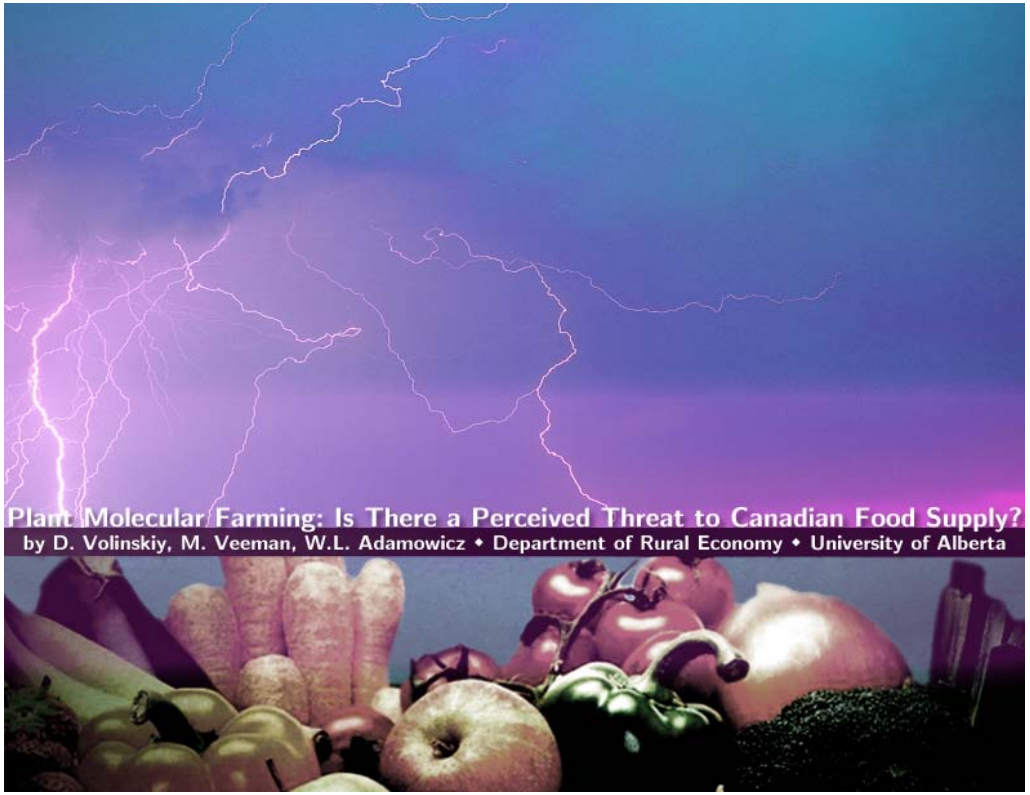

Rationale and Objectives

Plant-based production of food as well as non-food compounds such as pharmaceuticals and industrial products is being pursued through genetic engineering, as reflected in the terminology of "plant molecular farming" — PMF

Few PMF products have been commercialized worldwide, but research trials of plant-based pharmaceuticals and related products have been occurring for some years and research on PMF is supported by the public and private sectors in Canada

Regulatory policy regarding the potential release and commercialization of PMF plants has yet to be established

Applications of PMF are expected to have many benefits, but also to be the source of appreciable risks

Benefits are large-scale, low-cost methods to produce new proteins, vaccines and pharmaceuticals, as well as industrial products, such as bio-enzymes, bio-fuels and bio-plastics

versus

Risks include the possibility of accidental contamination of the food chain by PMF materials, contamination of the natural environment, and the possibility of ingestion of PMF materials by wildlife

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Having a clear understanding of public views of these risks and benefits is important to develop sound and well-balanced PMF regulation

This study uses data from a 2005 nation-wide survey to gain insights into citizens' perceived PMF benefits and threats

The major research question we pose is threefold:

1. Are PMF issues more/less riskier from people's point of view as compared to to other potential risky practices of food production or threats such as BSE?
2. Are PMF issues more/less riskier from people's point of view as compared to to other potential risky agricultural practices and methods?
3. Once pros and cons to PMF are weighed, do PMF benefits exceed PMF risks, and, accordingly, should PMF be pursued in Canada?

Methodology and Data

A sample of 1,574 respondents, aged 18 years or older, drawn from a national representative panel with the aid of an international market research company was used to provide data for this study

Respondents were queried on risk, benefit and priority rankings for various types of PMF applications

Respondents were also queried on PMF research budget allocations for five categories of PMF research (other research)

Friedman tests were conducted on the relative risk and benefit scores.

Friedman test, which is also known as nonparametric two-way ANOVA, operates on the standard two-way layout: treatments (risk categories, etc.) and observational units — people

Friedman test replaces the actual scores from rating (Likert) scales with their ranks for the whole set of alternatives, which makes the test applicable for randomized complete block design as used in the study

The test can be used with non-independent treatments. This means that one's assessment of, say, a particular source of food supply risk does not have to be assumed independent of one's assessment of other items.

Food Production Risks

Q1. Please indicate the risk that you believe applies to each of the issues listed below.

Statements	Your Opinion				
Bacteria contamination of food	O High risk	O Moderate risk	O Slight risk	O Almost no risk	O Don't know/Unsure
Pesticide residuals in food	O High risk	O Moderate risk	O Slight risk	O Almost no risk	O Don't know/Unsure
Use of hormones in food production	O High risk	O Moderate risk	O Slight risk	O Almost no risk	O Don't know/Unsure
Use of antibiotics in food production	O High risk	O Moderate risk	O Slight risk	O Almost no risk	O Don't know/Unsure
Genetically modified/engineered crops to increase crop production	O High risk	O Moderate risk	O Slight risk	O Almost no risk	O Don't know/Unsure
Drugs (i.e. medicines) made from plant molecular farming though genetic modification/engineering	O High risk	O Moderate risk	O Slight risk	O Almost no risk	O Don't know/Unsure
Genetically modified/engineered crops to increase nutritional qualities of food	O High risk	O Moderate risk	O Slight risk	O Almost no risk	O Don't know/Unsure
Genetically modified/engineered crops to produce industrial products like plastics, fuel or industrial enzymes	O High risk	O Moderate risk	O Slight risk	O Almost no risk	O Don't know/Unsure
BSE (mad cow disease)	O High risk	O Moderate risk	O Slight risk	O Almost no risk	O Don't know/Unsure
Use of food additives	O High risk	O Moderate risk	O Slight risk	O Almost no risk	O Don't know/Unsure
Fat and cholesterol content of food	O High risk	O Moderate risk	O Slight risk	O Almost no risk	O Don't know/Unsure

Source:	$\bar{R}^{\dagger}$	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)
Bacteria	0.53	*	*	*	*	*	*	*		*	*
Pesticides (b)	0.43		*		*	*	*	*	*	*	
Hormones (c)	0.40			*	*	*	*	*	*	*	*
Antibiotics (d)	0.43				*	*	*	*	*	*	
GM crops (e)	0.48					*	*	*	*		*
PMF drugs (f)	0.59								*	*	*
PMF foods (g)	0.57							*		*	*
PMF products (h)	0.61								*	*	*
BSE (i)	0.55									*	*
Additives (j)	0.49										*
Cholesterol (k)	0.43										
Observations		1284									
Test statistic		879.87									
P-value		≈ 0									

† Average ranks $\bar{R}$ transformed to fall into $[0,1]$: $\bar{R}_j \leftarrow (\bar{R}_j - R_{\min})/(R_{\max} - R_{\min})$; values $\bar{R}_j$ **closer to 1 indicate lower risk**

‡ Asterisk (*) indicates sources that are different at least at 0.01 significance level

✓ **PMF drugs/foods/products appear to be the least significant perceived sources of risk among all the items included**

PMF medicine and nutritionally improved foods are equally risky; PMF industrial products are the least risky treatment overall, featuring even less risk than the former two

The highest risk was perceived to about using hormones in food production (0.40), followed by similar concerns about pesticides antibiotics, and high cholesterol foods (each ranking 0.43)

Let's now look at effects of respondents' demographic characteristics on their risk ratings (distribution E-statistics)

Table 1: Food Supply Risks: Respondent Groups

Groups	Composition	E-statistic (p-value)
Gender	Male (49%) vs. female (51%)	22.911 (0.009)
Rural location	Rural area (33%) vs. metro area (67%)	14.305 (0.177)
Education	College+ (43%) vs. before college (57%)	22.742 (0.008)
Geographic region	(1) BC (12%) (2) Prairies: AB, MB, SK, and NT (18%) (3) ON (38%) (4) QC (25%) (5) Atlantic: NB, NL, NS, PE (6%)	203.899 (0.000)

Most groups feature distinctively different distribution of risk score ranks. In fact, it is only the rural-urban grouping that does not show any difference. The implication is

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✓ **Except for rural location, other major socio-demographic characteristics of respondents did play a role in their assessment of food supply risks**

Figure 1: Rank Distribution by Gender

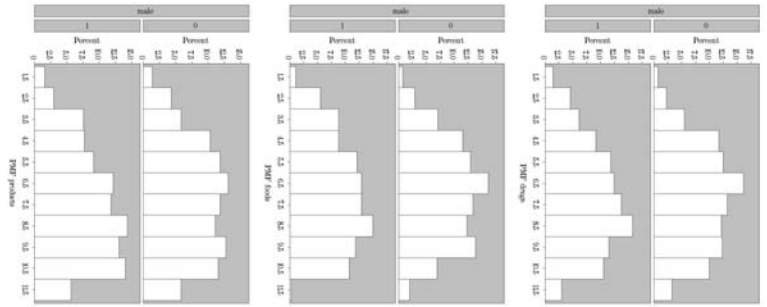


Figure 2: Rank Distribution by Education

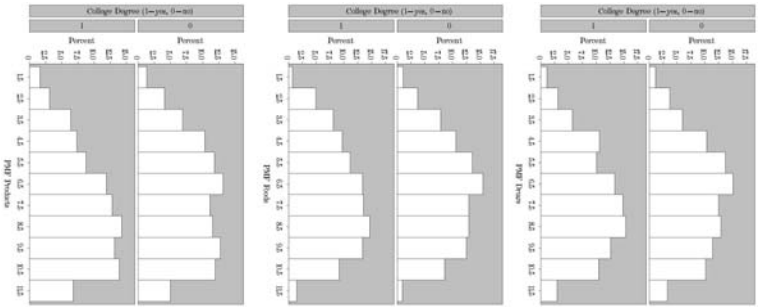


Figure 3: Rank Distribution by Region: PMF Drugs

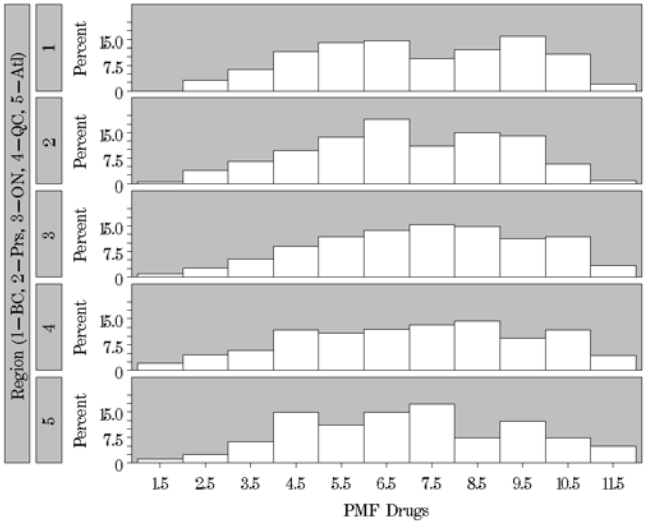


Figure 4: Rank Distribution by Region: PMF Foods

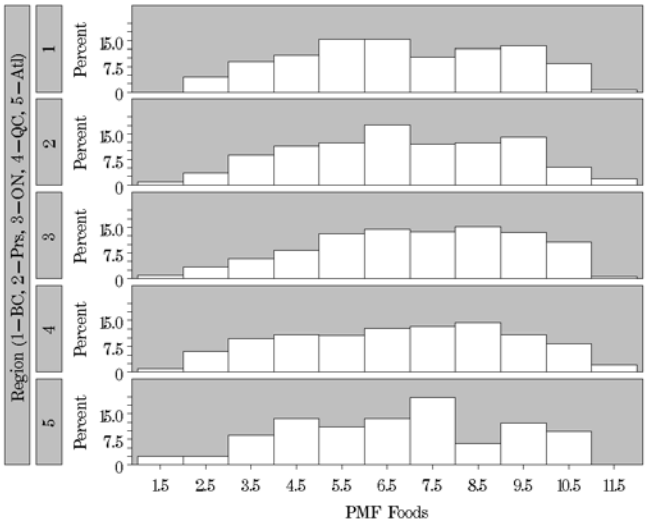
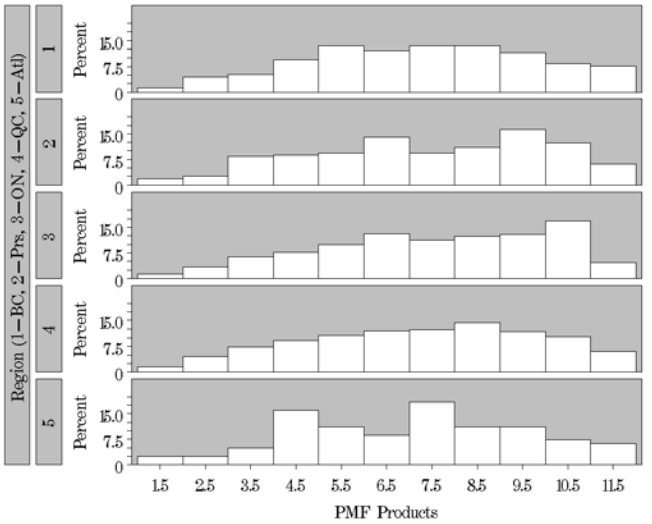


Figure 5: Rank Distribution by Region: PMF Products



☑ **Female and non-college respondents are slightly more conservative in their assessment of PMF food supply risk; to them, PMF appears to be more of a part of generic food contamination risk.**

☑ **There appears to be a large diversity of attitudes toward PMF food risks in Québec, some polarization in the Prairies' provinces and Ontario, on the contrary appears to be the most homogeneous.**

Indirect Risks: Environmental Damage

Q2. We would also like to have your opinion on possible environmental safety issues that might result from modern agriculture. Please indicate the risk that you believe applies to each issue.

Statements	**Your Opinion**
Water pollution by chemical run-off from agriculture	O High risk O Moderate risk O Slight risk O Almost no risk O Don't know/Unsure
Use of genetically modified/engineered crops to increase crop production	O High risk O Moderate risk O Slight risk O Almost no risk O Don't know/Unsure
Use of genetically modified/engineered crops used for drugs (i.e. medicine) production	O High risk O Moderate risk O Slight risk O Almost no risk O Don't know/Unsure
Use of genetically modified/engineered crops to increase nutritional qualities of food	O High risk O Moderate risk O Slight risk O Almost no risk O Don't know/Unsure
Use of genetically modified/engineered crops for industrial products like plastics, fuel or industrial enzymes	O High risk O Moderate risk O Slight risk O Almost no risk O Don't know/Unsure
Agricultural waste disposal (e.g., animal manure disposal)	O High risk O Moderate risk O Slight risk O Almost no risk O Don't know/Unsure
Soil erosion from agricultural activity	O High risk O Moderate risk O Slight risk O Almost no risk O Don't know/Unsure
Use of herbicides and pesticides	O High risk O Moderate risk O Slight risk O Almost no risk O Don't know/Unsure
Adverse effects of agriculture on biodiversity	O High risk O Moderate risk O Slight risk O Almost no risk O Don't know/Unsure

Table 2: Environmental Risks: Average Ranks and Comparisons

Source:	$\bar{R}^{\dagger}$	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)
Chemical run-off	0.31	*	*	*	*	*	*		*
GM crops (b)	0.53		*	*	*			*	
PMF drugs (c)	0.60					*	*	*	*
PMF foods (d)	0.59					*	*	*	*
PMF products (e)	0.61					*	*	*	*
Waste disposal (f)	0.51							*	*
Soil erosion (g)	0.51							*	*
Herbi/pesticides (h)	0.31								*
Biodiversity (i)	0.53								

† Average ranks $\bar{R}$ transformed to fall into $[0, 1]$: $\bar{R}_j \leftarrow (\bar{R}_j - R_{\min})/(R_{\max} - R_{\min})$; values $\bar{R}_j$ **closer to 1 indicate lower risk**

‡ Asterisk (*) indicates sources that are different at least at 0.01 significance level

All PMF treatments feature the least risk of producing environmental damage. No PMF risk is significantly different from other PMF risk at the confidence level of the test

The most prominent sources of risk are chemical run-off from agricultural fields and using pesticides and herbicides in conventional agriculture (ranked 0.31 as contrasted to PMF risks' range of 0.59–0.61)

PMF risks have almost the same range of riskiness in both Q1 and Q2, while the lower extremum is much lower with environmental damage: 0.31 for the run-off and pesticides/herbicides versus 0.40–0.43 for pesticides/herbicides and also hormones and antibiotics in Q1.

Pros and Cons: Risks and Benefits Separately

Q7. We would like to have your opinion about potential risks that might result from plant molecular farming. Please check the risk rating that you believe may come with each type of PMF.

Use of PMF	Overall riskiness of this practice
PMF to produce better and cheaper medical drugs	O High risk O Moderate risk O Slight risk O Almost no risk O Don't know/Unsure
PMF to produce better and cheaper industrial products	O High risk O Moderate risk O Slight risk O Almost no risk O Don't know/Unsure
PMF to produce more nutritious and cheaper foods	O High risk O Moderate risk O Slight risk O Almost no risk O Don't know/Unsure

Q8. We would like to have your opinion about potential benefits that might result from plant molecular farming. Please check the benefit rating that you believe each type of PMF may bring.

Use of PMF	Overall benefit potential of this practice
PMF to produce better and cheaper medical drugs	O High benefit potential O Moderate benefit potential O Slight benefit potential O Almost no benefit potential O Don't know/Unsure
PMF to produce better and cheaper industrial products	O High benefit potential O Moderate benefit potential O Slight benefit potential O Almost no benefit potential O Don't know/Unsure
PMF to produce more nutritious and cheaper foods	O High benefit potential O Moderate benefit potential O Slight benefit potential O Almost no benefit potential O Don't know/Unsure

As before, higher ranks mark less riskier uses:

- PMF to produce drugs: 0.57 (was 0.59–0.60)
- PMF to produce foods: 0.47 (was 0.57–0.59)
- PMF to produce industrial products: 0.62 (was 0.61)

The rankings are generally consistent with results from Q1 and Q2. PMF to produce industrial products is perceived to be relatively the safest use of PMF. It is followed by PMF-derived drugs. The most risky use of PMF is to produce foods

Perceptions of PMF benefits are significantly different between production of drugs and a group of PMF foods and products. Now higher ranks mark more beneficial uses:

- PMF to produce drugs: 0.60
- PMF to produce foods: 0.46
- PMF to produce industrial products: 0.44

Pharmaceuticals appear to be by far the most beneficial use of PMF

Positive attitudes toward medical uses of PMF and the overall dislike of PMF uses in food production was observed in European consumers by studies using Eurobarometer surveys

Pros and Cons: Risks versus Benefits

Q10. What are your beliefs about the general relationships between the risks and benefits of plant molecular farming?

- O Risks probably significantly outweigh benefits
- O Risks probably moderately outweigh benefits
- O Risks probably slightly outweigh benefits
- O Risk probably roughly equivalent to benefits
- O Benefits probably slightly outweigh risks
- O Benefits probably moderately outweigh risks
- O Benefits probably significantly outweigh risks
- O Don't know/Unsure

Q11. In general, do you believe plant molecular farming should be pursued in Canada?

- O Yes
- O No
- O Don't know/Unsure

The null hypothesis of no relationship between responses to Q10 and Q11 was soundly rejected with Kendall's τ-test.

☑ **There was a strong tendency among those respondents for whom PMF benefits outweigh risks to vote for PMF research in Canada and vice versa**

Nearly a quarter of respondents that produced definite responses to questions Q7 and Q8 said they did not know or were unsure whether PMF research should be pursued in Canada

A recent study found that between 35 and 45% of European respondents displayed ambivalent attitudes towards biotechnology applications

Ambivalence was measured from responses to Q7 and Q8 using and index method

Values of Kendall's τ covariation measure are, by PMF use:

- PMF to produce drugs: 0.088
- PMF to produce foods: 0.077
- PMF to produce industrial products: 0.073

In all cases, albeit not strong, positive covariation between the ambivalence index and indecision was definitely present in respondents

Recap of Findings

(a) Survey respondents do not appear to have seen PMF among major threats of food supply contamination or damage to the environment

(b) Point (a) above notwithstanding, it should not be implied that PMF does not contain any risk *per se*. The average ranks for PMF risks were in the range 0.4–0.6, which roughly correspond to respondents giving "slight" to "moderate" risk scores to PMF types

(c) 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 foods has the least favorable ratio. This finding is in agreement with previous research

(d) Respondents seem to be more concerned about environmental effects of PMF than food supply contamination

(e) In general, responses are consistent both across several similar questions and in terms of expected causality

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