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Unacknowledged Health Benefits of Genetically Modified Food: Salmon and Heart Disease Deaths

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The marketing of genetically modified (GM) salmon will lower salmon prices and increase consumption of salmon, an exceptionally good source of omega-3 fatty acids linked to lower risk of heart disease. We estimate that the resulting increase in omega-3 intake will prevent between 600 and 2,600 deaths per year in the United States.

Key words: genetically modified, salmon, omega-3, coronary heart disease, regulation.

Researchers are busily assessing possible adverse health and environmental risks of genetically modified (GM) foods in accordance with European Union directives (European Executive Council, 2000), international agreements (Convention on Biodiversity, 2000), and United States (US) regulatory policy (US Food and Drug Administration [FDA], 1992). Genetically modified foods may offer great benefits, both directly as with nutritionally superior "Golden Rice" (Ye, 2000), and indirectly through improved diets, but regulators do not formally consider such benefits in their decision making (European Executive Council, 2000; FDA, 1992).

The case of GM salmon illustrates both the potential magnitude of the health benefits from indirect nutritional improvements and the problem with the regulators' generally one-sided approach, which is ultimately derived from the "precautionary principle." The protein to genetically modify salmon is now under review by the Food and Drug Administration's (FDA) Center for Veterinary Medicine, which is considering its safety and efficacy as an animal drug and is consulting with other agencies on risks to wild salmon (which are protected by the US Endangered Species Act). Apparently excluded from the regulatory calculus is the substantial effect of GM salmon on reducing the risk of coronary heart disease (CHD), the number one cause of death in the US (National Center for Health Statistics, 2000).

By growing year-round, GM salmon can reduce fish farmers' costs. Lower production costs would lower prices, increase salmon consumption, and boost intake of omega three (n-3) fatty acids. These fatty acids significantly lower the risks of CHD and other health problems (Rosenberg, 2002).

Rational policy requires regulators to carefully compare the risks and the benefits of GM food. A small number of GM salmon, if accidentally released and not previously sterilized, could threaten a local species by creating hybrid offspring (National Research Council, 2000). A sensible evaluation of these risks, however, must involve some comparison with the full social benefits of GM salmon. These are likely to range from economic gains to fish farmers to effects on consumer's health.

To illustrate the importance of a frequently neglected category of benefits from GM foods—improved nutrition—we estimate declines in heart attacks from GM salmon by focusing on four factors.[1] They represent the effects of (a) n-3 fatty acid intake on heart disease risk, (b) salmon consumption on n-3 intake, (c) salmon prices on salmon consumption, and (d) farming costs on salmon retail prices. We estimate that GM salmon would prevent between 600 and 2,600 deaths in the US annually, with a best estimate of roughly 1,400.

Health Effects

Omega three fatty acids can reduce risks of fatal cardiac arrest. Two long-chained highly polyunsaturated fatty acids, docosahexaenoic acid (DHA, 22:6 n-3) and eicosapentaenoic acid (EPA, 20:5 n-3), are thought to have this benefit because they provide strong antiarrhythmic action on the heart, serve as precursors to prostaglandins, and provide anti-inflammatory and antithrombotic actions.

Recent studies confirm earlier research that n-3 intake lowers the risk of CHD for men and women of varying health. A study of 11,323 survivors of myocardial infarction found that a randomly assigned dose of

1. *We assume* $\Delta H \cong e_{H\text{n-3}}\ e_{\text{n-3}c}\ e_{cP}\ e_{PC}\ \frac{\Delta C}{C}\ H$ *, where H denotes the number of heart attacks in a given population over a year, C is the cost of producing salmon,* e_{yx} *represents the percentage change in y caused by a one percent change in x (assuming other relevant variables are held constant), and c and P represent the intake of n-3 fatty acids and the retail price of salmon, respectively. This equation can be derived by assuming that H, n-3, c, P, and C are related through a series of nested differentiable functions.*

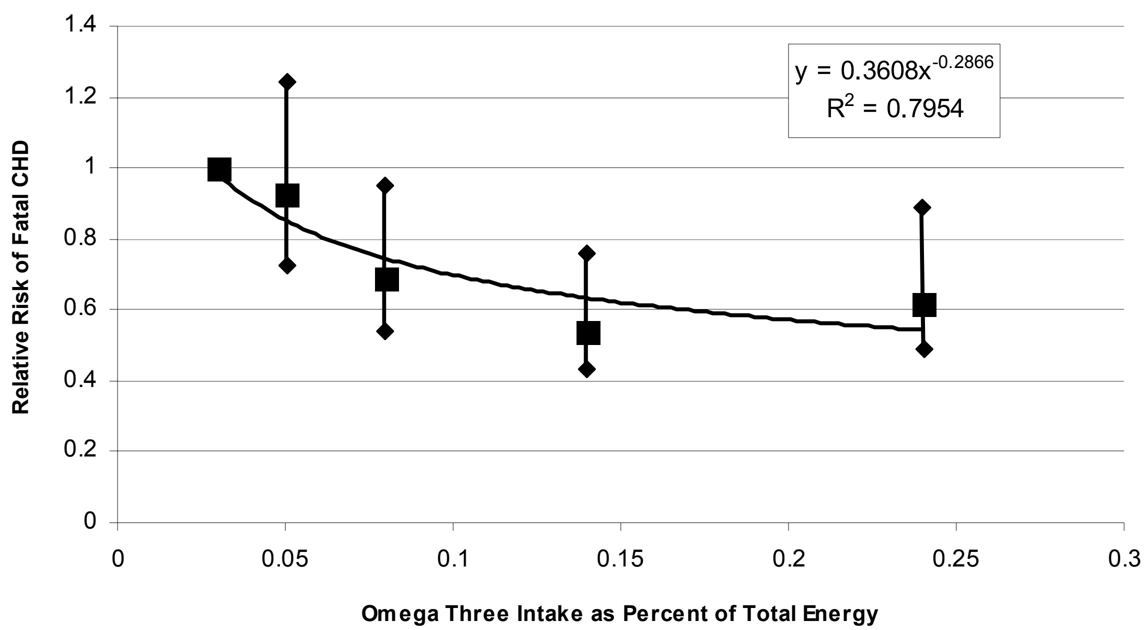

Figure 1. Omega three intake and fatal CHD risk.

Note: We present Hu et al.'s (2002) point estimates of relative risk and the 95% confidence limits as ■ and ◆ respectively.

one gram per day reduced the risk of sudden death by half within 4 to 8 months (GISSI, 2002). Albert et al. (2002) found that n-3 fatty acids in fish are strongly associated with a reduced risk of sudden death among men without prior evidence of cardiovascular disease. Hu et al. (2002) report a significant relationship between n-3 fatty acid intake and the relative risk of fatal CHD among women without previous diagnoses of CHD or cancer.

As Hu et al. (2002) show that risk varies nonlinearly with n-3 intake, we estimate that a one percent increase in n-3 intake lowers CHD fatalities by 0.29% by fitting an exponential function (see Figure 1).

Intake of n-3 fatty acids may also protect against health conditions that we choose not to quantify, including rheumatoid arthritis and asthma (Calder, Yaqoob, Thies, Wallace, & Miles, 2002), epileptic seizure (Schlanger, Shinitzky, & Yam, 2002), endometrial cancer (Terry, Wolk, Vainio, & Weiderpass, 2002), age-related macular degeneration (Seddon et al., 2001), prostate cancer (Terry, Lichtenstein, Feychting, Ahlborn, & Wolk, 2001), and premature birth (Allen & Harris, 2001). These benefits exist despite generally smaller risks from contaminants such as mercury and dioxin (Egeland & Middaugh, 1997; Anderson & Wiener, 1995).

Nutritional Effects

We estimate that salmon, the richest source of n-3 fatty acids, provides 8.2% of n-3 intake (DHA plus EPA) for adults, based on US Department of Agriculture survey data (US Department of Agriculture, 1999).[2] A one percent change in salmon consumption should increase total n-3 intake by 8.2%, assuming n-3 intake from other sources is unchanged.[3]

Although a drop in the price of salmon may also change consumption of other foods, we ignore such effects because we lack appropriate data.[4] Our approach may overstate the benefits of cheaper salmon if substitutes (such as mackerel) are rich in n-3, but we believe it is more likely to understate the benefits, because substitutes include foods high in saturated fat (such as beef).

Some recent reports suggest that farmed salmon is inferior to wild salmon in terms of n-3 content (Murphy,

2. *Alpha-linolenic acid, a third n-3 fatty acid, is not considered by Hu et al. (2002), so we do not consider it here.*

3. *Because total n-3 intake is the sum of n-3 concentrations in various foods times the amount of each food consumed, the percentage change in n-3 intake resulting from a one percent change in c is simply the share of total n-3 intake that comes from salmon, provided that substitutes to salmon have negligible n-3 levels.*

2003). Our analysis of USDA data, however, suggests otherwise. Alaska chums, the most important salmon species for US consumers after Atlantic salmon (Welch, 2000), have lower levels of n-3 than farmed Atlantic salmon, either raw or cooked with dry heat. Sockeye, chinook, and pink salmon, either raw or cooked with dry heat, also have lower levels of n-3 in 100-g servings than farmed Atlantic salmon.[5] In addition, both raw wild Atlantic salmon and wild coho cooked with dry heat have lower n-3 levels in 100-g servings than raw farmed Atlantic salmon and farmed coho cooked with dry heat respectively. Given that recent epidemiological studies suggest reduced fatality risk from increased daily intake of n-3 (GISSI, 2002; Hu et al., 2002), these data suggest that farmed salmon have health benefits at least as large as those of wild fish.

Consumer Response

Empirical research suggests that a one percent decline in the price of farm-bred salmon leads to a one percent increase in consumption (Bjorndal, Salvanes, & Gordon, 1994). We use this estimate, ignoring possible premiums that some consumers may be willing to pay for conventional salmon.

Farming Costs and Retail Prices

In the absence of an appropriate, integrated model of salmon supply and demand,[6] we first assume simply that changes in farmers' unit costs have a proportional effect on the price that farmers receive for farmed salmon. This would be the case if salmon farming were competitive and had constant returns to scale, so that salmon farmers' costs determined the market price of fish. Competitive international spot markets in fact determine salmon prices (Abbors, 2000), and the law of one price holds for an international market with five salmon species (Asche, Bremnes, & Wessels, 1999).

The prices that farmers receive, along with market structure and processing costs, affect retail prices. In French fish markets, a one percent drop in international salmon prices lowers retail prices by 0.165% (Guillotreau, Le Grel, & Simioni, 2002). This relation may be valid for the US. In 1998 in France, supermarkets (which are the predominant retail outlet in the US) sold nearly 75% of retailed, fresh seafood, and more than 80% of fresh salmon (Guillotreau et al., 2002). In France, 45% of fresh salmon was consumed in restaurants, where much salmon is also consumed in the US (Reuters, 2000).

Given this estimate and an assumption of a perfectly competitive market for farmed salmon at the producer level, a one percent decrease in the cost of farmed salmon will lead to a 0.165% drop in the retail price of salmon.

Conclusion

The health effects of GM salmon are large enough to interest policy makers. Given that GM salmon could lower the cost of farming salmon by half (Reuters, 2000), the preceding data suggest that GM salmon would reduce the risks of fatal CHD by about 0.2%. Because about 720,000 Americans aged 35 and older died from heart disease in 1999 (National Center for Health Statistics, 2000), a reduction of 0.2% amounts to about 1,400 deaths per year.[7] To characterize the uncertainty associated with this estimate we conduct a Monte Carlo simulation, summarized in the Appendix. The simulation, which does not address model uncertainty, shows that a 90% confidence interval for the number of deaths averted per year in the US would range from 570 to 2,630. A range that reflects uncertainty in the choice of models used here and in underlying studies would be much larger. Although these benefits seem large, they should be compared with the environmental risks posed by GM salmon (National Research Council, 2002).

Regulators' focus on potential adverse health effects of GM foods, without regard to health benefits, does not provide an adequate basis for rational policy. Policies restricting the introduction of GM foods that offer

4. *We are unaware of a model that integrates demand for salmon and other individual fish species with demand for animal products such as beef, pork, and chicken. Huang (1997), however, has developed an integrated analysis of prices of canned fish and other products and their effects on intake of polyunsaturated fatty acids and other nutrients. Other research (Chen, Shogren, Orazem, & Crocker, 2002) has begun to integrate economic analysis of diet and exercise with epidemiological analysis of health.*
5. *Authors' calculations are from US Department of Agriculture Economic Research Service, "Nutrient Data Laboratory," available on the World Wide Web at http://www.nal.usda.gov/fnic/cgi-bin/nut_search.pl.*
6. *Pascoe, Sean, Mardle, Steen, and Asche (1999) present a model combining economic, physical, and biological relationships among different species, but the results of three alternative scenarios differ significantly, and the authors do not argue that one is superior.*
7. *This estimate assumes that the effect of n-3 fatty acids on CHD estimated by Hu et al. (2002) applies to all men and women aged 35 and older.*

lower-cost access to healthier foodstuffs may unintentionally curtail or postpone opportunities to improve public health. Although we have addressed only the health benefits of GM salmon, other GM foods with beneficial nutritional properties (such as canola oil) could offer similar benefits if new genetic varieties lowered their relative prices. Although these types of health benefits are distinguishable from those associated with changes in nutritional content resulting from genetic modification, all nutrition-related effects should be considered in regulating GM foods.

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Appendix

To characterize the uncertainty in the reduction in heart attacks from the introduction of genetically modified salmon, we conduct a Monte Carlo simulation and estimate that a 90% confidence interval for the CHD deaths averted from GM salmon would run from about 570 per year to 2,640 per year. Our analysis includes only the sources of uncertainty for which we have acceptable information about the underlying distributions. Thus we include uncertainty in the health effect, the nutritional effect, the price elasticity of demand, and the effect on retail prices, as measured by standard errors estimates of these parameters.[8] We summarize in Table 1 the assumptions in our simulation. We include only the uncertainty associated with our estimates of the relationships between n-3 and the risk of CHD fatalities and do not consider the full uncertainty in Hu et al's (2002) estimates, including whether and to what extent the estimated health effects are applicable to men. We also neglect uncertainty associated with whether consumers will respond to price declines of GM salmon as if it were untreated salmon and the effect of GM salmon on the cost of fish farming.

Our simulation implies that there is only a five percent chance that the number of deaths averted would be fewer than 570 per year, and that there is only a five percent chance that the deaths averted would exceed 2,630 per year.[9] See Figure 2.

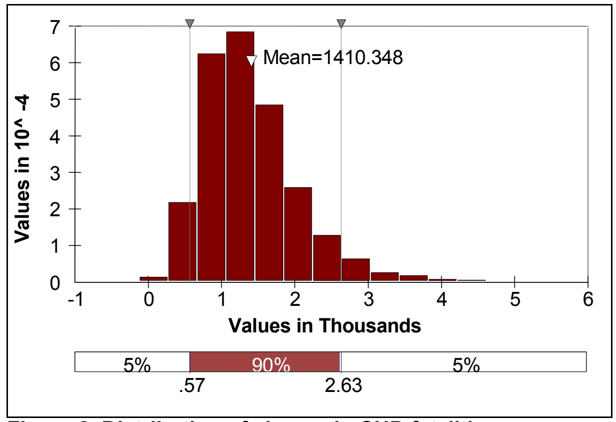

Figure 2. Distribution of change in CHD fatalities.

8. *We ignore variations in the contribution of salmon to n-3 intake, because Figure 1 suggests they are irrelevant to determining the percentage change in risk.*

9. *Using the @Risk software program, we run 10,000 iterations using Latin Hypercube sampling.*

Table 1. Summary of a Monte Carlo simulation.

Parameter	Variable	Estimated Value, Assumed Standard Deviation (), and Distribution
Percentage change in coronary heart disease fatalities resulting from a one percent change in n-3 fatty acid intake	$e_{H\text{n-3}}$	.29 (.084) normal
Percentage change in n-3 fatty acid intake resulting from a one percent change in salmon consumption	$e_{\text{n-3}c}$	.082 (.009) normal
Percentage change in salmon consumption resulting from a one percent change in the retail price of salmon	e_{cP}	1 (0.2) log normal
Percentage change in the retail price of salmon resulting from a one percent change in the cost of salmon farming	e_{PC}	.165 (.0432) log normal
Percentage change in the cost of salmon farming	$\frac{\Delta C}{C}$	.5
Implied percentage reduction in fatal coronary heart disease, calculated as the product of the preceding variables		.00232
Baseline incidence of fatal coronary heart disease (cases per year in the US)	H	720,000 among all adults over 35
Implied absolute change in annual coronary heart disease fatalities among adults over 35	ΔH	1,410, with 90% confidence interval from 570 to 2,630

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