions is not rejected. Survey respondents did not see an appreciable difference in PMF-derived potential benefits of new jobs, versus increased capacity to produce cheaper new medicines.

## Containment of PMF plants

In Question Q5 respondents were asked to vote for one of six forms of containment restrictions that should apply to PMF research. These ranged from “allow to be grown in fields like conventional crops” (least restrictions) to “allow only in completely sealed facilities (e.g., underground)” (most restrictive). Kendall’s concordance measure was calculated between the ranks in the first two risk-related questions Q1, Q2, and the required level of containment as indicated in people’s responses to Q5 (see Table 6). These indicate a sharp contrast in levels of association between Q1 and Q5 as versus Q2 and Q5.

**Table 6. Concordance between Risk Ranks and PMF Plant Containment Requirements.**

| | Risks to food supply (Q1) | | | Risks to the environment (Q2) | | |
|---|---|---|---|---|---|---|
| | PMF drugs | PMF foods | PMF products | PMF drugs | PMF foods | PMF products |
| PMF using food crops to produce medicinal drugs | -0.04 (0.577) | -0.03 (0.166) | -0.04 (0.312) | 0.13 (0.172) | 0.40 (0.062) | -0.01 (0.822) |
| PMF using non-food crops to produce medicinal drugs | 0.05 (0.333) | 0.02 (0.725) | -0.01 (0.932) | 0.21 (0.162) | 0.25 (0.141) | 0.15 (0.143) |
| PMF using food crops to produce industrial products | -0.03 (0.434) | -0.02 (0.211) | 0.03 (0.175) | 0.24 (0.071) | 0.36 (0.006) | -0.04 (0.748) |
| PMF using non-food crops to produce industrial products | 0.03 (0.631) | 0.01 (0.983) | -0.01 (0.905) | 0.19 (0.242) | -0.07 (0.537) | 0.24 (0.074) |
| PMF using food crops to improve nutritional quality of foods | 0.07 (0.256) | 0.09 (0.146) | 0.05 (0.176) | 0.35 (0.051) | 0.61 (0.024) | 0.37 (0.042) |

Notes [a] Positive values indicate positive association: "higher risk means stricter containment requirements". P-values are in parentheses.

Interestingly, the estimated concordance measures for Q1 and Q5 vary in sign and are all small (the maximum value is 0.09) and insignificant. This may suggest that risks of food supply contamination by PMF are not perceived to be related to how carefully PMF research plants are separated from conventional plants. In contrast, estimated concordance measures for Q2 and Q5 are mainly positive, sometimes quite large (the maximum value is 0.61), and mainly significant at 10%. It appears that environmentally-conscious respondents were generally also concerned to have a high level of precaution in containment of PMF research plants.

**Attitudes to PMF overall**

Questions Q6 and Q7 summarize respondent's attitudes, overall, to PMF activities. Specifically, Q6 provided respondents the opportunity to weigh the pros and cons of PMF activities by indicating whether and to what extent PMF benefits exceed PMF risks. As an extension that seeks to sum up individuals' assessment of PMF activities, Q7 asks if PMF should be pursued in Canada. It is of interest to test whether respondents were consistent in these two different assessments.

The regular (Pearson) correlation between the responses to the two questions is not a suitable measure of dependence for this purpose, since both questions solicited qualitative (but ordered) responses. Concordance, the tendency of two factors to change co-directionally, was measured and tested against the null hypothesis of responses to Q6 and Q7 being unrelated. To this end, Kendall's statistic was calculated and tested against zero: the null hypothesis is that neither concordance nor discordance are present.

The ordering in Q6 is apparent and responses to Q7 were coded for consistency with this test. The obtained value of Kendall's statistic was 0.406 (1396 complete responses available). The null hypothesis of no relationship between responses to Q6 and Q7 was soundly rejected with a p-value nearly zero. That is, there was a strong tendency among those respondents for whom PMF benefits outweigh risks to vote for PMF being pursued in Canada (and vice versa).

Nearly 25% of respondents who had given definite responses to questions Q3 and Q4 (risks and benefits of three different types of PMF applications), said they did not know or were unsure whether PMF should be pursued in Canada. Indecision in stated preference questions may have various causes (Bateman and Willis, 1999); two that are frequently cited are general unfamiliarity with the issue and ambivalence.

A recent study (Costa-Font and Mossialos, 2005) found that between 35% and 45% of European respondents displayed ambivalent attitudes towards biotechnology applications. The design of questions Q3 and Q4 allows assessment of the extent to which ambivalence about PMF may have caused indecision with respect to the Q6 assessment of whether PMF activities should be pursued in Canada. Ambivalence was measured from responses to Q3 and Q4 using the index method of Gainous and Martinez (2005) and Thompson, Zanna, and Griffin (1995):

$$I_j = \frac{Risk_j + Benefit_j}{2} - | Risk_j - Benefit_j |, \qquad (2)$$

where $I_j$ is the ambivalence index for a PMF use *j*, and $Risk_j, Benefit_j$ are the scores obtained from questions Q3 and Q4. The ambivalence index ranges from -0.5 to 4 with intervals of 0.5. Risk and benefit scores were obtained by subtracting the initial responses from 5 so that the benefit/risk would increase with the score. Responses from Q7 were recoded so that 1 indicates indecision ("don't know/unsure") and 0 indicates a "yes" or "no" answer. Kendall's statistic was again used to test for absence of relationship between each of the constructed ambivalence indices and the indecision indicated in Q7 responses. The values of Kendall's association measures for these tests for the three types of PMF applications are:

- PMF to produce better and cheaper drugs: 0.088,
- PMF to produce more nutritious and cheaper foods: 0.077,

- PMF to produce better and cheaper industrial products: 0.073.

In all cases, the p-value of the test is below 0.0001, indicating a positive, though not strong, association between the ambivalence index and indecision of respondents on whether or not PMF should be pursued in Canada.

### *Part I Conclusions*

Our findings suggest somewhat mixed feelings of Canadian citizens regarding PMF. While not seen as major threats to food safety or damage to the environment, the PMF applications considered are seen as moderate indirect risks. While use of PMF to produce more nutritious and cheaper food is not seen as highly risky, this does not have as favorable a benefits-to-risks ratio as for medicinal or industrial applications of PMF. This feature may not be surprising given that there tends to be a general lukewarm feeling by many (and active opposition by some) toward GM/GE foods in Western countries. Yet, the survey found that, overall Canadians generally tend to be relatively comfortable with PMF applications, particularly if this relates to medical and industrial uses, but also if this leads to improvements in nutrition and price of food.

## Part II: Plant Molecular Farming: Ordered Probit Analysis of Canadian Consumers' Concerns

This stage of this project also involved analysis of data from the Canada-wide survey of 1574 respondents, collected in November 2005, in which assessments of risks and benefits from several different types of applications of agricultural biotechnology to plants were queried. Complementing the non-parametric analysis summarized in the preceding sections (in Part I of this report), in Part II econometric analysis of the risk rankings that were provided by respondents in response to Q1 and Q2 of the survey was undertaken in order to identify the intensity of beliefs and concerns held by different respondents. These questions in Q1 included queries, presented in random order, of risk rankings for use of genetically modified/engineered crops to increase crop production; the production of medicines made from plant molecular farming through genetic modification/engineering of crops; use of genetically modified/engineered crops to increase nutritional quality of food; and genetically modified/engineered crops to produce industrial products like plastics, fuel or industrial enzymes. The risk implications for the environment were also queried in terms of risk rankings for these GM/GE/PMF applications (in Q2), where questions were again presented in random order.

Data on the socio-economic and demographic characteristics of respondents were also collected, as were responses to attitudinal questions, including respondents' assessments of their own level of familiarity with PMF, opinions on their likely sources to obtain information on these applications, their most trusted sources of information, and their views on regulation and liability. This component of the current report focuses on modelling the risk ratings given by respondents relative to individual respondent's socio-economic and demographic characteristics and their views on trust.

It may be of interest to some readers to assess the results reported in this part relative to similar analyses that were undertaken for the other food risk isues that were queried in this 2005 survey. These are given in an earlier CMD report (see Veeman & Li 2007).

## *Statistical Methods for Part II*

The major analytical focus of this part of the report is the application of ordered probit analysis in models that relate the ordered risk rankings reported by respondents to individual respondent's socio-demographic characteristics and their views of trust in the food system, proxied by a trust variable (trust in various sources of information).

The basis of the ordered probit models is the recognized association between individuals' socio-demographic characteristics and their risk perceptions (for example, see Dosman et al, 2001). In addition, trust and lack of trust in the laws, regulators and organizations that are associated with controlling and limiting risky situations is believed to be associated with risk perceptions (Slovic 1993). Ordered probit models explicitly recognize the ordered risk rankings of respondents and thus, *a priori,* are well suited to this type of analysis. Following Greene (2003) these models are described as:

$$y_{mn}{}^{*} = x\beta + \varepsilon_{mn} \qquad (1)$$

where m=4 refers to each of the cited four PMF safety issues; and
$n$ =1, 2…..z, refers to the n-th respondent.

Ordered probit models assume that the rating measures that are available are based on the unobserved continuous dependent variable, y*. However, rather than y*, only the categorical value, $y$ , is observed. In these applications, the four category values represent the four risk rankings. Specifically, the four risk ranking categories are given values 0, 1, 2 and 3:

$y = 0$ if y* < $\mu_0$ (where $\mu_0$ equals zero) (4)

$y = 1$ if 0 <= y* < $\mu_1$

$y = 2$ if MU1 <= y* < $\mu_2$

$y = 3$ if MU2 <= y* < $\mu_3$

where y is the observed choice of risk ranking categories given in the survey responses. Boundary values between the different categories are the parameters ( $\mu$ ) to be estimated. The $\mu$ parameters are labelled here based on the category value for which they are the lower bound. For example, $\mu_2$ in is the lower bound for the category with value 2. We designate the lowest effective boundary value as zero. The estimated $\mu$ values follow the order $\mu_0 < \mu_1 < \mu_2 < \mu_3$. The distributions of the error terms $\varepsilon$ are assumed to be normal (Greene 2003).

The postulated explanatory variables in the ordered probit models include dummy variables indicating gender where males (MALE) are specified by 1, relative to female respondents, designated as 0. The respondents' age (AGE), whether there are children in the household (CHILD), level of education at the University level (UNIVER) or otherwise, and their income category (INCOME) are postulated explanatory variables, as are their region of residence and a trust proxy. The residence variables indicate whether the household is located in British Columbia, (BC); the prairie region (PRAIRIE); Ontario (ONT); or Quebec (QC). The trust proxy variable indicates whether respondents expressed trust in friends (TFRIEND); newspapers and magazines (TNEWS); the internet (TINTER); doctors and nurses (TDOCTOR); University scientists (TUNIVER) or the government (TGOV).

## *Analysis, Results and Discussion for Part II*

It is of interest at this point to refer back to the relative risk rankings for different food and environmental issues. As noted in Part I, the various GM/GE applications are certainly not ranked as the highest risk issues amongst either of the sets of cited food or environmental risk categories. The results from testing ordered probit models applied to the various food and environmental risk rankings in order to assess how these risk rankings are influenced by various socio-economic and demographic factors are summarized in Tables 7 through 10. Each of these tables gives estimated parameters for the variables postulated to explain the food risk and environmental risk applications, respectively.

Tables 8 and 10 present the estimated marginal effects for the significant explanatory variables for each of the two sets of ordered probit models, respectively. As expected, it is found from the ordered probit analysis that several socio-economic and demographic factors tend to influence risk perceptions. For example, the estimated marginal effects in Table 7 imply that respondents living in the Province of Quebec (QC) were more likely than others to view the use of GM/GE to increase crop production as a risky issue: as indicated by the marginal effects in

Table 8, Quebec respondents were 11% more likely than others to choose "high risk" than "moderate risk." Having a child living in the household led to a significant but relatively small increase in the probability of higher risk ratings being chosen. In contrast, males (MALE) and those with higher income (INCOME) tended to be less likely to rate the use of GM/GE to increase crop production as a high risk for food. However, gender was the only variable that was significant in the models explaining risk ratings of GM/GE crops used for medicines, while gender and income were the only significant variables explaining risk categories for GM/GE crops to increase nutritional qualities of food. For "Use of GM/GE crops for industrial products like plastics, fuel or industrial enzymes," there are significant marginal effects for gender, income and the trust proxy variable—those who indicated that they trusted information from University research scientists (TUNIVER). Males, those with higher incomes, and those with trust in scientists are less likely to indicate this as a high risk issue.

## Table 7. Estimation Results of Ordered Probit Models of Food Risk Rankings

| | Use of GM/GE to increase crop production | | Use of GM/GE crops to produce medicines | | Use of GM/GE to increase nutritional quality of food | | Use of GM/GE crops to produce industrial products | |
|---|---|---|---|---|---|---|---|---|
| | Coeff. | t-ratio | Coeff. | t-ratio | Coeff. | t-ratio | Coeff. | t-ratio |
| Intercept | 0.462 | 2.813 | 0.777 | 4.592 | 0.745 | 4.511 | 0.551 | 3.278 |
| MALE | 0.277*** | 4.785 | 0.226*** | 3.831 | 0.204*** | 3.531 | 0.279*** | 4.725 |
| AGE | -0.003 | -1.555 | -0.001 | -0.263 | -0.003 | -1.227 | 0.001 | 0.41 |
| CHILD | -0.052** | -2.123 | -0.038 | -1.576 | -0.033 | -1.4 | -0.012 | -0.51 |
| UNIVER | 0.024 | 0.356 | 0.071 | 1.04 | -0.015 | -0.231 | 0.04 | 0.584 |
| EMPLOY | -0.085 | -1.381 | -0.113 | -1.808 | -0.114 | -1.86 | -0.077 | -1.234 |
| INCOME | 0.024** | 2.13 | 0.014 | 1.194 | 0.024** | 2.132 | 0.027** | 2.304 |
| BC | 0.042 | 0.313 | 0.088 | 0.635 | 0.077 | 0.576 | 0.073 | 0.53 |
| PRAIRIE | 0.115 | 0.906 | 0.139 | 1.067 | 0.173 | 1.358 | 0.219 | 1.681 |
| ON | 0.093 | 0.794 | 0.114 | 0.947 | 0.176 | 1.493 | 0.138 | 1.15 |
| QC | -0.301** | -2.468 | -0.156 | -1.243 | -0.162 | -1.32 | -0.152 | -1.217 |
| TFRIEND | -0.107 | -0.962 | -0.05 | -0.444 | -0.058 | -0.534 | -0.131 | -1.201 |
| TNEWS | 0.077 | 1.06 | 0.131 | 1.768 | 0.015 | 0.214 | 0.114 | 1.547 |
| TRADIO | -0.074 | -0.844 | -0.153 | -1.747 | -0.07 | -0.809 | -0.049 | -0.56 |
| TINTER | 0.055 | 0.979 | 0.069 | 1.207 | 0 | 0.008 | 0.006 | 0.111 |
| TDOCTOR | -0.132 | -1.745 | -0.145 | -1.921 | -0.205 | -2.75 | -0.054 | -0.718 |
| TUNIVER | 0.059 | 1.002 | 0.099 | 1.64 | 0.102 | 1.725 | 0.156*** | 2.605 |
| TGOV | 0.079 | 1.127 | 0.089 | 1.24 | 0.129 | 1.86 | 0.086 | 1.195 |
| Mu( 1) | 0.78 | 27.207 | 0.944 | 30.478 | 0.845 | 28.683 | 0.888 | 29.486 |
| Mu( 2) | 1.673 | 40.682 | 1.893 | 47.463 | 1.827 | 46.001 | 1.733 | 45.772 |
| restrictedll | -2025.7 | | -1909.3 | | -2000.6 | | -1957.3 | |
| chi | 81.05 | | 59.86 | | 63.85 | | 80.14 | |
| df | 17 | | 17 | | 17 | | 17 | |
| obs | 1504 | | 1421 | | 1480 | | 1437 | |

Note: ** denotes significance at 0.05 level; *** denotes significance at 0.01 level.

**Table 8. Marginal Effects of Significant Variables Explaining Food Risk Rankings**

| Issues | Explanatory Variable | High risk ranking | Moderate risk | Slight risk ranking | Almost no risk |
|---|---|---|---|---|---|
| GM/GE to increase crop production | MALE | -0.095 | -0.012 | 0.049 | 0.059 |
| GM/GE to increase crop production | CHILD | 0.018 | 0.002 | -0.009 | -0.011 |
| GM/GE to increase crop production | INCOME | -0.008 | -0.001 | 0.004 | 0.005 |
| GM/GE to increase crop production | QC | 0.107 | 0.007 | -0.056 | -0.058 |
| GM/GE for medicines | MALE | -0.056 | -0.034 | 0.03 | 0.06 |
| GM/GE to increase nutritional qualities | MALE | -0.056 | -0.026 | 0.03 | 0.052 |
| GM/GE to increase nutritional qualities | INCOME | -0.007 | -0.003 | 0.004 | 0.006 |
| GM/GE for industrial products | MALE | -0.068 | -0.043 | 0.026 | 0.085 |
| GM/GE for industrial products | INCOME | -0.007 | -0.004 | 0.003 | 0.008 |
| GM/GE for industrial products | TUNIVER | -0.038 | -0.024 | 0.015 | 0.047 |

## Table 9. Estimation Results of Ordered Probit Models of Environmental Risk

| | Use of GM/GE to increase crop production | | Use of GM/GE crops to produce medicines | | Use of GM/GE to increase nutritional quality of food | | Use of GM/GE crops to produce industrial products | |
|---|---|---|---|---|---|---|---|---|
| | Coeff. | t-ratio | Coeff. | t-ratio | Coeff. | t-ratio | Coeff. | t-ratio |
| Intercept | 0.535 | 3.241 | 0.729 | 4.413 | 0.635 | 3.86 | 0.416 | 2.484 |
| MALE | 0.292*** | 5.069 | 0.232*** | 4 | 0.184*** | 3.196 | 0.271*** | 4.597 |
| AGE | -0.003 | -1.224 | -0.001 | -0.448 | -0.002 | -1.179 | 0.001 | 0.289 |
| CHILD | -0.029 | -1.218 | -0.039 | -1.632 | -0.037 | -1.58 | -0.023 | -0.968 |
| UNIVER | -0.034 | -0.51 | 0.075 | 1.126 | -0.022 | -0.333 | 0.022 | 0.316 |
| EMPLOY | -0.057 | -0.924 | -0.072 | -1.167 | -0.105 | -1.725 | -0.096 | -1.537 |
| INCOME | 0.03*** | 2.634 | 0.038*** | 3.366 | 0.039*** | 3.43 | 0.043*** | 3.702 |
| BC | 0.064 | 0.48 | -0.012 | -0.09 | 0.079 | 0.591 | 0.018 | 0.135 |
| PRAIRIE | 0.205 | 1.621 | 0.118 | 0.932 | 0.21 | 1.664 | 0.202 | 1.574 |
| ON | 0.159 | 1.355 | 0.036 | 0.307 | 0.164 | 1.407 | 0.08 | 0.677 |
| QC | -0.36*** | -2.943 | -0.316*** | -2.589 | -0.21 | -1.717 | -0.223 | -1.802 |
| TFRIEND | -0.187 | -1.675 | -0.172 | -1.554 | -0.072 | -0.652 | -0.062 | -0.566 |
| TNEWS | 0.038 | 0.526 | 0.075 | 1.029 | 0.093 | 1.284 | 0.095 | 1.3 |
| TRADIO | -0.008 | -0.095 | -0.105 | -1.212 | -0.063 | -0.723 | -0.054 | -0.615 |
| TINTER | 0.064 | 1.141 | 0.057 | 1.007 | 0.071 | 1.27 | 0.051 | 0.895 |
| TDOCTOR | -0.135 | -1.803 | -0.103 | -1.37 | -0.143 | -1.924 | -0.07 | -0.918 |
| TUNIVER | 0.033 | 0.565 | 0.069 | 1.168 | 0.062 | 1.055 | 0.092 | 1.529 |
| TGOV | 0.095 | 1.372 | 0.114 | 1.631 | 0.144 | 2.08 | 0.154 | 2.171 |
| Mu( 1) | 0.996 | 31.83 | 1.015 | 32.116 | 0.935 | 30.697 | 0.866 | 28.78 |
| Mu( 2) | 1.947 | 44.964 | 2.056 | 48.942 | 1.933 | 47.098 | 1.792 | 44.836 |
| restrictedll | -1982.5 | | -1939.21 | | -1989.48 | | -1951.8 | |
| chi | 112.41 | | 85.8 | | 76.75 | | 90.17 | |
| df | 17 | | 17 | | 17 | | 17 | |
| obs | 1499 | | 1469 | | 1487 | | 1435 | |

**Note: ** denotes significance at 0.05 level; *** denotes significance at 0.01 level.**

**Table 10. Marginal Effects of Significant Variables Explaining Environmental Risk Rankings**

| Issues | Variable | High risk | Moderate risk | Slight risk | Almost no risk |
|---|---|---|---|---|---|
| GM/GE to increase crop production | MALE | -0.089 | -0.023 | 0.057 | 0.055 |
| GM/GE to increase crop production | INCOME | -0.009 | -0.002 | 0.006 | 0.006 |
| GM/GE to increase crop production | QC | 0.117 | 0.017 | -0.073 | -0.061 |
| GM/GE for medicines | MALE | -0.057 | -0.035 | 0.04 | 0.052 |
| GM/GE for medicines | INCOME | -0.01 | -0.006 | 0.007 | 0.009 |
| GM/GE for medicines | QC | 0.084 | 0.041 | -0.06 | -0.065 |
| GM/GE to increase nutritional qualities | MALE | -0.05 | -0.023 | 0.031 | 0.042 |
| GM/GE to increase nutritional qualities | INCOME | -0.011 | -0.005 | 0.007 | 0.009 |
| GM/GE for industrial products | MALE | -0.075 | -0.033 | 0.038 | 0.07 |
| GM/GE for industrial products | INCOME | -0.012 | -0.005 | 0.006 | 0.011 |

The estimated class probabilities implied by the results in Table 10 for environmental risks of GM/GE applications are generally similar to those in Table 8 for food risks, but show some differences in detail. Males and respondents with higher incomes appear to be less likely to see the use of GM/GE to increase crop production as risky to the environment; those from the Province of Quebec are more likely to see this as environmentally risky. In contrast to respondents who reside in Quebec, males and those with higher income are less likely to see the use of GM/GE crops to produce medicines as risky to the environment. Similarly males and those with higher incomes are less likely to see the "use of GM/GE crops to increase the nutritional qualities of food" as risky to the environment. A similar pattern applies to risk categorizations for the "use of GM/GE crops for industrial products like plastics, fuel or industrial enzymes."

## *Part II Conclusions*

From the analysis of the ordered probit models that assess the impact on respondents' ordered risk rankings of their demographic, socio-economic and other characteristics it is seen that risk rankings given to the GM/GE/PMF applications that are cited are consistently associated with gender, income, and location of residence. Trust also seems to have an influence on respondents' risk perceptions, at least in some applications.

# Part III: Alberta Food Processors' Views of Food Safety

## *Survey of Alberta Food Processors*

This part of the report draws from the MSc thesis of Lynne Fletcher (Fletcher 2010). Its purpose is to identify the nature of influences on food safety practices and related views and decisions of Alberta food processors. A survey of Alberta food processors was undertaken to assess how Alberta food processors rank and respond to food safety issues relative to: their perceptions of consumers' concerns, their value chains, whether formal or informal; and government regulations and guidelines. One focus of assessment is the whether and how food processors identify and react to or accommodate public and stakeholder views and concerns. The survey that was developed obtained data in 2008 from 42 representatives of Alberta firms that process food products.

In the first part of the survey, characteristics of respondent firms were queried in terms of their sector, size, length of time the firm had operated, whether and where they exported their food products, and whether they had adopted or planned to adopt the food safety strategies of a hazard analysis critical control point plan (HACCP) or ISO certification. Other characteristics queried concerned whether there were employees specifically dedicated to food safety control, whether their products had been recalled, membership in a value chain, CFIA inspection, whether their customers inspect the firm's facilities, whether their end consumers' concerns were included in the design stage of their risk management planning, their perceptions of government regulations and whether external funding is available to improve the food safety of their facility. In subsequent sections of the survey respondents were asked to react to, in the form of rating scales, numbers of statements regarding their own food safety practices and strategies, their perceptions of their end consumers' views on food safety issues and practices, and the impact of their food safety practices on their own business performance.

Overall, the sample is judged to be generally representative of the Alberta food processing industry although, in terms of the numbers of firms relative to the provincial distribution of food processors, grain and oilseed processors are somewhat under represented, while fruit and vegetable processors, and dairy processors are over represented. Meat processors were accurately represented in term of the number of firms with respect to the provincial distribution but not in terms of their size. The respondent firms had varying levels of experience within the food industry, ranging from less than one year to 70 years in business. Most of the firms had been in business for between six and forty years. Surviving firms evidently require industry experience, which may enable them to respond to changing market conditions. Firms tended to agree that they consistently met minimum safety standards. Chemical guidelines were reported to be met least consistently but, on average, still ranked well above the neutral response (three). Respondents for the participating firms generally agreed that government regulations were adequate and self-reported meeting the guidelines.

### *Statistical Methods for Part III*

Two non-parametric tests, the Wilcoxon signed rank test and the Kolmogorov-Smirnov (K-S) test, were applied, using SPSS 15.0, to examine the survey data and the respondent firms' food safety behaviour. The Wilcoxon signed rank test is a nonparametric test which can be used as an alternative to the one sample *t*-test for paired data sets (Larsen and Marx 2001). When the samples meet the assumptions of the *t*-test, the Wilcoxon signed rank test tests for a significant difference between the means of the two groups; it tests for a difference in the distributions when the assumptions are not met (Winkler and Hays 1970, p. 857). In this case the Wilcoxon signed rank test was used to assess differences in the distributions of Alberta food industry firms' responses in order to identify whether these distributions were equivalent to, or statistically significantly different from, each other. The three pairs of treatments examined relate to: 1) whether or not respondent firms themselves rank specified food safety issues (i.e. residues, contaminants and allergens) similarly to how they perceive their consumers to rank these food safety issues; 2) the perceived relative importance by firms of selected practices (such as good manufacturing practices, ISO, and HACCP) to food safety provision and to improving business performance; and 3) whether firms' views of potential risks (such as employee hygiene, pesticides and spoilage) to food safety provision are seen by them to be equivalent hazards to the firms' business performance. For example, one set of treatments includes the set of questions: "How does *your facility* rank the relative hazard of: [chemical residues, pathogen contamination, etc]" and "How do *your end consumers* rank the relative hazard of: [chemical residues, pathogen contamination, etc]." Each question within these two treatments asked respondents to indicate their responses on a five-level rating scale from "very dangerous" to "very safe." The three different sets of treatments (on food safety issues; benefits to business; and hazards to business) included six, eight or ten specific questions, respectively.

The one sample Kolmogorov-Smirnov (K-S) test is also applied to determine whether the distributions of survey responses are significantly different from a normal distribution, specifically for responses to survey questions relating to firms' attitudes and beliefs, export status, and HACCP status. Thus the K-S test was used to evaluate the strength of respondent's attitudes toward and perceptions of the issues under consideration in each question. For example, respondents were asked to indicate whether "*The presence of GM or GM-derived ingredients is an issue of risk communication relative to your consumers,*" on a five-point rating scale from "strongly disagree" to "strongly agree." The more strongly respondents agreed or disagreed with the statement, the closer the average rank was to the tails of the rating scale, rather than being distributed normally about the mean rank of three, which indicated neither agreement nor disagreement with such a statement. One of the goals of this study was to identify opinions and the strength of respondent's attitudes toward government regulations and to food quality and safety, including possible concerns relating to genetic modification of food; several questions in the survey relate to these issues.

## Results, Analysis and Discussion of Pair-wise Tests of Relative Food Safety Hazards

Table 11 gives average responses to each of the ten food safety issues that respondents were asked to consider in the first pair of treatments. The rating scale in these two treatments was anchored between the ranks of "very dangerous" (scaled as 1) and "very safe" (scaled as 5). The Wilcoxon signed rank test null hypothesis is that the perception of the specific risk issues expressed by the firm, e.g., for allergens, is the same as the firm's perceived risk ranking for the same issue by its end-consumers.

The null hypothesis was rejected at $\alpha = 5\%$ or higher levels of significance for four of the ten risk issues queried, specifically for "GMO sourced ingredients," "allergens," "animal disease," and "pesticide residue." In each case respondent firms perceived their consumers to rank the issue, on average, as being more dangerous to food safety than the firms themselves ranked these issues. For "allergens" the average hazard ranking that respondents assigned was "dangerous", however, respondents perceived their end consumers to rank allergens as more dangerous, as seen in Table 11, which may reflect the individual-specific nature of food allergies. For "GMO sourced ingredients" the distributions of the two sets of responses were also significantly different: while these firm's own assessments of the danger to food safety of "GMO sourced ingredients" and their views of their customers' assessments of this feature both led to average rank values within the neither "dangerous" nor "safe" category, on average, consumers are perceived to rank GMO sourced ingredients as being significantly less safe than do the industry respondents themselves.

**Table 11: Industry Average Risk Rankings and Perceptions of Consumers' Risk Rankings (n=41)**

| Survey question / Food safety issue | How does your facility rank the relative hazard of these food safety issues [1]: | How do your end consumers' rank the relative hazard of these food safety issues [2]: |
|---|---|---|
| Chemical residues / contamination (process based, cleaners or disinfectants, etc.) | $2.5^{a}$ | $2.4^{go}$ |
| Pathogen contamination | $2.3^{b}$ | $2.2^{gh}$ |
| Physical contamination (broken needles, rubber gloves, chewing gum, hair, metal) | $2.4^{ab}$ | $2.1^{hi}$ |
| Allergens | $2.6^{abc}$*** | $2.2^{ghi}$*** |
| Trans fatty acids | $3.3^{d}$ | $3.0^{jk}$ |
| GMO sourced ingredients | $3.5^{e}$** | $3.1^{jlm}$** |
| Animal disease (BSE, Foot and Mouth) | $3.2^{e}$*** | $2.7^{ko}$*** |
| Pesticide residues | $3.0^{cdf}$** | $2.6^{n}$** |
| Food origin (foreign vs. domestic or local) | $3.3^{e}$ | $3.1^{ln}$ |
| Trust (lack of consumer trust) | $3.1^{f}$ | $3.1^{m}$ |
| [1,2] Average score from a scale of 1("Very dangerous") to 5 ("Very safe") | | |

**Notes:** *, **, ***: indicates a significant difference between the distribution of responses to the variable in each column at 10%, 5%, or 1% level respectively. The distribution of responses for each factor was compared between the treatments. Thus for "allergens" the distribution of responses within treatment one (in this case: the hazard level respondent firms assign to each food safety issue), indicated in the center column, was compared to the distribution of responses for treatment two (which in this case is the hazard level respondent firms perceive this customers to apply to each food safety issue), indicated in the right hand column. Asterisks indicate a significant difference between the distribution of responses under treatment one versus under treatment two. The distribution of responses about factors under consideration were also compared to other factors within each treatment, using the Wilcoxon signed rank test. Within each treatment, responses to each factor were compared to responses for each other factor within the treatment to evaluate if different factors posed different levels of risk. Superscripts a to m refer to the results, at the $\alpha = 5\%$ level, of the Wilcoxon Signed Rank tests conducted within each column. Factors with the same superscript did not have significantly different response distributions at the $\alpha = 5\%$ level when tested by the Wilcoxon Signed Rank Test. Many of these results show that these responses had similar (i.e. not statistically significantly different) response distributions.

The risk issue for which there is the largest discrepancy between the average of respondent firms' rankings of the risk to the firm and the perceived risk ratings that they ascribed to their customers, is "animal disease." Respondent firms, on average, perceived animal disease to be neither dangerous nor safe, while, on average, they perceived their consumers' to rank animal disease as "dangerous." "Pesticide residues" were also ranked on average by industry respondents as neither dangerous nor safe to the food safety of their operations, but it was perceived that their end consumers assign pesticide residues an average rank of "dangerous" to food safety, as seen in Table 11.

To assess relative differences in firms' perceptions of safety amongst the various cited food safety issues, rather than between the different treatment applications outlined above, the different risk issues within each treatment were also matched and evaluated using the Wilcoxon signed rank test, i.e. firms' response distributions to "allergens" were individually compared to their response distributions to the other issues (eg "GMO sourced ingredients," "pesticide residues" etc). Table 11 also illustrates the statistically significant differences among the ten food safety issues that resulted from this assessment, as indicated by superscripts and the explanatory note. For example, the distribution of responses by industry respondents to "chemical contamination residues" is significantly different at $\alpha = 5\%$ levels of significance from their response distributions for "pathogen contamination," "trans fatty acids," "GMO sourced ingredients," "animal disease," "pesticide residue," "food origin," and "[lack of] trust." "Pathogen contamination" was perceived to be more dangerous than "chemical residues" while the other six issues were ranked, on average, as less dangerous to food safety.

Respondents' perceptions of end consumers' risk rankings for different food hazards also demonstrated a significant difference in the distribution of responses to "chemical residues" relative to the five other cited issues. In this case, on average, "chemical residues" were ranked as more dangerous than: "physical contamination," "trans fatty acids," "GMO sourced ingredients," "food origin" and "[lack of] trust". Thus respondent firms perceived a significant difference between the risk to their operations from chemicals, ranked as dangerous on average, relative to pesticide residues, which were ranked as neither dangerous nor safe on average. Nonetheless, respondent firms did not perceive a difference between the distributions of perceived risk rankings by their end consumers for these two issues. Respondent firms, on average, ranked consumers' perceptions of both "chemical residues" and "pesticide residues" as dangerous to food safety. Similar tests to those reported above, which were applied to the entire group of respondents, were also performed for different groups of respondent firms, based on firm size, sector, and export status; these details are largely omitted from this report but are in Fletcher (2009).

## *Results, Analysis and Discussion of Pair-wise Tests of Responses On Factors Affecting Food Safety Provision and Business Performance*

Respondents were also asked to respond to two sets of questions on the following eight factors/practices: good manufacturing practices (GMPs), "HACCP", "ISO", "product recall system", "product traceability", "supplier certification", "wastage record system", and "reworking record system". The first of these sets of questions (treatments) asked: "*State the importance of each of these factors to the provision of food safety*" while the second (treatment 2) asked: "*State the importance of each of these factors on improving firm business performance.*" Firms were asked to rank each factor on five-part response rating scales which ranged from "very important" to "very unimportant." Using similar methods these responses to a pair of treatments which queried eight factors in two contexts were also assessed. Table 12 gives the average responses to the questions within these two treatments.

The null hypothesis for the Wilcoxon signed rank tests summarized in Table 12 is that the distribution of firms' responses for each factor is equal across the two treatments. Testing the responses of the aggregated Alberta industry sample of respondents indicated that "GMPS" and "HACCP" are two factors for which the null hypothesis of equally distributed rankings of importance was rejected (at $\alpha = 1\%$ for GMP and 10% for HACCP). The responses suggest that the most important factor seen for both food safety provision and improving firm business performance was "GMPs," followed by product traceability, and then by both a product recall system and HACCP. Both GMPs and HACCP use were perceived to be more important for providing food safety than for improving business performance. The distributions of responses to questions regarding "GMPs" were statistically significantly different from those querying the cited seven other factors, both for food safety provision and for improving business performance.

**Table 12: Average Ratings Given to the Importance of Specific Food Safety Practices for Food Safety Provision and their Impacts in Improving Firm Business Performance (n=41)**

| Survey scale question<br>Factor | State the importance of each of these factors to the provision of food safety [1]: | State the importance of each of these factors on improving firm business performance [2]: |
|---|---|---|
| Good Manufacturing Practices (GMPs) | 4.71*** | 4.51*** |
| Hazard Analysis Critical Control Points (HACCP) | 4.24[ab]* | 4.10[cde]* |
| ISO 22000 | 3.00 | 3.07[f] |
| Product recall system | 4.24[a] | 4.12[c] |
| Product traceability | 4.37[a] | 4.24[d] |
| Supplier certification | 4.10[a] | 3.98[e] |
| Wastage record system | 3.32 | 3.54[f] |
| Reworking record system | 3.46[b] | 3.56[f] |
| [1,2] Average score from a scale of 1("Very unimportant") to 5("Very important") | | |

**Notes:** *, **, ***- indicates a significant difference at 10%, 5%, or 1% between the distribution of responses to the variable in each column.

## *Results, Analysis and Discussion of Pair-wise Tests of Firms' Views of Factors Affecting Food Safety Risks and Business Performance*

In the third pair of sets of questions, respondent firms were queried about the risks of six potential hazards: "employee hygiene", "GM sourced ingredients", pathogen contamination", "physical contaminants", "pesticides" and "spoilage", to the provision of each of food safety and to business performance. The Wilcoxon signed rank test of the distribution of responses of aggregated Alberta food processor applies to treatments based on the question sets of: "*State the risk each of the following poses to the provision of food safety*" (treatment one) and "S*tate the risk of each of the following to business performance*" (treatment two). These tests rejected the null hypothesis of no differences between the distributions of respondents' views of the risk to food safety relative to the distribution of respondents' views of the risk to business performance arising from four of the ten queried hazards at the $\alpha = 10\%$ level of significance. These four hazards are "pathogen contamination", "physical contaminants", "pesticides" and "spoilage", as seen in Table 13.

**Table 13: Comparison of the Importance of Risks to Each of Food Safety Provision and Business Performance for the Aggregate Industry Sample (n=41)**

| Survey question / Factor | State the risk each of the following poses to the provision of food safety [1]: | State the risk of each of the following to business performance [2]: |
|---|---|---|
| Employee hygiene | 2.63[a] | 2.54[d] |
| GM sourced ingredients | 3.42 | 3.22 |
| Pathogen contamination | 2.66[ab]** | 2.27[e]** |
| Pesticides | 2.98[c]* | 2.63[df]* |
| Physical contaminant | 2.59[b]** | 1.24[ef]** |
| Spoilage | 2.83[abc]** | 2.44[def]** |
| [1,2] Average score per factor on a scale from "Very dangerous" (1) to "Very safe" (5) | | |

**Notes:** The distribution of responses for each factor was compared between the treatments. Thus for "employee hygiene" the distribution of responses within treatment one (in this case: the risk it poses to the provision of food safety.) indicated in the center column, was compared to the distribution of responses for treatment two (which in this case is the risk posed to business performance), indicated in the right hand column. Asterisks indicate a significant difference between the distribution of responses under treatment one versus under treatment two. The distribution of responses about factors under consideration was also compared to other factors within each treatment, using the Wilcoxon signed rank test. Within each treatment, responses to each factor were compared to responses for each other factor within the treatment to evaluate if different factors posed different levels of risk.

*, **, ***: indicate a significant difference at 10%, 5%, or 1%, respectively, between the distribution of responses to the variable in each column.

Superscripts a to f refer to the results, at the α = 5% level, of the Wilcoxon Signed Rank tests conducted within each column. Factors with the same superscript did not have significantly different response distributions at the α = 5% level when tested by the Wilcoxon Signed Rank Test. Many of these results show that these responses had similar (i.e. not statistically significantly different) response distributions.

Overall, physical contamination is seen by Alberta food processors as the riskiest of six cited issues to food safety and firm business performance. GM-sourced ingredients are seen as the lowest risk of these cited issues, being ranked as neither dangerous nor safe for the aggregate sample of respondents. Pathogen contamination was ranked, on average, as more dangerous to business performance than to food safety, which was also the case for "physical contaminants", "pesticides" and "spoilage". This was not the case for employee hygiene and GM sourced ingredients. However, testing on subgroups of firms indicated that exporters were an exception to the assessment of the danger of GM sourced ingredients. This subgroup responded that GM sourced ingredients posed a less serious risk to food safety than to business performance. In general, however, risks to food safety were seen as risks to business performance.

## *The Strength of Firms' Views About Food Safety and Quality: Results, Analysis and Discussion of Kolmogorov-Smirnov Tests*

The strength of respondent's attitudes and opinions expressed in term with agreement issues is evaluated using independent one sample Kolmogorov-Smirnov tests that determine whether or not the distributions of firms' responses to 12 different statements are distributed normally around the neutral rating choice of "neither agree nor disagree", "neither dangerous nor safe" or "neither important nor unimportant," as relevant. As the strongest attitudes and rankings are found at the tails of the response rating scales, one reason for finding non-normality arises when respondents' responses are skewed toward the tails. The more respondents that answered either "strongly agree" or "strongly disagree," the stronger is the rejection of the one sample K-S test. The null hypothesis in each one sample K-S test is that the responses will follow a normal distribution. The queried statements are in column one of Table 14.

The balance of Table 14 gives the average numerical rank of responses for the specified attitudinal statements (where "Strongly agree" is coded 5 and "Strongly disagree" is coded 1) and the distributions, in percentages, of responses to each of these statements. The null hypothesis that the distribution of responses followed a standard distribution was rejected for all twelve statements at the $\alpha = 10\%$ level of significance. At the $\alpha = 5\%$ level of significance the distribution of the responses indicate industry respondents have common opinions regarding the following ten statements: "*Any media attention to your industry is positive*," "*Your end retailers have the majority of the bargaining power in your value chain*," "*Your customers provide you with processing standards for purchasing your products*," "*Your food safety systems are sufficient for meeting consumer concerns*," "*Your food safety systems are sufficient for meeting customer demands*," "*Your food safety systems are effective*," "*The presence of GM or GM derived ingredients is an issue of risk communication relative to your consumers*," "*The presence of GM or GM derived ingredients is an issue of food safety*," "*Your products are labelled," "May contain GM ingredients,"*" and "*You would lose customers if your products were labelled," "May contain GM ingredients."*

**Table 14: Kolmogorov-Smirnov Test Results for Survey Responses of the Aggregate Sample to Attitudinal Statements, Average Responses and Response Distributions for Statements, (n=41)**

| | Total | Average | Strongly disagree | Disagree | Neither agree nor disagree | Agree | Strongly agree |
|---|---|---|---|---|---|---|---|
| | K-S Z statistic<br>*Asymp. Sig. (2-tailed)* | | *Percent of respondents* | | | | |
| Any media attention to your industry is positive | 1.371<br>*0.047*** | 2.8 | *12.2%* | *29.3%* | *36.6%* | *9.8%* | *12.2%* |
| Any media attention to your industry is a source of consumer distrust and lost revenue | 1.300<br>*0.068** | 2.7 | *14.6%* | *31.7%* | *29.3%* | *19.5%* | *4.9%* |
| Your end retailers have the majority of the bargaining power in your value chain | 1.823<br>*0.003**** | 3.4 | *7.3%* | *7.3%* | *36.6%* | *34.1%* | *14.6%* |
| Your customers provide you with processing standards for purchasing your products | 1.657<br>*0.008**** | 3.3 | *9.8%* | *14.6%* | *19.5%* | *46.3%* | *9.8%* |
| Your food safety systems are sufficient for meeting consumer concerns | 2.135<br>*0.000**** | 4.2 | *0.0%* | *4.9%* | *9.8%* | *46.3%* | *39.0%* |
| Your food safety systems are sufficient for meeting customer demands | 1.280<br>*0.075** | 4.3 | *0.0%* | *0.0%* | *7.3%* | *58.5%* | *34.1%* |
| Your food safety systems are effective | 2.793<br>*0.003**** | 4.3 | *0.0%* | *0.0%* | *4.9%* | *56.1%* | *39.0%* |
| Your value chain insists on identity preservation of all its raw ingredients | 1.416<br>*0.036*** | 3.8 | *0.0%* | *9.8%* | *31.7%* | *29.3%* | *29.3%* |
| The presence of GM or GM derived ingredients is an issue of risk communication relative to your consumers | 1.416<br>*0.036*** | 2.9 | *12.2%* | *14.6%* | *51.2%* | *17.1%* | *4.9%* |
| The presence of GM or GM derived ingredients is an issue of food safety | 1.702<br>*0.006**** | 2.9 | *12.2%* | *19.5%* | *43.9%* | *14.6%* | *9.8%* |
| Your products are labelled "May contain GM ingredients" | 1.794<br>*0.003**** | 2.0 | *43.9%* | *22.0%* | *29.3%* | *2.4%* | *2.4%* |
| You would lose customers if your products were labelled "May contain GM ingredients" | 2.088<br>*0.000**** | 3.2 | *9.8%* | *4.9%* | *53.7%* | *19.5%* | *12.2%* |

*, **, ***- indicates a significant difference between the distribution of responses and a normal distribution with 90%, 95%, or 99% confidence

At the α = 10% level of significance the distribution of responses by the aggregate industry sample rejected the null hypotheses of a normal distribution for two statements, "*Any media attention to your industry is a source of consumer distrust and lost revenue,*" and "*Your food safety systems are sufficient for meeting customer demands*," as seen in Table 14. Respondents generally disagreed with the statement "*Any media attention to your industry is a source of consumer distrust and lost revenue*," and generally agreed with the statement "*Your food safety systems are sufficient for meeting consumer concerns*." The three statements which received the highest level of agreement were "*Your food safety systems are effective*," "*Your food safety systems are sufficient for meeting customer demands*," and "*Your food safety systems are sufficient for meeting consumer concerns*." The three statements most disagreed with were "*Your products are labelled "May contain GM ingredients,"*" "*Any media attention to your industry is a source of consumer distrust and lost revenue*," and "*Any media attention to your industry is positive.*"

To test firms' attitudes toward food safety issues, the distribution of firms' responses to a set of questions regarding issues of food safety and risk, (to which the Wilcoxon signed rank test had earlier been applied), was also examined using the K-S test (see Table 15). Ten issues which may influence food safety and/or food safety perceptions were queried, specifically: "chemical residues", "pathogen contamination", "physical contamination", "allergens", "trans fatty acids", "GMO sourced ingredients", "animal disease", "pesticide residues", "food origin" and "(lack of) trust." (see column 1 of Table 15; codings were "very safe"=5; "very dangerous"=1). The null hypothesis of normally distributed responses was rejected for six of the 10 issues at α = 5% level of significance, suggesting non neutral opinions for: "chemical residues", "physical contamination", "pathogen contamination", and "allergens", as well as "trans fatty acids" and "GMO sourced ingredients". However, the latter two issues were generally ranked as either very safe or neither dangerous nor safe while "chemical residues", "physical contamination", "pathogen contamination", and "allergens" tended to be ranked as dangerous. The null hypothesis was rejected with respect to two other issues at the α = 10% level of significance: "animal disease" and "food origin". The majority of respondents ranked the latter two issues as neither dangerous nor safe, however nearly one-fifth (19.5%) ranked "animal disease" to be very dangerous; regardless, a number of respondents ranked both issues as very safe, as seen in Table 15.

**Table 15: Kolmogorov-Smirnov Test Results for Aggregate Respondents' Ranking of Potential Food Safety Issues, Average Response and Response Distribution per Issue, (n=41)**

| | Total | Average | Very dangerous | Dangerous | Neither dangerous nor safe | Safe | Very safe |
|---|---|---|---|---|---|---|---|
| | K-S Z statistic | | | | | | |
| Factor | *Asymp. Sig. (2-tailed* | | *Percent of respondents* | | | | |
| Chemical residues / contamination (process based, cleaners or disinfectants, etc.) | 1.473 | 2.5 | *29.3%* | *29.3%* | *14.6%* | *14.6%* | *12.2%* |
| | *0.026*** | | | | | | |
| Pathogen contamination | 1.701 | 2.3 | *39.0%* | *29.3%* | *4.9%* | *17.1%* | *9.8%* |
| | *0.006**** | | | | | | |
| Physical contamination (broken needles, rubber gloves, chewing gum, hair, metal) | 1.797 | 2.4 | *36.6%* | *31.7%* | *7.3%* | *7.3%* | *17.1%* |
| | *0.003**** | | | | | | |
| Allergens | 1.656 | 2.6 | *19.5%* | *39.0%* | *19.5%* | *7.3%* | *14.6%* |
| | *0.001**** | | | | | | |
| Trans fatty acids | 1.912 | 3.3 | *4.9%* | *17.1%* | *48.8%* | *4.9%* | *24.4%* |
| | *0.001**** | | | | | | |
| GMO sourced ingredients | 2.339 | 3.5 | *0.0%* | *9.8%* | *58.5%* | *7.3%* | *24.4%* |
| | *0.000**** | | | | | | |
| Animal disease (BSE, Foot and Mouth) | 1.277 | 3.2 | *19.5%* | *7.3%* | *34.1%* | *7.3%* | *31.7%* |
| | *0.077** | | | | | | |
| Pesticide residues | 1.171 | 3.0 | *14.6%* | *24.4%* | *29.3%* | *9.8%* | *22.0%* |
| | *0.129* | | | | | | |
| Food origin (foreign vs. domestic or local) | 1.332 | 3.3 | *12.2%* | *7.3%* | *41.5%* | *14.6%* | *24.4%* |
| | *0.057** | | | | | | |
| Trust (lack of consumer trust) | 1.051 | 3.1 | *19.5%* | *17.1%* | *22.0%* | *22.0%* | *19.5%* |
| | *0.219* | | | | | | |

*, **, ***- indicates a significant difference between the distribution of responses and a normal distribution with 90%, 95%, or 99% confidence

The distribution of firms' scaled responses to questions on firms' views about the importance of common food safety practices were also assessed using the K-S test (see Table 16). These questions queried respondents about the importance of five practices in modern food safety provision: "risk analysis", "regulating food safety primarily to protect consumers' health," "using a "farm-to-table" approach to deal with potential hazards," "HACCP system adoption as a basis for risk management," and "the distribution of better information along [the] value chain to inform consumers and help them make more informed purchases", as in column one of Table 16.

**Table 16: Kolmogorov-Smirnov Test Results for Aggregate Respondents' Ranking of Important Trends in Modern Food Safety Provision, Average Response and Response Distribution per Trend, (n=41)**

| | Total | Average | Very unimportant | Unimportant | Neither important nor unimportant | Important | Very important |
|---|---|---|---|---|---|---|---|
| | K-S Z statistic | | *Percent of respondents* | | | | |
| | *Asymp. Sig. (2-tailed)* | | | | | | |
| Risk analysis | 1.920 | 3.9 | *2.4%* | *2.4%* | *22.0%* | *53.7%* | *19.5%* |
| | *0.001**** | | | | | | |
| Regulating food safety primarily to protect consumers' health | 1.848 | 4.4 | *2.4%* | *0.0%* | *4.9%* | *41.5%* | *51.2%* |
| | *0.002**** | | | | | | |
| Using a "farm-to-table" approach to deal with potential hazards | 1.684 | 3.9 | *0.0%* | *7.3%* | *22.0%* | *46.3%* | *24.4%* |
| | *0.007**** | | | | | | |
| Hazard Analysis Critical Control Points (HACCP) system adoption as a basis for risk management | 1.545 | 4.0 | *2.4%* | *4.9%* | *22.0%* | *29.3%* | *41.5%* |
| | *0.017*** | | | | | | |
| The distribution of better information along your value chain to inform consumers and help them make more informed purchases | 1.654 | 3.8 | *2.4%* | *2.4%* | *29.3%* | *46.3%* | *19.5%* |
| | *0.017*** | | | | | | |

*, **, ***- indicates a significant difference between the distribution of responses and a normal distribution with 90%, 95%, or 99% confidence

The responses rating the importance of these specified risk management practices are summarized in Table 16; in testing, "Very important" is coded as 5 ; "Very unimportant" as 1. At $\alpha$ = 5% or higher levels of significance, the null hypothesis of a normal distribution was rejected for each practice cited, with "risk analysis", "regulating food safety primarily to protect consumers' health," "using a "farm-to-table" approach to deal with potential hazards," "HACCP system adoption as a basis for risk management," and "the distribution of better information along [the] value chain to inform consumers and help them make more informed purchases" all generally being ranked as important or very important.

Finally, K-S tests were also applied to the responses to questions on firms' assessments of the importance or otherwise of specific potential signals of food quality to their end-consumers; these are listed in column one of Table 17. Again, "Very important" is coded as 5, while "Very unimportant" is 1. Overall, the most important signal of food quality was assessed as "consistent food safety," which the majority of respondents ranked as very important, followed in importance by "flavour", "appearance", and "smell". The fifth most important of the signals of food quality to the Alberta food processor respondents was "brand reputation". The least important signal of quality, with an average rank of neither important nor unimportant, was "GMO sourced ingredients", as seen in Table 17.

**Table 17: Kolmogorov-Smirnov Test Results for Aggregate Sample Responses Regarding Signals of Food Quality to the End Consumer: Average Response and Distribution per Signal, ((n=41)**

| | Total | Average | Very unimportant | Unimportant | Neither important nor unimportant | Important | Very important |
|---|---|---|---|---|---|---|---|
| | K-S Z statistic | | | | | | |
| | *Asymp. Sig. (2-tailed)* | | *Percent of respondents* | | | | |
| Brand reputation | 2.061 | 4.4 | *0.0%* | *2.4%* | *7.3%* | *36.6%* | *53.7%* |
| | *0.000**** | | | | | | |
| Certifications (Health Check, organic, etc.) | 1.280 | 3.8 | *0.0%* | *9.8%* | *31.7%* | *29.3%* | *29.3%* |
| | *0.075** | | | | | | |
| Consistent food safety | 2.671 | 4.6 | *0.0%* | *2.4%* | *2.4%* | *24.4%* | *70.7%* |
| | *0.000**** | | | | | | |
| Food origin (foreign vs. domestic or local) | 1.298 | 3.7 | *0.0%* | *12.2%* | *29.3%* | *34.1%* | *24.4%* |
| | *0.069** | | | | | | |
| GM free | 1.758 | 3.4 | *2.4%* | *9.8%* | *48.8%* | *22.0%* | *17.1%* |
| | *0.004**** | | | | | | |
| GMO sourced ingredients | 1.772 | 3.1 | *9.8%* | *9.8%* | *53.7%* | *17.1%* | *9.8%* |
| | *0.004**** | | | | | | |
| Healthful ingredient lists | 1.430 | 3.8 | *4.9%* | *2.4%* | *26.8%* | *36.6%* | *29.3%* |
| | *0.033*** | | | | | | |
| Internal quality assurances | 1.615 | 3.9 | *0.0%* | *2.4%* | *39.0%* | *24.4%* | *34.1%* |
| | *0.011*** | | | | | | |
| Labels | 1.512 | 4.1 | *0.0%* | *0.0%* | *26.8%* | *36.6%* | *36.6%* |
| | *0.021*** | | | | | | |
| Packaging | 1.801 | 4.3 | *0.0%* | *0.0%* | *9.8%* | *46.3%* | *43.9%* |
| | *0.003**** | | | | | | |
| Smell | 2.242 | 4.5 | *0.0%* | *0.0%* | *7.3%* | *36.6%* | *56.1%* |
| | *0.000**** | | | | | | |
| Texture | 2.040 | 4.4 | *0.0%* | *0.0%* | *14.6%* | *34.1%* | *51.2%* |
| | *0.000**** | | | | | | |
| Flavour | 2.516 | 4.6 | *0.0%* | *0.0%* | *4.9%* | *31.7%* | *63.4%* |
| | *0.000**** | | | | | | |
| Appearance (i.e. product colour, bruises) | 2.433 | 4.6 | *0.0%* | *0.0%* | *4.9%* | *34.1%* | *61.0%* |
| | *0.000**** | | | | | | |

*, **, ***- indicates a significant difference between the distribution of responses and a normal distribution with 90%, 95%, or 99% confidence

### *Principal Component and Binary Logit Models to Analyze Firms' Adoption of Management Practices: Results, Analysis and Discussion*

Principal component analysis was conducted on 1, respondent food industry firms' assessments of signals of food quality and 2, their potential motivations to adopt HACCP, an important element of food safety management. SPSS 15.0 was used in each case. Factors were extracted using a verimax rotation. Those factors with eigenvalues exceeding one are identified in the tables of results (see Tables 18 and 19). A third analysis assessed factors associated with non-adoption of HACCP; results for this are not formally presented in this report.

The analysis of firms' assessments of specified signals of food quality (these are listed in columns 1 of Table 17 and 18) was undertaken to assess commonalities among these quality measures that might enable these to be grouped, as a basis for better understanding of the major motivators of the basis of firms' food safety practices. The results of this component of the analysis are summarised in Table 18. Four factors are identified, as indicated in Table 18. These indicate: 1, The importance to food firms of *sensory* based quality measures of quality (smell, flavour, appearance and texture; 2. The importance to firms of their own ability to *control* quality (certifications, internal quality assurance, and food origin); 3. Firms' assessments of the importance of provision of quality-based *information* signals to their customers (labels, healthful ingredient lists, packaging, and brand reputation; and 4. Issues associated with avoidance of *concern* (not having consistent food safety and being undecided with respect to having GM sourced ingredients or being GM ingredient free are the characteristics which group in the fourth factor).

**Table 18: Principal Component Analysis of Responses from Aggregate Sample re Signals of Food Quality to the End Consumer, Mean Ranks and Factor Loadings (n=41)**

| | Mean | Factor 1: sensory based quality | Factor 2: control | Factor 3: information | Factor 4: concern |
|---|---|---|---|---|---|
| Smell | 4.5 | **0.950** | -0.047 | 0.136 | -0.022 |
| Flavour | 4.6 | **0.922** | -0.054 | 0.194 | 0.010 |
| Appearance (i.e. product colour, bruises) | 4.6 | **0.912** | 0.044 | 0.069 | -0.025 |
| Texture | 4.4 | **0.694** | 0.086 | 0.349 | -0.242 |
| Certifications (Health Check, organic, etc.) | 3.8 | 0.000 | **0.826** | 0.066 | -0.005 |
| Internal quality assurances | 3.9 | 0.045 | **0.824** | 0.018 | -0.115 |
| Food origin (foreign vs. domestic or local) | 3.7 | -0.061 | **0.596** | 0.150 | 0.148 |
| Labels | 4.1 | 0.235 | 0.065 | **0.846** | -0.095 |
| Healthful ingredient lists | 3.8 | -0.084 | 0.101 | **0.780** | 0.160 |
| Packaging | 4.3 | 0.313 | 0.210 | **0.630** | -0.051 |
| Brand Reputation | 4.4 | 0.348 | -0.053 | **0.561** | -0.028 |
| Consistent food safety | 4.6 | 0.232 | 0.362 | 0.025 | **-0.806** |
| ingredients | 3.1 | -0.016 | 0.499 | -0.144 | **0.665** |
| GM free | 3.4 | 0.122 | 0.512 | 0.332 | **0.618** |
| % of Variance Explained | - | 24.4% | 17.4% | 17.0% | 11.5% |

The second principal component analysis was conducted to assess possible motivations of firms' for HACCP adoption. For the group of firms that had adopted (or planned to adopt) HACCP programs, responses to queries regarding proposed motivators of HAACP adoption (see column 1 of Table 18 for the listing of these) are grouped by this process, as summarized in Table 19. This analysis generated five explanatory factors. The first of these, which can be labelled *responsive product quality,* explains 22.4% of the variation in firms' decisions to adopt HACCP. Respondents with motivations for adopting HACCP that are described by the first factor operate in each of the four food sub-sectors and are generally exporters. The majority of HACCP adopters described by the first factor are small size firms. Factor two, termed *regulation motivated* explains 17.7% of the variation in firms' reasons for HACCP adoption. Respondents motivated by the second factor to adopt HACCP included firms of all sizes and sectors. All respondents that were members of a value chain were motivated by this factor. Numbers of the other respondents motivated by this factor had customers who inspected the firm's facilities.

The third factor generated by the principal component analysis of motivators of HACCP adoption is termed *external drivers.* This describes firms which seem to strive to comply with industry, value chain and government requirements and is similar to the third of three principal component factors reported in a previous study of HACCP adoption by Ontario food processors[1] (Herath and Henson 2006), suggesting some similarities in HACCP adoption motivators across regions within Canada. All respondents motivated by the third factor to adopt HACCP had their facilities inspected by their customers and most indicated that they included end consumer concerns in the design stage of their risk management. Half of the respondents motivated by factor three to adopt HACCP were medium/large in size and all but one respondent motivated by factor three were exporters. The third factor explains 15.5% of the variation in motivations to adopt HACCP. Factor four, termed *financially driven* explains 12.9% of variation in motivations to adopt HACCP. Respondents motivated by this factor were generally small exporters that reported taking end consumer concerns into consideration in the design stage of their risk management, did not generally belong to a formally coordinated value chain, but had their facilities inspected by their customers. Factor five, termed *customer focus* explains 10.9% of the variation in motivations to adopt HACCP. The respondents motivated by factor five include all respondent firm sizes. Most of them are exporters that have their facilities inspected by their customers.

[1] However, Herath and Henson (2006) only reported three factors explaining HACCP adoption in Ontario. The first factor explained 52.0% of the variation in HACCP adoption in Ontario and displayed a market oriented focus. Their second factor was *improvements to internal efficiency* and explained 10.8% of the variation. Factor three, *external drivers*, only explained 5.4% of the variation in Ontario HACCP adoption.

**Table 19: Principal Component Analysis of Responses from the Aggregate Sample re Potential Motivations to Adopt HACCP, Mean Ranks and Factor Loadings (n=41)**

| Motivational Factors | Mean | 1st Factor | 2nd Factor | 3rd Factor | 4th Factor | 5th Factor |
|---|---|---|---|---|---|---|
| **Expected impact on ability to deal with customer complaints** | **4.3** | **0.900** | 0.191 | 0.163 | 0.152 | 0.066 |
| **Expected impact on product traceability** | **4.3** | **0.898** | 0.097 | 0.145 | -0.131 | 0.020 |
| **Expected impact on shelf life of products** | **4.0** | **0.831** | 0.195 | -0.006 | 0.003 | 0.078 |
| **Expected impact on risk of product recalls** | **4.4** | **0.759** | 0.130 | 0.122 | 0.227 | 0.114 |
| **Expected impact on product quality** | **4.3** | **0.631** | 0.131 | 0.053 | 0.266 | 0.197 |
| **Expected impact on ability to retain existing customers** | **4.3** | **0.631** | 0.139 | 0.196 | 0.244 | 0.494 |
| **Expected impact on customer complaints** | **4.0** | **0.594** | 0.062 | -0.082 | 0.031 | 0.506 |
| **Expected ability to meet anticipated regulatory requirements** | **4.6** | 0.187 | **0.885** | 0.075 | -0.206 | -0.010 |
| **Expected ability to meet existing regulatory requirements** | **4.5** | 0.240 | **0.837** | 0.048 | -0.179 | 0.130 |
| **Expected ability to meet anticipated future customer requirements** | **4.7** | -0.019 | **0.788** | 0.222 | 0.200 | 0.305 |
| **Expected impact on product safety** | **4.5** | 0.116 | **0.767** | -0.010 | 0.229 | 0.257 |
| **Wish to apply good practice** | **4.6** | 0.214 | **0.758** | -0.121 | -0.334 | -0.105 |
| **Expected impact on ability to attract new customers** | **4.6** | 0.457 | **0.534** | 0.197 | -0.112 | 0.364 |
| **Expected ability to comply with government recommendation** | **4.3** | 0.023 | 0.122 | **0.947** | 0.022 | -0.030 |
| **Expected impact on ability to access new markets** | **4.2** | 0.110 | -0.016 | **0.927** | 0.020 | 0.187 |
| **Industry/trade organization recommendations** | **3.8** | 0.248 | 0.177 | **0.841** | -0.037 | -0.121 |
| **Expected impact on need for customers to inspect plant** | **3.6** | 0.113 | -0.117 | **0.667** | -0.308 | 0.495 |
| **Expected impact on product wastage** | **3.4** | 0.240 | 0.012 | -0.153 | **0.927** | 0.035 |
| **Expected ability to reduce costs of production** | **3.2** | 0.001 | -0.172 | 0.422 | **0.833** | -0.140 |
| **Expected ability to get a higher price for the products** | **3.4** | 0.224 | -0.155 | -0.249 | **0.803** | 0.072 |
| **Expected impact on ability to gain greater share of existing markets** | **4.2** | 0.194 | 0.132 | -0.027 | 0.065 | **0.817** |
| **Expected ability to meet existing customer requirements** | **4.5** | 0.118 | 0.257 | 0.111 | -0.068 | **0.723** |
| **Percent of Variation Explained** | - | 22.4% | 17.7% | 15.5% | 12.9% | 10.9% |

The final section of this component of the project involved the testing of two binary probit models. Model One examined firm's characteristics as motivators of HACCP adoption while Model Two included both characteristic and attitudinal variables as explanators. This component of the analysis indicated the importance to adoption of HACCP of the size of: the firm: the larger is the size of the firm, the higher is the probability of HACCP adoption. This finding is consistent with results published by Holleran, Bredhal and Zaibet (1999) regarding the impact of firm size on ISO adoption and also provides support for the existence of a structural element to HACCP adoption. Expressed concern by firms regarding the effects of media attention and their assessment of the importance of product traceability to improving firm business performance also appear to be associated with HACCP adoption.

## Summary and Conclusions

One stage of the project involved analysis of data from a Canada-wide survey of 1574 respondents, collected in November 2005, in which assessments of the risks (and benefits) from several different types of applications of agricultural biotechnology to plants were queried. Although relatively few respondents expressed familiarity with PMF technologies prior to this survey, the nature of the perceived benefits of four cited types of GM applications appears to influence respondents' risk rankings considerably. Extended statistical analysis of risk- rankings was undertaken in order to assess the consistency and intensity of beliefs and concerns held by different respondents; these were analyzed in two ways,first, using non-parametic analysis of risk-benefit assessments and second, relative to individual respondent's socio-economic and demographic characteristics. Even though contamination of food supplies and the environment were seen as major risks of PMF technologies, the use of genetic modification/genetic engineering to produce medicines, industrial products ("like plastics, fuel or industrial enzymes") or increased nutritional qualities of food were all rated to be less risky than the use of genetic modification/engineering to increase crop production.

This finding suggests that where there is an apparent potential personal or socially-accepted benefit in GM/GE applications, respondents tend to rate these as being less risky than those activities or innovations that have less apparent benefits. This is consistent with literature on qualitative risk assessment which has found that individual's assessments of risk tend to be influenced by utility. From our findings, it seems that GM/GE applications are seen to be more acceptable (less risky) where these provide recognized potential personal or social benefits. In contrast, "use of GM/GE crops to increase crop production" is not judged to be as beneficial as potential PMF applications that focus on output modifications perceived to have utility, such as with new medicinal, nutrition and/or industrial products. Overall, PMF is not seen as a major threat to food safety or the environment, but as a moderate indirect risk. The use of PMF to produce better and cheaper medical drugs appears to have the best benefits-to-risks ratio, while using PMF to produce more nutritious and cheaper food has the least favorable benefits to risk ratio.

The following conclusions can be drawn from the findings discussed in Part I.

1. Survey respondents did not see PMF as major potential sources of food contamination or damage to the environment.
2. Even so, PMF was seen as the source of some risk. Average ranks for PMF risks were in the range of 0.4-0.6, corresponding to respondents' assessments of "slight" to "moderate" risk scores.
3. The use of genetically modified/engineered crops to increase crop production was seen as more risky than the various PMF applications. This finding is in accordance with observations, from risk perception literature, that activities that are perceived to have little benefit tend to be seen as more risky.
4. The use of PMF to produce better and cheaper medical drugs is viewed as having the best benefits-to-risks ratio, while using PMF to produce more nutritious and cheaper foods has the least favorable benefits-to-risks ratio.
5. Finally, consistent assessments of risks and benefits were found from several somewhat different sets of questions.

In the second part of the project an alternative approach to analysis of the November 2005 survey-based risk rankings for a variety of food and environmental issues, including PMF applications of plant biotechnology, was applied. These are reported in Part II of this report. Ordered probit models are postulated and tested to assess the relationship of relevant demographic and socio-economic factors to respondents' risk ratings. These suggest that risk perceptions are consistently associated with gender, income and location of residence. Trust also seems to be associated with the risk ratings, at least in some applications. For example, the results imply that respondents living in the Province of Quebec were more likely than other Canadians to view the use of GM/GE to increase crop production as a risky issue. Quebec respondents were 11% more likely than others to choose "high risk" than "moderate risk" for this biotechnological application. Having a child living in the household led to a significant but relatively small increase in the probability of higher risk ratings being chosen. In contrast, males and those with higher income tended to be less likely to rate the use of GM/GE to increase crop production as a high risk for food. However, gender was the only variable that was significant in the models explaining risk ratings of GM/GE crops used for medicines, while gender and income were the only significant variables explaining risk categories for GM/GE crops to increase nutritional qualities of food.

For "Use of GM/GE crops for industrial products like plastics, fuel or industrial enzymes," there are significant marginal effects for gender, income and the trust proxy variable—those who indicated that they trusted information from University research scientists. Males, those with higher incomes, and those with trust in scientists are less likely to indicate this as a high risk issue.  The estimated class probabilities implied by the results for environmental risks of GM/GE applications are generally similar to those for food risks, but show some differences in detail.  Males and respondents with higher incomes appear to be less likely to see the use of GM/GE to increase crop production as risky to the environment; those from the Province of Quebec are more likely to see this as environmentally risky. In contrast to respondents who reside in Quebec, males and those with higher income are less likely to see the use of GM/GE crops to produce medicines as risky to the environment. Similarly males and those with higher incomes are less likely to see the "use of GM/GE crops to increase the nutritional qualities of food" as risky to the environment. A similar pattern applies to risk categorizations for the "use of GM/GE crops for industrial products like plastics, fuel or industrial enzymes."

Overall, these survey data also showed that although relatively few respondents expressed familiarity with PMF technologies, the nature of four cited types of GM applications appreciably influences respondents' rankings of risks associated with these applications

The tendency for genetic modification of food not to be seen as a major potential risk to food safety or to the business performance of their firms was also seen for food processors, although the sampled representatives of food processing firms in Alberta did consider that this food issue was more likely to be considered as an issue of concern by their end consumers. Overall, it appears that Canadians do not see PMF as a major threat to food safety or the environment, but as a moderate or mild indirect risk.

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