Evaluation and Development of Aquaponics Production and Product Market Capabilities in Alberta

Ids Initiatives Fund Final Report
Project #679056201
August 17, 2004

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Contents

Abstract

Aquaponics facilities contain contains plant and fish components together in one recirculation system. The fish water, rich in nutrients, is used for plant growth, while the plants are used as biofilters for water regeneration. An aquaponics module based on Rakocy model, University of Virgin Islands, was constructed at the Crop Diversification Centre South, Brooks, in 2002. Although this model proved to be efficient in outdoor conditions, it had not been tested under Canadian greenhouse applications before.

An extensive study during first year of operation demonstrated the technical feasibility of aquaponics technology under Alberta growing conditions. More than 60 different crops and varieties were tested in the greenhouse. Production trials for 24 crops (5 greenhouse vegetables and 19 herbs) were conducted to evaluate which crops would grow well under this system. A protocol was developed for aquaponics production in Alberta. This trial produced the highest yields reported in the literature for aquaponics technology. The yields of two major greenhouse crops, cucumber and tomato, calculated on annual basis exceeded average values for commercial greenhouse production based on conventional hydroponic technology in Alberta.

A marketing study revealed in general a positive consumer response. The food safety issue was one of the major consumer concerns expressed during the surveys. These concerns were answered in the detailed food safety study, which confirmed that the aquaponically grown produce did not contain the most common pathogens and had less chances of contamination than field grown produce. The new technology has a potential for Alberta. It is important to disseminate aquaponics information, including environmental aspects, across the province through education and awareness programs.

Introduction

Aquaponics is a new agricultural industry with potential in Alberta. It is the combined culture of fish and plants in a recycling aquaculture system. The plants use the nutrients from fish effluent for growth. Through environmentally sustainable technology, locally grown high value products can be produced and marketed year round. Aquaponics operations are inherently diversified operations as they offer two profit centres: fish and plants.

This group received a New Initiatives Funding Grant last September for the 2002 fiscal year. The funds were used to construct an aquaponics module at CDC South, Brooks using skills and knowledge of American experts from the University of the Virgin Islands where aquaponics production is at a commercial scale. The evaluation of this model under Alberta conditions in greenhouse system with supplemental heating for both the fish and the crop, was the major objective of this study.

Previous aquaponics demonstration at the Lethbridge Community College's (LCC) Aquaculture Centre of Excellence pointed to a strong potential for growing greenhouse crops in aquaculture effluent. Preliminary results in Brooks in 2002/2003 fiscal year also showed that fish waste could be an adequate source of nutrients for intensive crop production.

The projected yields under the conditions of standard greenhouse technology and plant density were about 40 kg of tomatoes meter-2 year-1, 100 cucumbers meter-2 year-1. These yields far exceeded the average yields of greenhouse vegetables produced by other organic technologies. The estimated fish biomass production is 3100 kg with gross revenue $16,000 year-1.

However, the limited time did not allow evaluation of the system operated in full mode production, as not all tanks were occupied by fish. Further research in both locations, was required to measure the yield of the fish and crops.

The purpose of this project was to continue the evaluation of aquaponics technology for crop yield, fish yield, economic feasibility and the market potential for high value niche products in Alberta. The CDC South, Brooks system included a stand alone, warm water system, with closely integrated fish tanks and greenhouse crop production. The Aquaculture Centre of Excellence in Lethbridge used an add-on system, where a greenhouse facility has been developed as an add-on to the existing aquaculture facility.

The result of this work will help contribute to the diversification of Alberta's plant and animal production sectors. Aquaponics may stimulate an opportunity for diversification for small and medium-sized greenhouse and fish farms.

Objective

Crop Diversification Centre South – key objectives

- Evaluation of the stand-alone, warm water fish model at CDC South under Alberta conditions and add-on system in Lethbridge Community College.

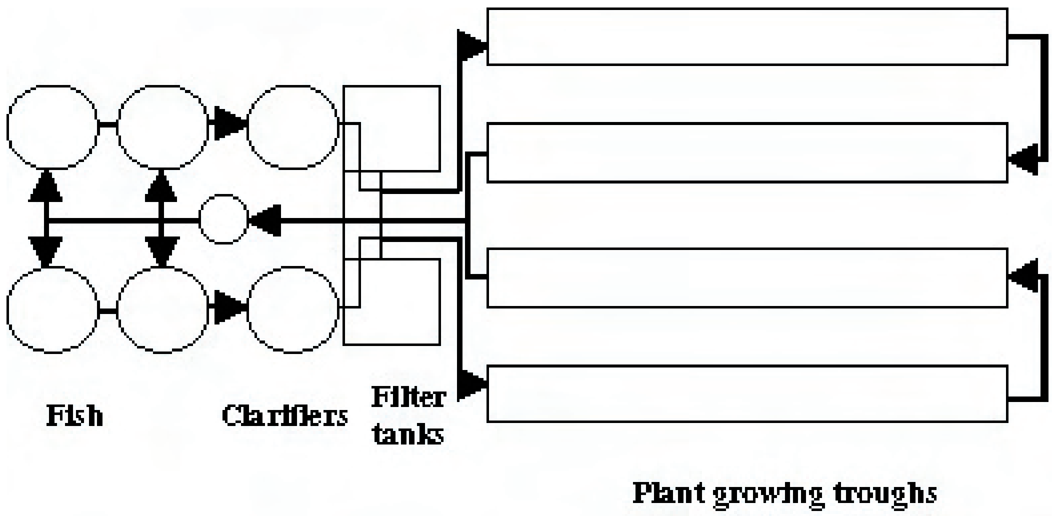
- Achieve sustainable balance between fish and plant parts of aquaponics system. Optimizing plant crop yields for greenhouse vegetables including tomato, mini cucumbers, basil and other crops in a computer controlled environment using nutritional balance data obtained from the previous trial in a stand-alone aquaponics system.

- Complete a detailed cost of production for aquaponics, based on the above fish and plant objectives.

Methods

Recirculation systems

Figure 1. Brooks Aquaponics Facility (BAF)



The facility consisted of three greenhouses (each 7.6 m wide x 15.5 m long) in a straight line separated by storage areas (each 2.9 m wide x 7.6 m long).

One greenhouse contained the aquaculture equipment and the other two contained the plant trays. The aquaculture area held four fish tanks, two clarifiers, five settling/degassing tanks, one central sump tank and a base mixing barrel for a total system capacity of 71750 L.

Fish were raised in four fiberglass culture tanks (2.4 m dia x 1.2 m deep, 5600 L capacity) arranged in two series of two tanks each. Fish tank effluent moved through two conical clarifier tanks (each 4500 L) that removed most of the solids through a series of baffles. Accumulated solids were drained from the clarifiers daily and stored in a holding tank for later application to field crops.

Water moved from the clarifiers into two rectangular settling tanks (each 750 L) then into a joint degassing tank. These small tanks removed the rest of the solids and CO^2 from the fish effluent by filtration through plastic netting. The net filter provided extended surface area for residing ammonifying and nitrifying bacteria to mineralize organic waste. Water from the degassing tank flowed into four plastic-lined, concrete plant troughs (each 0.9 m wide x 30.5 m long x 0.45 m deep, 9000 L capacity) arranged in two series of two.

The outflow from the plant troughs moved into a small sump tank (1000 L) where a submersible pump continuously circulated the water back to all fish tanks via a mixing barrel. Fresh water was plumbed into the sump tank area, through a heat exchanger and boiler system capable of keeping the water consistently warm (~ 24.5ºC for tilapia).

When the float valve in the sump tank lowers with the water level it triggered the addition of more fresh water. Thus, the replacement rate adjusted automatically. Water circulated through the system at 400 L min -1. Each fish tank received a flow of 100 L min -1 and each plant tray received a flow of 200 L min–1. This gave a turnover time of once per hour for the fish tanks and once every 45 minutes for the plant trays.

The greenhouse and recirculation system is under full-computerized control (Argus Control System Ltd). The computer collects some data on a daily basis using specific probes. Environmental parameters in the greenhouse such as temperature and humidity are maintained at stable levels by the computer using heaters/coolers and humidifiers. Irradiation in the greenhouse is also being monitored. The recirculation system is aerated using air blowers and diffusers and had a liquid oxygen backup. Water temperature, oxygen levels, electric conductivity (EC), and pH are monitored continuously by the computer control system

At the Aquaculture Centre of Excellence in Lethbridge aquaponics is added onto an existing fish culture facility. Nutrient rich waters from a carp culture system were pumped via a side stream pipe, to a 9.1 m x 27.4 m greenhouse. The greenhouse holds numerous fiberglass trays, hooked up in series so that water fed the troughs and ends up in an outdoor sump tank. It is then pumped back to the fish culture facility, reconnecting prior to the rotating drum filter. In the Lethbridge Aquaculture Centre of Excellence, the aquaponics component complemented the biological filtration system by removing more dissolved nutrients and reducing the water exchange rate.

Fish culture

Eric Hutchings, provincial aquaculture specialist, provided his expertise to conduct fish trials. Fish growth trials at the Brooks aquaponics facility were carried out at 24.5 °C in a 24-week growth cycle with staggered production. Each tank initially received 600 tilapia of 100 g mean wet weight. The Alberta Fish Farmers Association supplied fish every 6 weeks. A research permit under the Provincial Fisheries Act has been obtained and renewed prior to each fiscal year. The expected food conversion ratio (FCR) was 1.3 at 90% feeding efficiency. Fish were fed 3.2 mm pellets up to a mean size of 300 g, and 4.8 mm pellets beyond 300 g. Food was provided through automatic feeders linked to the computer control system. Feeding rates started at 2.5 % day -1 for 100 g fish and was gradually reduced to 1.25 % day -1 for fish of 400 g. With this regime, fish were expected to reach a market size (700 g) in 24 weeks. At the end of the trials, all fish were returned to the Alberta Fish Farmers Association. For the add-on aquaponics system in Lethbridge, fish growth was not assessed because we were not attempting to balance fish and plant production. Normally there will be substantially more fish and nutrients in the add-on systems than the plants can manage alone.

Plant culture

The plants grown were selected according to their commercial importance and their conductivity factor (CF, 100 µS = 1 CF) that indicates their tolerance to different concentrations of minerals and their ability to extract minerals including nitrogen. Three groups will be tested:

- •Group 1, high CF (20-45, tomato and egg plant)
- •Group 2, medium CF (10-20, lettuce, basil, chives, spinach, parsley and cucumber)
- •Group 3, low range of CF (2-10, water cress)

Plants were also selected based on their ability to grow fast and resist disease. Plant seedlings were grown in rockwool and transferred to holes in styrofoam sheets floating in the plant troughs. The plants were grown in the greenhouse at an air temperature of 22-25 °C, an irradiation level ³ 300 µmol photons m-2 sec-1 photosynthetically available radiation (PAR), and a 16:8 day: night photoperiod provided by natural and artificial lights. Water pH was maintained near 6.2 by the addition of either Ca $(OH)_2$ or $KHCO_3$ (alternate on weekly basis) to increase pH, or H_3PO_4 to reduce pH. This pH was considered optimal to maximize mineral uptake and plant growth and it was not harmful to the tilapia. As with the fish, plant growth trials were staggered so that the total plant production was roughly balanced with fish production. Each crop was rotated to avoid spikes of high mineral concentration from excessive fish waste input. Seedlings of cucumbers and tomatoes were transferred to the facility every three weeks and basil every two weeks to ensure uniform consumption of the minerals during operation. The crops were routinely monitored for pests and diseases. Biological crop protection was carried out as required through integrated pest management (IPM). Predatory insects and hyperparasites were used for chemical-free protection. The plant growth trial protocol was standardized among the stand-alone and add-on facilities.

The protocol of the trials was adjusted according to initial results observed. For example, plant selection was subject to change when lettuce and culantro did not perform well under the experimental conditions. The total biomass of plants growing was adjusted according to trends in dissolved nutrient concentrations of the recirculation water.

Data collection and analysis

The key variables of interest are:

- Crop yield
- Fish biomass production
- Mineral concentrations in recirculating water
- Plant mineral content

Fish food input and mortality data were recorded daily. One hundred + randomly selected fish per tank were weighed every two weeks in order to estimate mean fish size, fish production, and to adjust feeding levels accordingly. Mature fruits of tomato and cucumber were collected two times a week following common practice in commercial greenhouse facilities, and basil was cut and re-grown every two weeks during the growth trials. Other tested crops were transplanted to the facility, harvested and yield recorded at the end of growth trial. Total biomass was estimated at the end of the growth periods for all plant crops.

Water quality was measured on a daily (temperature, EC, pH and DO), weekly (ammonium and nitrate) and monthly (P, K, Ca, Mg, Na, SO_4, Fe, Mn, B, Zn, Cu, Mo) basis. The selected minerals measured represent the majority of mineral ions in fish effluent that can be potentially harmful for fish at high concentrations. These are also important nutrients for plant growth. Our preliminary work with this aquaponics system indicated that the non-nitrogenous dissolved wastes did not exhibit marked short-term fluctuations in concentration once the system was stabilized. Therefore we conducted complete analysis of the mineral composition on a monthly basis. Daily EC measurements were used as an index of short-term changes in total mineral concentration. Plants were analyzed for total N, P, K, Ca, Mg, Na, SO_4, Fe, Mn, B, Zn, Cu and Mo. Total N was determined using a CNH analyzer.

Results

Plant production

Crop Diversification Centre South, Brooks

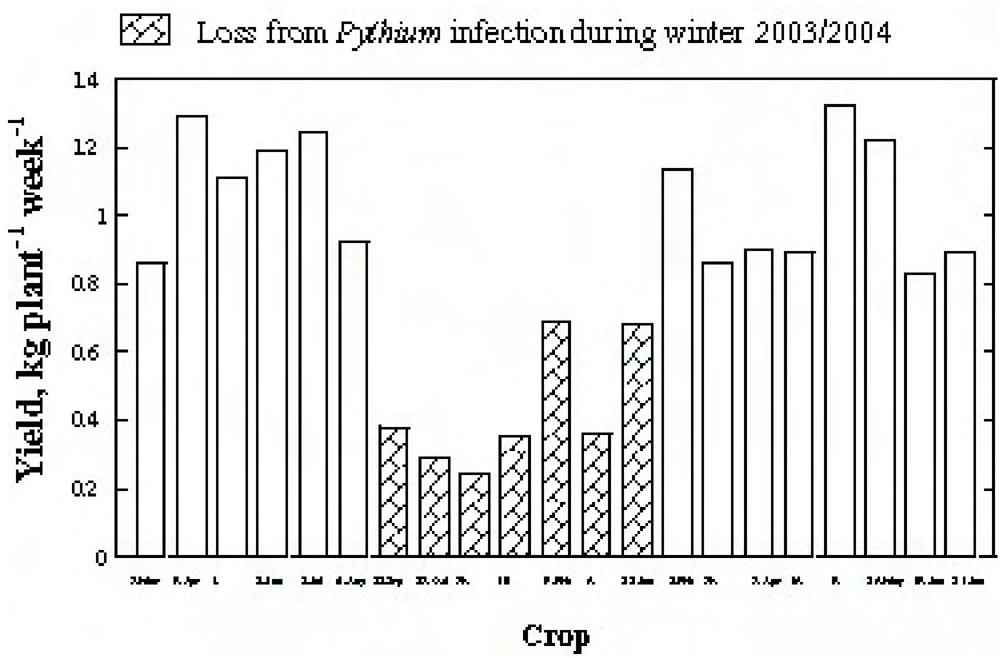
The facility in Brooks started in December after 600 fingerlings were placed in the tank #1. The first plants were transplanted in the middle of January. During the reporting period from April 1, 2003, till March 31, 2004, a number of crop species were tested in stand-alone aquaponics system. The total number of crops was sixty. Three major crops tested in the Brooks facility included tomato, cucumber and basil. Each crop occupied one trough. The forth trough was used to grow a variety of crops. The first two months of plant production was characterized by slow plant growth and number of deficiencies due to lack of nutrients (Fig. 2).

Figure 2. Iron deficiency in Faba vulgaris plants grown aquaponically

The absence of nutrients in the beginning visibly affected biomass accumulation. That was anticipated due to lack of nutrients in the beginning of aquaponics production cycle. The symptoms included nitrogen, phosphorous, potassium, iron and other microelement deficiencies. However, there was a significant difference in severity of the observed symptoms among different species. Lettuce proved to be the most affected and portulaca showed minimum deficiency symptoms. Aquatic plants such as water hyacinth, frog bit, crystal wort and azolla were not affected by the nutrient deficiency at all. These plants are known for their ability to extract nutrients from very diluted solutions and can be used as efficient biofilters. Gradual accumulation of the nutrients led to dramatic improvement of the plant growth after two months of operation.

The situation dramatically changed when aquaponics solution accumulated enough nutrients for crop production. Mini cucumber variety Alamir reached peak of production by April 2003 (1.29 kg plant-1 week-1, Fig. 3).

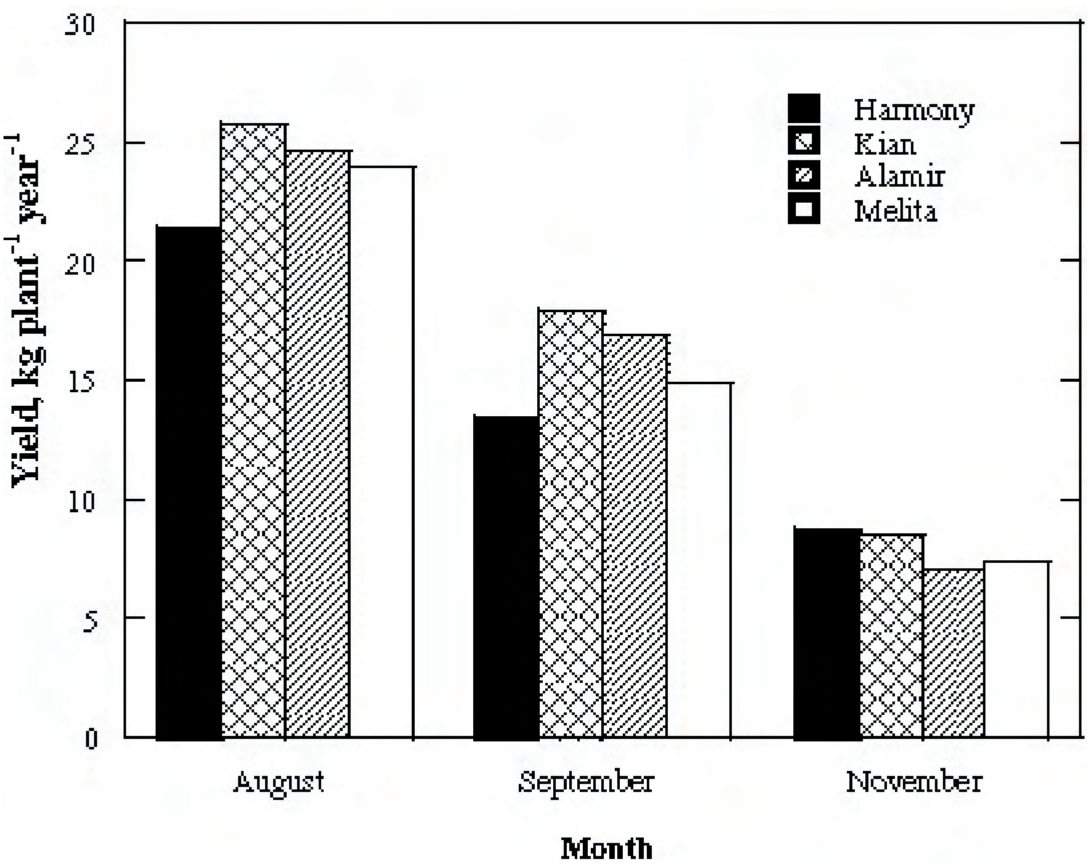
Figure 3. Mini cucumber production, cv. Alamir, 2003/2004



The high production period continued until September, then yield started decreasing. The problem was identified as a root rot caused by Pythium aphanidermatum by the Plant Pathology Program led by Dr. Ron Howard. After consultations with Dr. James Rakocy, the Director of Aquaculture Centre, University of Virgin Islands, the problem was contained by weekly cleaning sedimentations tanks, which served as a breeding ground for *P. aphanidermatum* zoospores.

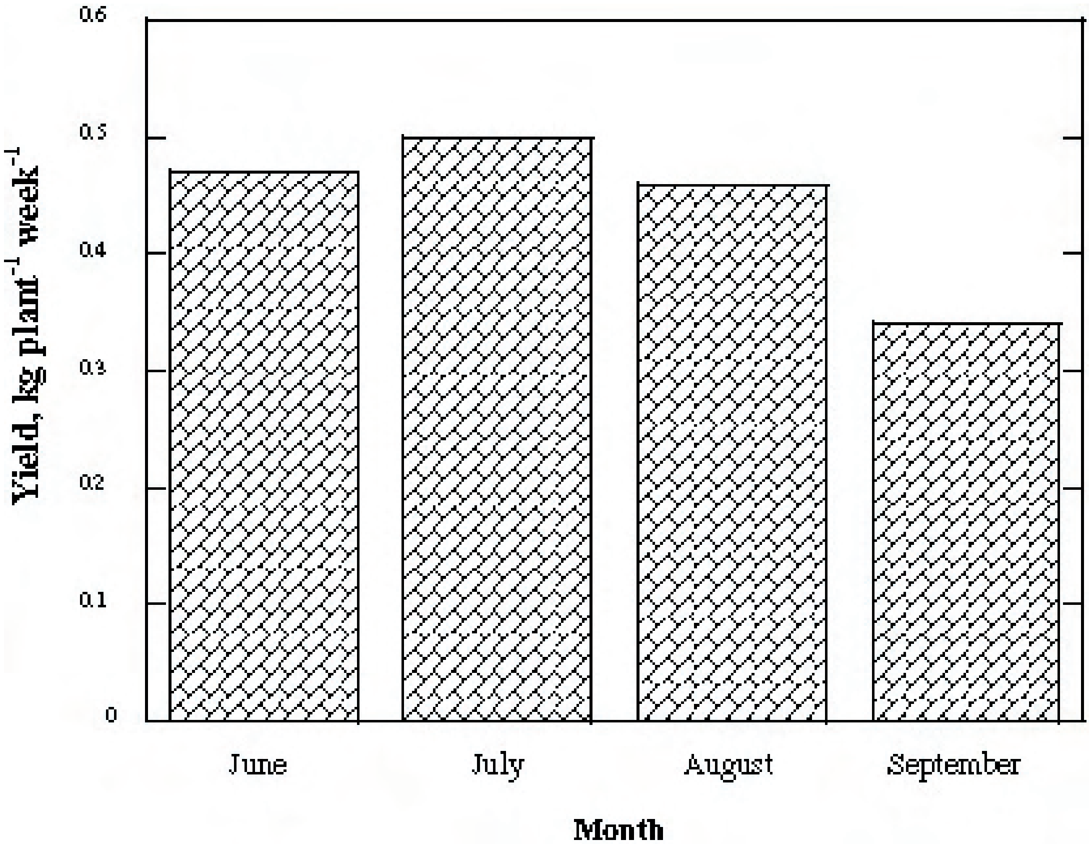
One of the possible reasons of increased susceptibility of cucumbers to *P. aphanidermatum* was decreased light period in the fall. In February 2004 the yield was restored to summer 2003 levels. The projected level of mini cucumbers in stand-alone aquaponics facility per year during *P. aphanidermatum*-free period in 2003/2004 considerably surpassed the average level in the industry. Cv. Alamir was compared with three other varieties of mini cucumbers including Harmony, Kian and Melita. There were no significant differences between four varieties except cv. Harmony showing slightly slower growth in August and September (Fig. 4).

Figure 4. Yield of different mini cucumber cultivars grown



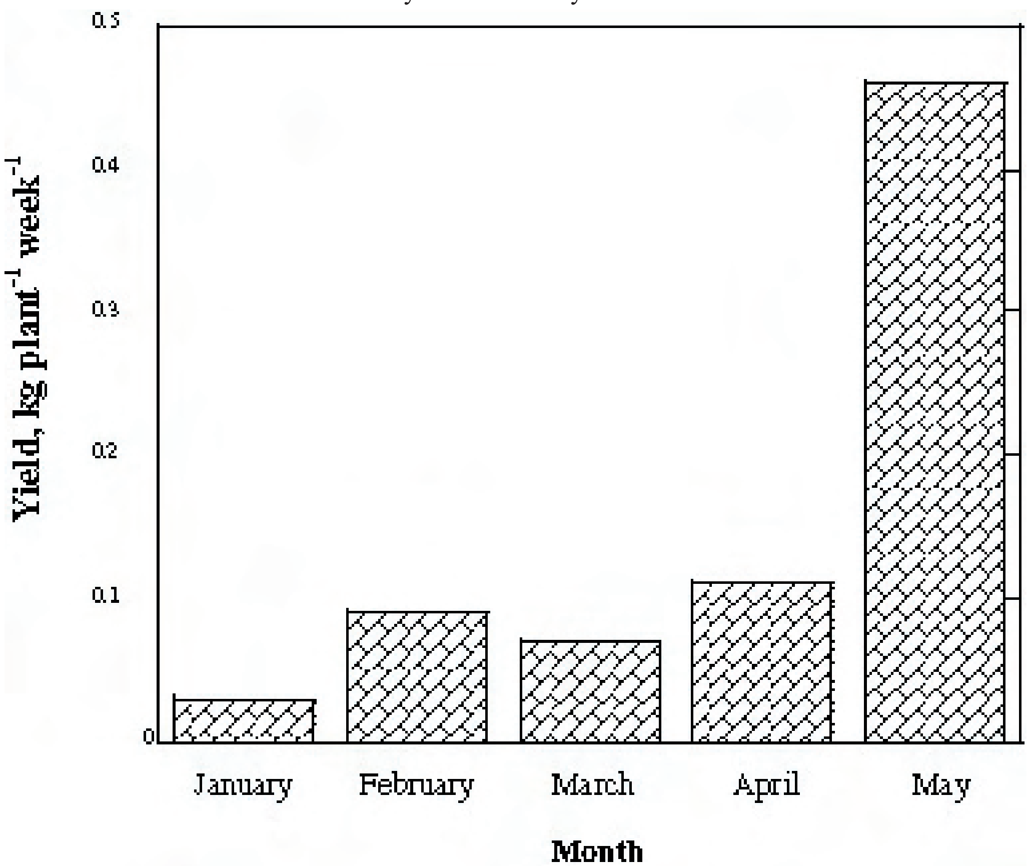
Tomato varieties performed well in aquaponics exceeding the average yield level in the industry by 10-15% (Fig. 5).

Figure 5. Production of Heirloom tomatoes in aquaponics in 2003



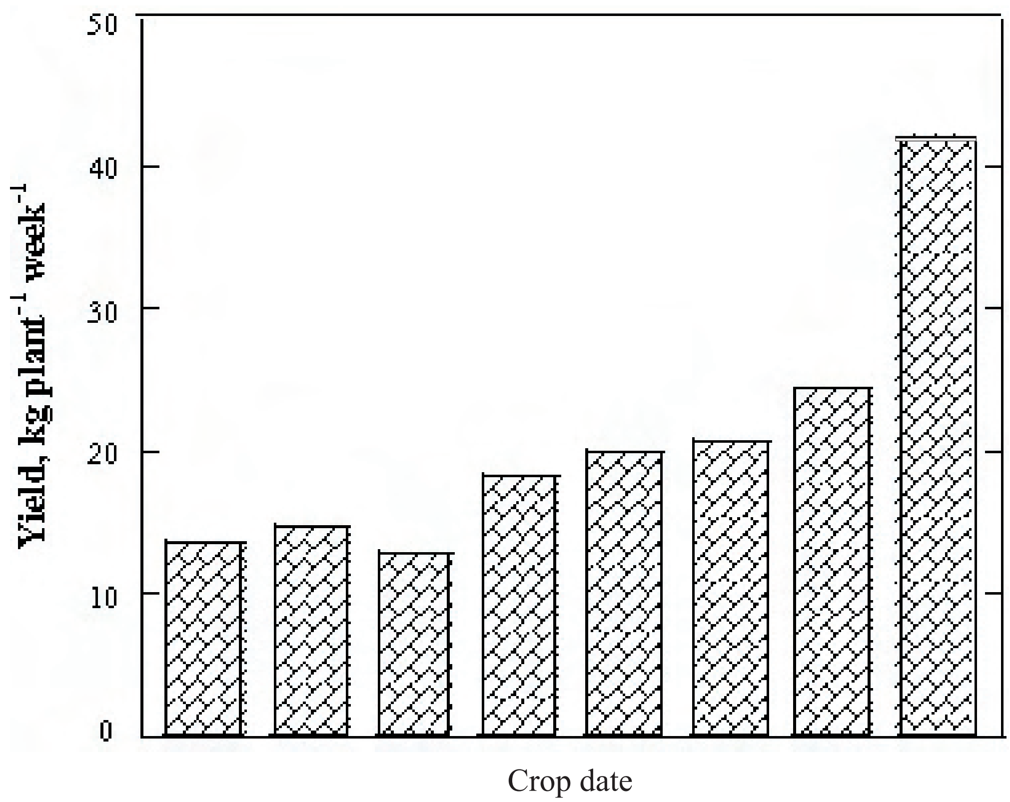
However, the low yield of Roma tomatoes in the winter 2004 indicated the need for higher light conditions for this cultivar (Fig. 6). The adequate level of irradiation in May increased the yield more than four times.

Figure 6. Roma tomato production winter 2004



The basil crop was definitely one of the most successful crops in aquaponics (Fig. 7).

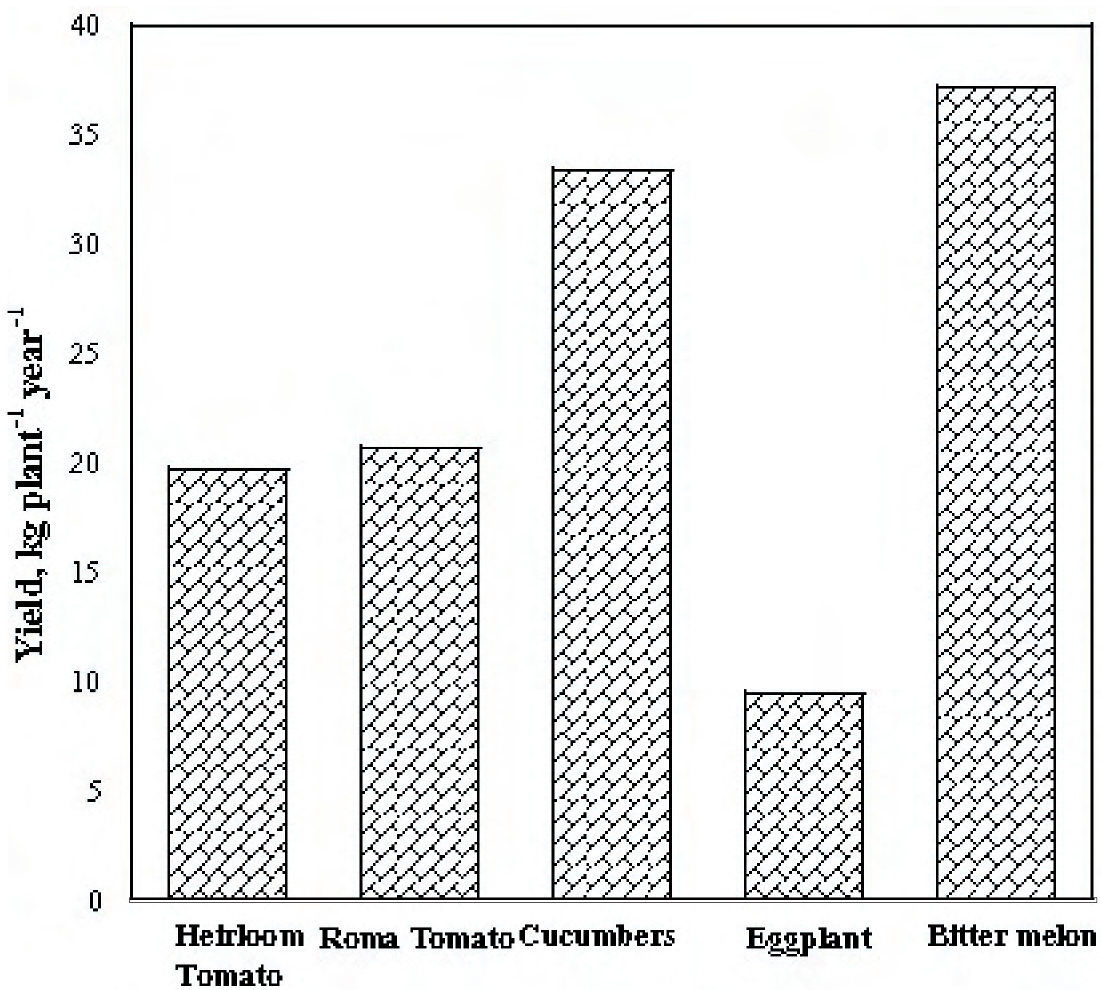
Figure 7. Annual production of basil, cv. Genovese, in aquaponics



The yield was steadily growing from 13 kg m-2 year-1 to 42 kg m-2 year-1 increasing more than 3 times. There were not any problems observed with pests and diseases for the reported fiscal year. We suggest that this growth in production reflected gradual accumulation of favorable factors for this crop in aquaponics system.

Among other vegetables, Japanese eggplant and bitter melon, were tested. Both crops produced good yields (Fig. 8).

Figure 8. Annual production of vegetables in aquaponics

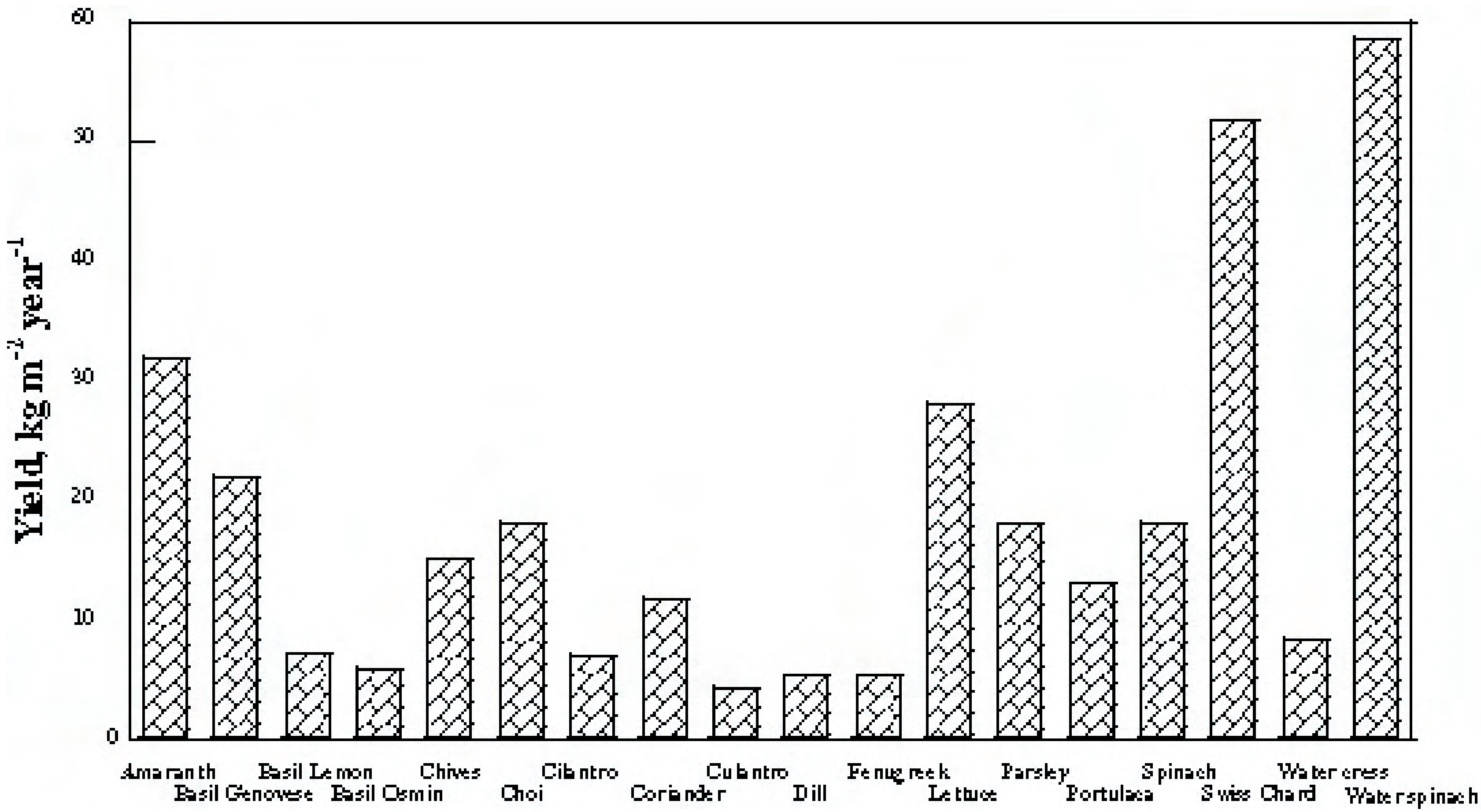


However, the yield of bitter melon was high 37.2 kg plant-1 year-1. This crop was produced for ethnic market in Alberta can potentially provide a steady cash flow for a greenhouse grower.

Up to 60 different crops were tested for the reporting period. Most of them were culinary herbs (Fig. 9).

Culantro was the slowest growing crop producing only 4 kg m-2 year-1. The highest yield was produced by Swiss Chard and water spinach (51.5 kg m-2 year-1 and 58.3 kg m-2 year-1 respectively).

Figure 9. Annual production of herbs in aquaponics



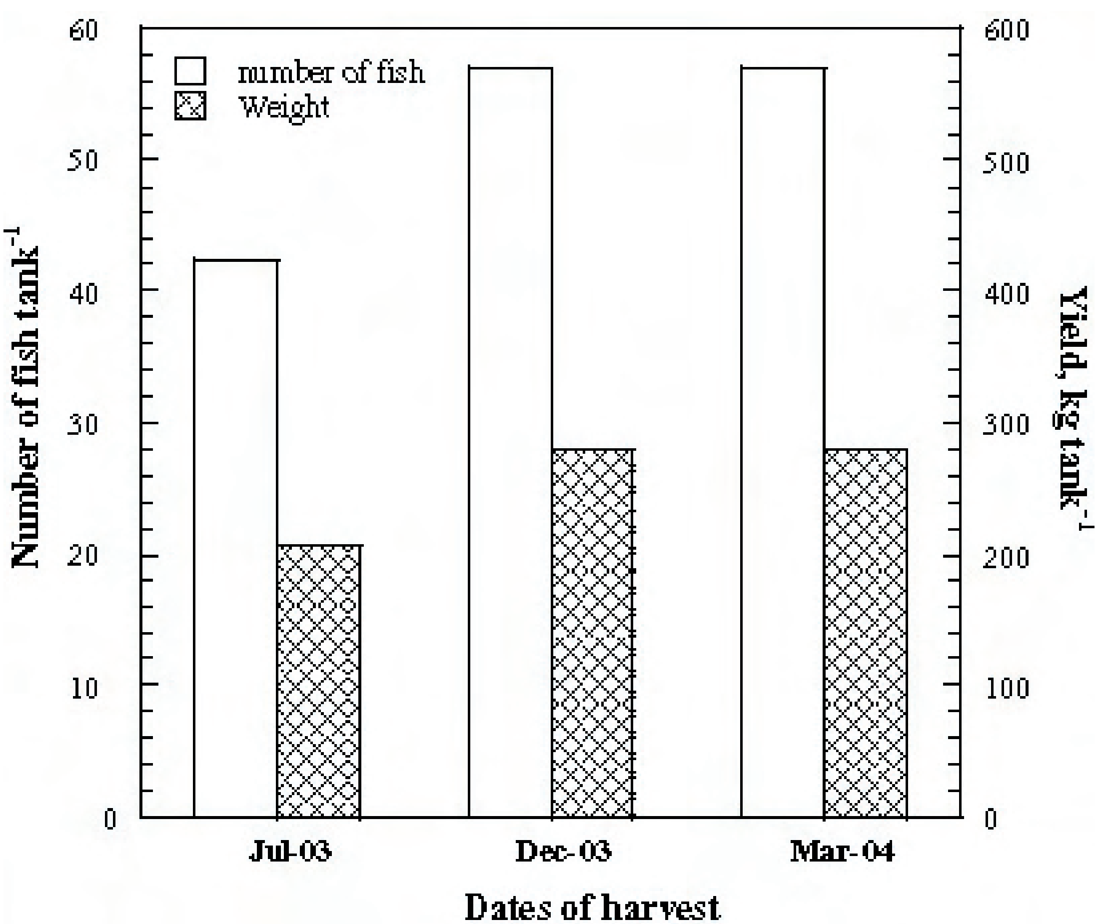
Add-on system in Lethbridge

The period in add-on aquaponics system started in April 21, 2003, and ended in September 7, 2003. Despite of the continuous production surpassing average production in fertilizer free soil based greenhouse operations, the yields of the same crops were considerably lower compared to stand-alone system (Appendix A and B, and Fig. 4). For example, weekly production of mini cucumbers in stand-alone system during Pythium free period was varying from 0.86 kg plant-1 week-1 to 1.32 kg plant-1 week-1, while the same crop was producing from 0.1 kg plant-1 week-1 to 0.7 kg plant-1 week-1. This could be indicative of less favorable nutrient conditions in the add-on system, inexperienced greenhouse staff, or unregulated greenhouse temperatures when compared to stand-alone system. The same trend was observed for other crops.

Fish production.

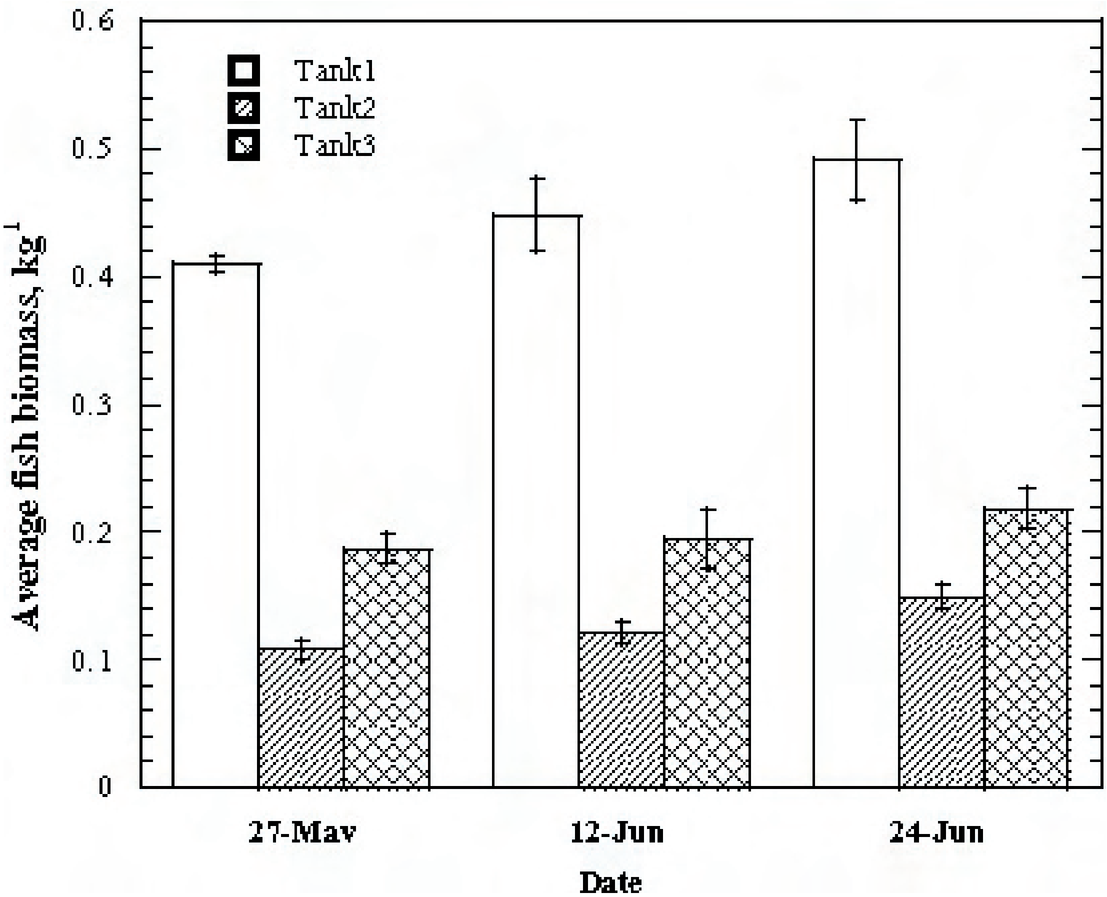
The fish production was monitored through fish sampling every second week. The results showed that the biomass increased steadily in all fish tanks (Fig. 10).

Figure 10. Fish production in 2003/2004 fiscal year



However, the mortality was high in the beginning of the reported fiscal year reaching 30%. The number of fish in tank #1 dropped from 600 to 420 in July 2003 (Fig. 11).

Figure 11. Fish production rate in May-June, 2003



It was suggested that the low quality of fingerlings was the major cause of the problem. The situation was considerably improved when the company providing fingerlings changed a supplier. A significant number of fish (up to 25%) was lost in September due to a power outage. The incident suggested that a backup power generator should be a compulsory requirement for running aquaponics operations. Despite of the lower than expected production in 2003/2004 fiscal year, no major problem in aquaculture was associated with the water quality.

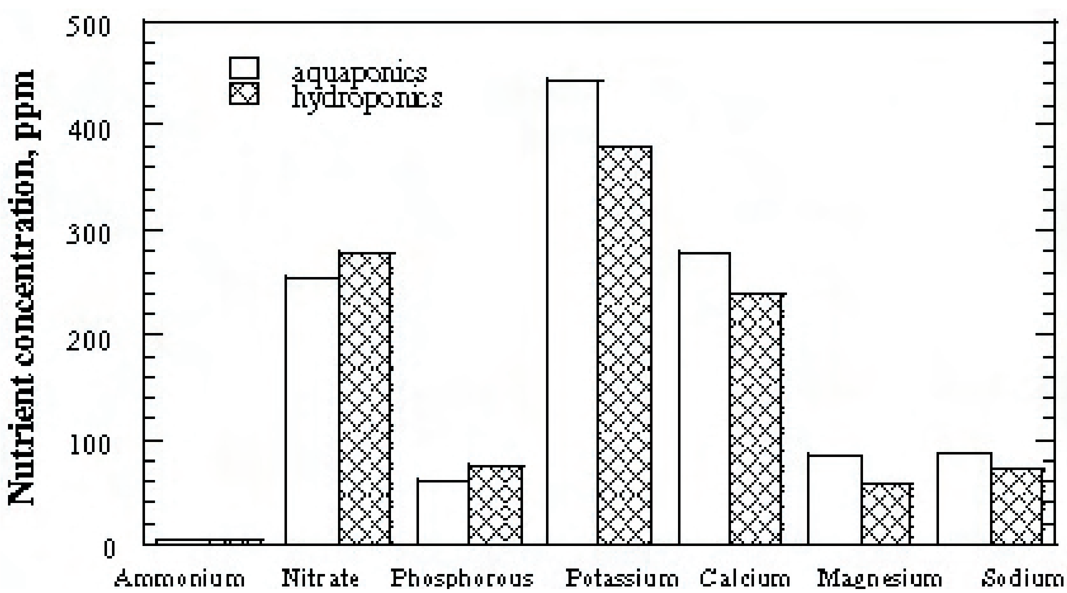
Water quality, pH and the nutrient balance in the fish effluent

The nitrogen cycle is a central factor of bioproductivity in natural and artificial ecosystems. Ammonia is the main component in the excrements of freshwater teleosts (Walsh et all, 2000, 2001, McDonald and Wood, 2002), although the recent research reveal significant portion of urea in the fish excrements too (McDonald and Wood, 1998). Nevertheless, urea is fast transformed into ammonia through the abundant urease activity. Ammonia is oxidized in two-step reaction by nitrifying bacteria with production of nitrate. This process is called nitrification. The nitrification is a crucial process in aquaculture as it reduces level of ammonium, which is a major cause of toxicity for farmed fish. The efficiency of nitrification is higher in alkaline solution, pH 7,5-8.0, which is the reason for relatively high pH in most aquaculture facilities. In our experiment we decreased pH to 6.2 in order to increase solubility of the minerals. The aquaponics system is based on plant uptake as the major mechanism of the nutrient control in the fish effluent. Since ammonium absorption by the plants is considerably faster than that of nitrate, the ammonium level did not reach the toxic threshold during the reported period. In addition, the toxic level of free ammonia was decreased at lower pH as equilibrium between NH4+ and NH3 is favored toward NH4+ in acidic conditions. The level of ammonium in the facility decreased from maximum 5.0 ppm to less than 0.5 ppm, which suggests that aquaponics approach provides one of the best water quality control in the industry.

The preliminary analysis showed high pH 8.6 in the solution. This conditions favored precipitation of Ca, Mg, Fe, and most of the microelements (except Mo) in the form of phosphates and sulfates. Iron deficiency was the most notable (Fig. 2).

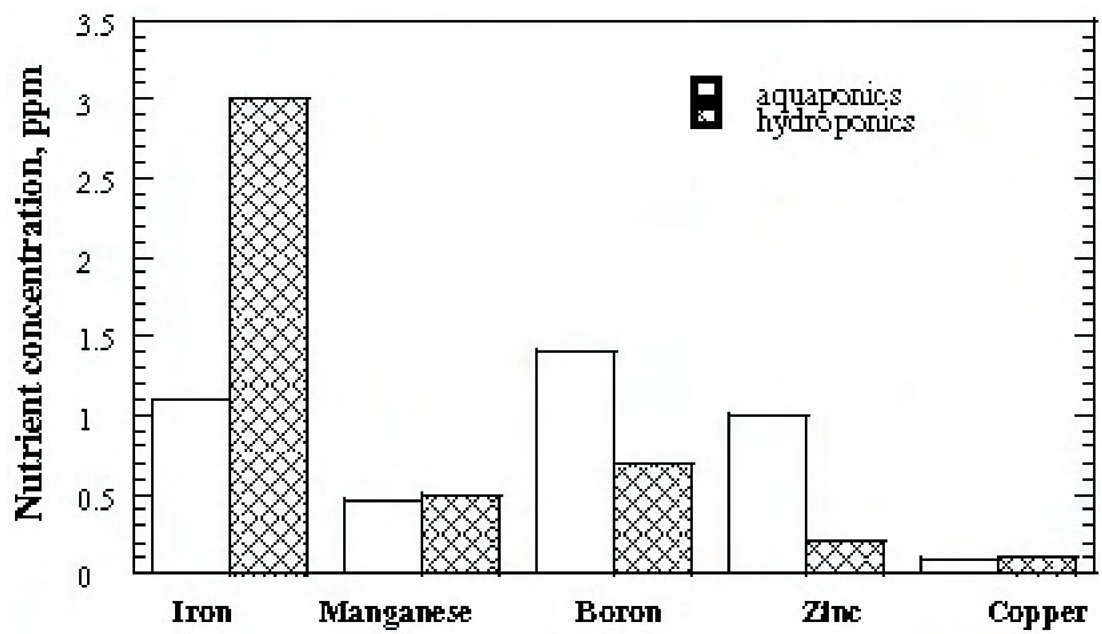
The pH was gradually decreased from 8.6 to 6.2 using phosphoric acid. These conditions led to fast accumulation of Mg and Ca due to natural abundance of these elements in the local water source. A moderate amount of Na (about 0.5 mM) was also observed. However, it never reached a toxic threshold due to extensive plant growth and absorption of excess of sodium. The N-NO3-level gradually increased from 0 to 10 mM, which provided sufficient source of nitrogen for plants (Fig 12). The iron and microelements were add to the solution to reverse the deficiency symptoms.

Figure 12. Concentration of acroelements and sodium in aquaponic solution as compared with standard hydroponic mixture



Since the concept of aquaponics implies use of fish feed as a major source of nutrient for the plant production, the nutrient balance in the fish feed is crucial for the plant production. The requirements for potassium are different for plants and for fish. Fishmeal, the major component of the fish feeding formulations is depleted in potassium. The measured level of potassium in the fish effluent was 10 fold less than that of calcium and 5 fold less than sodium in the beginning of the experiment. Normal ratio between Ca and K should be from 2:1 to 1.5:1 and should not drop below 1 to 1. Ca and Na interfere with K uptake. The increased level of these elements can cause severe K starvation. Thus, the preliminary observations in aquaponics system revealed an intrinsic nutrient imbalance in the system based on fish feeding formulations as the only source of the plant nutrients. The existing aquaponics systems use either calcium or potassium hydroxide supplements in order to control pH. In such systems, however, potassium level is not controlled by the plant demands, but rather by pH. We offer a new concept in aquaponic production based on potassium and other nutrients supplements. The balance between the plant nutrients in the fish effluent was controlled by the addition of supplements limited to iron and potassium to provide the best nutrient regime for the maximum plant production. However, the fish effluent provided the major portion of the nutrients. After six months of operation the macro- and micronutrient balance in aquaponics facility closely mimicked a standard commercial mixture with minimum supplements with minerals (Fig. 12 and 13).

Figure 13.
Concentration of six major microelements in aquaponic solution as compared with standard hydroponic mixture



Leaf analysis showed no deficiencies in aquaponically grown plants of cucumbers (Fig. 14 and 15).

Figure 14. Diagnostics of macroelements in leaf tissue of cucumber plants grown in aquaponics

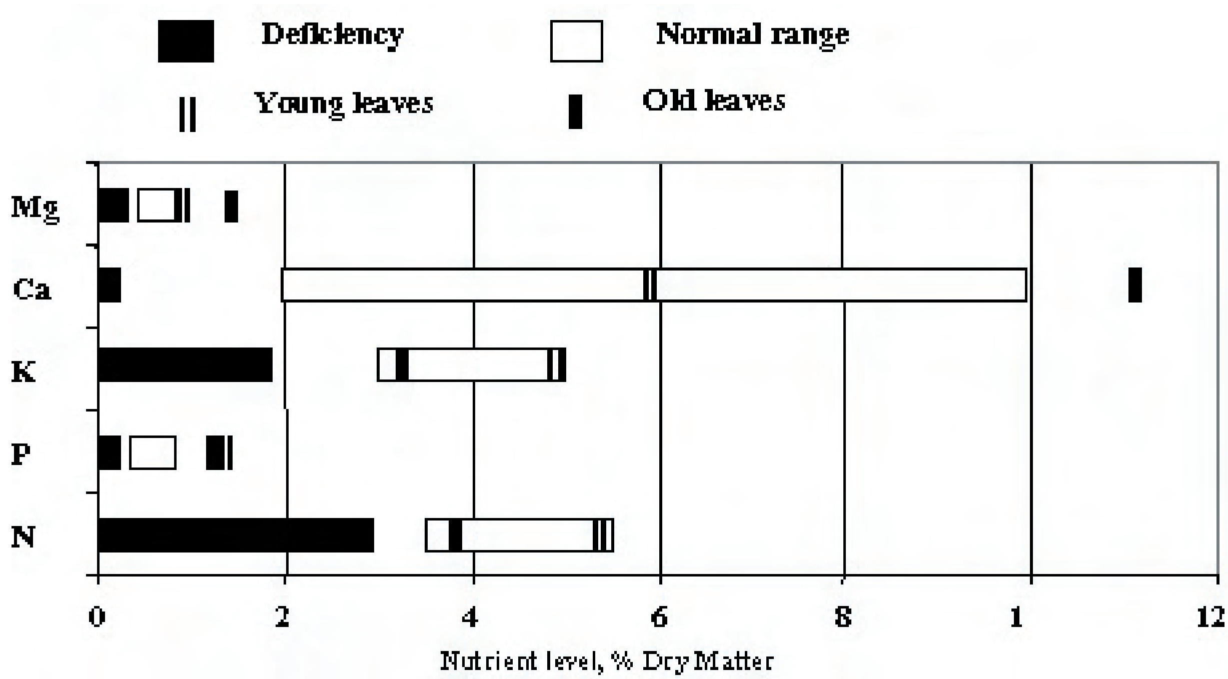
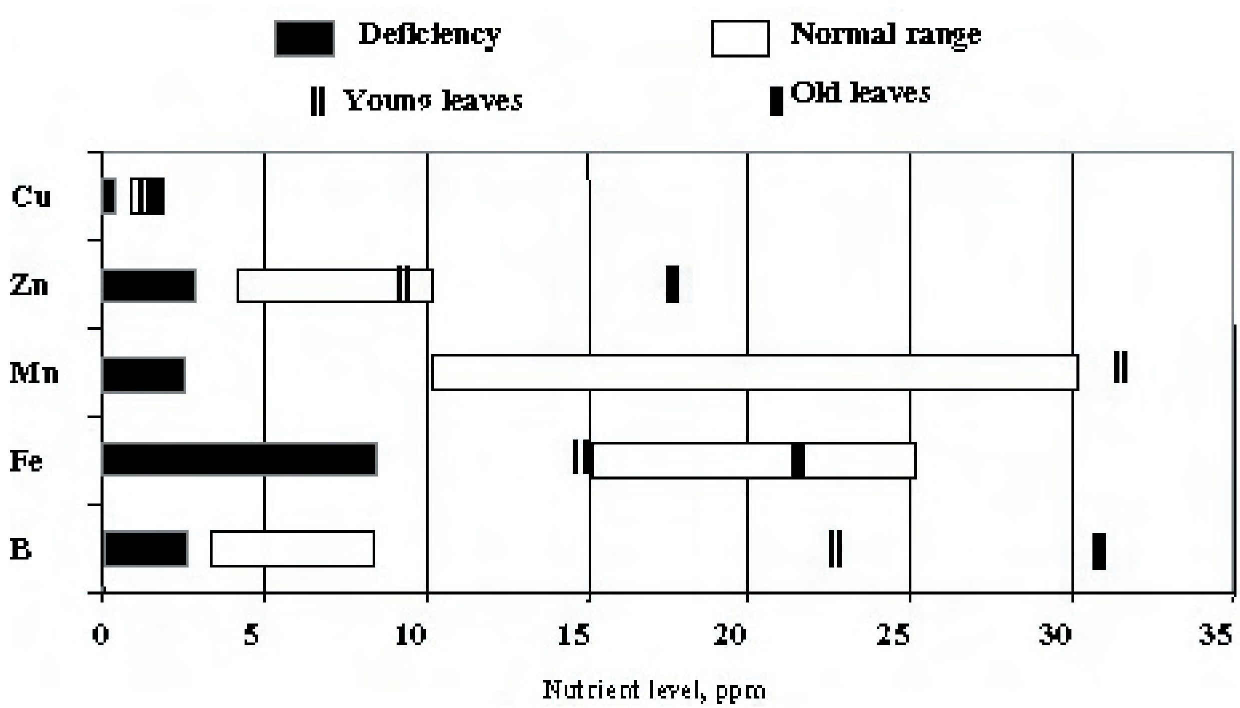


Figure 15. Diagnostics of five major microelements in leaf tissue of cucumber plants grown in aquaponics



Potential for Organic Production

The potential of aquaponics for organic production is high. There is a number of retailers supplying organically certified minerals. Rock potassium sulfate containing up to 50% K_2O and soluble kelp powder can be used as adequate organically certified potassium supplements. The aquaponics project offered a new opportunity to develop a whole new industry based on supplies for organic hydroponics.

The negotiations with companies based in Alberta, Ontario, BC in Canada as well as in US and Australia are on the way to collaborate on aquaponics project in Brooks. These companies include AgriChem Inc (Ontario), HydroCorp Inc (Ontario), Agri-Growth International Inc (Alberta), IMP (Alberta), Nutri-Tech Solutions Pty Ltd (Australia) etc.

This project can stimulate a new industry of soluble organically certified supplements replacing conventional mineral fertilizers. For example, these supplements may include soluble kelp powder containing biologically active components besides potassium. These components were shown to have a positive effect on crop production and development. The emerging aquaponic industry may have a considerable impact on supplying industry.

The other approach is a development of plant-based fish feed. This feed will have more potassium and will be more balanced for growing plants. The existing fish feed is based on fish meal, byproduct from the fish industry. The limited supply of fish meal hampers the development of fish farming in Canada and all over the world. Thus, new products based in plants are the key factor for the expansion of the fish farming. In the last case, the aquaponics production will be an imperative for future aquaculture industry.

Problems encountered during aquaponics operation in 2003/2004

Power outage in aquaponics facility
Solution: backup generator, automatic oxygen backup system including oxygen probes and oxygen backup tanks

High fish mortality in the beginning of 2003/2004 fiscal year
Solution: higher quality fingerlings, on-site hatchery with the quality control

Nutrient deficiency in the beginning of aquaponics operation
Solution: start-up nutrient supplementation during the initial period of operation

Some crops including lettuce and parsley developed glassiness problem due to high root pressure in warm water aquaponics system
Solution: selection of resistant cultivars and crops for warm water aquaponics production

Surge of ammonium after trough cleaning procedure
Solution: avoiding using bleach in aquaponics operations

Root rot caused by *P. aphanidermatum*
Solution: regular cleanups of clarifying tanks, which serve as a breeding ground for pathogenic fungi

Flooding of aquaponics facility
Solution: maintenance of water level control system

Conclusions

Technical feasibility study in 2003/2004 fiscal year demonstrated high results and viability of aquaponics technology in Alberta.

Stand-alone recirculation system, which can be balanced more effectively, was more efficient in crop production than add-on recirculation system.

Crop production can reach higher levels in aquaponics compared to the average production in the industry based on conventional hydroponics technology.

Conditions of aquaponic production can be effectively controlled to considerably increase crop production and improve water quality.

Staggered crop and fish operating and maintenance schedules effectively prevented spikes in nutrients concentrations during production period.

Decrease of pH from 8.6 to 6.2 was the crucial factor improving the crop output in both stand-alone and add-on aquaponic systems.

Ammonium level important for fish production can be sustained at low level at pH 6.2.

Iron and potassium, but not calcium and magnesium, are the limiting factors in aquaponics when pH is adjusted.

Aquaponics system has an intrinsic capacity of self-regulation and balancing nutrients in the solution.

The nutrient balance necessary for optimal crop production can be reached within six months of operation or earlier.

The rate of fish biomass production in aquaponics is comparable with conventional aquaculture operation.

Commercially available products of biological control are efficient tools to suppress pests in aquaponic conditions.

Presentation to the Industry

The results of aquaponics study were presented to the industry during a conference; workshops; and meetings of industry groups, professional associations, open houses and tours in Brooks and Lethbridge facilities. The oral presentations were given for the Alberta Horticultural Congress November 14 2003, Edmonton, Alberta, and during two workshops for growers in Redcliff (Red Hat Coop) and Lacombe (Pik'n Pak) in August and September, 2003.

On May 13, 2003, the aquaponics team at Crop Diversification Centre South (CDCS) including Eric Hutchings, Pat Cote, Brice Kozak, and Nick Savidov showed off the aquaponics project at an Open House of Greenhouse Crops Program, with over 100 growers and industry representatives in attendance. Visitors were shown through the aquaponics facilities and also were able to attend a poster display. Due to success of the Open House in May and requests from other growers the second Open House was held in August in collaboration with Special Crops Program.

The 2nd annual meeting of Alberta Aquaponics Group (AAG) and a workshop on aquaponics were held at CDC South on December 2, 2003. The meeting included eight presentations about the project and aquaponic technology, round table discussions and tour in Brooks Aquaponics Facility (BAF). Various issues of aquaponics production, marketing, economics and food safety were discussed in depth among other issues related to the technology.

The project was discussed during regular meetings of Alberta Greenhouse Growers Association and Alberta Fish Farmers Association Boards of Directors.

Industry Reaction

The reaction from the industry was positive. The project enjoyed a tremendous industry support during the 2003/2004 fiscal year. In the same year the project attracted attention of professional growers, general public and mass media. Different groups from the industry and general public toured the facility on weekly basis, sometimes several times a week. Over dozen interviews were given to mass media for reported period and several articles about the project were published across Alberta for the same period.

A stakeholders group called Alberta Aquaponics Group-AAG was formed during the December 12th meeting in 2002. This was an industry-led initiative aimed at helping advise in the development of the aquaponics research in the Province. The group included representation from fish and organic crop growers, a town development official, private entrepreneurs and experts from the governmental and academic institutions. The second meeting of AAG was held on December 2, 2003 at CDC South. AAG proved to be an important tool through which the information about the new technology was disseminated in the industry. The growers Doug Millar, Mark McNaughton and Kurt McNaughton, members of Alberta Fish Farmers Association - AFFA, are active participants of the aquaponics project. This growers started their aquaponics operations with the logistic support from aquaponics project team. AFFA provided matching grants for three successful grant applications including application to Federal Aquaculture Collaborative Research and Development Program Department of Fisheries and Oceans Canada – ACRDP DFO. This and other applications would be impossible without active industry support.

An “Aquaponics Short Course”, originally scheduled March 2003, showed considerable industry interest, with people registering from eastern and western Canada and the USA. The intended small, hands- on seminar had turned into large meeting group. The Federal government’s AquaNet, an education arm had committed considerable funds to offset expenses. This course was canceled due to lack of information about aquaponics production technology in Alberta that time. The successful results of NIF aquaponics project in 2003/2004 fiscal year will pave the road for the first aquaponics course in Canada in spring 2005 held in Alberta.

Recommendations

The project must be carried over into 2005-2006 as well in order to obtain sufficient crop production data before it can be presented to the industry for commercialization purposes.

Acknowledgments

The project team is grateful to Steering Committee on Aquaponics Project for providing directions and useful discussions during 2003/2004 fiscal year.

Note: The marketing and food safety studies on aquaponics are attached to this report in Appendixes C, D, E, F, G and H

Appendixes

Aquaponics

Aquaponics is cutting-edge technology based on recycling nutrients produced by fish and growing high value organic vegetables without synthetic fertilizers. The water is filtered by the plants and returned pure to the fish tanks. Organic food production is a rapidly growing industry in North America and this operation plans to tie into those markets

Organic greenhouse operations are higher risk because of the greater potential for yield loss from diseases and various nutrient disorders. Aquaponics may reduce this risk because it is a soil-free technology and is an example of sustainable agriculture.

The complexity and uniqueness of growing fish and plants in a closed system required strong involvement form experts from many areas including crop and fish production, economics and marketing.

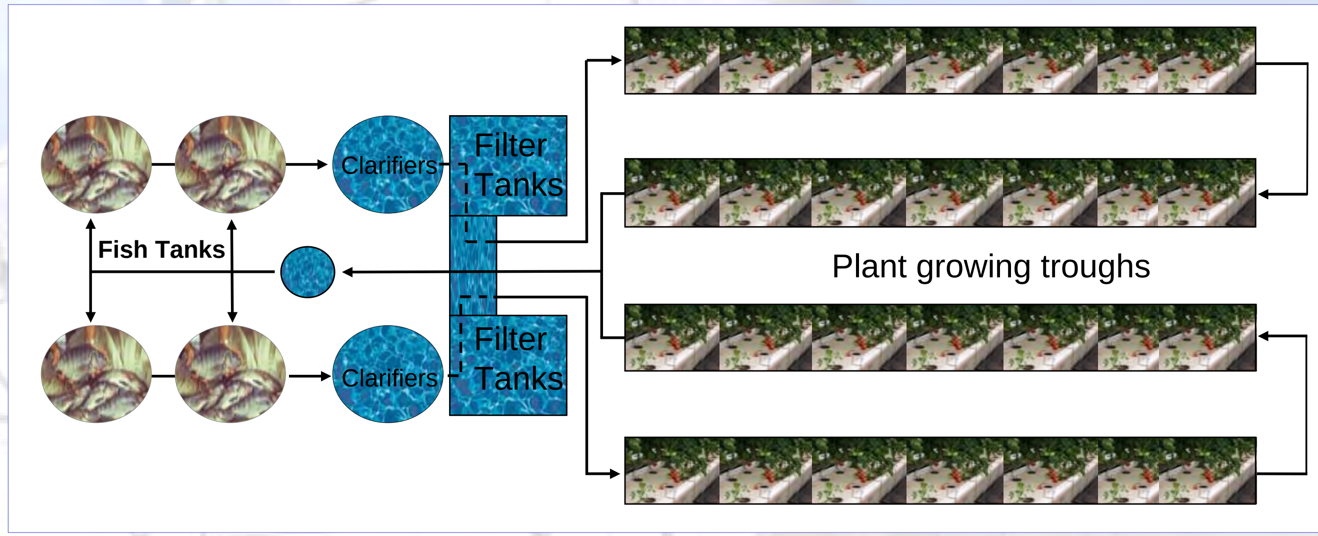
An aquaponic system was built, based on the University of Virgin Islands design, as a prototype for commercialization in Alberta, Canada in 2002.
The system consists of four fish rearing tanks (5 m^{-3} each) and four raft hydroponics troughs (29 m^{-2} each).

To test commercial feasibility of aquaponics under Alberta's climatic conditions the food fish tilapia was selected in combination with several conventional greenhouse plants (cucumber, tomato, etc.), herbs, medicinal plants, and nutraceutical plants.

A protocol was developed for producing aquaponic crops in Alberta. More than 60 different crops and varieties were tested in a greenhouse. Based on this preliminary evaluation, five greenhouse vegetables and 19 herbs, were grown in trials to determine production levels. Yields of tomatoes and mini-cucumbers reached 20.7 kg/plant^{-1} year^{-1} and 33.4 kg/plant^{-1} year^{-1} . This exceeds the average values of commercial greenhouses in Alberta that employ conventional hydroponic technology. During the 2-year study, the yield of Genovese basil increased from 13 kg m^{-2} year^{-1} to 42 kg m^{-2} year^{-1} as production and harvesting methods were refined.

This study demonstrated the technical feasibility of the aquaponic technology in Alberta. Evaluation of the economic feasibility is under way.

How water moves through the Aquaponics system



Acknowledgements

Alberta Fish Farmers Association
Greenview Aqua Farms
Lethbridge Community College
Air Liquide Canada
Westgrow
Applied Bio-nomics Ltd.
Dr. Jim Rakocy and Don Bailey
Sam's Oriental Restaurant and Market
Argus Control Systems Ltd.

Alberta
AGRICULTURE, FOOD AND RURAL DEVELOPMENT

Crop Diversification Division
Greenhouse Crops Program
Crop Diversification Centre South
Brooks, Alberta

Appendix A

Add-on Aquaponics System Aquaculture Centre of Excellence,

Lethbridge Community College.
Summary of research.

Location: Lethbridge Community College, Aquaculture Center of Excellence

Study Length: May 1 to October 20, 2003

Accomplishments: Evaluated the production of three kinds of cucumbers (Long English, Alimar, Gherkin) and four kinds of tomatoes (Cloe, New Yorker, Pear and Grape) as well as lettuce (Butter Crunch), several herbs (basil, chives, dill, parsley, and oregano) and several kinds of water plants (water lilies, frog bit, water hyacinth, water lettuce, and duck weed).

Results:

1.When the greenhouse (10 m x 30 m) was fully stocked nutrient availability limited production. Drum filters likely remove a significant amount of potential nutrient.

2. Some vegetables, particularly greenhouse cucumber (Long English) and tomato (Cloe, New Yorker) cultivars are particularly suited to aquaponics for the point of view of both good production and relatively low susceptibility to insect pests.

3. Plants must be grown, from seed germination to harvest without soil to avoid problems with root diseases.

Successes:

1. Cucumbers all grew well but Long English were the most productive

2. The most productive tomato cultivars were New Yorker and Cloe

3. Te other cultivars of tomatoes and cucumbers would have to command a price premium of two to ten times to make them economic.

Work Still Required:

1. Determine the threshold fish feeding level needed to support a given area of greenhouse.

2. Determine the operating protocol that would maximize seasonal production and profitability.

3. A more detailed evaluation of the nutrient levels present in the recirculating water under various operating conditions.

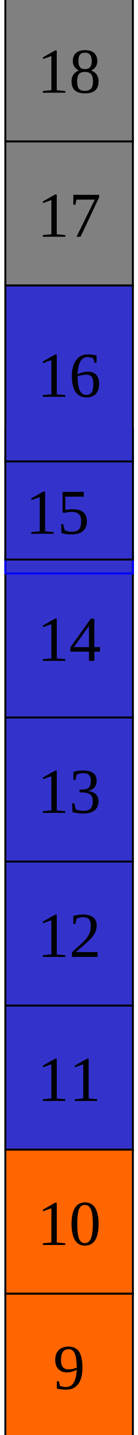
Appendix B

Add-on Aquaponics System at Aquaculture Centre of Excellence,Lethbridge Community College. Figures.

Large Greenhouse
March

7&8 seeded
3/1/03 (Brooks)

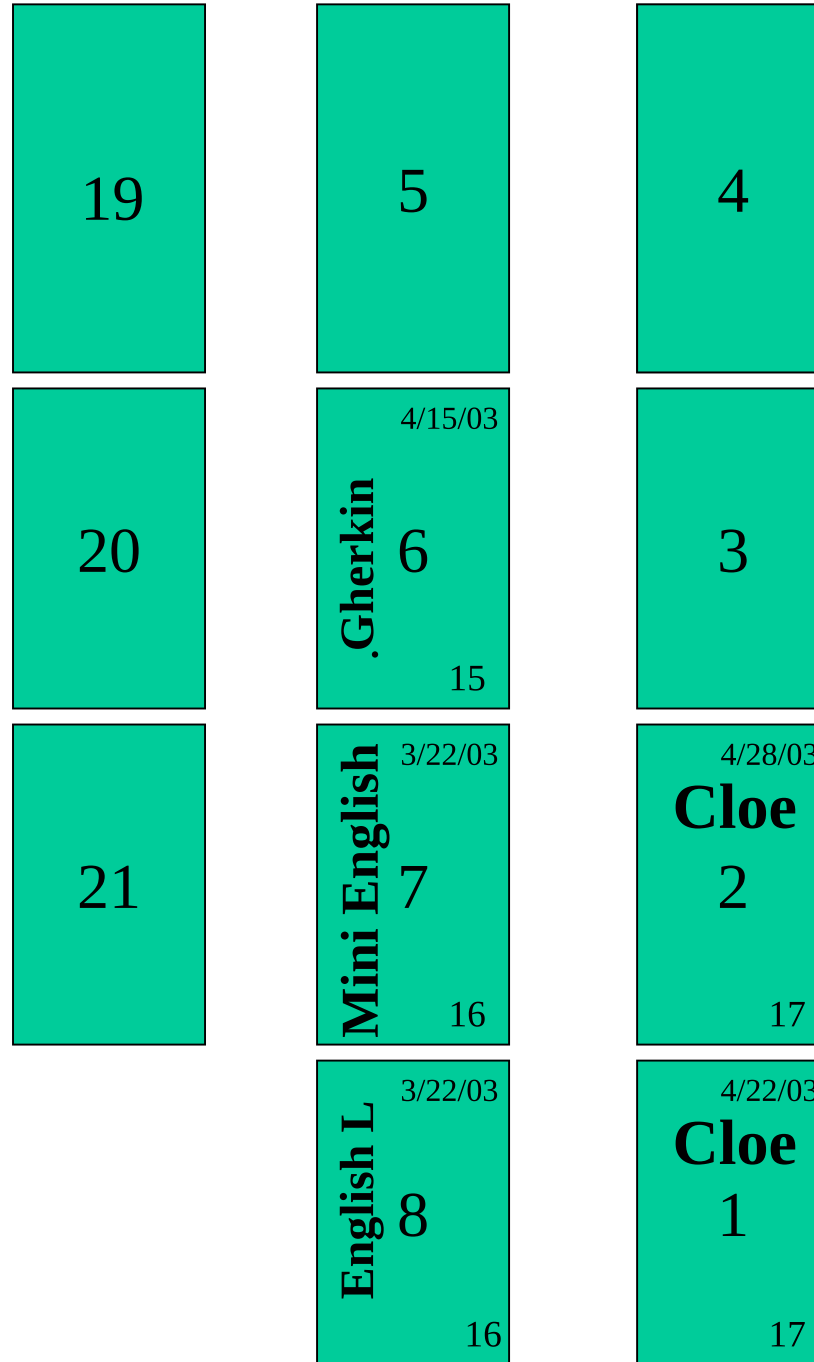
Large Greenhouse
April

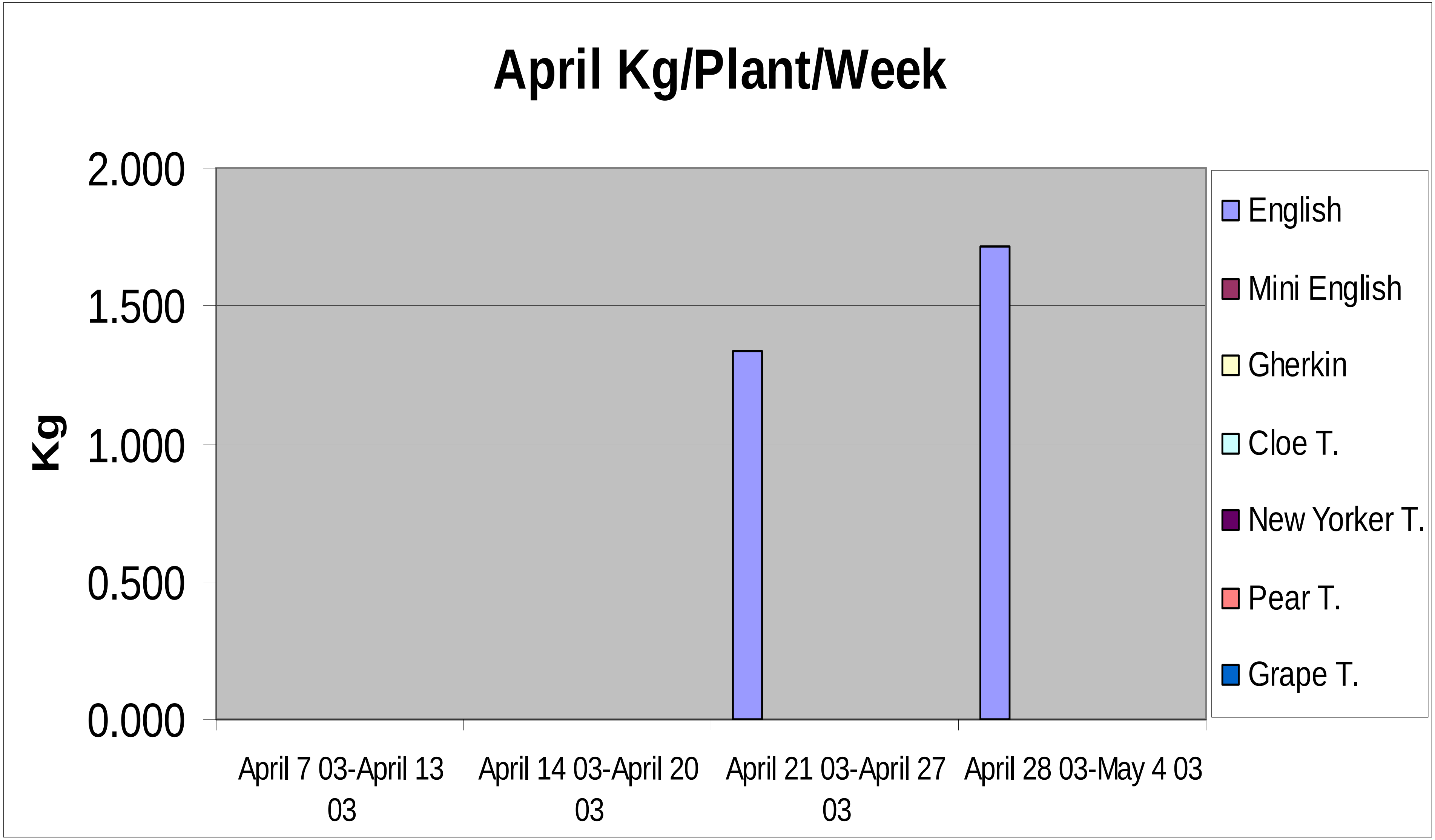


1,2&6 seeded
4/1/03

4 cloe plants found in pond
divided into Tray 1 & 2

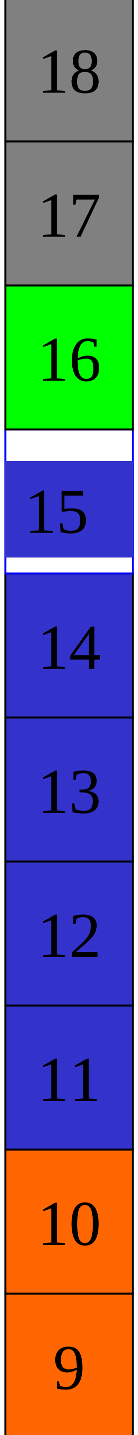
15 Gherkins Tray 6
In system 4/15/03





April Kg/Plant/Week
Kg
2.000
1.500
1.000
0.500
0.000
April 7 03-April 13 03
April 14 03-April 20 03
April 21 03-April 27 03
April 28 03-May 4 03
English
Mini English
Gherkin
Cloe T.
New Yorker T.
Pear T.
Grape T.

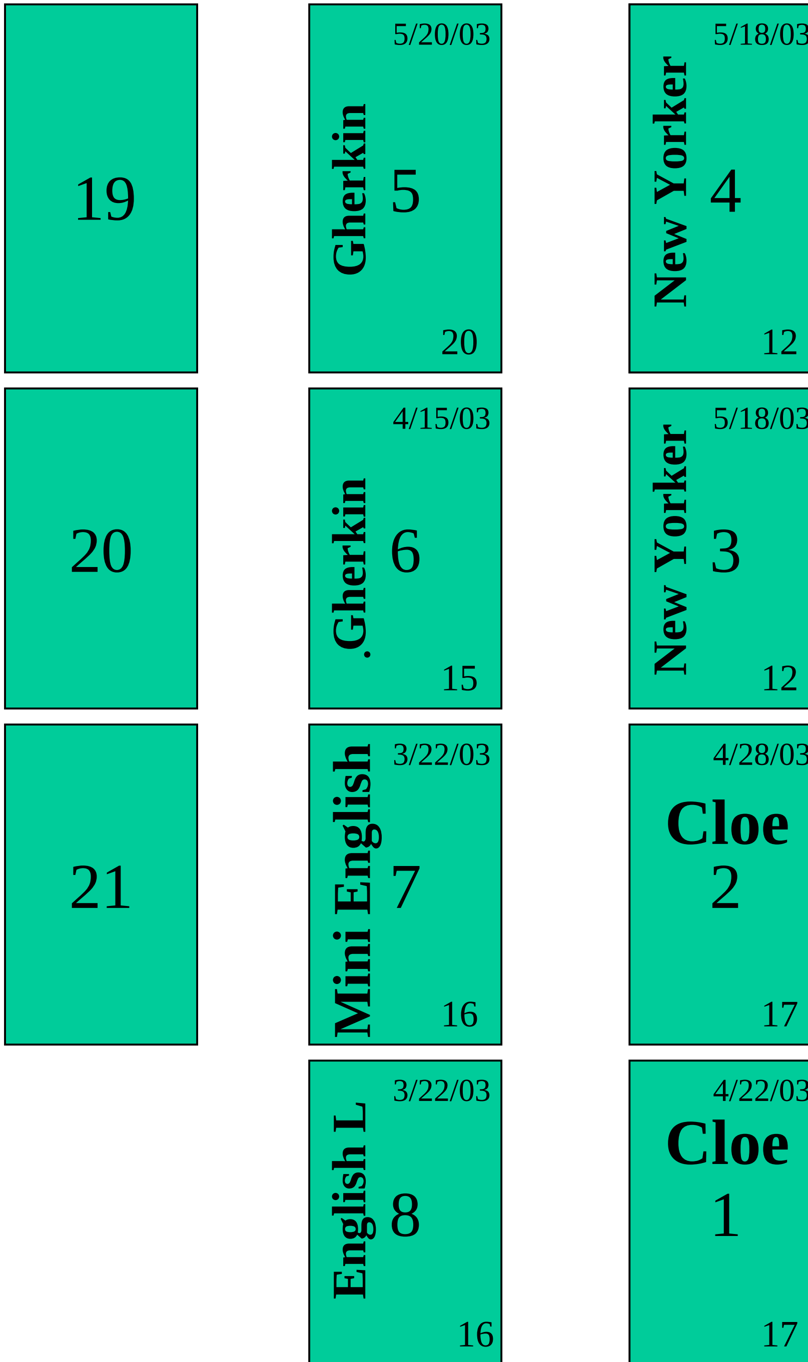
Large Greenhouse
May

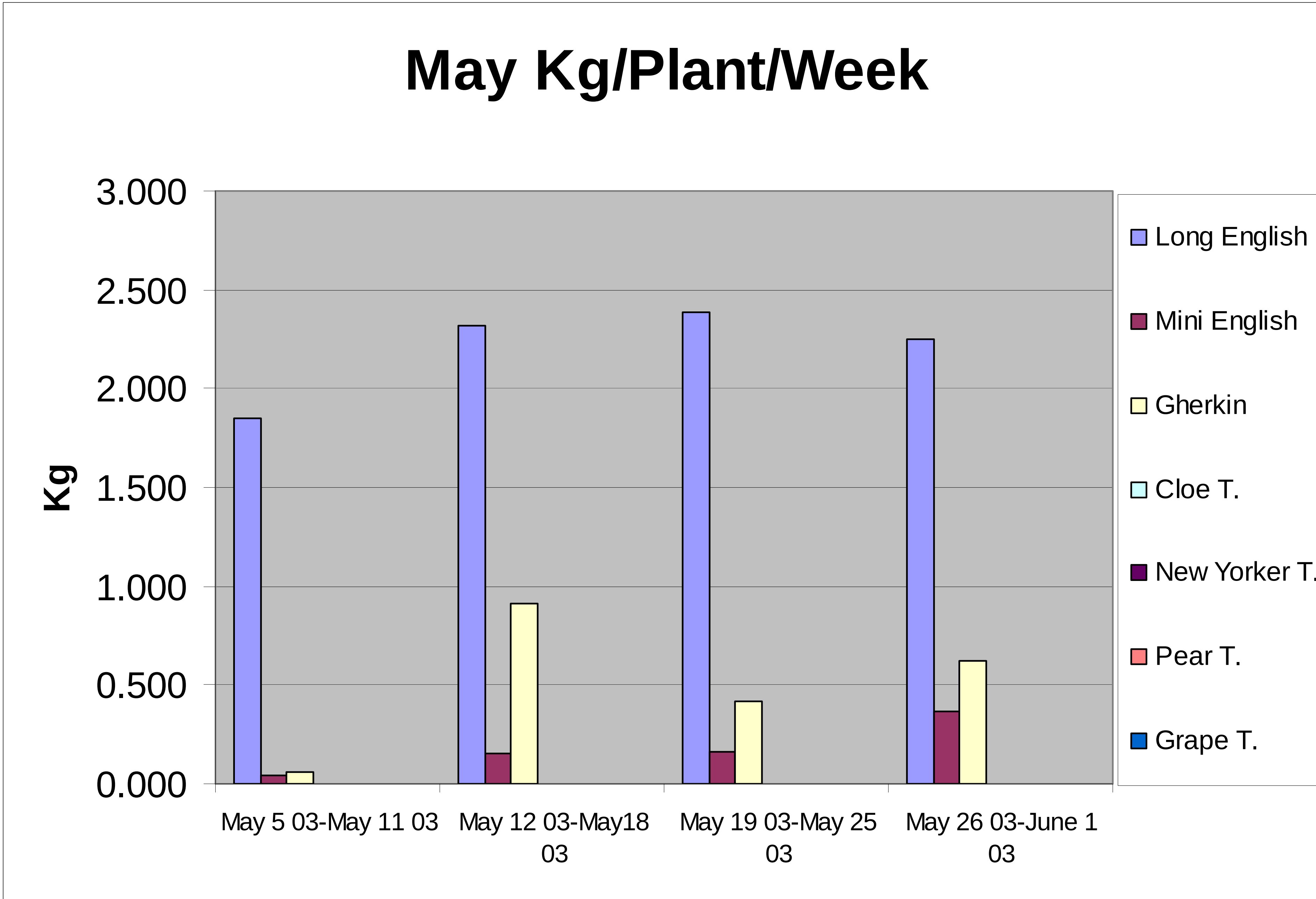


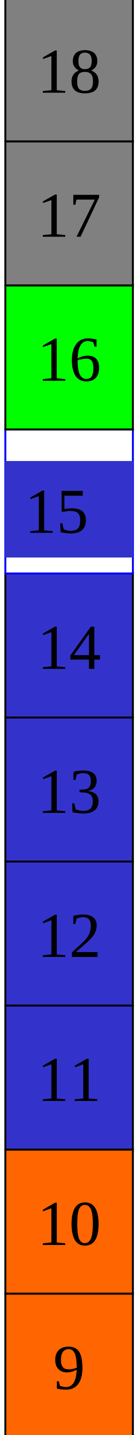
5 seeded
5/7/03

Tray 3 & 4 New Yorkers
transplanted from soil 5/18/03

20 Gherkins in
system 5/20/03
Tray 5




May Kg/Plant/Week
Kg
3.000
2.500
2.000
1.500
1.000
0.500
0.000
May 5 03-May 11 03
May 12 03-May18 03
May 19 03-May 25 03
May 26 03-June 1 03
Long English
Mini English
Gherkin
Cloe T.
New Yorker T.
Pear T.
Grape T.



Large Greenhouse
June

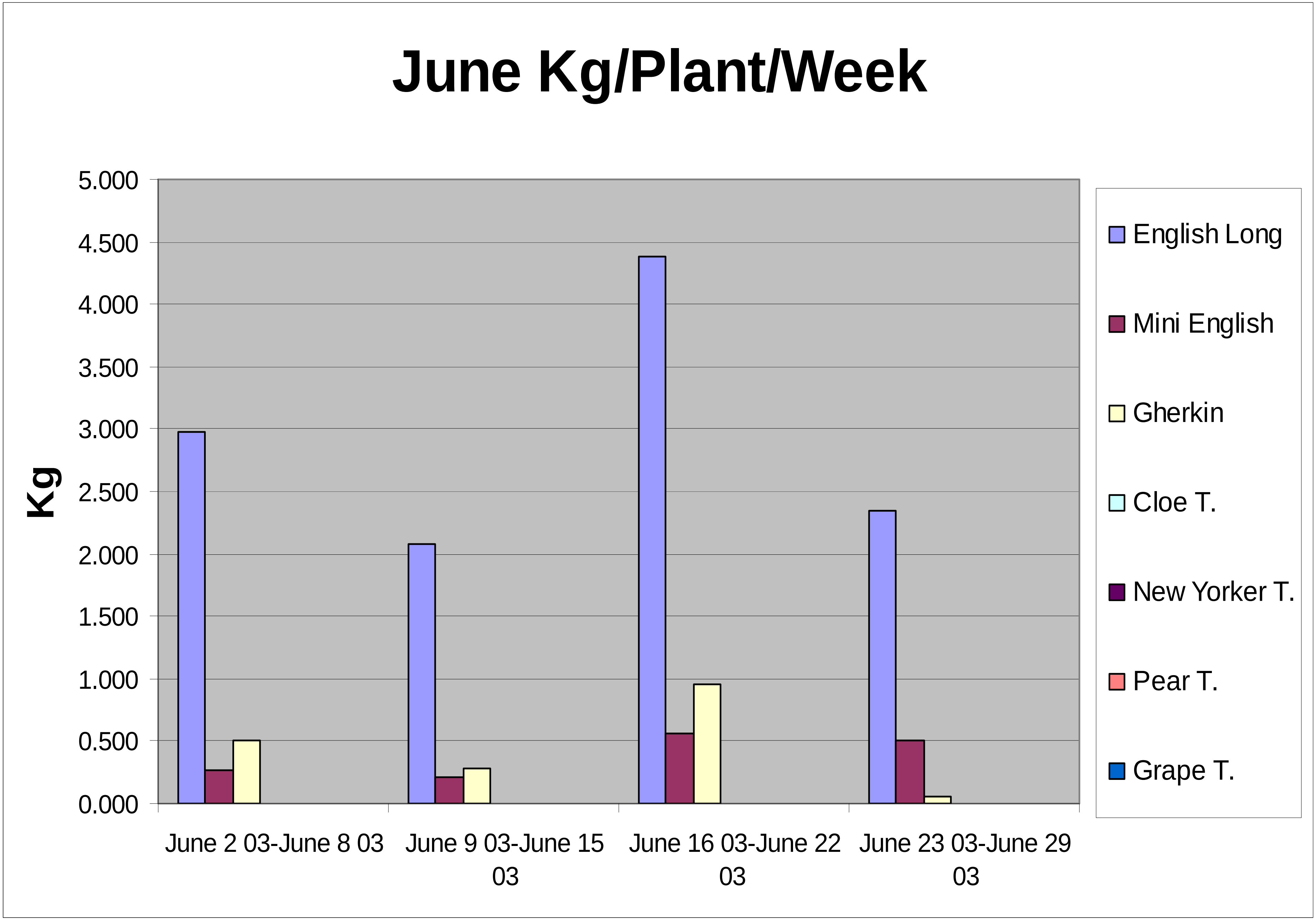
Gherkins seeded
6/3/03

20 Gherkins in
In system 6/18/03
Tray 5

North Wall Gherkins
Seeded 6/24/03

Tray 7 Replaced
With 20 Gherkins
From Brooks6/27/3

Tray 8 Replaced
with 16 L.E 6/26/03
From Brooks


June Kg/Plant/Week
Kg
5.000
4.500
4.000
3.500
3.000
2.500
2.000
1.500
1.000
0.500
0.000
June 2 03-June 8 03
June 9 03-June 15 03
June 16 03-June 22 03
June 23 03-June 29 03
English Long
Mini English
Gherkin
Cloe T.
New Yorker T.
Pear T.
Grape T.

Large Greenhouse
July

18	
17	
16	Gherkin - 6
15	Gherkin - 6
14	Gherkin - 6
13	Gherkin - 6
12	Gherkin - 6
11	Mini - E - 6
10	Mini - E - 5
9	Mini - E - 8

20 Grape and
20 Pear Tomatoes
Transplanted from soil
Trays 19 & 20 7/2/03

20 Mini E in system
Tray 21
7/11/03 from Brooks

19 Mini E in system
North Tray
7/11/03 from Brooks

Tray 6 replaced with
17 L.E 7/22/03

30 Gherkins in system
7/18/03 10 from Brooks
20 Seeded here
North Tray

3 Gherkins Added
to Tray 6 from
Brooks 7/18/03

Gherkins seeded 07/31/03

7/2/03 **Grape T.** 19 — 20

7/2/03 **Pear T.** 20 — 20

7/11/03 **Mini E.** 21 — 20

5/20/03 6/18/03 **Gherkin** 5 — 20

4/15/03 7/22/03 **English L.** 6 — 3 • 17

3/22/03 6/27/03 **Gherkins** 7 — 20

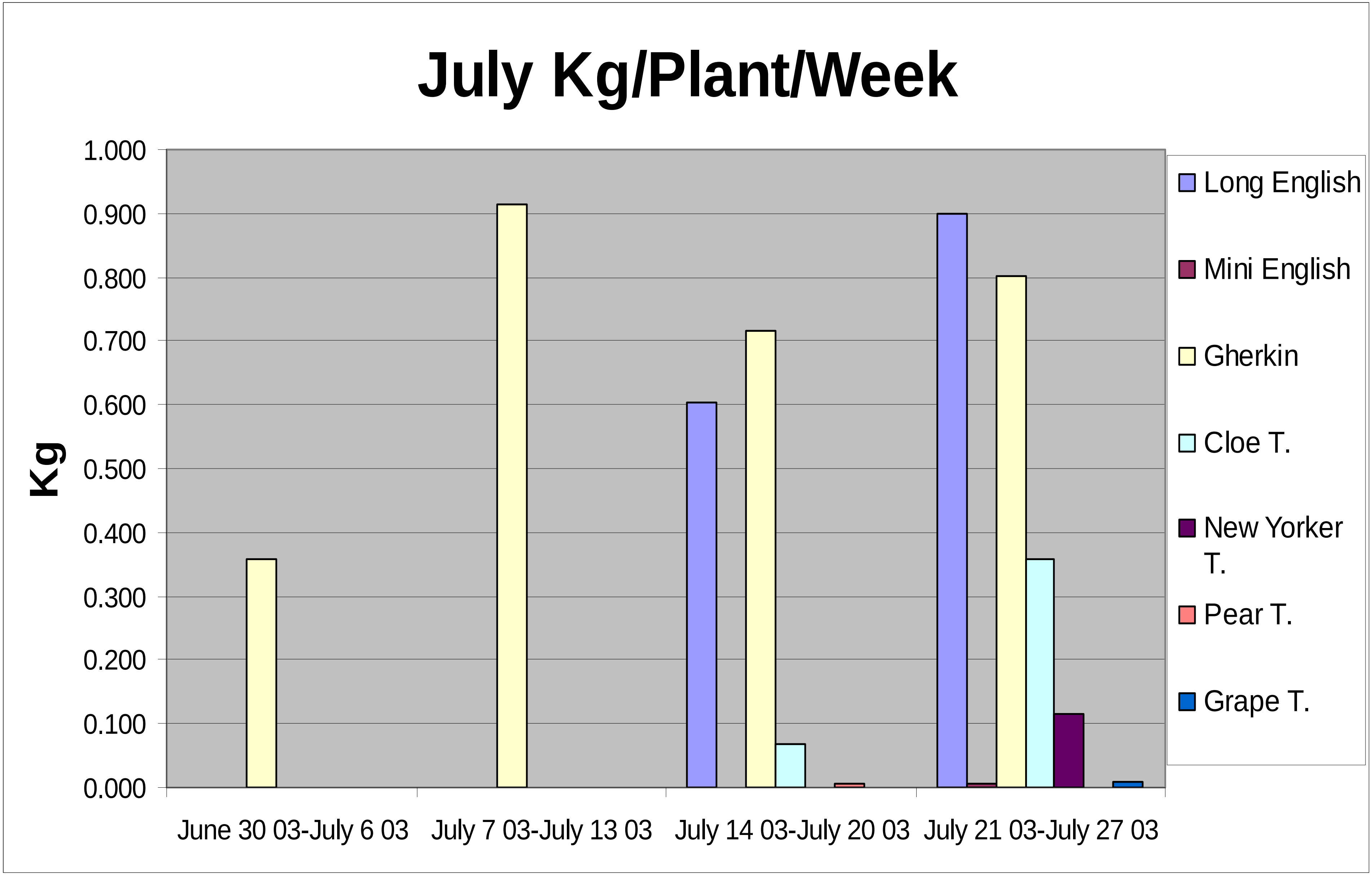
3/22/03 6/26/03 **English L.** 8 — 16

5/18/03 **New Yorker** 4 — 12

5/18/03 **New Yorker** 3 — 12

4/28/03 **Cloe** 2 — 17

4/22/03 **Cloe** 1 — 17



July Kg/Plant/Week
Kg
1.000
0.900
0.800
0.700
0.600
0.500
0.400
0.300
0.200
0.100
0.000
June 30 03-July 6 03
July 7 03-July 13 03
July 14 03-July 20 03
July 21 03-July 27 03
Long English
Mini English
Gherkin
Cloe T.
New Yorker T.
Pear T.
Grape T.

Large Greenhouse
August

18

17

16 Gherkin - 6

15 Gherkin - 6

14 Gherkin - 6

13 Gherkin - 6

12 Gherkin - 6

11 Mini - E - 6

10 Mini - E - 5

9 Mini - E - 8

Tray 5 Replaced
with 20 Gherkins
on 8/14/03

Gherkins seeded
on 08/19/03

10 Mini
10 Long
Seeded 08/27/03

7/2/03
Grape T. 19
20

5/20/03
6/18/03
8/14/03
Gherkin 5
20

5/18/03
New Yorker 4
12

7/2/03
Pear T. 20
20

4/15/03
7/22/03
English L. 6
3 17

5/18/03
New Yorker 3
12

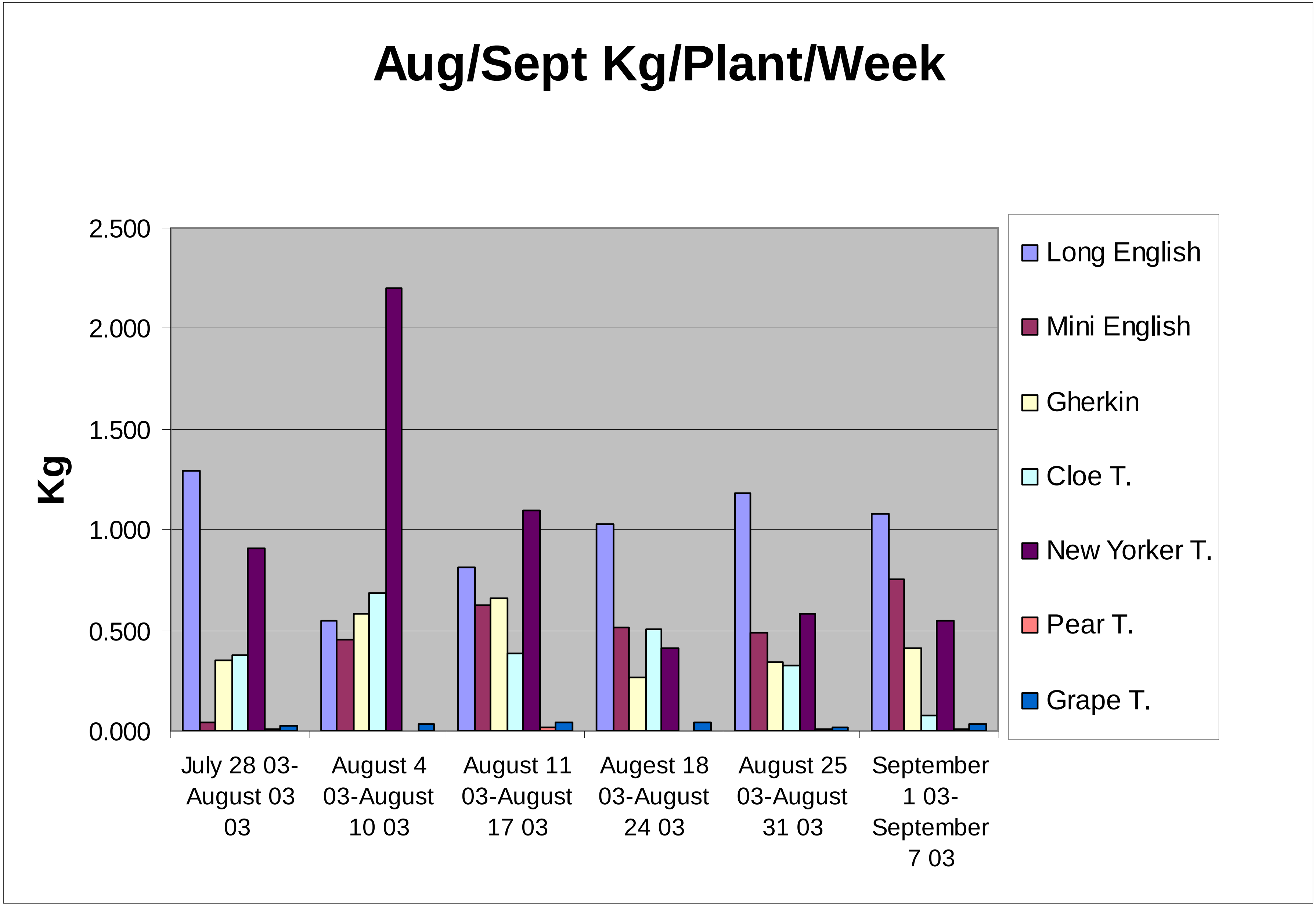
7/11/03
Mini E. 21
20

3/22/03
6/27/03
Gherkins 7
20

4/28/03
Cloe
2
17

3/22/03
6/26/03
English L. 8
16

4/22/03
Cloe
1
17



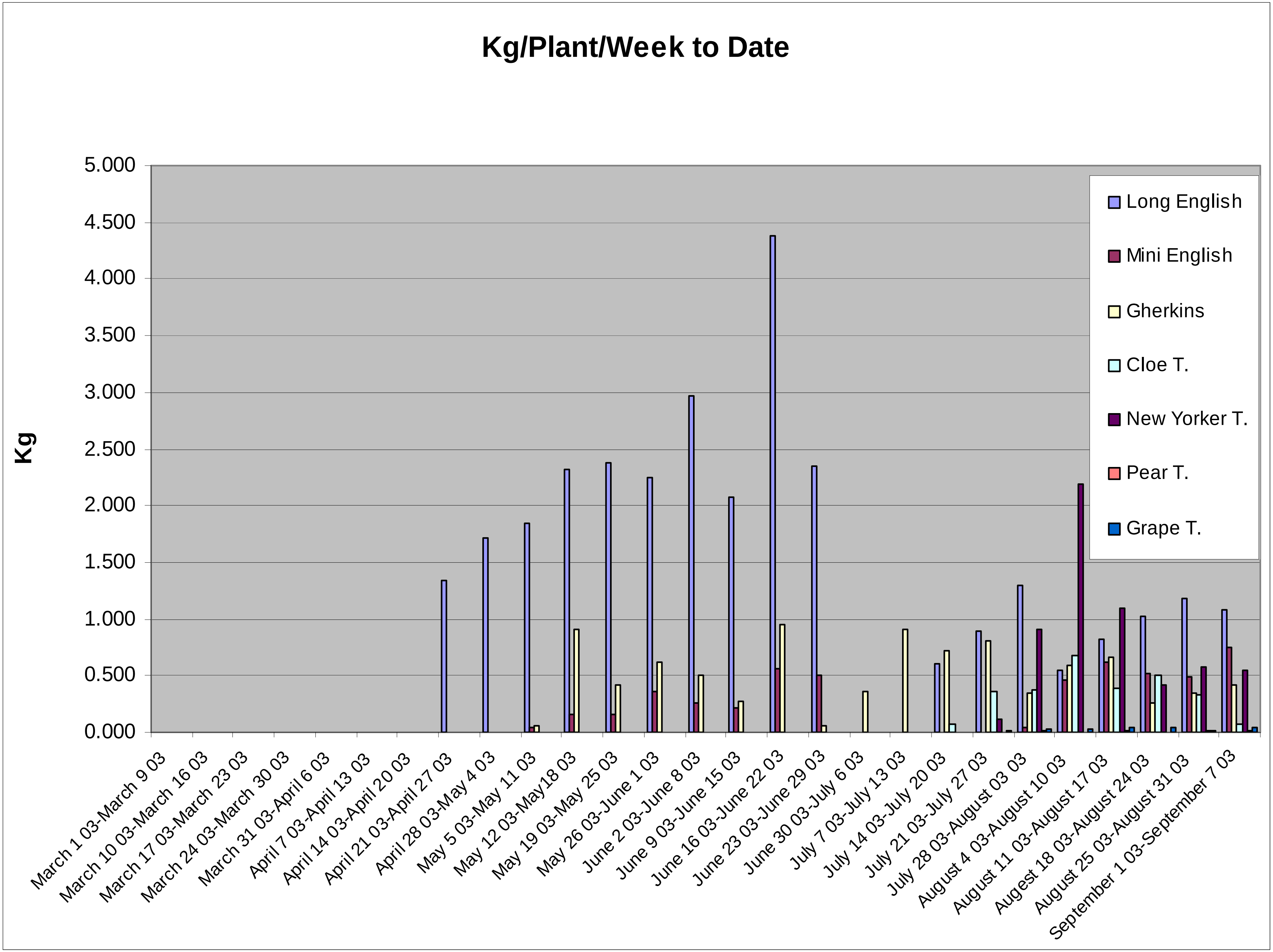
Aug/Sept Kg/Plant/Week
Kg
2.500
2.000
1.500
1.000
0.500
0.000
July 28 03-August 03 03
August 4 03-August 10 03
August 11 03-August 17 03
Augest 18 03-August 24 03
August 25 03-August 31 03
September 1 03-September 7 03
Long English
Mini English
Gherkin
Cloe T.
New Yorker T.
Pear T.
Grape T.

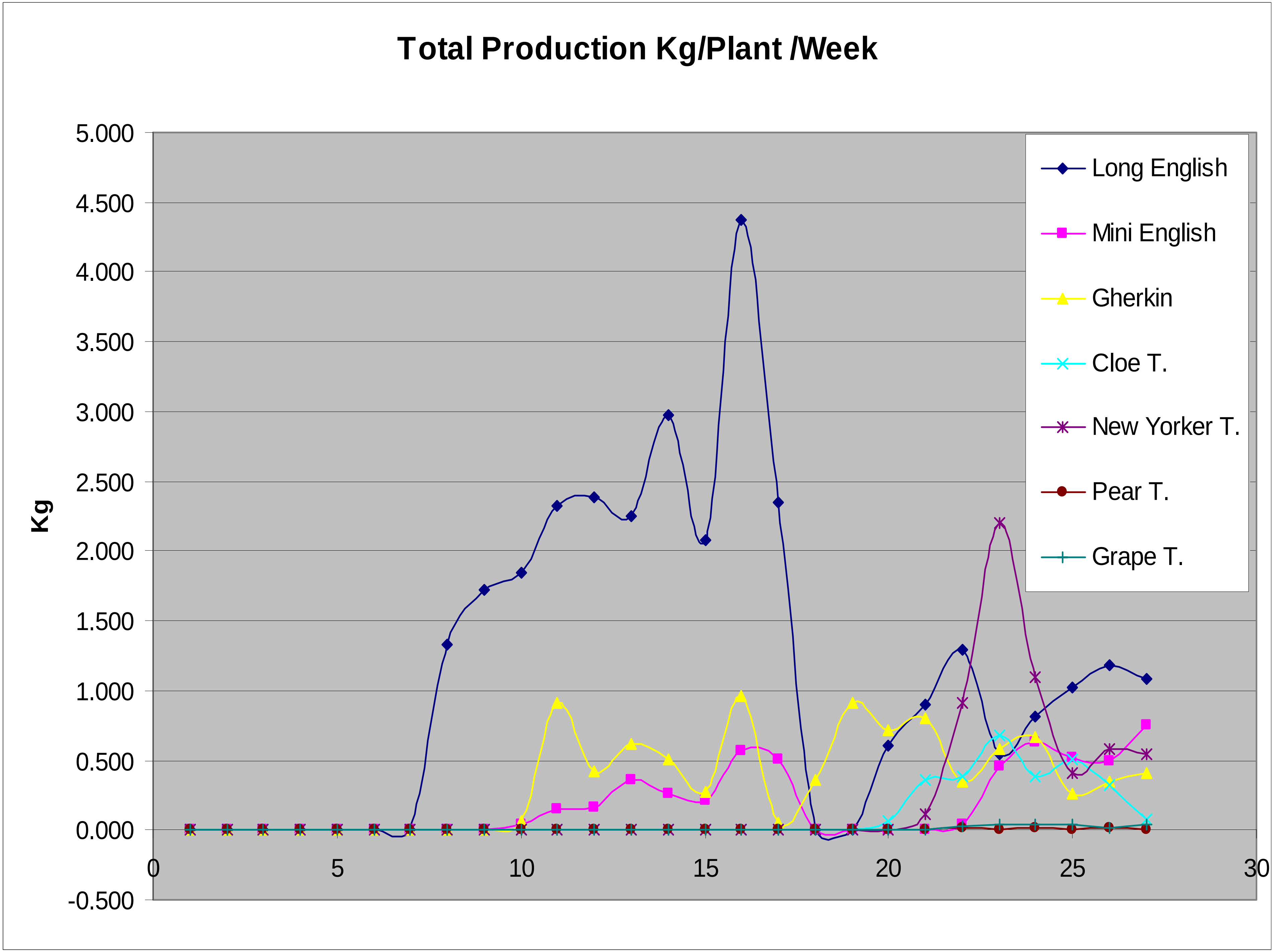
Large Greenhouse
September

18	
17	
16	Gherkin - 6
15	Gherkin - 6
14	Gherkin - 6
13	Gherkin - 6
12	Gherkin - 6
11	Mini - E - 6
10	Mini - E - 5
9	Mini - E - 8

20 Gherkins in
System 9/8/03
Tray 7

Grape T. 19 7/2/03 20	Gherkin 5 5/20/03 6/18/03 8/14/03 20	New Yorker 4 5/18/03 12
Pear T. 20 7/2/03 20	English L. 6 4/15/03 7/22/03 3 • 17	New Yorker 3 5/18/03 12
Mini E. 21 20	Gherkins 7 3/22/03 6/27/03 9/08/03 20	Cloe 2 4/28/03 17
	English L. 8 3/22/03 6/26/03 16	Cloe 1 4/22/03 17


Kg/Plant/Week to Date
Kg
5.000
4.500
4.000
3.500
3.000
2.500
2.000
1.500
1.000
0.500
0.000
Long English
Mini English
Gherkins
Cloe T.
New Yorker T.
Pear T.
Grape T.
March 1 03-March 9 03
March 10 03-March 16 03
March 17 03-March 23 03
March 24 03-March 30 03
March 31 03-April 6 03
April 7 03-April 13 03
April 14 03-April 20 03
April 21 03-April 27 03
April 28 03-May 4 03
May 5 03-May 11 03
May 12 03-May18 03
May 19 03-May 25 03
May 26 03-June 1 03
June 2 03-June 8 03
June 9 03-June 15 03
June 16 03-June 22 03
June 23 03-June 29 03
June 30 03-July 6 03
July 7 03-July 13 03
July 14 03-July 20 03
July 21 03-July 27 03
July 28 03-August 03 03
August 4 03-August 10 03
August 11 03-August 17 03
Augest 18 03-August 24 03
August 25 03-August 31 03
September 1 03-September 7 03



Total Production Kg/Plant /Week
Kg
5.000
4.500
4.000
3.500
3.000
2.500
2.000
1.500
1.000
0.500
0.000
-0.500
0
5
10
15
20
25
30
Long English
Mini English
Gherkin
Cloe T.
New Yorker T.
Pear T.
Grape T.

Appendix C

Aquaponics in Alberta:

An Environmental Industry Scan

July 2003

Lori-Jo Graham,
Business Development Specialist
Business and Innovations Division
Alberta Agriculture, Food and Rural Development

Summary Table 1. SWOT Assessment of Aquaponics Industry in Alberta

	Positive	Negative
Internal	**Strengths** • Great Publicity/Marketing Value – Locally Grown, Environmentally Responsible • Researchers are On The Job • Food or Medicinal Quality: Can Claims of Exceptional Quality be backed up by Science? • Environmentally Friendly • Natural Checks • Diversified Venture with Two Major Profit Centres • High Production Volume • Variety of Marketing Channels • Relationship Marketing • Hot Topic – Great Optics for AAFRD	**Weaknesses** • Consumers Willingness to Pay (WTP) • Challenge to Keep System in Balance • Requires Hardy Fish Stock • Heavy Feeders and Other Production Requirements • Physical Portability • Aquaculture and Greenhouse Production: Two Highly Technical Operations • Why Has Commercial Industry Not Happened Yet? • Cold Weather Climate • Hot Summers • Is It Totally Environmentally Safe? • Bottom Line, "Can I Make Money?" • Cost of Nutrients Are Minor • Labour and Management Issues • Major Start-Up Investment • Marketing Requirements Are High • Rural Distribution System • One Talapia Distribution Channel
External	**Opportunities** • Development of Regional Cuisine and Farm Direct Sales • Remarkable Growth in Canadian Organic and Natural Markets • Making More Healthy Eating Choices • Fish- A Functional Food • Worldwide Demand Increasing for Talapia • Taking A Bite out of the Specialty Vegetables Market • Growth of Gardening - Backyard Ponds • Potential for Agri-tourism • Other Applications of the Aquaponic System • Retooling • Ecological Energy Alternatives • High Value Niche Markets • Returns for Certified Organic • Branding Opportunity • Proprietary Rights • Should there be Government Grants or Tax Incentives?	**Threats** • What IS Talapia?: It's Not Part of Our Culture • Fashion Obsolescence • Food Desirability • Technological Obsolescence • No Place to Process in the Province • Food Safety and Product Liability Issues • Wild vs. Farmed Fish Debate • Greenwashing • Intensive Livestock • Competition in the Greenhouse and Aquaculture Industries • High and Rising Energy Costs • High Value Fish Mean High Development Cost • Is This the Next Ostrich? • A Question of Managing Risk • Where best to tax payers dollars? • Alarm Bells for Food Safety in Alberta • Regulations – Road Blocks or Speed Bumps? • Wild Vs. Farmed – American Politicians and Corporations Weigh In

Summary Table 2. Aquaponics Research Recommendations

Social	❑ What is the premium price that direct marketers will have to receive in order to make the necessary margins? ❑ Are products produced by aquaponics more nutritious? If so, how can this be effectively communicated to consumers?
Technological	❑ Sensory Perception Tests, or taste testing, is required to determine whether aquaponically grown produce is desirable or less than field, conventional, hydroponics grown products. Nutritional analysis is also required. ❑ What are the additional nutrient requirements of aquaponically grown plants? What are the differing labour requirements of different crops and fish? ❑ What is the shelf life of aquaponically grown plants? What are the differences in the salt levels? ❑ How best technically and economically can the various retooling strategies be achieved?
	❑ What are the potential environmental hazards or issues? How can they be mitigated? ❑ What systems must be in place for consumers to believe that the food is safe or at least believe that it can be monitored to control safety issues? There are currently no internal regulating body or guidelines for aquaponic products. Who regulates this emerging industry? What happens if there is an incident? Who would be responsible? What would be the consequences of a negative incident traced back to an Alberta aquaponic producers? It could bring down the whole industry. What would have to be in place to create quality assurance? Who will create the Best Management Practices or Good Manufacturing Practices? What are the labeling issues and requirements?
Economic	❑ Where is the money being made? Are the fish component and the plant component equal profit centers? Or does one hold more potential over the other, and therefore should have more labour, marketing, management and resources invested in it? Many speculate that it is more so the plants, is this correct? ❑ What are the expected yield volumes for aquaponically grown plants and fish? How does this compare with conventional and hydroponic greenhouse operations? Can these volumes be sustained throughout the seasons and continuous cropping? ❑ Fundamental question: Cost Per Square Foot? This is the greenhouse industry standard for the question“ Can I make money?” What are the costs per square foot for specific crops aquaponics operations? Compared to conventional greenhouse production? Compared to hydroponic production? ❑ What is the gross margin potential? This needs to be studied. No comprehensive economic data available currently in the public domain.
Political	❑ What would a risk management assessment of an aquaponic enterprise look like?

Purpose and Research Methodology

The purpose of the **environmental scan** is to provide a snapshot of *internal factors,* factors within the industry*,* which may affect the potential of an aquaponics in Alberta. These are assessed as *strengths* and *weaknesses.* It also provides a gauge of the industry's ability to react to the *opportunities* and *threats* caused by *external factors* such as current and forecasted trends and issues. This is known as a SWOT assessment (Strengths, Weaknesses, Opportunities and Threats. Six key areas are covered, known as a STEEP analysis (Social, Technical, Environmental, Economic and Political).

Snapshot of the Aquaponics Industry

The scan is intended to highlight areas that the industry may perform well in as well as potential problem or weak areas as seen from the snapshot today. It can be used as tool to create strategic action plans. Negatives can be mitigated and advantage can be taken of opportunities. Since this industry is in its infancy, several notes will appear on areas requiring *further research*.

> The controlled environment (greenhouse) commercial aquaponic industry is in its infancy, both in the U.S. and around the world. Currently there are less than five large-scale (+1 acre) facilities around the world and only two in the U.S. While several smaller operations are scattered around the country, most are on the "family farm" scale, rarely exceeding ¼ acre.
>
> The Evolution of Aquaponics, Aquaponics Journal, www.aquaponics.com

Aquaponics is the marriage of aquaculture (farming fish) and hydroponics (growing plants without soil). This recirculating system technology, which provides a model for sustainable food production, is based on centuries old know-how. Modern research has been evolving for the past 25 years.

A commercial industry in aquaponics is in its infancy and may prove to have profit potential in Alberta. There are currently two research stations and at least three small scale commercial greenhouse aquaponic facilities, (each in various stages - one in research with farm direct sales, one in small scale commercial sales, one in a production hiatus) (See appendix). Expansion in this industry will likely come from established aquaculture and greenhouse operations.

The greenhouse industry is well established in Alberta. Its size is estimated at 275 acres (111 ha) distributed among approximately 400 growers. The value is estimated to be about CDN $110 million. Fifty two percent of greenhouses are seasonal; primarily bedding plants, and 48% are year round, mostly vegetables. Greenhouse Industry Profile 2003 AAFRD

Aquaculture is an emerging industry in Alberta. It is currently worth CDN $10.8 million. Producers range from hobby farmers to large commercial organizations. They produce: table fish, fingerlings for ponds and conservation, fish for biological weed control and fee-fishing operations. Many species are eligible; rainbow trout makes up the majority of sales. Alberta grown tilapia have a small share of the live market, which is sufficient to meet current market demands in Alberta. Canadian Aquaculture Industry Alliance 2003

Strengths

Great Marketing – Locally Grown, Environmentally Responsible

> "The (newly adopted) national Agricultural Policy Framework aim is to increase profitability for producers by giving them the tools and capabilities to respond to constantly changing consumer demands for safe food produced in an environmental responsible way. Globe and Mail, June, 2003

Aquaponic system of production is right where the market is headed - consumers are demanding safe food produced in an environmentally responsible way. The fact that aquaponic products are locally produced, and therefore "leaving a small footprint on the earth, is an added bonus. Terms such as "natural", "environmentally friendly", "pesticide free", "organic" have growing attraction to consumers. A product image and branding campaign could be built around these features.

Weaknesses

Consumers Willingness to Pay (WTP)

The cost of aquaponic production is higher compared to conventional and hydroponic operations. Since you are creating a premium product in cost, and ideally in quality as well, means you need premium customers willing to pay a premium price. How high of a premium will the market bare? Will high demanding consumers continue to choose your product over lower cost alternatives?

Direct sales may provide the best opportunity for aquaponic sales as consumers are willing to pay extra for attributes such as locally grown and natural products.

> ***Research Note*****:** What is the premium price that direct marketers will have to receive in order to make the necessary margins?

Opportunities

Development of Regional Cuisine and Farm Direct Sales

> "Regional Cuisine is usually defined as locally grown and/or produced food that reflects the distinctive cultural character of the area. Regional cuisine can also be defined by both the food produced and consumed by the inhabitants of a region…Local producers and processors are in an excellent position to provide safe, clean, nutritious, fresh food and unique products into foodservice." Trends and Drivers Within Alberta Foodservice, AAFRD, May 2002

Market demand has grown for locally produced fresh and value added products. Local markets are especially suitable for smaller producers, such as aquaponic operations. The key is to provide a consistent quantities and quality product whether it is year round, seasonal or requested for specialty promotions.

There is also the feel good aspect of supporting local family farms and in turn, rural Alberta. However the conventional "red barn, wheat and cows" image of the family farm needs to be reinvented in the minds of consumers to allow for an aquaponic system of crops and fish to fit.

Social

Remarkable Growth in Canadian Organic and Natural Markets

How many Canadians are eating organic food?

- 71% (approximately 21.8 million) of Canadian have at least tried organic foods
- 26% (approximately 8 million) have never purchased any organic food
- 40% (12 million) have purchased organic foods fairly often (more than one to two times per year)
- 18% of the total survey considered themselves regular or heavy buyers October 2000, Environics International Organic Survey

How many consumers in our regional markets (Alberta and British Columbia)?

- 3.3 million consumers
- Heavy - Alberta 12% and British Columbia 30%
- Light - Alberta 27 % and British Columbia 22%
- Over half of these consumers (1.77 million) come from the Big Three – Edmonton, Calgary and Vancouver Organic Consumer Profile, AAFRD, 2003

According to the above survey, **consumer perception** plays an important role in this market trend. Sixty four percent of Canadians (49 percent of Albertans) strongly or somewhat agree that organically grown foods are much safer and healthier than conventionally grown food. There is a willingness to pay (WTP) a premium for organic products; sixty eight percent strongly or somewhat agreed that they would pay (59 percent in Alberta) a 10 percent premium for organic foods.

As with many agricultural industry organics is experiencing a bi-polar growth. The fastest growing segments are the small direct marketing farm and on the other end of the scale, the large corporate farms. The small operation, which in aquaponics has been referred to as "the add on" may hold strong potential. As well, the large corporate facility over one acre in size may also hold economically feasible.

It is unclear at this point whether aquaponic operations can or will be certified organic. This will rest on the expertise and willingness of the local certifying bodies. Growth of the natural market is also occurring, though estimates vary depending on how products are classified. Products which make claims of "pesticide free", "natural" or "hormone free" fall into this category, but are not subject to the same rigors of organic products nor can products which are not produced and processed by a certified organic body claim to be organic.

Making More Healthy Eating Choices

Healthy eating choices are becoming more important to Canadians as we see the soaring rates of heart disease, diabetes and obesity in North American making the daily headlines.

***Research Recommendation*:** Are products produced by aquaponics more nutritious? If so, how can this be effectively communicated to consumers?

Fish, A Functional Food?

"A functional food is similar in appearance to conventional foods, is consumed as part of a usual diet, and has demonstrated physiological benefits and / or reduces the risk of chronic disease beyond basic nutritional functions.

Medicinal Food News, 2003

Function foods are predicted to be the next big boom in the market place. Stories of fish being high in omega–3 fatty have already attracted a lot of consumers. Fish may also be a source of other functional benefits such as anti-oxidants and calcium. If marketers of talapia can substantiate scientific proof that their fish is the fish of functional food choice, consumers will likely listen and make the switch.

Research Recommendation**:** Are products produced by aquaponics higher in Omega-3 fatty acids as compared to other commonly consumed table fish? What are the other functional benefits of aquaponically grown fish or plants?

Worldwide Demand Increasing for Talapia

"Worldwide harvest of farmed tilapia surpassed 800,000 metric tons and was second only to carps as the most widely farmed freshwater fish in the world"

Southern Regional Aquaculture Centre 2000

Talapia is a fish consumed since ancient times. It is a culinary staple in several modern cultures, including Asian and African based cultures. Talapia is a "simple" fish and therefore hardy and very adaptable to temperature and other environmental changes. Thus it is often the fish of choice in aquaponic systems.

The demand of for talapia is rising in North America. Producers though, concentrate on live fish markets to avoid direct competition with low cost producers such as Costa Rica and Indonesia" Swim to Tilapia for Profits, AgVentures, Feb-March 2002 This has also be the case, thus far, locally in Alberta.

Taking A Bite out of the Specialty Vegetables Market

"The average consumer ate 428 pounds of vegetables in 2000, compared with 387 pounds in 1990…Produce companies say chefs are setting the trend in baby vegetables…consumers see gourmet meals featuring mini greens and want to make similar meals at home"

Veggies Go Baby Bite Sized, CBSNEWS.com, April 7, 2003

Health consciousnesses and the quest for new and different food choices are some of the factors driving the growth of the specialty vegetable market. The current trend toward baby vegetables works well with the aquaponic greenhouse system as harvesting can take place on shorter intervals than field grown counterparts.

Gardening is Growing – People are Taking the Plunge into Backyard Ponds

"Gardening has surpassed golf as the number-one outdoor leisure activity in Canada. Women and men of all ages participate - with over 80% of Canadians gardening in one way or another. The popularity of gardening will continue to grow as much as 52% over the next ten years. Total revenues in the gardening industry in Canada have doubled in the last decade to an estimated $4.3 billion."

Canada Blooms: The Toronto Flower and Garden Show, 2003

The horticulture industry holds much potential both as a method of production and a source of potential consumers for horticulture related products. One of the hottest trend in gardening is "backyard ponds". Aquaponics system is ideally suited to produce hardy aquatic plants and fish to thrive in these mini aquatic ecosystems. It is also speculated that certain species of aquatic pond plants may also be able to fix metals found in the water of aquaponic systems (Curt McNaughton, personal interview, April 2003)

"Fish Hooks Ag-tourists"

There an emerging opportunity for a few operations in Alberta to open there doors to tourists, school and industry tours. Mini aquaponic systems have been used as teaching tools in schools for several years. The Internet contains many more examples of aquaponic facilities in schools as compared to commercial facilities.

Two tourist attractions, which feature aquaponic systems, draw an international clientele. A major attraction at Disney's Epcot Centre is an aquaponics system biosphere. Dr. Rakocy tells of an island resort where they use an aquaponic system to grow their own fish and plants. It is not totally self sufficient, but provides a good tool to market their hotel. Hotel guest eat their home- grown dinners looking down upon the plants and fish of the hotel's aquaponics system.

What IS Talapia? It's Not Part of Our Culture

> "Since it is a relatively new fish to American consumers…attempting to market talapia through local retail outlets may prove to be unsuccessful unless some attempt is made to educate consumers about tilapia"
>
> Randy Sell, Department of Agricultural Economics, North Dakota State University, AgVentures, Feb-March 2002

Talapia is not part of our culture or regional cuisine. A considerable amount of marketing dollars will need to be spent on educating the consumer when marketers are ready to move passed local ethnic markets.

Fashion Obsolescence

Niche markets are the home of lots of opportunity, but they also are the home of a fickle consumer whose demands are constantly changing. These consumers do demand high quality and consistency, but they also want new and different things. Marketers will have to provide a premium product that will stat one step ahead of the low-cost producers who will move into the market when they see the opportunity open up.

There will continue to be a demand for the *types of crops* grown in aquaponic systems   (vegetables, herbs, ornamental plants). Whether consumers will desire that these products are *aquaponically grown* is another question. Will the "unique" or "environmental feel good" publicity burnout in a few months or years? Will other factors perhaps, superior quality, takeover in the minds of the consumers?

Food Desirability

Will consumers feel that plants grown in fish excretements are desirable or undesirable? Will people make a positive association of a recirculating eco-sytem or a negative one of smelly fish manure? This a potential stumbling block which may counteract positive environmental message campaigns.

Threats

Technological

Strengths

Researchers are On The Job

Multi-million dollar research facilities in several countries and States, including Reutgers (New York), University of Vermount, and the University of Virgin Islands, are researching aquaponics since its inception in the 1970s. Advancements are continual.

Food or Medicinal Quality: Can Claims of Exceptional Quality be backed up by Science?

> "In blind taste tests participants were much more likely to prefer talapia grown in our aquaponic system than its farmed counterpart."
> Personal interview with Eric Wells, Ocean Arcs International, April, 2003

> ***Research Recommendations*****:** Sensory Perception Tests, or taste testing, is required to determine whether aquaponically grown produce is desirable or less than field, conventional, hydroponics grown products. Nutritional analysis is also required.

Weaknesses

Challenge to Keep System in Balance

Keeping a balance in system which suits both plants and livestock (fish) is essential and yet one of the biggest challenges. There are concerns with ph levels, temperature differentials and concentration of elements. Eric Wells, Oceans Arc International, feels that this is a level of expertise that is often overlooked. The novice operator must figure the time and expense of mastering this into his start-up budget.

How Hardy is Your Fish Stock?

"The trick will be finding the high dollar fish species that can withstand the aquaponic environmental conditions as well as the hardy talapia"
Aquaponics Journal, First Quarter, 2003

High dollar sales could be found in the aquarium trade, but which species could thrive in fluctuating water quality, high stocking and feeding rates?

Are You a Heavy Feeder?

Crop selection is critical not only for markets, also for production capabilities. For instance, fruit crops are heavy feeders (require a lot of nutrients) therefore leafy greens may be a better option. There are also large differences in expertise, and time, required between crops. For instance a pepper crop requires a high level of expertise while a spinach crop requires a lower level.

Technological

***Recommendations**:* What are the additional nutrient requirements of aquaponically grown plants? What are the differing labour requirements of different crops and fish?

Highly Perishable Products

Both fish and crops are highly perishable products. The shelf life is less for hydroponically grown plants than soil based counterparts. Quality preservation is an issue especially for high-end restaurant trade. Distribution systems will have added technical requirements to ensure products are arriving to consumers what they the consumer considers to be the perfect condition. This includes temperature controlled transport, proper packaging, and Just In Time (JIT) delivery capabilities.

Research Recommendations: What is the shelf life of aquaponically grown plants? What are the differences in the salt levels?

Aquaculture and Greenhouse Production: Two Highly Technical Operations

Fish are highly susceptible to variations in temperature and water quality. Mortality rates may be as high as loosing your entire fish stock. This requires highly skilled and committed operators. Though not as quick in time, similar things can be said of greenhouse operations.

How many entrepreneurs will want to learn and work in two highly technical operations? Will greenhouse growers be interested and willing to grow fish? Will fish farmers be interested and willing to grow greenhouse plants?

Why Has Commercial Industry Not Happened Yet?

Aquaponic technology has been around for 20 years, with several major universities research facilities committing sizeable research time and resources. Why are there so few commercial enterprises? Is it a technical or economic feasibility issue?

Opportunities

What Else Is the Aquaponic System Good for?

Researchers at institutes are working on other applications for this technology. Other uses include such as ameliorating waster water and researching species. Perhaps Alberta may find as Oceans Arc International (Vermount), these areas provide more opportunity for commercial scale operations. Personal interview with Eric Wells, Ocean Arcs International, April, 2003

Retooling

Potential entrants into aquaponics will be coming from different experience and resource bases. Models should be constructed for instance for: producer with a hog barn wanting to enter the industry, producers with existing fish farms wanting to add a greenhouse, greenhouse operators wanting to add fish to their system.

***Research Recommendations*:** How best technically and economically can the various retooling strategies be achieved?

Threats

Technological Obsolescence

Currently, there is not another potential commercially viable system to move certified organic nutrients to plants in a greenhouse other than aquaponics. The barriers to organic production include: no liquid organic nutrients on the market that can move through necessary irrigation systems, all current organic nutrients are low on the fundamental elements especially nitrogen, and organic greenhouse production using soil based medium can not produce any where near the yields of non-organic hydroponic production.

Technology could change and erase this competitive advantage for aquaponics. Some Quebec greenhouse producers are pursuing organic production.(Personal Interview, Dr. Mohyuddin Mirza, Greenhouse Industry Development Specialist, 2003).

No Place to Process in the Province

As with other livestock derived products, there are better margins in processed product than raw or live. Labour costs for talapia processing are much lower in many countries such as Costa Rica, Indonesia and others in the Pacific Rim. Can we compete?

There is no federally approved processing plants for fish in Alberta. With currently relatively low volume, is it probable that a fish processing plant will succeed in the near future?

Research Question:

Is it economically feasible for a fish slaughter plant in the province? What alternatives are there for co-processing in other processing plants? What opportunities and assistance are and could be available for new product development for fish value added products?

Environmental

Strengthens

Environmentally Friendly

> "The closed loop system mimics a natural system; the fish consume food and their waste is naturally converted to nitrate and other nutrients, the nutrients in the water are then taken up by the plants. The fish supply necessary plant supplements and the plants act as a natural water filter, a win/win situation" Nick Savidov, "Aquaponics, An Environmentally Friendly Production System" Agri-News Jan. 6, 2003

This is a recirculating system, a small scale ecosystem, no wastes going out into the environment. There is a limited need for supplements. This is a soiless culture so many of the diseases of conventional soil based farming are not a concern. Natural methods such as aphid are used for pest control.

Natural Checks

> "No chances to cheat…dead fish tell the truth"
> Dr James Rakocy, Presentation, Crop Diversification Centre, South, May, 2003

There is an internal self-checking for chemical use to test for natural or organic production. If chemicals or other foreign substances are used the water balance or quality is skewed causing mortality in the fish. This may be attractive to consumers questioning the authenticity of organically grown produce.

Weaknesses

Cold Weather Climate

What will grow well in greenhouses in Alberta? Do year round operations or operations which have a growing season from early spring to late fall make more sense in our climate? What are the cost comparisons?

It Gets Hot Here, Too

In the summer time there is concern with regulating the heat. Leafy greens tend to bolt or get straggly and quality/appearance suffers. Crop performance and selection is important for grower to understand.

Is It Totally Environmentally Safe?

For instance, are the polystyrenes from the rafts used for the plants leeching chemicals into the water? Are there other environmental hazards that may come to the forefront and tarnish the environmentally friendly image?

Research Recommendations: What are the potential environmental hazards or issues? How can they be mitigated?

Is this food safe? What are the Product Liability Issues?

Canadians' Top Four Food Concerns*

1. bacterial contamination
2. pollution in the air, water and soil
3. food safety
4. use of chemical pesticides

* Each with 89 to 91 percent of the population ranking these as very or somewhat concerned Environics, International Ltd. (2001) Food issues monitor survey 2001. Subscribe for reports to the World Wide Web at: http://www.environics.net/eil/

Five Key Food Safety Issues Identified: Aquaculture and Aquaponics

1. Drug residues in fish (drugs mostly used as off label); what about the fish?
2. AMR organisms of animal and human health consequences (no research done internationally and whether this is a food safety concern or not, if done, is very subjective)
3. Pathogens prevalence in fish and vegetables grown in this environment (ex. E. coli 0157:H7 is a huge concern with consumers and others in the food chain)
4. Parasites (unknown and with aquaponics confirmed outbreaks implicated with lettuce consumption and Edwardsiella tarda)
5. Chemical residues (ie. heavy metals, pesticides) (no idea about

potability of water or if water is contaminated does it affect the safety of the fish)

E-mail communication, Daryl Loback, March, 2003

Research Recommendations: What systems must be in place for consumers to believe that the food is safe or at least believe that it can be monitored to control safety issues? There are currently no internal regulating body or guidelines for aquaponic products. Who regulates this emerging industry? What happens if there is an incident? Who would be responsible? What would be the consequences of a negative incident traced back to an Alberta aquaponic producers? It could bring down the whole industry. What would have to be in place to create quality assurance? Who will create the Best Management Practices or Good Manufacturing Practices? What are the labeling issues and requirements?

Opportunities

Ecological Energy Alternatives

Can we find an ecological friendly source of energy to compliment this system? Research in Vermount has evolved to focus on the quest for economically viable alternative energy sources. Alternative include micro turbines run by methane gas, solar power, and excess gas from oilfields.

Threats

Something Fishy – The Wild vs. Farmed Debate

> "Here is my take on it: If you can, try to eat mainly wild fish. Why? Because being out in the wild allows the fish to eat the kind of food that increases their omega-3 fatty acids. Wild fish also tend to have more muscle and less fat. All of this points to a heart-healthy choice, which is probably the reason you eat fish in the first place." Dr. Sanjay Gupta, CNN.com/health, November, 2002

Fish tended to be synonymous with purity and health. Now, influences such as David Suzuki's expose on lice on farmed fish stalks in British Columbia and potential degradation of native/indigenous fish stocks, many consumers and chefs are increasingly looking for fish from wild stocks. On the other hand, wild fish stocks are also susceptible to concerns. High mercury levels found in tuna has caused the USDA to issue a warning for pregnant women in the US to limit their intake of the fish),

Greenwashing

> "Greenwashing…corporations that put more money, time and energy into slick PR campaigns aimed at promoting their eco-friendly images, than they do to actually protecting the environment."
>
> <www.corpwatch.com> September, 2002

Greenwashing is a new term which has entered the business lexicon. Greenwashing occurs when a company uses an approach or technology for the sole reason of appearing environmentally responsible. There is a danger that this technology could be water down by its use in this manner.

Intensive Livestock

The research facilities at CDC-South and Lethbridge are currently using a fish tank and trough system. Stocking numbers range from 600 to700. In tanks relatively small sized tanks. Would some consumers this an intensive livestock operation and therefore paint it with the same negativity?

Economic

Strength

Diversified Venture with Two Major Profit Centres

Aquaponics presents an opportunity to rethink the family farm to bring in more money at the farm gate. Though not limited to family farm size, it has larger scale operations potential as well. Two profit centers for producers: fish and plants. If fish goes through a low cycle then you have your plant revenue to rely on and visa versa.

Variety of crops is vast. Potential crops include: table vegetables, specialty vegetables, herbs, flowers, ornamentals, and aquatic plants. Value added potential is strong as well. Such as salad mixes, pesto, essential oils, and flower arrangements. Cross marketing potential is also present with through for instance, including recipes for talapia or ethnic vegetables on each other's packaging fish and vegetables.

Operators may position themselves as "fuller" service provider by producing multiple products for one supplier. For instance, providing a local pizza restaurant with many of its vegetable toppings. It is also conceivable that products could be produced year round Though costs may be higher and therefore prices may have to increase in winter months. It is also possible that crops could be rotated throughout the year. For instance, orchids could be grown in the spring/summer months for the wedding season and poinsettias could be grown in late fall/winter for the Christmas season.

Research Recommendations: Where is the money being made? Are the fish component and the plant component equal profit centers? Or does one hold more potential over the other, and therefore should have more labour, marketing, management and resources invested in it? Many speculate that it is more so the plants, is this correct?

High Production Volume

Estimates for production crop capabilities vary greatly. Some experts looking at the industry claim it has the potential to produce more than conventional or hydroponics other claim it produces considerably less.

Research Recommendations: What are the expected yield volumes for aquaponically grown plants and fish? How does this compare with conventional and hydroponic greenhouse operations? Can these volumes be sustained throughout the seasons and continuous cropping?

Variety of Marketing Channels

There is an array of marketing channels from which producers can connect. They include: farm direct (farm gate, farmer's markets, agri-tourism); Hotel Restaurant, and Industrial (HRI) (white table cloth, local restaurant, restaurant chains, hospitals); specialty retail markets (health food, whole food, ethnic, organic); vegetable/herb wholesale and garden retail centers.

Relationship Marketing

There is strong potential to develop and maintain a loyal customer base that values your service as much as your product. However, low cost producers are constant competition in the vegetable/herb industry.

Weakness

Bottom Line, "Can I Make Money?"

"Very few aquaponic operations today are profitable. In fact, I could probably count the economically successful one on one hand."

R. Charlie Shultz, Aquaponic Journal, First Quarter, 2003

"After several years of research, we have been unable to develop a commercial model, which could be feasible for producers…
I have worked in several diversified industries including pastured poultry, mushrooms and vericulture. This by far has been the most challenging to find profit potential"

Eric Wells, Ocean Arcs International, 2003

There has been many aquaponic facilities in operation over the past 30 years, why are there so few profitable ones. It is it due to poor crop selection, growing lower margin/high competition crops rather than niche market and high dollar crops? Or has it more to do with costs vs. returns internal to the aquaponic system? Is aquaponics better suited for a hobby or for commercial applications?

Research Recommendations: Fundamental question: Cost Per Square Foot? This is the greenhouse industry standard for the question" Can I make money?" What are the costs per square foot for specific crops aquaponics operations? Compared to conventional greenhouse production? Compared to hydroponic production?

Cost of Nutrients Are Minor

The cost of nutrients in greenhouse production account for 3 to 5% of total cost of production or as Oceans Arcs International quantifies it ½ cent per plant. Can you ask premium on price to make a profit margin over and above your additional operating costs (including water systems, filtration, fish, expert labour requirements)? Is there still need to supplement some crops?

Research Recommendations: What is the gross margin potential? This needs to be studied. No comprehensive economic data available currently in the public domain.

Labour and Management Issues

"It takes a special person to take on an aquaponic operation. The producer needs to have in-depth expertise in fish production, greenhouse production, water quality and marketing."

Eric Wells, Oceans Arc International, personal interview, May 2003

The aquaponic system requires high level of management. How much more time and effort will the addition of this system require. For instance if you are a fish farmer, how much more time will the greenhouse take? Where will skilled labour come from? Should there be training courses a colleges dealing solely with aquaponic production?

Major Start-Up Investment

Need to have cash flow and time to ride the producers through the learning stage – when you are gaining know-how, but not necessarily profit. Due to the above requirements, it may be on the high end in this industry compared to others.

As mentioned previously the potential success of this industry will likely rest on to opposite ends of the spectrum, the large corporate aquaponic greenhouses and on the other you have the local, perhaps seasonal, add on to existing fish farms or greenhouses, direct marketing their produce. The later will have considerably less start-up investment requirements.

Marketing Requirements Are High

Niche markets require considerable amount of marketing time, effort and expertise. In order to accessing high-end specialty niche markets you must spend time researching and developing markets. In most cases they must drop a product off their shelve or menu to place your product there. Then you become the target and you must stay ahead of lower cost producers or higher level service providers.

The challenges of marketing locally grown farmed fish are well known (competition with Idaho, competition within Alberta, lack of processing facilities). Aquaponic systems produce a high volume of fish. Where will the markets be?

Rural Distribution System

"How do you move your produce from more remote rural places, like Rumsey into high- end Calgary markets, and still be competitive with an already premium priced product?"
Curt McNaughton, MDM Aqua Farms Ltd, Personal Inverview, March 2003

In order to defray distribution and marketing costs to individual producers there is potential for cooperatives, can you tap into established distribution systems ie. Brokers, highway courier systems?

Opportunity

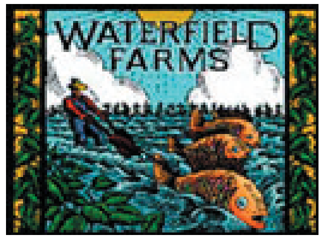
High Value Niche Markets

Rather than focusing on staple or "garden variety" produce, more profitability may be realized through specialty vegetables, medicinal crops or ornamental plants. Proper market research and cost comparisons are vital.

Returns for Certified Organic

As stated previously, there is strong potential for aquaponic production to be certified organic. A premium price for organic status could be realized. Though input costs will also rise for sourcing and transporting organic nutrients and In grated Pest Management controls; and higher costs to maintain may also be required to maintain organic distinction in storage, transport and processing.

Branding Opportunity



Waterfield Farms, <http://www.bioshelters.com/index.htm>

There is great potential to creative a branding campaign for this unique based product. However, by claiming that your product is more pure infers that the competition's is somewhat impure or inferior. How will greenhouse, such as the Red Hat Cooperative, and aquaculture companies react to this? However branding can prove costly especially the more industry players involved. Branding must be targeted to the market(s) with your highest competitive advantage to be effective.

Proprietary Rights

Due to the unique system, there may be potential to build a franchise supported by a brand image for aquaponics. A company could sell aquaponic package comprised of technology, business and consulting. A businesses in the United States, Crop King, is currently operating and can be found on the Internet at www.CropKing.com

Threat

Competition is Tough Out There

A number of well established small and large-scale competitors. Competitors include: established vegetable/herb food brokerage system, greenhouse growers including large greenhouses and cooperatives, such as Red Hat in southern Alberta, and small local greenhouses and imports from British Columbia and the United States. Products must be placed properly to produce profits.

The aquaculture industry in Alberta faces strong competition from imports mainly from Idaho and British Columbia. In the talapia market, competition is mainly from frozen products produced in Idaho and countries in other parts of the world with lower labour costs such as Costa Rica and Ecador. Alberta's competitive advantage is in the live market, where are fish is fresh and promptly transported.

High and Rising Energy Costs

"Recent rapid escalation of natural gas and electricity prices have dampened further expansion prospects of (the greenhouse) industry"
The Economics of Production and Marketing of Greenhouse Crops in Alberta, Nabi Chaudary, Alberta Agriculture, Food and Rural Development, 2001

What is the impact of increase in the price of natural gas?

> "In 2002 both cucumbers and peppers showed a negative return on equity but tomatoes showed a positive return. This is because of better price/kg of tomatoes. During 2003 season, it appears that return will be negative for all three vegetables, due to increases in electricity and natural gas prices…it is becoming increasingly difficult to pass on cost increases to consumers."
>
> Greenhouse Industry Overview 2003, Alberta Agriculture Food and Rural Development

> "The cost of energy was 10% of the total cost of production up to the late 1990s, today the cost of energy is 46% of the total. This has had a significant impact on the greenhouse industry" Personal Interview, Dr. Mohyuddin Mirza, Greenhouse Industry Development Specialsist, July, 2003 Energy prices, which account for a large portion of the cost of production, have escalated over the last few years causing serious impact on the balance sheets of established greenhouses and precluding new entrants from entering the industry. Will the trend toward higher energy prices continue in this post-deregulation environment in Alberta? Can we reasonably look at expanding into aquaponics when energy costs are so prohibitive even for conventional greenhouses?

Oceans Arks International are currently looking at renewable energy alternatives such as wind, biomass, co-generation, methane and micro turbines (Eric Wells, personal interview, 2003) In fact, this is now the major focus of their aquaponic research. Operators of conventional Alberta greenhouses are also searching for alternative energy sources as well.

High Value Fish Mean High Development Cost

> "We are looking for a higher value fish than talapia, but who will take on the high costs of going through the hoops of licensing this new species."
> Curt McNaugton, MDM Aqua Farms Ltd. Personal interview, March, 2003

Licensing new fish species for production in Alberta, takes considerable time and cost. Who will or should bear the cost and effort of introducing new fish species for aquaponics producers or government?

Political

Strengths

Hot Topic – Great Optics for AAFRD

Locally grown food produced by environmental sustainable method using an innovative technology – looks like a win/win situation for Alberta producers and the department of Alberta Agriculture, Food and Rural Development.

Weaknesses

One Talapia Distribution Channel

Currently, there is only one distributor handling talapia from the farm gate in Alberta. Producers are in position of dependency unless other channels can be found. Should other channels be investigated?

Lack of an Integrated Management Plan for Aquaculture In the Province

Aquaculture is an emerging industry in Alberta and many government bodies have responsibilities in the area including Alberta Agriculture, Food and Rural Development, Canadian Food Inspection Agency, and Fish and Wildlife Division of Alberta Sustainable Resource Development. Issues such as international trade, regulating and marketing fish, and business practices need to be addressed to ensure the positive future development of the industry. This planning should be done in partnership with the Alberta Fish Farmers Association.

Opportunities

Should There Be Government Grants or Tax Incentives

This is an innovative agricultural technology should there be more financial assistance (loans or grants) available for new entrants in Alberta?

Threats

Regulations – Road Blocks or Speed Bumps?

Aquaculture is a very regulated industry. As previously stated, there are high costs associated with the approval process for new fish species. Currently, there is a regulation, which stipulates that talapia cannot be raised west of Calgary. There may be potential for growing field crops using aquaponics in the summer months. Regulatory issues would include: leisensing, containing the fish so they do not mix with natural waterways and again food safety issues.

Wild Vs. Farmed – American Politicians and Corporations Weigh In

These politically motivated actions in the United States may have future impact on Canadian consumers, not only of salmon, but of all fish.

Alarm Bells for Food Safety in Alberta

We are now operating in a post-BSE era in Alberta. What will be the political impact on the regulations for food safety?

Is This the Next Ostrich?

Due diligence must be done before decisions are made to move ahead. Decisions to make invest long term AAFRD dollars and encourage industry to develop must be based on sound business principles not passionate ideals.

A Question of Managing Risk

Are we piggybacking one emerging industry (aquaponics) on another (aquaculture)? Are producers managing their risk load or would they be adding to it? Should we concentrate on adding value and enterprises on established industries?

Research Recommendations: What would a risk management assessment of an aquaponic enterprise look like?

Where best to tax payers dollars?

Is it better to invest efforts in the development of an aquaponics industry or negotiating with energy companies to create a special energy plan for the greenhouse industry? Energy is the main variable cost of production – a 10% difference would make a huge impact on the industry.

Appendix One.

Survey of Significant North American Aquaponic Operations

Alberta

Crop Diversification Centre – South, Brooks, AB
Lethbridge Community College, Lethbridge, AB
Greenview AquaFarm, near Calgary, AB
Circle M Trout Farm, near St. Paul, AB
MDM Aqua Farms Ltd. near Rumsey, AB

Canada

Future Aqua Farms
Carla MacQuarrie, Peter Lenihan, and Dave and Joanne Roberts – Owner/Operators
Aquaponic company producing spinach, basil and herbs for Farmer's Markets and high-end restaurants.
West Chezzetcook, Nova Scotia
Website:

United States - Research

University of the Virgin Islands Agricultural Experiment Station
James E. Rakocy, Ph.D. Research Professor of Aquaculture
Dr. Rakocy is lead research for an outdoor aquaponic system and aquaponic teaching school.
RR 2 Box 10, 000 Kingshill US Virgin Islands 00850
Phone: 809-692-4301
Fax: 809-773-6176
email: james.rakoxy@uvi.edu

Oceans Arc International
Erik Wells, Project Manager, OAI Food Group, University of Vermount, Burlington, USA
Erik heads an initiative at Ocean Arks to develop ecologically-based agriculture systems for Vermont and beyond. His responsibilities include the operation of the Ocean Arks research facilities and project planning.
Phone: 802-860-0011
Cell: 802-734-6296
E-mail: erk@farmecology.org
Website: http://www.oceanarks.org/about/

The State University of New Jersey Rutgers Rutgers Cooperative Extension New Agricultural Experiment Station
This is an aquaponic/aquaculture teaching and research facility.
102 Ryders Lane, New Brunswick, NJ
Phone: 732-932-9271
Fax: 732-932-8726
Website: www.cook.rutgers.edu/~ocpe

The Freshwater Institute System
A non-profit organization which focuses on providing freshwater solutions for local farmers. They have an aquaponic demonstration program growing crops such as basil, lettuce, and wetland plants. Tilapia is thefish species. In addition to providing technical assistance

to farmers, the Institute provides educational training materials to high school biology & agriculture teachers. The Institute offers 5-6 aquaponic workshops a year.
P.O. Box 1746
Shepherdstown, WV 25443
304-876-2815
304-870-2208 Fax
Attn: Mr. Marten Jenkins, Mr. Larry Selzer
m.jenkins@freshwaterinstitute.org
hppt://wwwlconservationfund.org/conservation/freshwater/indes.html

The Cabbage Hill Farm System

The foundation is dedicated to the preservation of rare breeds of historic farm animals and the practice of sustainable agriculture and aquaponic greenhouse production techniques. Tilapia fish and leaf lettuce are the main products of the Cabbage Hill Farm system, though basil and watercress are also grown in smaller quantities.

115 Crow Hill Road
Mount Kisco, NY 10549
914-241-2658
914-241-8264 Fax
Contact: Annie Farrell
E-mail: veglady@aol.com
Website: http://www.cabbagehillfarm.org/home.html

United States - Commercial

S & S Aqua Farm
Tom and Paula Speraneo, Owners/Operators/Aquaponic System Consultants
"The Speraneos grow fresh basil, tomatoes, cucumbers, mixed salad greens, and an assortment of vegetable, herb, and ornamental bedding plants in their greenhouse. Interest in the Speraneo system has resulted in over 10,000 visitors to their small farm in Missouri, including agriculture researchers and government officials from dozens of foreign countries. To handle the numerous inquiries and requests for assistance, the Speraneos assembled a resource packet that features a design manual with technical specifications for an S & S Aqua Farm-style aquaponic system." ATTRA
8386 County Rd. 8820
West Plains, MO 65775
417-256-5124
E-mail: snasquasys@townsqr.com
Website: http://towsqr.com/snasqua

Waterfield Farms
This is a recirculating aquaponics facility. The entire system is contained in a large solar-heated greenhouse called a Bioshelter. Bioshelters' primary product is Tilapia. The primary produce grown is whole basil plants, and pesto has been recently added. There current markets are local markets/grocery stores (all in a 2-hour drive to preserve freshness and environmental sensitivity), and Asian markets in Boston
John Reid, President
500 Sunderland Rd
Amherst, Massachusetts

Phone: 413-549-3558
E-mail: john@bioshelters.com
Website: http://wwwlbioshelters.com/index. htm

Aquaponic Resources

Aquaponics Journal
Rebecca L. Nelson, Managing Editor
A journal, published quarterly, which specializes in information on aquaponics.
Nelson/Pade Multimedia Mariposa, CA. USA
Phone: 209-742-6869
Website: www.aquaponics.com

The Growing Edge Magazine
The Growing Edge is a bi-monthly trade magazine on high-tech gardening systems like hydroponics, bioponics, aquaponics, and ecologically-based pest management. Moon Publishing
P.O. Box 1027
Corvallis, OR 97339
800-888-6785
541-757-0028 Fax
tom.alexander@growingedge.com
http://www.growingedge.com

Appendix Two.

Alternative Terms for Aquaponics and Related Technology

- Ecosystem Greenhouses
- Agricultural Eco-park
- Bioshelters
- Living Machines
- Waster Water Gardens
- Biocycle System
- Aquascape
- Bioponics
- Recirculating Systems
- Aqua Farm
- Hydroaquatic

Appendix Three.

Suggested Aquaponic Crop Selection Criteria

The following is a suggested guide to aquaponic crop selections.

- Market demand
- Market value
- Distribution characteristics - maintain freshness, hardiness in transport, inexpensive proper packaging
- Appearance - unique, interesting, whole, miniature (one bite), omparison to field grown especially for herbs (what are people expecting)
- Quality – nutrition as compared to other systems
- Specialty market - if ethnic than Asian or ethnicities that consume tilapia
- Labor intensity required
- Desirability as an organic product - will they pay extra for this?
- Test four different types

- Hardiness
- Length time to maturity
- pest management considerations (IPM)
- Heavy feeder?
- Consumer feedback (Lethbridge Community College Satisfaction Surveys)
- Input from specialist in vegetable industry, greenhouse business, regional cuisine, organics

Appendix D

Feasibility of Farm Direct Marketing Aquaponic Vegetables

Focus: Alberta Approved Farmers' Markets

Eileen Kotowich,
Project Assistant
Ag-Entrepreneurship Division
Alberta Agriculture, Food and Rural Development

The aquaponics research project is a joint project between Alberta Agriculture, Food and Rural Development and the Aquaculture Centre of Excellence (A.C.E.) at the Lethbridge Community College. The purpose of the research is to develop and evaluate aquaponics operations as well as investigate product market opportunities in Alberta.

One arm of the research was to investigate the feasibility of aquaculture farmers diversifying into an aquaponic operation and subsequently marketing the vegetables direct to consumers. Alberta Approved Farmers' Markets, the most common farm direct marketing channel, were selected as the research venue because of the established consumer base and diverse market locations.

An explanatory display was set up and consumers were invited to sample several varieties of cucumbers and tomatoes. They were surveyed with respect to their perceptions of taste and quality, as well as perceptions of vegetables being healthier, willingness to purchase, willingness to pay a premium and demographics.

When considering whether or not aquaponics production is an economically viable option for fish farmers to pursue, additional costs associated with marketing through an Alberta Approved Farmers' Market need to be included in the cost of production calculation. These are:

- *Transportation costs associated with transporting the vegetables to market.
- *Insurance costs – liability (often needed in order to vend at an Alberta Approved Farmers' Market), product liability, and vehicle.
- *Labour costs during all phases of production and marketing. This should include the producer's labour as well as any hired labour.
- *Farmers' Market costs – table/stall rental, table purchase (if the market doesn't supply), table covering, bags, scale, displays, coolers, signs, promotional items (aprons, business cards, brochures, etc.)

Producers need to have a multitude of diverse skills to run an aquaponics operation – production, marketing, finance and human resources.

Identifying a target market is critical to the success of this type of operation. Consumer demographics (age, ethnic mix, income, spending patterns) can vary significantly by market size and location. Choosing an Alberta Approved Farmers' Market at which to vend will require additional research by the producer. The market chosen may influence the pricing strategy.

In conclusion, most of the consumers rated the taste and quality of the vegetables as excellent or very good. They also felt the vegetables were healthier than conventionally grown vegetables because they are grown without using chemicals. Most consumers said they would purchase the vegetables if they saw them at an Alberta Approved Farmers' Market but the data is inconclusive on whether or not they would pay a premium for them. Food safety is an issue for some consumers and needs to be addressed.

Background

The aquaponics project consists of the evaluation and development of aquaponics production and product market capabilities in Alberta. The aquaponics project has two facilities involved in researching the feasibility of a mainstream aquaponics industry.

One facility is located in Brooks at CDC – South. This facility is researching the feasibility of encouraging greenhouse operators to diversify their operations to include an aquaculture facility. With this operation, the primary crop is the vegetables and the secondary crop is the fish. They are exploring marketing the vegetables commercially as well as researching the feasibility of operating year round.

The second facility is located in the Aquaculture Centre of Excellence (A.C.E.) at the Lethbridge Community College (LCC). At this location, the research is focused on developing a model that demonstrates economic feasibility for fish farmers interested in diversifying their operations to include an aquaponic greenhouse. It is expected that the greenhouse would be an add-on to an existing aquaculture facility. Due to the limited size of such an operation, research with respect to the marketing of the vegetables focuses on the feasibility of the vegetables being sold direct to the consumer.

The Farm Direct Marketing Initiative of the Ag-Entrepreneurship Division was approached to research the feasibility of marketing aquaponic vegetables direct to consumers. It was felt the best farm direct marketing channel to explore would be Alberta Approved Farmers' Markets.

Research Objectives and Methodology

The purpose of the study was to determine consumer acceptability and "willingness to buy" aquaponic vegetables when sold from a farm direct venue. In addition, consumer demographics and target market information was collected.

Farm direct marketing is based on the trust relationship that develops between producer and consumer. It allows the producer to assume the accountability and rewards of delivering quality agrifood products directly to the consumer through a variety of marketing channels. Examples of farm direct marketing channels include: Alberta Approved Farmers' Markets, farm gate sales, farm stores, u-pick ventures, mail order, direct to restaurant (where we assume the chef is the end user), community supported agriculture, municipal buying clubs and e-commerce. Successful farm direct marketing involves consistently supplying quality products in a clean and customer-friendly environment.

The farm direct marketing channel chosen for the study was the Alberta Approved Farmers' Market. This channel, above all others, supplies an immediate consumer base to survey and determine preferences. Four small and four medium sized markets were chosen for the research and are discussed in more detail on page 6. Additional farm direct marketing channels will also be reported on so that producers are aware of all the options available to them.

An explanatory display was developed and taken to each market. It explained that a joint research project with Alberta Agriculture, Food and Rural Development and the Aquaculture Centre of Excellence at the Lethbridge Community College was being conducted. It also described benefits of aquaponic vegetables and showed pictures of vegetables growing in the greenhouse.

It was felt that the only way to gauge consumer preferences and acceptability of the vegetables was if they tasted the products. Vegetables for sampling were taken to each market. These included Long English cucumbers, Mini English cucumbers, Gherkins, Chloe tomatoes, New York tomatoes, Grape tomatoes, and Pear tomatoes (when available). Herbs were also taken but were displayed as opposed to sampled. This gave consumers an idea of the types of herbs that could be grown, the vitality of the plants and the aroma of fresh herbs.

A consumer survey (Appendix 1) was developed. Consumers were invited to complete the survey after sampling the vegetables. Most consumers were unwilling to take the time to complete the survey but they were willing to talk about the products. In order to get some written feedback, I took notes of the products sampled, the comments made, and general demographic information (gender and age). Approximately 1000 consumers sampled vegetables at the eight Alberta Approved Farmers' Markets visited. The Senior Statistician with Alberta Agriculture, Food and Rural Development advised that since the goal of the project was to get a sense of consumer opinions and perceptions of the products, statistical significance wasn't a concern.

Consumer demographic data from the *Alberta Farmers' Market and Consumer Profile and Economic Impact Study* was also analyzed. This extensive study of Alberta Approved Farmers' Markets was completed in 2002 and contains relevant data with respect to consumer demographics and buying habits.

Carla MacQuarrie with Future Aqua Farms Limited in Nova Scotia was interviewed. Future Aqua Farms Limited is a successful aquaponic operation in the Halifax area. They sell their fish and vegetables primarily to white tablecloth restaurants in Halifax but they also sell vegetables at the farmers' market in Halifax. See Appendix 4 for the complete interview.

Analysis and Results

The information gathered will be presented using the four Ps of marketing – product, place, price, and promotion.

Product

The research surrounding the product focused on consumers' *perceptions* of the taste and quality of the vegetables. Food desirability was a concern going into the research project. Would consumers react negatively to vegetables grown in fish effluent? With some exceptions, the reaction was very positive. Most consumers viewed the fish effluent as they would any other fertilizer and didn't react negatively to vegetables grown aquaponically. They also felt a closed loop system that recirculates water is good for the environment. Above all, taste and quality were the "selling features" of the products sampled and most consumers weren't concerned how they were grown. The most common comment from people was - "It doesn't taste fishy!"

Some consumers simply felt the vegetables didn't taste as good as "dirt grown" or organic vegetables. Some of the tomatoes sampled were not completely ripe which had an impact on the flavour.

Sampling was critical to the success of the research project. A lot of consumers were turned off by the initial explanation of the process but were very enthusiastic about the taste and quality of the vegetables after having tasted them.

Insurance is another issue that arose during the research. One of the markets required proof of liability insurance before being allowed to attend. This rule applies to all vendors at that market and is a growing trend at many of the Alberta Approved Farmers' Markets in the province. In addition to liability insurance, Alberta Agriculture, Food and Rural Development encourages food vendors to purchase product liability insurance whenever there is a risk, however small, of consumers becoming ill after consuming their products. These two types of insurance are a cost of doing business but are in place to protect the producer.

Which vegetables were grown and when those vegetables were harvested also received some comments. One individual commented that he wasn't interested in the tomatoes because they were varieties of which he had never heard. Many people recognized the name "gherkin" as a variety of pickling cucumber but a lot commented on the samples as being too big to use as a pickling cucumber. A vendor at the Brooks market, who was selling mini English cucumbers, commented that her cucumbers as well as my samples were too big if you are trying to attract an Asian crowd. They like the mini English to be no more than three to four inches long and both of ours were at least six inches long. We had noticed that the New York tomatoes tended to split. Interestingly, this did not concern most people. In fact, several people commented that they weren't buying their tomatoes because they looked perfect but rather because of their taste. If they wanted perfect looking tomatoes, they would buy them from the grocery store.

Food Safety

Food safety concerns are outlined very clearly in the Environmental Industry Scan. Food safety is a concern of the farm direct marketing research project. A.C.E. will conduct food safety research but it hadn't been started prior to this arm of the project being undertaken. Food safety can not be stressed enough. Because the number of producers growing aquaponic vegetables would be relatively small, a single incident of an illness traced back to an aquaponically grown vegetable could destroy the industry in Alberta.

Following are the types of food safety comments that came up during the farmers' market research:

- "Is there anything in their [the fish] food that would pass through to the vegetables and be harmful to humans?"
- "Are any tests done on the vegetables for nutrient content?"
- "Farmed fish are not healthy." (A discussion surrounding this comment caused the consumer to expand on the comment and state that since she believed farmed fish are not healthy, then any vegetables grown in their water are also not healthy.)
- "What about the possible use of growth hormones and antibiotics with the fish?"
- "…bacteria in the water getting into the vegetables."
- "How do you ensure the bacteria counts are at acceptable levels? They would have to be higher than in the wild simply because there are so many fish in the tank. How is that controlled?"
- "Fish are dirty."
- "Is the Styrofoam used in the greenhouse safe and food grade?"

The answers to these questions need to be researched and resolved prior to producers entering into an aquaponic operation. Producers need to respond to consumer concerns with scientific data. In some cases, the concern can be addressed by simply educating the consumer on the process while other concerns, such as bacteria levels, may require scientific testing be performed.

Negative consumer perceptions of food safety can have a huge impact on the sale of the vegetables.

Prior to visiting any farmers' market, a conversation was held with the market manager of the St. Albert market. She stated that she wouldn't even let an aquaponic producer into her market unless the Health Inspector for Capital Health had approved the vegetables. She felt there might be food safety issues and she was unwilling to risk any product liability claims. Prior to being able to sample at the Lethbridge market, the Health Inspector for the Chinook Regional Health Authority had to give approval as well. In this situation, it was simply a matter of explaining the sampling procedure. I did ask if there were issues because the vegetables were aquaponic and he said no. However, he came by the display on the day of the market and asked what aquaponics was and how it was different from hydroponics. This shows that what he actually approved and what he *thought* he approved were two very different things. It is important that the producer have full support from the health authority prior to selling the vegetables at an Alberta Approved Farmers' Market or through any other farm direct marketing channel.

Food vendors selling at Alberta Approved Farmers' Markets have unique status under the *Public Health Act* and Food Regulation. However, each regional health authority can establish additional standards to those set out in the Act. This means that even though the product meets the standards as outlined in the Act, additional standards may have to be adhered to, depending on the health authority the producer is dealing with. A producer needs to work closely with the health inspector in the region he lives in as well as the region he wants to sell into because the standards could be different.

Carla MacQuarrie with Future Aqua Farms Limited commented that they have an "open door policy" for any of their customers to come and judge their production methods themselves. Whether anyone takes them up on this offer is irrelevant. The simple fact that they are willing to have customers see how they are operating builds consumer confidence.

Place

As noted above, Alberta Approved Farmers' Markets were chosen as the venue for the sampling portion of the research. Farmers' markets are the oldest and most common form of marketing direct to the consumer. The Alberta Approved Farmers' Market program is an accreditation program administered by Alberta Agriculture, Food and Rural Development that certifies farmers' markets across Alberta.

Farmers' markets offer several opportunities:

- Minimal marketing, packaging, advertising, and promotion costs.
- Prices are higher than wholesale.
- Established market base.
- Inexpensive channel to test market new products.

Eight Alberta Approved Farmers' Markets were chosen to visit. These markets were chosen because they are representative of the markets aquaponic producers would likely attend. They are dverse in both size and location (province-wide with the exception of the Peace, urban and rurl and, indoor and outdoor). General comments bout each market visite appear in ppendx

Market*	Date/Times	Location/ Community Served
Innisfail (medium market)	Thursday 10 am – 1 pm	Indoor - Arena Services a rural community
Brooks (small market)	Thursday 4 pm – 7 pm	Indoor – Shopping Mall Services a rural community
Strathmore (medium market)	Friday 4 pm – 8 pm	Outdoor – Park Rural/urban mix – farming community that is also a bedroom community to Calgary
Lethbridge (medium market)	Saturday 8 am – 12:30 pm	Indoor – Exhibition grounds Urban market
Calgary Grassroots Northland (medium market)	Tuesday 3:30 pm – 7:30 pm	Outdoor – Shopping Mall Urban market
Edmonton Callingwood (small market)	Wednesday 12 noon – 6 pm	Outdoor – Shopping Mall Urban market
Vegreville (small market)	Friday 7:30 am – 12 noon	Indoor – Hall Services a rural community
Smoky Lake (small market)	Saturday 10 am – 12 noon	Indoor – Arena foyer Services a rural community

*Small markets: less than 25 vendors; medium markets: 25 – 100 vendors; large markets: more than 100 vendors.

General comments about the demographics of the consumers who sampled the vegetables are as follows:

*Primarily female
*Aged 36 – 65. Rural markets had more elderly consumers than urban markets.
*Majority have at least completed high school
*More consumers at the small, rural markets mentioned they are on a fixed income than consumers at the other markets.

Characteristics of Alberta Approved Farmers' Market Consumers

When marketing a product, it is critical the seller identify a target market. Individuals within a target market all possess similar characteristics. Sales will be increased if marketing efforts are focused on the target market as opposed to trying to be all things to all people. The more narrow the description of the target market, the more focused the marketing efforts.

The information collected from the research does not conclusively identify a target market. The data collected gives an indication of willingness to purchase by generally female consumers who value certain attributes in their vegetables: taste, quality and produced in a chemical-free environment. Which market should a producer attend? The answer to this question will depend upon a number of factors, some of which are personal to the producer but also which may be influenced by characteristics of each chosen Alberta Approved Farmers' Market such as size, consumer demographics, competition, etc.

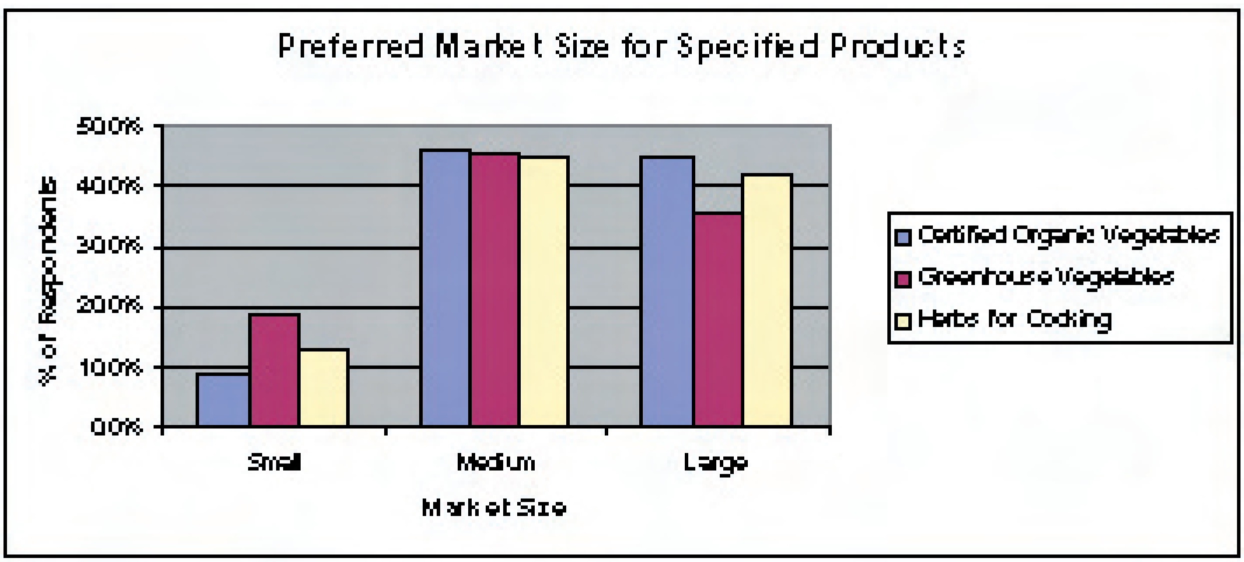
The *Alberta Farmers' Market Vendor and Consumer Profile and Economic Impact Study* conducted in 2002 provides some additional information on consumer demographics broken down by market size across Alberta (Appendix 3). The following table shows the most common response in each category:

Market Size*	Consumer Age	Income	Spending Patterns
Small	36 – over 65	$10,000 - $25,000	Up to $20
Medium	36 – 55	$40,000 - $55,000	$11 - $30
Large	36 –55	$65,000 - $80,000	$21 - $30 OR over $50

*Small markets: less than 25 vendors; medium markets: 25 – 100 vendors; large markets: more than 100 vendors.

The data tells us that small markets attract a larger percentage of seniors, income levels are generally lower, and consumers don't spend as much money at the market as do consumers at medium and large markets. Clearly, each market size attracts consumers having certain characteristics with respect to age, family income, and spending. (The majority of shoppers at Alberta Approved Farmers' Markets are female - 76%). Along with the other information collected, producers can use this data to help them identify characteristics of their target market as well as the size of market they should attend.

In addition, the *Alberta Farmers' Market Vendor and Consumer Profile and Economic Impact Study* indicates that some consumers go to Alberta Approved Farmers' Markets specifically to purchase certified organic vegetables, greenhouse vegetables, and/or herbs for cooking. (This is important to this research report because consumers may categorize aquaponic vegetables in one of these three categories.) When this information is looked at in relation to market size, consumers at medium and large markets are significantly more likely to purchase these items than consumers at small markets.



Price

The majority of consumers verbally indicated they would purchase the aquaponic vegetables. The majority of consumers also said they *felt* the aquaponic vegetables were healthier than conventionally grown vegetables, primarily because they are produced free of chemicals. Consumers were then asked how much they would pay, ie, would they pay a premium for the vegetables. This is important because it gives an indication of perception of value. Prices at farmers' markets are really "what the market will bear".

Consumers must perceive a value in the product (and the process in which it was produced) in order to willingly pay a premium. It was evenly distributed between those who said they would pay a premium, those who said they wouldn't pay a premium and those who didn't comment. Those who said they would pay a premium indicated they seek out organic vegetables, which are priced higher than conventionally grown vegetables, or they recognized that the process would be more costly. It was expected the consumers at the rural markets would be less willing to pay a premium. These markets are located in farming communities and attract more elderly consumers as well as consumers who grow their own gardens. Although the urban markets had higher percentages of consumers willing to pay a premium, two rural markets, Brooks and Strathmore, also had a large number of consumers expecting to pay a premium for chemical-free or organic vegetables.

The questionnaire asked consumers to indicate prices for products. Information was also personally collected from other vendors while visiting several Alberta Approved Farmers' Markets throughout the summer. This information is tabulated below.

Vegetable	**Price**		
	Each	**Per Pound**	**Per 5 Pound Bag**
Long English	$1 - $1.50	$1.50 - $2.00	$3.00 - $5.00
Mini English	$.25 - $.75	$2.00 - $2.50	
Gherkins	$.50	$2.00 - $2.50	
Tomatoes		$.70 - $3.00	
Pear Tomatoes		$2.00	
Grape Tomatoes		$2.00	
Herbs	$1 - $2/pkg		

Promotion

This segment of the marketing mix refers to how a producer promotes his products to the target market. Promotion can include, but not be limited to, brochures, business cards, pictures, newsletters, sampling, telling the farm story, company logo, word of mouth, paid advertising, news releases, etc.

It was very clear during the farmers' market visits that consumers were unaware of aquaponics. Many thought they knew what it involved but were usually confusing it with hydroponics. Education is going to be a large component of how this product will be sold. "Telling the farm story" will also be a large part of that education process – describing how you got into aquaponics, how you run your operation, how you believe in your product, etc. The pictures and samples used in the research were very helpful at showing consumers what is being done and convincing them that the product has merit.

One of the early discussions with the project team surrounded the issue of branding. Some members of the team felt it was important to brand the vegetables as aquaponically grown. Our feeling was that branding shouldn't be focused on unless consumers responded that they would buy the vegetables *because* they are aquaponically grown. In general, although consumers were genuinely interested in how the vegetables were grown, most consumers cared more about the taste and quality of the vegetables. Carla MacQuarrie with Future Aqua Farms Limited stated customers buy their vegetables because of the superior taste and quality – not because they are aquaponically grown.

General Comments from the Consumer Survey

∗People were willing to sample a good variety of the vegetables offered and were willing to verbally comment on the products.

Taste and Quality: Very Good to Excellent were by far the most prevalent comments. Some people would prefer a certain variety to another variety, some prefer more or less acid in their tomatoes, and some preferred the size of the mini English and gherkins over the long English cucumber.

Healthier: Most consumers felt the vegetables were healthier because they are chemical-free.

Premium: It was evenly distributed between those willing to pay a premium, those not willing to pay a premium and those who didn't comment at all. Whether to charge a premium is going to depend on the market and what that market will bear for price. This will require the producer to research the market and see what other vendors are charging, if there are natural and/or organic vegetables being sold and at what price.

Gender: More females than males sampled the vegetables.

Age: When looking at all markets combined, the majority of consumers are between 36 – 65 years of age. Again, the producer will have to research the particular market he wants to sell into because the demographics can be very different – age, ethnic mix and family income, in particular can all be very different depending on the market.

Price: Because very few people actually filled out the questionnaire section on pricing, this information is very limited. Information collected is a compilation of survey data, prices at the St. Albert and Vegreville markets as well as a greenhouse grower selling at the Edmonton Callingwood market.

Selling direct to consumers is all about building a relationship with the consumer. Once that relationship has been built and the trust has developed, it is often difficult to draw customers away from that vendor. The small to medium sized rural markets generally have at least one well-established vegetable vendor who has been selling at that market for a number of years. Breaking into these markets with the same vegetables that are already being sold will be difficult.

The small markets are typically rural markets. Consumers at these markets often grow their own gardens and so are unwilling to pay a premium for vegetables at the farmers' market.

The medium sized markets that are located in or near a large urban centre often attract consumers who are more willing to pay more for chemical-free, organic produce. They understand that it costs a little more to produce or is more labour intensive and so are willing to pay that premium.

Additional Farm Direct Marketing Channels

As noted above, there are several farm direct marketing channels to consider other than Alberta Approved Farmers' Markets. The channels that could be considered for the sale of aquaponic vegetables have been described below.

1. Farm gate sales

Farm gate sales are sales made to consumers directly from the farm. They may take the form of a seasonal roadside stand or a farm store, which could be a permanent structure that is operated year-round or it may also consist of a sales centre set up in the greenhouse where the vegetables are grown.

Producers still encounter costs, even though they are selling directly from the farm. Transportation costs are eliminated, but producers should still consider purchasing product liability insurance as well as general liability insurance because consumers will be coming to the farm and possibly coming in contact with farm hazards. Selling directly from the farm requires that the producer post hours of operation, determine parking areas and advertise the business possibly with paid advertising and/or highway signs. There may also be possible zoning or planning restrictions.

2. Community supported agriculture (CSA)

Community supported agriculture consists of a partnership between consumers and the producer. Consumers contract or buy "shares" in farm products in advance and the producer commits to supply a range of products over the entire season. Often consumers have the option to participate in planting and harvest. The arrangement can be initiated by the producer or by a group of consumers.

This arrangement guarantees the sale of the crop prior to it being planted but it does require some additional management of detailed crop records and yields. Product liability insurance would still be required. Depending upon the arrangement, the producer may deliver the product to the consumers, factoring these transportation costs into the selling price.

3. Municipal buying clubs

Municipal buying clubs are a marketing concept whereby the producer selects a target group of urban consumers who work in the same office building(s) or live in the same area. Product is pre-sold and delivered to consumers at a common location on specific dates. Trust and respect is earned by providing a consistent, quality product on time. Producers need to check the licensing and regulation requirements for the municipalities they are selling from and into.

Transportation costs need to be factored into the selling price, as do the additional levels of insurance needed – business insurance on the vehicle, product liability insurance, etc.

4. Direct sales to restaurants

Chefs are increasingly willing to buy direct from producers in order to find unique products or items that are difficult to purchase from distributors. This marketing channel is slightly different from the other farm direct marketing channels noted because the producer sells to the chef who adds value to the product and then sells the finished product to the consumer. The relationships developed are between the producer and the chef and the chef and the consumer rather than between the producer and the consumer. This method of marketing has the potential of building “brand” recognition. Producers are often able to realize much higher returns for their products than if they were sold through a distributor.

Products must be of top quality, fresh and available as needed. Specialty products, which aren't available in wholesale markets, are top sellers. Chefs also consider price, consistency, and reliability of supply and delivery. This method of marketing is most practical if the producer lives near a large urban centre simply because delivery costs would be reduced and there are more restaurants available to service.

5. Ag tourism

Ag tourism is the economic activity that occurs when people link travel with the products, services, or experiences of the agriculture and food system. There is a growing market of consumers who are intrigued by the mystique of their rural heritage and want to share in the harvest of food down on the farm.

As noted in the environmental industry scan, there is an opportunity for some aquaponic operations to open their doors to tourist, school, and industry tours. School tours are usually tied into the curriculum for particular grade levels. The producer would need to contact the local school board or the particular schools to discuss what he has to offer and how that ties into the curriculum.

Sharon Stollery with the Ag Tourism Initiative of Alberta Agriculture, Food and Rural Development was contacted with regards to tours of aquaponic facilities. In her opinion, certain questions need to be answered prior to offering tours.

- Can a number of people easily walk through the facility at one time?
- Is there a danger of contamination to the water if people/children touch the water in the fish tanks and/or the greenhouse? Can the facility be built so no one has an opportunity to touch the water?
- What species of fish are being raised and can they be easily seen in the tanks?
- Is there any part of the process that is not “tourist friendly”, ie, doesn’t *look or smell* pleasant? If this is the case, tours may be better suited for other producers (industry tours).
- What is the objective of offering tours – to raise educational awareness, to sell more products, to teach other producers and so expand the market?
- Do you feel comfortable speaking in front of a group of people?
- Do you feel comfortable having people walk through your facility?
- Have you considered charging a fee to turn the ag tourism component of your operation into a profit centre?

Ag tourism is often an add-on to a farm direct marketing enterprise. It can be a profit centre in itself but it usually complements the farm direct marketing business. Ag tourism can result in the public becoming more aware the business exists and of what it has to offer, resulting in increased sales.

Conclusions and Recommendations

Product

Very positive response to the aquaponic vegetables.

Taste and quality were rated as Excellent or Very Good by an overwhelming majority of consumers.

Producers should consider growing vegetables that won’t put them in direct competition with established vendors. Other marketing techniques could include offering “off-season” vegetables (offering tomatoes and cucumbers in early spring before conventional vegetables are available), adding value by providing recipes or preparation tips, using convenience packaging where all the ingredients for salsa or pesto are packaged together, etc.

Food safety is a concern with some consumers and market managers. Adequate testing and research will be needed to reassure the public.

Insurance, both liability and product liability, are a cost of doing business and should be considered as part of total costs. The Alberta Farmers' Market Association offers a group policy that meets the basic needs of each member market and vendor. If this meets the producer's needs, the group rates available may be lower than obtaining individual insurance.

Table or stall rental at farmers' markets need to be considered as part of total costs.

The cost of transporting vegetables to the farmers' markets needs to be considered as part of total costs.

Additional costs of selling at farmers' markets: table (some markets don't supply), table covering, displays, bags, scale, signs, canopy (if outdoors, this is critical), coolers, etc.

Labour is a critical cost that is often overlooked when considering total costs. Even though many producers do all the work themselves and do not hire additional labour, it should still be factored into total costs.

Place

There are several marketing channels available for farm direct marketing but the most common is the farmers' market. With approximately 100 Alberta Approved Farmers' Markets throughout Alberta, producers have a good variety to choose from. Which market is chosen will depend on several factors:

Size of the market and the producer's ability to produce enough vegetables for that size of market.

•Location of the market and distance from the farm. With rising insurance rates and gas prices, transportation needs to be factored in to final costs.
Consumer demographics
•Other vendors, ie what they are selling

It is critical to research the Alberta Approved Farmers' Market(s) from which you want to sell. The information you need to collect will include:

•Market size – how many vendors
•Market location – urban vs. rural
•Consumer age and income levels
•Competition – how many other vegetable vendors, what types of vegetables are they selling, are they adding value or convenience packaging, are they supplying recipes or cooking tips, what prices are they charging, etc?
•Market set-up – indoor vs. outdoor, power available, tables supplied, stall size, table fees, etc.

Small markets are probably the least desirable markets to attend for a number of reasons:

• They have a lower consumer base upon which to draw.

- They often have at least one well-established vegetable vendor. Because of the relationship that vendor has established with the consumers, it will be an uphill battle to try to attract the limited number of consumers away from that vendor.
- The consumer base is more likely to be elderly and living on a fixed income. This will prevent the producer from achieving a premium for his product.
- Consumers at small markets tend to spend less than consumers at medium and large markets.

Large markets may also present some difficulties for aquaponic producers:

- Large markets are usually seen as “destination” markets, attracting a large number of consumers. As a result, large volumes of product are needed to be able to sell at a large market. If the aquaponic facility were simply an add-on to an aquaculture operation, would it be able to produce enough products to sell at a large market? Research would have to be conducted on each market to see how much produce would be necessary for that market.
- Large markets often have a waiting list of potential vendors. Often to be selected to vend at a large market, the producer needs to have a unique product. It is questionable whether the market manager would view aquaponic vegetables as unique. Research on each market would have to be conducted in this regard.

Price

Research on pricing would have to be conducted on each market the producer would like to sell at. This would include investigating what other vendors are charging and if consumers would be willing to pay a premium, ie are other vendors with specialty vegetables (organic, etc.) charging and receiving a premium.

The research gave an indication of 2003 summer prices. These prices could be used to calculate the viability of the operation but it should be understood prices can vary from market to market as well as from year to year.

The research shows that medium and large markets are *more likely* to attract consumers who are willing to pay a premium but there is no guarantee they would perceive aquaponic vegetables as being more valuable.

Charging a premium simply because the vegetables are grown in a more costly aquaponic environment could be risky. Consumers did not always recognize or care that the process would be more expensive.

Promotion

One advantage of Alberta Approved Farmers’ Markets is that the market manager handles promotion of the market. This blanket promotion attracts a larger consumer base than individual advertising could hope to achieve. Once a consumer-base has been established, word of mouth will help to increase sales.

In general, consumers did not know what “aquaponics” meant. A lot assumed it meant the vegetables are grown in water (thinking of hydroponics) but they had no idea fish were involved. Education will be a critical component of every sale.

“Chemical-free” was far more important to the consumers who sampled the vegetables than “aquaponically grown”. But above all, taste and quality was the deciding factor and was what impressed the consumers the most. This leads me to conclude branding the vegetables as “aquaponically grown” isn’t critical in the short term.

Every person who walks by your table at a farmers’ market is a potential customer. However, not every potential customer is part of your target market. Some consumers will always have issues with how the vegetables get their nutrients. Some people will always believe that aquaponic vegetables do not taste as good as “dirt grown”. The test is recognizing these individuals and not expending a lot of time and energy trying to convince them of something they don’t and won’t believe in.

Sampling is critical. If the vegetables are being marketed as having superior taste and quality, consumers need to be convinced.

Marketing products direct is not for everyone. Farm direct marketing requires skills that may not be necessary if marketing through conventional channels. People skills are the most obvious because every sale involves interacting with the consumer, educating, providing tips and recipes, telling the farm story, etc. Some of the other skills required can be found in *Direct Marketing for Rural Producers,* an Alberta Agriculture, Food and Rural Development factsheet.

In conclusion, selling aquaponically grown vegetables at Alberta Approved Farmers’ Markets is feasible. Consumers reacted very positively to the vegetables and generally indicated they would purchase the vegetables at an Alberta Approved Farmers’ Market. The specific market the producer wants to sell into will impact the vegetables grown. It is critical that the producer research the optimum harvest point for each type of vegetable so that he is taking top quality vegetables to market. Educating the consumer on aquaponics is critical as there is a general lack of knowledge in the marketplace. Issues of food contamination could have a devastating impact on the industry and need to be addressed. Being able to reassure consumers with solid data will only help to strengthen the industry.

Producers need to consider all the costs of production and marketing as outlined earlier to determine whether or not producing aquaponic vegetables is economically viable. The purpose of this research project was not to determine economic viability, although the information collected can be used in that final analysis. As well, producers need to consider if they have the time and the additional skills necessary to market their products direct to the consumer, as market focused skills are different than production focused skills.

Appendix 1, Aquaponics Project
Consumer Survey

In order to gauge consumer attitudes towards aquaponically grown vegetables, I invite you to take a few minutes to complete this survey. Your opinions and comments are invaluable. **Please note: your responses are treated as confidential and anonymous.**

1. Which vegetables did you sample today?

1. ______________ 2. ____________________ 3. _____________________ 4. ____________________

For the following two questions, if you sampled more than one vegetable, please indicate which vegetable receives which rating if they are to receive different ratings.

2. After having tasted an aquaponically grown vegetable, indicate how you rate the **taste** of the product(s)? (Circle appropriate number.)

1 – Poor 2 – Fair 3 – Good 4 – Very Good 5 – Excellent

Comment:____

3. After having tasted an aquaponically grown vegetable, indicate how you rate the **quality** of the product(s)? (Circle appropriate number)

1 – Poor 2 – Fair 3 – Good 4 – Very Good 5 – Excellent

Comment:____

4. Do you feel aquaponically grown vegetables are healthier than conventionally grown vegetables? Yes No

5. Would you pay a premium for aquaponically grown vegetables over conventionally grown vegetables? Yes No

a. How much would you pay for: (please respond in all categories)
i. Long English Cucumbers ________each ______per pound _ per 5 lb bag
ii. Mini English Cucumbers _______each ______per pound _ per 5 lb bag
iii. Gherkins ________each ______per pound _ per 5 lb bag
iv. Tomatoes _______per pound
v. Small Pear Tomatoes _______per pound
vi. Grape Tomatoes _______per pound
vii. Basil ________per package
viii. Dill ________per package
ix. Italian Parsley ________per package
x. Oregano ________per package
xi. Chives ________per package

6. Demographics
a. Gender: Male Female
b. Age:
15 –24 years 25 – 35 years 36 – 45 years
46 – 55 years 56 – 65 years over 65 years

c. Level of education:

Less than high school High school Vocation/technical school

College diploma/certificate Some university University degree

d. Average annual family income level:

under $10,000 $10,000 - $24,999 $25,000 – $39,999

$40,000 – $54,999 $55,000 – $64,999 $65,000 – $79,999

$80,000 - $99,999 $100,000 - $120,000 more than $120,000

Appendix 2, Summary of Farmers' Market Sampling

Innisfail

•Medium sized market with approximately 65 vendors.
•Located in the arena.
•Market runs from 10 am to 1 pm on Thursdays. It was very busy at the beginning but slowed down after 11:30 – no lunchtime crowd.
•Observation of consumer demographics: female aged 46 and older. There were some younger consumers with children.
•The market has two large vegetable vendors – Innisfail Growers and a Hutterite colony. The market by-laws state that no more than two large growers are allowed at any one time although smaller vendors will be considered depending upon the products they have to sell. This is due to consideration of market saturation.
•Very good interest in the products sampled with positive response.
•Food safety comments:
•Some concerns mentioned about what the fish were eating. Is there anything in their food that would pass through to the vegetables and be harmful to humans?
•Concerned the plants are getting all the nutrients they need. Are any tests done on the vegetables for nutrient content? Feel they are probably healthier than hydroponic vegetables.
•Most of the people sampling said they would buy the vegetables but not at a higher price. Prices would have to be competitive with other growers.

Comments

"not as good as mine"
"not as good as dirt grown" (This is a farming community where a lot of the consumers have their own gardens so a grower would be competing against that perception.)
"wouldn't pay a premium"
"would have to charge the same as the other growers"
"pear tomato had a musty taste" -- *only mentioned once so may be the particular tomato and not indicative of the variety*
"taste like fresh vegetables and not store-bought USA products. Prefer to be able to buy Canadian."
"Healthier than general vegetables but not healthier than mine which are organic"
General concern about trying to enter a market like Innisfail that has established vegetable vendors – it is going to be difficult to attract consumers away from those vendors because a relationship has already been developed.

Brooks

•Small market with less than 15 vendors.
•Located in the mall.
•Market runs from 4 pm – 7 pm on Thursdays.
•Observation of consumer demographics: female baby boomers
•There were at least three vegetable vendors but each seemed to be selling different products so there isn't as much competition between vendors.
•Very positive response for the research because it is being conducted partially at CDC – South.
•Even though it was a small market, more consumers seemed to recognize the need to pay more for the vegetables because they are chemical-free.

Comments

•"Taste is very impressive. Firmness is good – appears veggies would last longer."
•"Would pay a premium but not a lot"

Strathmore

•Medium sized market with about 35 vendors.
•Located outdoors in a parking lot adjacent to the Kinsmen Park.
•Market runs from 4 pm – 8 pm on Fridays.
•Observation of consumer demographics: female baby boomers

Very positive response from consumers.
A lot of the consumers would expect to pay a premium. This could be because of Calgary's urban influence.

Comments
- "I wouldn't pay a premium. Just the thought of how they are grown!"
- Taste very good until the process was explained – then Yuck!
- "Grow more common varieties"
- "Great idea"

Lethbridge
- Medium sized market with about 65 vendors
- Located indoors at the Exhibition Grounds
- Market runs from 8 am – 12:30 pm on Saturdays
- Observation of consumer demographics: good mix of male and female but still primarily baby boomers
- Lots of vegetable vendors but all seem to be fairly busy so the market must not be saturated. With that many
- vendors, a new vendor would need to find a niche. There were a lot of requests to purchase the long English cucumbers and the mini English cucumbers so that may be the niche in that market – this year.

Comments
- "Would prefer dried herbs over fresh"
- "The tomatoes have no taste when compared to organically grown"
- "Better than anything else in the market"
- "Skin is a little tough" (tomatoes)
- "I'm an impulse buyer so I need samples"

Calgary Grassroots Northland
- Medium sized market with about 50 vendors
- Located outdoors in the Northland Mall parking lot
- Market runs from 3:30 pm – 7:30 pm on Tuesdays
- Observation of consumer demographics: very good mix of both males and females, more of an ethnic mix than seen at the more rural markets, aged between 35 – 55.
- Very busy market – I didn't stop cutting vegetables for over an hour and a half. One of the other vendors said it was slower than normal but the weather was keeping people away (cool, cloudy, windy)
- More consumers would expect to pay a premium. This is likely because of the urban influence where they are used to having to pay more for organic and chemical-free. This group is also further removed from the farm and seemed more likely to negatively react to how the vegetables are grown. This indicates a need to do a lot more educating at this type of market. At the same time, many consumers felt it was a great idea because of how the water is recycled and not wasted.

Food safety comments:
- "Farmed fish not healthy"
- "What about the possible use of growth hormones and antibiotics with the fish?"
- Bacteria in the water getting into the vegetables. Story about bean sprouts being contaminated because the water had bacteria.
- "How do you ensure the bacteria counts are at acceptable levels? They would have to be higher than in the wild simply because there are so many fish in the tank. How is that controlled?"
- "Fish are dirty!"
- Just the idea of how they are grown turned some people off.
- Seemed to be a lot more negative comments/concerns than received at the other markets.
- Need to be willing to give samples so people can taste the difference. Once people tasted the vegetables, the response was very positive.

Comments
- "What kind of stones are used to hold the plants up? Do they get some minerals/nutrients from the stones?"
- Lots of positive comments about the closed loop process.

•More people said they are drawn towards chemical-free produce but they don't search it out.
An off-duty Health Inspector stopped by. We talked about the process and she didn't have any concerns about the safety of the vegetables. It was her assumption, however, that the vegetables are tested regularly for any sorts of residual bacteria that may be harmful to humans.
A few "not as good as dirt" comments – about the same as at other markets.

Edmonton Callingwood

•Small sized market with less than 25 vendors.
•Located outdoors under the breezeway at the Callingwood Shopping Centre.
•Market operates 12 noon – 6 pm on Wednesdays. This market also operates on Sundays and expands to be a medium sized market. Most of the vendors work both markets with additional vendors being added on Sundays.
•Observation of consumer demographics: mostly female between 35 – 55
•Quite a few comments "not as good as mine" so need to assume that consumers in the area have their own gardens.

Comments

•Taste – "first thing I noticed – nice and tangy"
•Quality – "like that there's no chemicals, pesticides, etc."
•Health – concern around the fish farming aspect. "I don't buy farmed fish"
•Taste – "so good. Thanks for growing these. They are so good"
•Premium – "would pay a premium but not so high that only the rich can buy. We all have to eat healthier."
•"ooo fish poop! I don't know if I like that. Fish are dirty!"
•"Gull Lake vegetables are tasteless. These are wonderful!" (referring to Gull Lake Greenhouse who was also a vendor.)
•"How do you know the plants have all the nutrients they need?" This particular individual wouldn't even try the vegetables and was a Safeway employee.
•Concerns about farmed fish – Pacific and Atlantic salmon. This sort of bad press could be very harmful to the success of aquaponics. It doesn't matter that Albertans aren't growing salmon – it's the idea around "farmed" fish.
•People seem to see a real value in greenhouse crops because they are so clean. They likely wouldn't pay more for this feature but it may be something that attracts them to the producer and then they can be sold on taste and quality.
•Greenhouse vendor was right across from my table. All their products are grown hydroponically. He was selling a lot of the same vegetables. He felt the taste and quality was very similar to his product.
•During the early markets before anyone else has tomatoes and cucumbers, the same greenhouse vendor sold about 100 – 150 pounds of tomatoes and cucumbers combined at the Wednesday market and at the Sunday market, ie need 300 pounds per week. Once the conventional vegetables come on stream in the summer, he only sells about 50 pounds combined per market.

Vegreville

•Small market with less than 15 tables.

•Located in the Elks Hall

•Market operates 7:30 am – 12 noon

•Observation of consumer demographics: majority are females although there are also quite a few male consumers. Age 55+.
•The older consumers were very reluctant to try the samples. The main vegetable vendor is a Hutterite colony that has been selling at the market for years. A very strong relationship has been built up with them and it was almost like consumers didn't want to be seen dealing with the competition or there was an extreme lack of trust in what I was doing. They weren't even interested in hearing about the product. This type of market would be VERY difficult to break into because of the relationship with the other vendor. A vendor selling hand creams says it is a fairly cut throat market – there was another smaller vegetable vendor in this summer and people would ask the Hutterites their price, ask him his price and then they would buy from the Hutterites because they would match his price.

Also need to be able to bring in vegetables that the other vendors can't grow well in soil such as long English cucumbers.

The Hutterites were impressed with the taste and quality of the vegetables and felt they tasted the same as the ones they were selling.

Smoky Lake

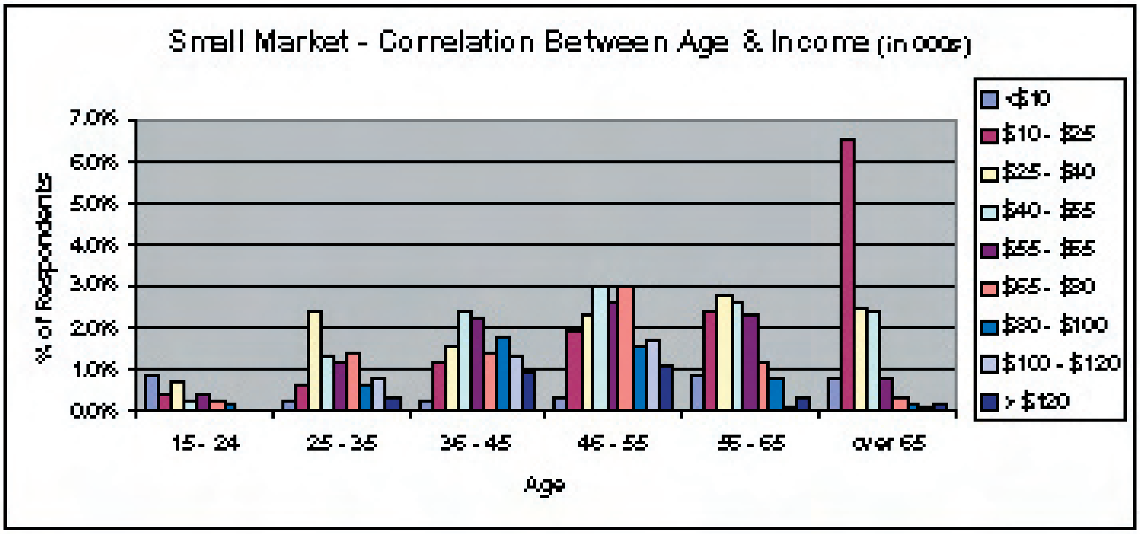
- Very small market with less than 10 vendors.
- Located in the foyer of the arena
- Market operates 10 am – 12 noon on Saturdays.
- Observation of consumer demographics: Mostly female aged 55 +
- Very strange market: everyone lined up at the door prior to 10 am. They all rushed in and were gone by 10:20.
- Vendors were leaving within the hour and no new consumers came in.
- Food safety comment: comment about the use of Styrofoam. Is it safe and food grade?
- Same as with Vegreville where many of the consumers were unwilling even to try the samples.
- No big vegetables vendors. Not sure of the impact of Linda's Market Garden.

Appendix 3

Consumer Demographic Data

This information is from the *Alberta Farmers' Market Vendor and Consumer Profile and Economic Impact Study.* The information is presented in order to get an indication of consumer demographics by market size. When broken down by gender, the patterns (age, income and spending habits) were similar for both males and females. Therefore, the data was combined for both genders.

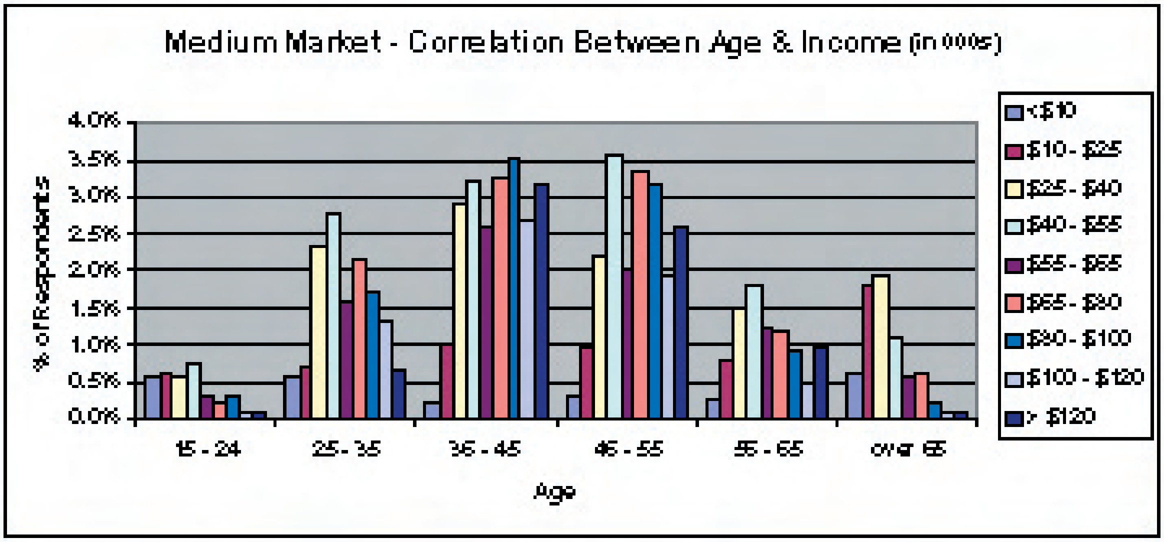
1. Correlation between consumer age and family income at markets with less than 25 vendors.



Conclusion:

Data shows that elderly shoppers at small markets have a low or fixed family income. A low family income indicates these consumers are less likely to be able to pay a premium for their produce. Baby boomers (46 – 55 years) reported the highest family incomes. If a producer is selling at a small farmers' market and they want to charge a premium for their vegetables, they should target baby boomers.

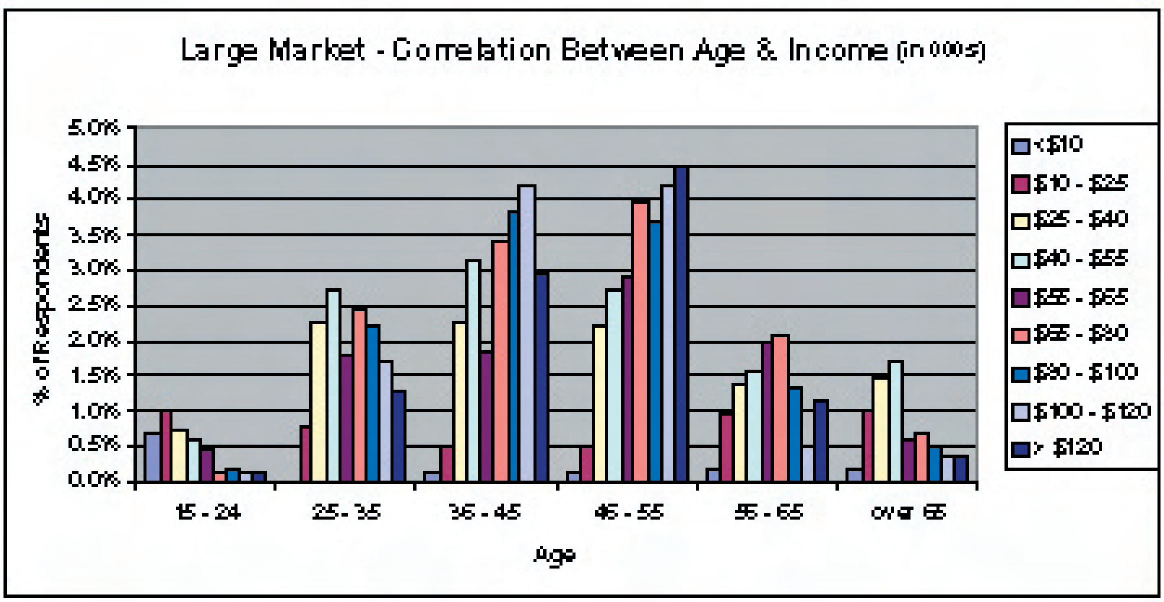
2. **Correlation between consumer age and family income at markets with between 25 – 100 vendors.**



Conclusion:

Individuals aged 36 – 55 report the highest family incomes. If charging a premium for the vegetables is necessary, this may be the age group to target.

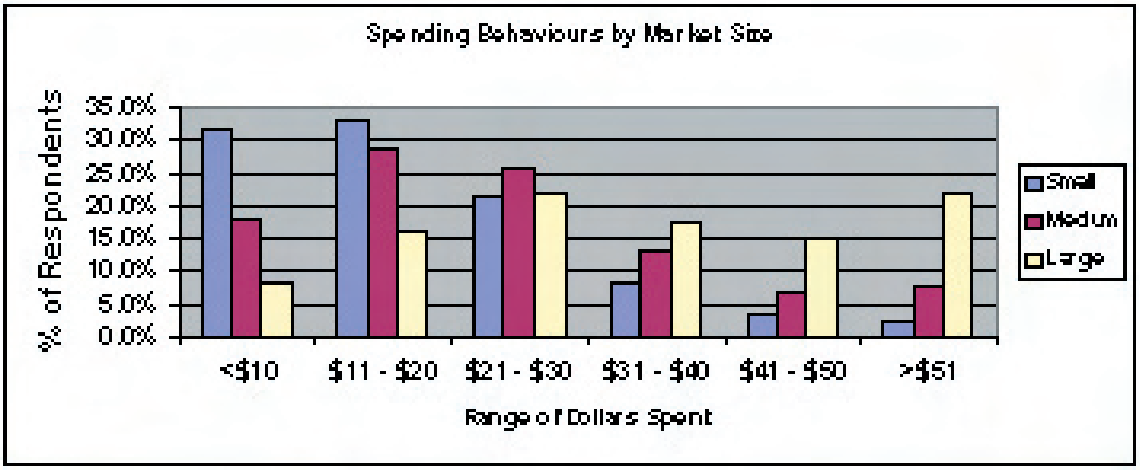
3. **Correlation between consumer age and family income at markets with more than 100 vendors.**



Conclusion:

Individuals aged 36 – 55 report the highest family incomes. If charging a premium for the vegetables is necessary, this may be the age group to target.

4. Spending Behaviours



Conclusion:

Consumers at small markets spend less than consumers at large markets.

Appendix 4

Interview with Carla MacQuarrie

Future Aqua Farms Limited located at Head of Chezzetcook, Nova Scotia

Background

Future Aqua Farms Limited, founded in 1998, is the first commercial warm water aquaponic facility to be operated in Nova Scotia. Future Aqua Farms has successfully demonstrated that aquaponics is viable in Atlantic Canada and after completing specific research & development objectives, are now supplying a variety of herbs, vegetables, and tilapia fish to niche markets in Nova Scotia. They were contacted to see if they had any key learnings that could be applied to Alberta operations. The interview was completed via e-mail.

It sounded from your voice mail message that the restaurants are your primary outlet and the farmers' market is secondary. Is this true?

Yes, we use the farmers' market to sell overflow from the restaurants.

Our operations in Alberta can't be certified organic because of issues with the fish food not being organic. Is that true in your case as well?

Not applicable – we haven't tried to get organic certification – we rather sell as organic producers based on quality product and have an open door policy for any of our customers to come and judge our production methods for themselves.

What vegetables do you produce and which ones do you sell at the farmers' market? Do you only attend one market or several?

We sell spinach and basil. We attend only one market – it is the largest (Saturday) market in Halifax.

How large is your farmers' market, ie how many vendors, how many consumers on a typical market day?

There are approximately 100 vendors, and probably 3,000-3,500 consumers on a typical Saturday. It is an indoor market in the downtown core, an area very popular with the tourists. There is a good mix of artisans, farmers (both produce and meat) as well as professionals (photographers, etc).

Does your market operate seasonally or year round?

Year round

Are the vegetables you sell at the market unique to the market?

No, we are not the only spinach/basil producers at the market. There are others but our product quality is so high that we have a base of regular customers.

Are you able to sell your fish and vegetables at the market or just the vegetables?

We typically sell just the veggies, but have, in the past, sold the fish as well.

In our situation, the term aquaponics is Greek to the consumer so we are faced with a huge education process for our consumers. Was that true in your situation as well?

Yes. We have a couple of info sheets at our booth to explain the process to those interested.

Have you been able to "brand" your product so that consumers buy your vegetables because they are aquaponic?

Generally, the consumer doesn't care about the fact that we are aquaponic. They care about the quality and taste of the product.

Are you able to command a premium price because the vegetables are aquaponic or are you price competitive with the conventional greenhouses?

Again, I think our premium price is a derivative from our premium product – not the fact that we are aquaponic.

Who are your primary customers (demographics) and did you have to do anything special to your products to attract them or was it simply an education process?

There is not a specific demographic that we target for the veggies. Typically it is organic/vegetarian types who visit the farmers' market in the first place – so they buy most of our stuff at the market. On the other hand, the restaurants we service are high end (white tablecloth) places that appreciate the quality of our product and the 0% waste.

We have vendors who started selling at the market as a last resort because they didn't know what else to do with their products. How did you start selling at the farmers' market? Did you research selling at the market or did you just give it at try and it worked?

In all honesty, it was a last ditch effort. We started out selling to chains (Loblaws) but then they implemented a policy where individual stores couldn't buy from local producers. Instead a local producer had to have sufficient supply to service the whole chain. So we started looking for other alternatives, and the farmers' market was the answer.

If you did market research, what did you do?

We met the produce managers around the city, visited farmers' markets, visited restaurants, and then started the long trial and error process. We started out doing 100% tomatoes, now we do all spinach and basil…and in between we have done everything from cucumbers to peppers to romaine lettuce to arugula to watercress…the list goes on. It is a matter of matching what grows well and what sells well – there is an equilibrium that you have to achieve.

Appendix 5
Resources

Alberta Farmers' Market Vendor and Consumer Profile and Economic Impact Study. Produced by Weststar Inc. on behalf of the Alberta Farmers' Market Association and Alberta Agriculture, Food and Rural Development. 2002.

Aquaponics in Alberta: An Environmental Industry Scan. Alberta Agriculture, Food and Rural Development. July 2003.

Direct Marketing for Rural Producers. Alberta Agriculture, Food and Rural Development. July 2003.

Farm Direct Sales: Know the Regulations. Alberta Agriculture, Food and Rural Development. October 2003.

Carla MacQuarrie, Future Aqua Farms Limited. Located in Head of Chezzetcook, Nova Scotia.

Sharon Stollery, Ag Tourism Initiative, Ag-Entrepreneurship Division, Alberta Agriculture, Food and Rural Development.

Appendix E

Current Market Opportunities in Alberta for Aquaponic Grown Fresh Vegetables

July 10, 2003
Compiled by Belinda Choban

Findings from Buyer Interviews:

After interviewing produce buyers from several different marketing channels in Alberta, I can summarize by stating that the uniqueness of aquaponic grown vegetables would not necessarily be a selling features in Alberta markets. In fact, most buyers were concerned with food safety issues that might occur in an aquaponic system. Fresh locally grown seems to be a greater attraction to the market place. However, regardless of production methods, opportunities for marketing fresh vegetables into Alberta markets is very good. Vegetable types, varieties, volumes and crop production techniques vary with the different marketing channels available. The greatest obstacles producers will face are:

•Finding the Right Market
•Meeting buyer requirements (what, how, when and how much buyers want)
•Establishing prices.

I've listed the Alberta Buyers in this report; plus I've italized those that I visited directed.

New Developments in the Alberta Fresh Vegetable Marketing Industry over the past 5 years:

Large Efficient Distribution Systems:

Large, efficient, global distribution systems exist and can offer lower prices to the consumer. Wholesalers have consolidated into Regional Distribution Centres and provide a quality control check for all larger chain stores. All larger retail chain stores in Alberta have their own wholesalers. Buying decisions are done by the head office and little opportunity exists to buy locally. Opportunities to buy locally are greater with smaller independent wholesalers who may buy centrally for the stores they supply.

For example: Western Grocer Wholesaler
Western Grocer is the wholesale arm for Westfair Foods Ltd., which is western Canada's wholesale/retailer for Weston Wholesalers. And Weston is the wholesale/retail division of George Westin's business, which is large in the bakery business and owns Loblaws Retail Foods and General Merchandise of which Loblaws Cos. is the grocery arm. In eastern Canada, the wholesaler is National Grocers, in Quebec it's Provigo and in the Maritimes it's Atlantic Wholesale. All supply their own chain retail stores. Product is moved through the wholesale office and regional distribution centres. In Alberta the wholesaler is Western Grocers and its retail chain stores are Real Canadian Superstore, Extra Foods & Canadian Wholesale Club; and its independent retail stores Lucky Dollar Foods & Shop Easy; and its Food Service distribution is Sun Spun Foods. All buying is done through Western Grocer's head office located in Calgary; and all products go through the central warehouse in Calgary. A producer may deliver direct to the stores only after the arrangements have been made with head office.

EDI (Electronic Date Interchange)

Some companies are using electronic systems, such as EDI to do their buying (Eg. Safeway & Western Grocers). Buying orders arrive by E-business and are product is sold to retailers before the crop is harvested. Supply / demand information flows instantly to all members in the grocery channel.

Food Safety

Buyers expressed a BIG concern for FOOD SAFETY in aquaponic vegetables. Daily monitoring of filtered water for pathogens was recommended. The big buyers require that all producers, brokers, distribution warehouses and transporters have a Food Safety Standard Procedure in place with a detailed audit trail to verify the implementation of these procedures.

Good Agricultural Practices (GAP)- becoming the 'norm' that will be expected of all producers. This involves an audit trail – records required of each harvest by units, per green house bed or field lot, with harvest date, shipping date, yields, volumes sold and to who, plus transport tracking and other information that would enable the product to be tracked back to the farm through the market channels. In the event of a Food Safety issue, all product from the lot of concern, can be 'pulled' from the food system, without disrupting the whole system.

Consumer Trends: Global verses Alberta

Global = convince / ready-to-eat foods / comfort, exciting foods, variety, exotic, ethnic, unique, image (local is better) and pleasurable eating, healthy / nutritional eating, safe foods, environmental friendly foods, cheap food but willing to pay higher prices for a perceived "value" or complete package (eg. nutritional food with experience and excitement). Canada:

Slower to adapt the trends than the US, but not everything is adapted at same rate.

Alberta retail & food service = consumer trends are dictated by buyers through a "product introduction practice"

At the larger stores, foodservice and at the wholesale level, large volumes of product are imported and buyers' must often fill a minimum order or a truckload. New products are introduced to the consumer on a trial run. If successful, then they enter the marketing system.

Alberta specialty stores, high end restaurants & direct marketing = consumer trends dictated by local consumers. Excellent development potential for fresh, local, unique products into these niche markets.

Private Label verses Brand Label:

Private Label specific to retailers *(eg. President's Choice)* is big. 45% of products sold in Europe and 25% in USA are sold via private label. Private label is used to provide products with a lower price (10 to 25% cheaper). Discount stores develop their own private labels at the expense of brand labeled products. A producer's branded product must be a market leader in order to not be threatened by a retailer's private label.

Implications:

Local smaller producers will need to go through a broker in order to get into the wholesale-retail system; due to centralized, large distribution centres, head office buying and food safety requirements.

- Local field growers are changing to greenhouse crops due to Food Safety issues.

•Local larger producers have an opportunity to enter the wholesale markets if volumes are large enough and save the wholesale their high transportation costs from imports.

•Smaller producers have large opportunities marketing to the small specialty stores, farmers markets and high-end restaurants. These outlets market to local consumers and offer the products that the local market requires.

Opportunities in Alberta for Marketing Aquaponic Grown Vegetables:

Broker – markets to wholesale, retail and specialty stores.
Eg. Sunfresh Farms, Edmonton

Broker – markets to food service / restaurant market outlets + specialty stores.
Eg. Chapman's Fresh Produce, Edmonton.

Marketing Cooperative – markets to wholesale, retail & specialty stores.
E.g. Red Hat Co-op, Redcliff

Specialty store & small independent wholesalers – produce does the marketing.
E.g. Community Foods (organic), Calgary
Eg. Wrayton's Fresh Market, Calgary

High to medium end restaurants – producer does the marketing; approximately 150 in Edmonton of which almost 50 are high end; plus more in Calgary.
Eg. Wrayton Fresh Market, Calgary

Direct to Consumer - Farmers Market and on-farm sales.
Eg. Lethbridge aquoponic project

Wholesaler –suggest marketing to a wholesale after the industry is well established and production is proven, large in scale and with a realizable, excellent quality product

Note: food safety will be reinforced (sooner or later) at all market outlets.

Wholesale Markets and their Requirements:

Wholesale - Grocery Retail

Western Grocers, Calg. (Westfair / Weston) - Superstore, Canadian Wholesale Club, Extra Foods, Lucky Dollar, Shop Easy – Buyer @ Calg. Price is a priority; therefore will carry 2nd grades along with 1st. grades. An estimated 30% to 40% of product is local (western Canada).

Sobeys, Edmt., Calg., Grand Prairie (Empire Co., NS) - IGA, Foodland, Foodtown, Thrifty Foods in BC, took over Agora. – Buyer @ Edmt. Quality and image is a priority; therefore requires product uniformity and best quality.

Macdonalds Consolidated, Calg. (Canada Safeway, CA) - Safeway stores, Lucerne Food Processor, Food for Less - Buyer @ Phoenix.

Product supply is a priority; therefore will carry a variety of sizes, grade, colour of the same product.

OverWaitea, Calg., (Jim Pattison, Van.) - Save-on-Foods, Urban Fare, Associated Grocers, Price Dollar Mart Foods, Cooper's Foods – Buyer @ Langley, BC. Product variety is a priority.

Grocery People, Edm. (Federated Co-op) - Grocery Store, Convenience Stores – Buyer @ Saskatoon. Product supply is a priority.

Costco – warehouse club - regional buying office at Burnaby, BC. No-frills, cash & carry, large volumes of palletized product is a priority.

Wholesale - Food Service

Sysco, Edmt., Calg. (Sysco, Texas) - largest US company for Food Service; bought out Serca (previously Scott National) plus I & S – Buyer @ Calgary

Gordon Foods, Edmt., Calg. - US company; bought out Bridge Brand – Buyer @ Calg.

Wholesale – Brokers (Western Canada)

***Sunfresh* Farms** (Edmt., AB)

Bassano Growers (Calg.,AB)

El Dorado Vegetable Farms (Redcliff, AB)

Gouw Quality Onions (Taber, AB)

Broker from Lower Mainland ? (BC)

Craven (SK)

Peak of the Market (MB) – a marketing board for root crops, sell other crops on their own.

Note: The brokers work closely together for setting price for the prairies. They decide whom to sell to (honor system). If a business sells for cheaper, than it's "On Ad" *(and therefore for a short time)*.

Wholesale – Co-operative

Red Hat Co-operative (Redcliff, AB)

Wholesale Prices:

Price is a major determining factor in wholesale markets. Local produce must be competitive in price to imported product minus transportation costs. Price is not stable. At times it could be like a roller coaster. Selling / buying contracts don't exist.

Product margin (mark-up) from wholesale purchase price to retail selling price is about 30 to 38% (some times higher on fresh produce).

Minimum Volumes, Grades and Packaging:

Orders are large, usually bi-weekly and must be consistence over an extended period of time, usually the entire production season. Product delivery to wholesale distribution centre occurs between 3 and 9 AM. Product is usually palletized by grower.

Product must be graded and packaged according to Federal and Provincial standards; and often above Canada #1 and USDA grading standards due to competitive imported product. Standards set by the Fresh Fruit and Vegetable Regulations, C.R.C. 1978, c.285 under the Canada Agricultural Products Standards Act. Additional Alberta regulations may apply as set by the Vegetable Sales (Alberta) Act and Regulations (Vegetable sales AR105/97 and Grade, Packaging and Fees s248/2002).

A broker provides a full service of products to any one who is buying; and will repack if needed. A co-operative often does all the grading and packaging for the producer plus the marketing.

Lettuce:

Canada #1 and Canada #2 grades, compact, no more than 8 wrapper leaves on crisp head types, green colour – no light green, no wilt, no split heads, no damage, no rust, decay or tip burn, no brown butts (indicates boron deficiency / reduced shelf life).

Head Lettuce

• min. order for wholesaler is 200 to 400 cases per week of 24 head count per case, 40 lb./case for jumpos (1.5 lb/hd.) and 32 to 38 lb/case for regular head size of 11 - 12" diameter. Heads are cello wrapped and butt is cut off close.

Leaf Lettuce

•min. order for wholesaler is 350 to 400 cases per week, 24 count per case.

Living Lettuce

• AB supplier, 18 count per box, 6 –8" dia., prefers large size, roots attached.

Romain Lettuce

•24 count per case, 40 lb. case, 10 – 12" height, prefers larger size, no blisters or black tips due to chilling injury

•Note: Wholesalers' buying priority is for crisp head lettuce, then leafy green, then leaf red, then Romaine. Alberta markets (& Western Canada) have a low demand for butter crunch; plus a good supply is available from BC at competitive prices. Eastern Canada has a very high demand for butter crunch lettuce.

Estimated production potentials: @ min. requirement of 10,000 heads / week and current greenhouse crop yields at 2 plants per sq. ft., ***5,000 sq. ft. of greenhouse production is required to supply one wholesaler on a weekly bases.*** *Brokers and Cooperatives will buy less volumes.*

This week's wholesale price for green house butterhead lettuce averages @ $ 17.00 per case. or at least $ 0.70 per head. At 10,000 head per week = ***$ 7,000.00 weekly gross returns.***

Alberta is a large importer of lettuce (especially field grown types). In 2002, Alberta imported $44,046,000 worth of lettuce.

Greenhouse Tomatoes:

Canada #1, Canadian Commercial grade and Canada #2 grade; uniformity in size, shape and maturity colour; pink to red preferred but could be mature, turning, semi-ripe or firm; no blotchy ripening, on ridges, no cracks, no damage, no scald, co blisters, min. 2" dia. but market prefers larger.

Tomato hothouse
•32 to 35 count per box, 15 lb (7 kg.) box with individual cups for each tomato. **Current market is saturated; advised not to grow.**

Tomato cluster or TOV
•5 kg box, clusters of 5 to 6 count of 2 to 3" dia. in separate mesh bags or bulk in clam hell with or without stems. Stem clusters must be green and fresh to touch. Stem smell appeals to customers and increases sales. Good seller.

Grape Tomato
•sold in pint size clamshells of 12/box.

Estimated production potentials: Current hothouse type tomato crops yield 60 kg/sq. m per growing season of 34 weeks harvest,(and 45 kg/sq. m for cluster type and 30 kg/sq. m for cherry type). Using a production average for all types at 6 kg. per box and 800 boxes per week = 4,800 kg. of tomatoes weekly. This adds up to a total of 27,200 boxes or 163,200 kg. over a 34 week harvest period. Using a production average of 50 kg/sq m, an estimated min. ***of 3,300 sq. m. (or 35,000 sq. ft. or just over 1 ac.) of greenhouse space is required for yearly production of green house tomatoes to supply a minimum order to one Alberta wholesaler.*** *Brokers and Cooperatives will buy less volume.*

This week's wholesale price averaged @ $17.00 for 15 lb. (7kg.) reds and $13.00 for 15 lb. TOV. With weekly sales of 4,800 kg, ***estimated gross returns per week for reds = $11,657.00 and $8,915.00 for TOV***

In 2002, Alberta imported $26180,000 worth of tomatoes.

Cucumbers

Canada #1 and Canada #2 grades, and seedless at small (280 – 317 mm min./max. length), medium (317 – 368 mm min/max l.), large (368 – 419 mm min/max l.) and extra large (greater than 419 mm length) and min. dia of 41mm; uniform green colour in over 85%, fresh, firm, straight, no decay, no sunscald, min. 152 mm length with other types.

Salad Cucumbers
•min. 150 to 300 cases / week; case = 25 lb. of 3-5" length (best @ 4") and 1.5" diameter, no min. count, no yellow, nice green consistent colour. Box is lined with plastic but not sealed, and with a large ventilation opening on the top plus sides. Wholesale price averages @ $1.00 / lb. **Still room in the market.**

Mini Cucumbers
• 25 lb box, low volumes.

Persian cucumbers
•25 lb box; **no market demand**

Seedless Greenhouse Cucumbers
•graded small, medium, large and extra large, with a 12 count per box. Each cucumber is shrink-wrapped. Bulk or lower grade are not shrink-wrapped**.** **Still room in the market place.**

Slicer Cucumbers (Field cucumbers – has seeds)

•24 count / box, 20 lb. box wt., 10" min. length; no yellow belly, waxed for longer shelf life. Also sold bulk in hamper size of 50 lb. net wt. Hamper has inconsistent sized cucumbers with an average count of 50 to 60 and average wt. of 1 lb./ cucumber. **Still room in the market.**

• Note: Still lots of room for more cucumbers in the market place. Cucumbers must be pre-cooled or they will heat up in the box especially when stacked onto a pallet at 9 boxes per layer and 5 layers high with no air movement through the boxes. Box count per pallet = 49 or 56 (depending on the product and box size).

Current green house cucumber production is over 50 acres with yields from 50 to 60 kg./sq m.

*Estimated production potentials: @ 200 cases per week, 20 lb. box slicers = 4,000 lb. or 4,800 count needed weekly. If slicers are harvested for 40 weeks, then 160,000 lb. or 192,000 cucumbers would be harvested during the season. If current greenhouse yields for slicers are 50 count / sq.m. per growing season of 40 weeks harvest, then approx.**3,840 sq. m. (or 41,300 sq. ft. or just over 1 ac.) of greenhouse space is required for yearly production of slicer cucumbers to supply one Alberta wholesaler.***

*If prices average at $10.00 / case, with 24 cucumbers /case and minimum weekly sale of 200 cases, then **weekly gross returns = $2,000.00***

Hot House Peppers

No grade standards for peppers. Follow buyers specs. But must be free of disease and damage, similar varietal characteristics, evenly sized.

Green Bell Peppers:

•**Not recommended**. Is cheaper from BC field production.

Coloured Bell Peppers

• (red, yellow, orange) = extra large size preferred; 5 kg. box; 20 to 25 count and min.4 inch diameter, bell shape, no green colour, thick walls, no bruising. Get premium price for extra large size. Smaller sizes and irregular shapes are called second label and sold for the thrifty shoppers. **Still some room the market place**.

Stop Light

• bag of red, yellow and green.

Fancy Peppers

•Long finger type, jalapeño, Caribe (yellow), smooth surface type, etc., 50 count per box. **Recommend production especially during off-season (winter);** but only if competitive in price with ground crops. Off-season price = $1.00 to $1.25 / lb. wholesale during off-season.

*Estimated production potential for green house peppers: @ minimum wholesale requirement of 400 boxes per week of 5 kg. per box = 2,000 kg. per week required. If the growing season has a 32 week harvest period, then 64,000 kg. / growing season would be required. Hot House pepper production averages at 20 kg./sq.m./growing season of 32 weeks**. Therefore***

a 3,200 sq.m. (or 34,500 sq. ft. or approx. 1 ac.) of greenhouse space is required for yearly production of hot house peppers to supply one Alberta wholesaler.

If price averages at $26.00 per 5 kg box, with min. weekly sales of 400 boxes, then ***weekly gross returns = $10,400.00***

In 2002, Alberta imported $15,453,000 of green house peppers.

Egg Plant

Yes, recommend growing, especially during off-season. But only if price competitive with ground crops. Types – Japanese, Chinese and Italian.

Note: Fancy peppers and Eggplants have a large dollar return, but greenhouse product must be competitive with ground crops.

Herbs

International Herbs from BC is the major supplier of field grown herbs during the summer growing season. Wholesalers feel that AB greenhouse production would not be competitive with ground crops during the summer. In the winter, International Herbs airfreight their herbs from Mexico, Hawaii and Israel. Winter herbs are packaged in Styrofoam boxes to protect from freezing. Shelf life = about 5 days.

Wholesalers recommendation: aquaponic winter production of herbs, especially the Asian, Viet Nemesis type, and possibly teaming up with International Herbs from BC so year round supply from this established company could be possible.

Minimum order required
•60 boxes / week of cilantro and curly parsley
•less than 20 boxes / week of Asian herbs
• average sales at more than 200 boxes / week of oregano, tarragon, mint, water crest, and Asian herbs.

Herbs are trimmed, triple rinsed and pre-cooled by producer. Packaged dry into 2 oz. plastic zip lock sealed bags with air removed. 6 bags per larger plastic perforated bag. No box size and no min. bag count per box. Stored at 33 to 34 degree F. at 75% RH. Self-life = about 5 days. Basil is stored at higher temperatures (50 degree F) otherwise it will get chilling injury and turn black.

Wholesalers suggested value added product: – clamshells with 250 g / package. Get larger dollar return.

Things to Consider When Selling into the Wholesale Market

•Must establish a good long-term relationship with buyer. Usually takes 3 years to get in.

•Must prove that you are serious about the business. A high level of service from the grower is required along with excellent product quality at a competitive price.
•be a proven grower with excellent product quality.
•must pre-cool product to maintain good shelf life.
• need proper packaging and above standards for grading product.

•supply large volumes, of consistent supply over an extended period of time.

Must play by the buyer's well-established rules. (eg., PLU or price look-up stickers, UPC or Universal Product Code to control inventory, food safety compliant, E-business.).

Buyer needs good incentives to buy local product and interrupt year round supplies from other sources (such as saving dollars from high transport costs with imported product).

Smaller grocery stores or chains are more willing to order products that local markets require and are more willing to buy directly from growers through direct store deliveries but only after arrangements are made with their wholesaler.

General Comments

Wholesalers prefer to buy local so long as the price is competitive with imported product.

Organic – increasing slowly; doubling each year over the past two years; is less than 5% of sales. The problem is in keeping the product separated from other product. Current packaging isn't good enough for quick differentiation of organic product at the cash register.

GMO products, ethical treatment of animal products and health products
• not an issue. Price is the major issue.

Shelf-Live is very important. Product core temperatures taken when product arrives at the warehouse.

On-farm Food Safety documentation is required by some and soon by all.

Specialty Stores / Small Independent Wholesalers / Retailers : (partial list)

(note: AB Agriculture's Regional Cuisine project plans to compile a complete list of Specialty stores in Alberta)

Community Natural Foods, Calgary – natural & organic products – Calg. buyer

Wrayton's Fresh Market, Calg. – specialty store, restaurant, hospitality

Sunterra Market, Edmt., Calg., - specialty stores, food service, hospitality – Calg. buyer

Organic Roots, Edmt. – organic store, food service

T & T, Edmt., Calg. - Oriental store with fresh fish market

From the Good Earth Produce Co., Edmt., - produce store

The Big Fresh, Edmt. – organic store

Excel Foods, Edmt. – specialty, natural / organic store

Harvest Haven, Lethbridge, AB – The Country Market - specialty store.

OR-KIDS Organic Market, Lethbridge, AB – specialty organic store

Lorendy's Organic Market, Sherwood Park, AB – organic store

Calgary Co-operative Association, Calg. - retailer

Pro Organics, Burnaby, BC - supply specialty vegetables to many Alberta stores & wholesale distributors – BC buyer

International Herbs, BC. – supply culinary fresh herbs to many Alberta retail stores & wholesale distributors – BC buyer

Urban Fare - some buying done locally

Note: Debaji's Fresh Market – out of business

General Comments

Buyers recommend that producers concentrate on FRESH and LOCAL, and not on WHAT to grow. **These stores will take almost almost anything**. Some also have deli bars and restaurants where they can easily use up unsold products. They cater to local consumer demand which is usually for fresh, locally-grown healthy products, organic / natural products and food service (deli bars, beverage bar, take away, ready to eat).

Requirements

Product must be very fresh and often unique or of the specialty type. It is therefore very perishable so should not be transported a great distance. Best if product is produced close to market for timely delivery. Food safety not yet required, but it's coming soon.

Volumes and Packaging

Volumes are very low @ 1 to 2 wholesale box sizes per product per week.

Product does not need to be graded and packaged according to regulations. Size, grading, boxing, packaging, volumes and supply consistency is very flexible. Best to use recycled plastic containers or new boxes – not old broken banana boxes. Product inconsistencies can be accommodated by using them in the restaurant or deli. Delivery is usually 2 times per week for highly perishables (Tues. and Thur.).

Food Service Markets – High End Restaurants

High-End Restaurants

Note: AB Agriculture's Regional Cuisine project plans to compile a complete list of high-end restaurants in Alberta with the names of their executive chefs.

Restaurant Brokers: (partial list)

Chapman's Fresh Produce, Edmt. – fresh / specialty produce to high-end restaurants and small independent wholesale / retail stores. Expanding more into med-end since has most of the contacts for high-end (i.e., smaller chains such as Kelsey's and not large chains, such as Smitty's, and no institutes)

Full Course Strategy, Edmt. - local product to high-end restaurants

Note: There are more in Calgary

Comments

Some restaurants are tied to their suppliers (especially the middle to low end restaurants plus large chains) but many high-end, independent restaurants and hotels have the independent purchasing power. Plus the Executive Chefs at these high-end restaurants are in competition with each other for something really different and of regional flavour.

Interviews done with Chefs in 2002 by AB Agriculture's Regional Cuisine project indicated that 71% of the fresh vegetables, 34% of the baby vegetables and 57% of the greens and edible flowers used by Alberta Chefs in high-end restaurants were Not sourced from Alberta.

Note: According to Canadian Restaurant & Food Services Association (CRFA), Alberta

Restaurants lead the country in highest per capita foodservice sales (meals and snacks) since 1999, reaching $1,384 in 2002 and exceeding the national average by $300.00

Price

This market is very price driven. Pricing is calculated on a plate size portion for each product. Vegetables, herbs and starch usually account for 20% of the plate portion cost. 80% is for protein (meat, fish, poultry). May pay up to 10% premium for superior or unique product. Pricing is much higher than retail marketing but not as high as Farmers' Market prices.

Cost calculation example: *If the average price for a meal is $12.00, then the non protein portion would be $1.00. From this $1.00 portion, about $.30 would go to each vegetable. If one squash plant produces 1 lb of mini squash per harvest, it could provide for 8 portion servings of 2 mini squashes per plate. At $.30 /serving = $2.64 gross sales per plant per harvest. Harvest occurs daily, sometimes twice a day. When assuming a min. daily harvest over 8 weeks (56 days)**, gross returns per plant would be almost $150**.*

Volumes and product size

Very small volumes per restaurant are required. A couple of cases per week of each product. Brokers will sell more and will often repack larger volumes into smaller ones for their clients. Product must also be mini sized or small enough to be bit size. (eg. 2-3 mini squashes on a plate). Often a large garden (1 to 2 acres) or a small sized greenhouse is large enough to supply 1 or 2 Chefs.

Requirements

Sales are based on good relationships developed over time with Executive Chefs.

Chefs prefer to meet with growers prior to planting, to discuss crops to grow. Contract growing may be established. Chefs require easy and immediate grower contact - timing is everything. Producer must have commitment and attention to detail. Product must be available when promised and in volumes ordered and uniform in size and quality.

Chefs are visual buyers and want free samples of the products. Food Safety is important.

Lots of labour required. Often produces will only last a couple years, because it can be demanding.

In Demand

Anything that is difficult for broker to find or difficult to ship (bruises easy, perishable…). Eg. Little Gem Lettuce (is a sweet lettuce). Anything that is colorful - not too much green because of competition. Regional food and slow food. Anything that has good presentation on the dinner plate. Anything that is small in size (1 to1.5 inch squash; 2 per plate) - it has to fit on a dinner plate – mouth size.

Not in Demand

Organics is not in demand plus all lettuce types and salad in the bag

can be purchased easy and cheap for $4 US for 3 lb. bag.

Suggestions for Aquaponics Project by Restaurant Broker

Herbs:

•pack in 1 lb bags -loose, label not required
• Basil is the biggest seller (about 50 lbs/week) ($5-6/lb) (Sell in 1 lb plastic bag, no bolting, 1st bud stage) any kind of basil (eg. Tye Basil)
• Rosemary – about 15-10 lbs/week
• Dill – "Fern Dill" only, not garden dill
• Others – about 10 lbs/week
• No Asian herbs, no cilantro (very cheap to buy)

Vegetables:

• Baby Beans – big demand locally because of hard to ship
• French Beans (Note: takes lots of plants) – big demand; hard to ship
• Yellow Wax beans (regular)
• Baby Squash (available locally only in August) – big item in demand.
• Squash + Beans = 200-300 lbs/week , broker will repack into 5 to 10 lb cases

Tomatoes:

•Italian restaurants want Romas
•High-end restaurants want Tomato-On-Vine (TOV), Hothouse (Beef Stake)
•Chefs like – Yellow Cherry & Yellow Teardrop

•Mini Bell Peppers & Cherry Peppers in demand. Not Hothouse Bell peppers, they come in cheap from US ($10US / 7 lb box)
•No cucumbers; but Long English are OK
•No interest in any types of lettuce (Butter leaf or Buttercrunch – comes from BC, Romaine, Read Leaf, Oak Leaf, Spring Mix, etc). Head lettuce bought by 24-Count, lettuce is very light, so field lettuce provide more product.

Direct Marketing

•Requires large time commitment for marketing
•Requires people skills – employees with friendly, courteous attitudes
•Requires location – close to high traffic areas or urban centres
•Requires liability insurance coverage
•Has low marketing investment and high stable return prices.
•Is easy to enter the market
•There is medium importance on product quality and shelf life; no grade & packaging standards.

Appendix F

MARKETING AQUAPONICS PRODUCE

Research proposal

Lynda Thai, Sheena McDonald, Mike Dooley, Lutty Kessy, Kevin Rahmani

Lethbridge Community College

October 14, 2003

The problem that you have identified for us is that you are unsure of the premium price consumers are willing to pay for Aquaponically produced vegetables.

We have identified four major research objectives for you to pursue:

How much more are consumers willing to pay?

Do consumers value locally and naturally grown produce that is pesticide free?

What time of year are consumers willing to purchase Aquaponically grown produce?

What volume of produce do consumers plan on buying?

Our class will undertake the following market research on your behalf:

We will conduct a telephone survey with approximately 800 randomly elected businesses and households. This will result in quantifiable solutions of your research objective.

Executive Summary

Introduction and Overview

On December 26th,27th, 28th and 31st, 2003, the Marketing 290 class of 2003 surveyed 661randomly selected households and business in southern Alberta. This study had four main research objectives:

To determine how much more consumers willing to pay for a premium product.

To establish if consumers value locally and naturally grown produce that is pesticide free?

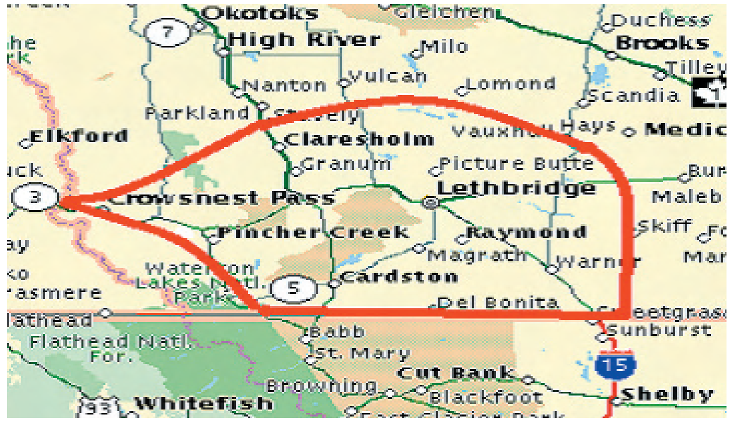
To determine what time of year are consumers willing to purchase Aquaponically grown produce?

To gather what volume of produce do consumers plan on buying?

Methodology

The survey consisted of households and businesses in Southern Alberta. This area included the following communities:

Taber	Lethbridge	Coutts	Coaldale
Vulcan	Frot McLeod	Crowsnext	Clasresholm
Glenwood	Pincher Creek	Cowley	Warner
Carmengay	Nanton	Milk River	Cardston
Sterling	Barons	Magrath	Enchant
Iron Springs	Raymond	Brocket	Nobelford



A sample of 661 business and households were randomly selected in Southern Alberta. Our class initially decided to purchase a phone number database from Telus. This however contained many numbers that we could not use. So we decided to randomly create 10 000 phone numbers ourselves using Microsoft Excel and the NXX numbers in use in the target area.

Telephone interviews were conducted at the Western Watts call centre in Lethbridge. Interviewers were connected to random numbers by the computer.

Numbers that could not be connected due to answering machines and residents not being home were sent back to the database and reused at a later point in time.

General Limitations

The survey was projected to take 250 hours at Western Watts to be put into a computer program, conduct the survey using their equipment and facilities and gathering the results.   We did not use all of the hours allocated to us because we had difficulties coding our survey into the Western Watts system, and gathering our random phone numbers. Because of this we were pressed for time and unable to complete the 800 surveys that we had projected to you.

During the survey writing stage, we felt that we could not gather representative data to completely fulfill objectives three and four. We were allotted only so much time to ask our portion of questions as we were expected to be combined with another survey. We realized that these objectives do not determine feasibility as objective one and two did. However, in the near future as you prepare to develop your marketing/business plan, you may want to investigate them further into detail.

Due to program difficulties at Western Watts we were unable to put the questions in such a way that the order in which they were asked would rotate. Because of this we feel that there is some degree of order bias. For example with our price questions we wanted to rotate the tomatoes and the eggs question every time we did a survey so that no two calls would have the same results. These questions also had to be worded in a certain way in order to get more accurate results using a more, less, exactly format.

Since this was survey was combined with the regional library survey, our portion was placed after their questions. Due to this placement we feel that some of the respondent's answers may not have been represented correctly.

This may have been because of a lack of interest in the library portion and that respondents were rushing their answers in order to complete the survey

Survey Results

Part 1 – Consumer perceptions of locally and naturally grow products

The population of Southern Alberta demonstrated optimism towards the subject of locally and naturally grown produce.

•76% feel that it is either very important or fairly important to obtain locally grown produce such as tomatoes and cucumbers

•52% of this group feel that it is either not very important or not important at all to have these vegetables grown in a greenhouse

•66% feel that it is either very important or fairly important to obtain products that are grown without the use of chemical fertilizers

•73% fell that it is either very important or fairly important to obtain a pesticide product

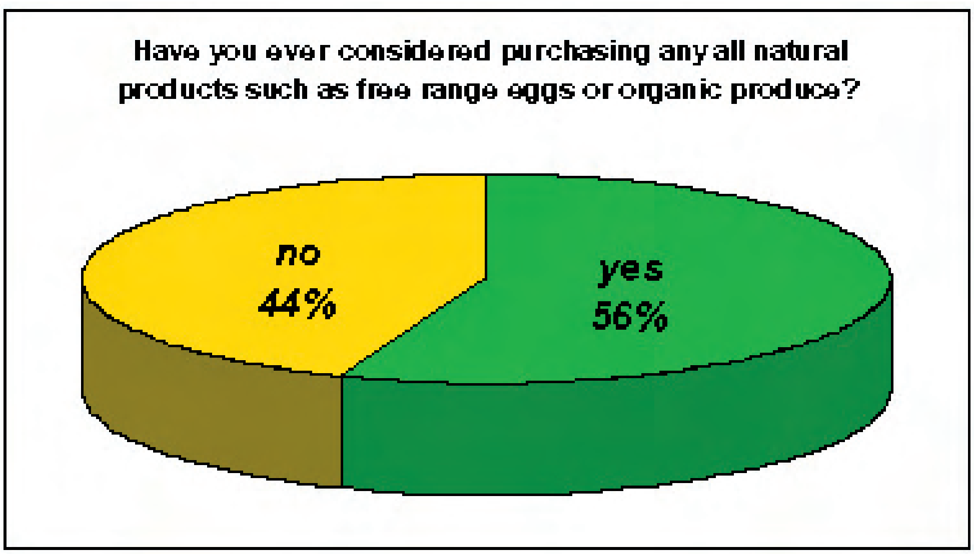
Part 2 – General Price Perception

The results have showed that the prices consumers are willing to pay are very similar for free-range eggs and organic vegetables.

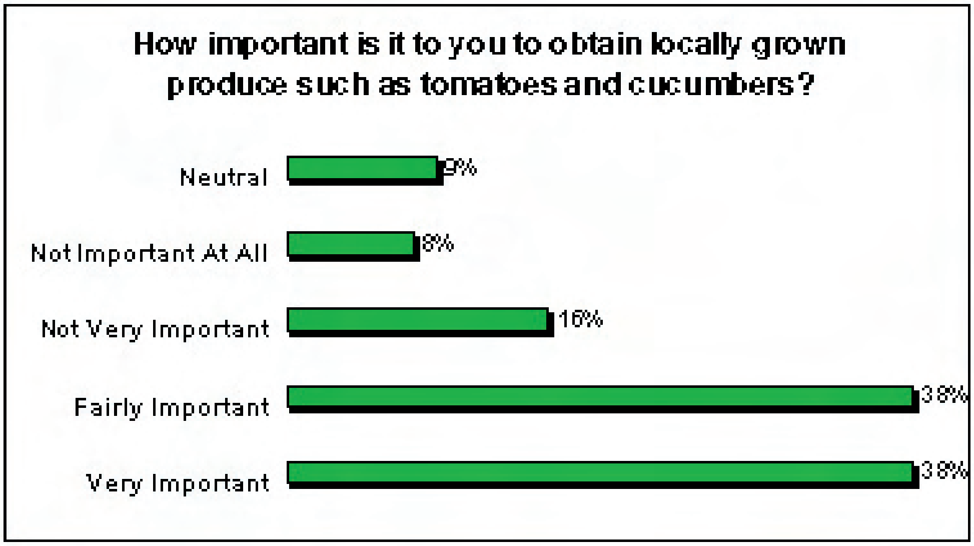
•Majority of the people are willing to pay a $3.00 premium for both free range eggs and organic vegetables

Survey Graphs

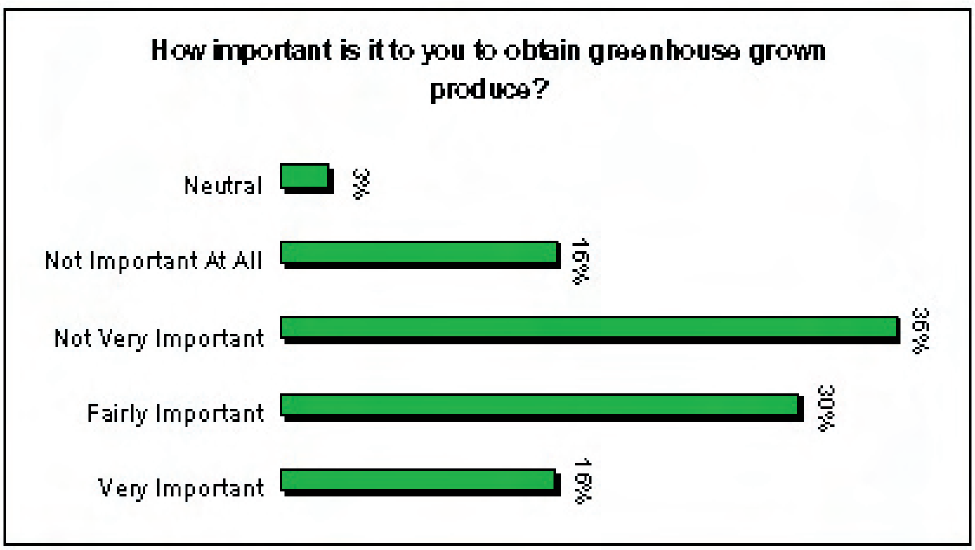
Eight questions were asked about topics related to produce:
In southern Alberta, based on the surveys completed, the data showed that 56% of the people considered buying all natural produce, and 44% of the populationion has never considered it.



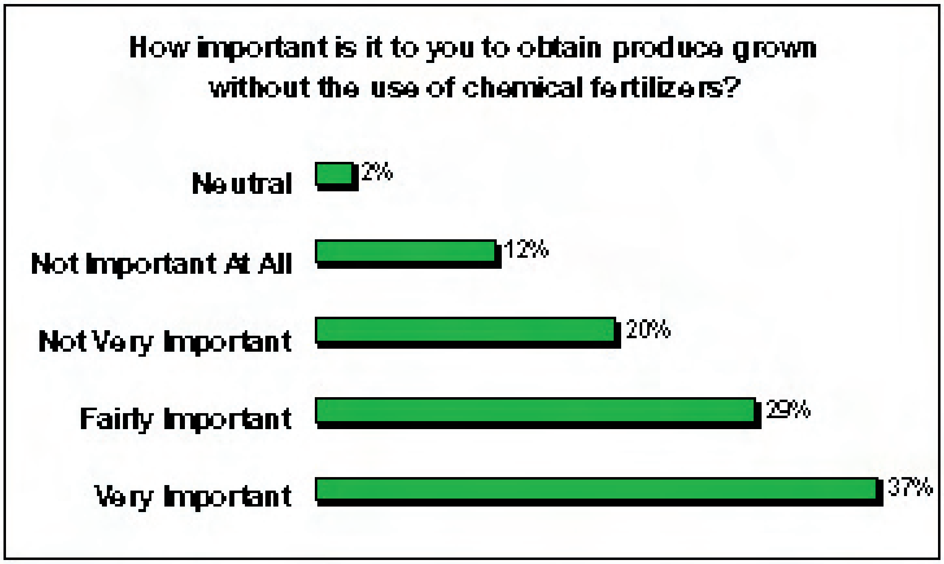
•76% of the southern Alberta population respondents showed that they either found getting locally grown produce fairly important or very important. 16% found said that it was not very important. 8% found to be not important at all, and 9% were neutral of this question.



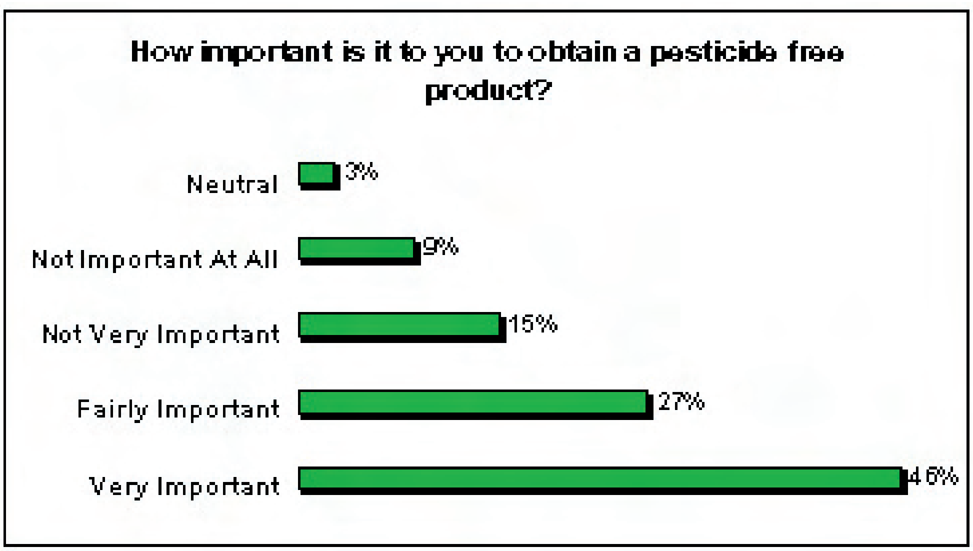
•The most common answer, with 36%, said that obtaining greenhouse grown produce was not very important. 30% of the respondents said that it was fairly important to them. The answer of not important at all and very important both received 16%, and 3% of the respondents remained neutral.



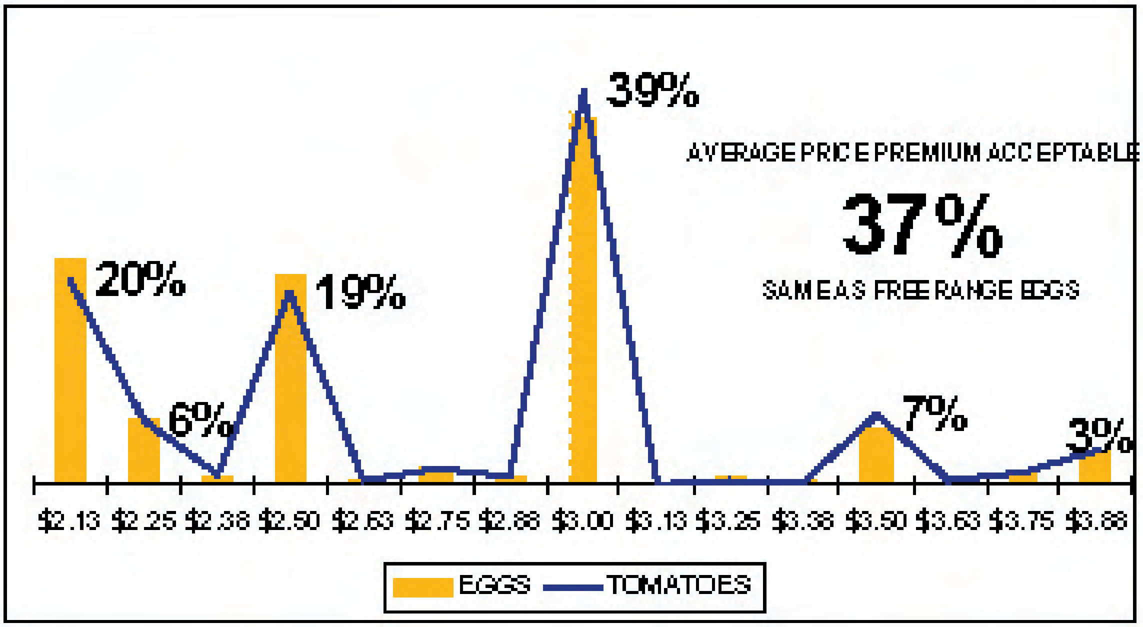
•The largest percentage, with 37%, said that obtaining produce grown without the use of chemical fertilizers was very important. 29% of the respondents said that is were fairly important. 20% found it to not very important. 12% found it to be not important at all, while 2% remained neutral on the matter.



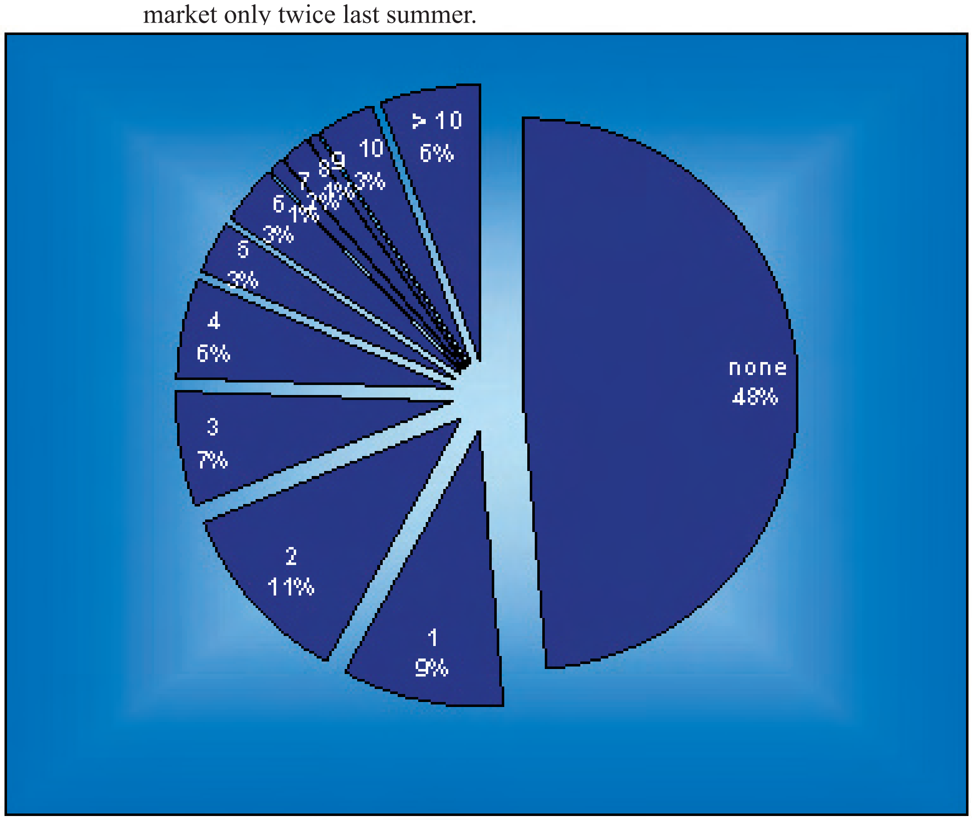
•A large number of the respondents (73%) said that it had a significant level of importance to them. 15% found it to be not very important, and 9% found it to be not important at all. 3% of the respondents remained neutral on this question.



- This graph exhibits the prices respondents are willing to pay for tomatoes and free-range eggs. Both are very similar and both have the majority of the respondents willing to pay, either $3.00 a pound, or $3.00 a dozen. This leaves a conclusion that an average price premium of 37%, the same as free range eggs.



This graph shows that a large number of respondents do not go to the farmers market (48%). The second highest percentage, 11%, visited the farmers market only twice last summer.



Survey results

661 households surveyed

1. Have you ever considered purchasing any all-natural products such as free-range eggs or organic produce?
YES 56% NO 44%

2. How many times did you go to the farmers market this past summer?
DID GO 52% DIDN'T GO 48%

3. How important is it to you to obtain locally grown produce such as tomatoes and cucumbers?

Very Important	Fairly Important	Not Very Important	Not Important At All	NEUTRAL
38%	38%	15%	8%	1%

4. How important is it to you to obtain greenhouse-grown produce?

Very Important	Fairly Important	Not Very Important	Not Important At All	NEUTRAL
16%	30%	36%	16%	2%

5. How important is it to you to obtain produce grown without the use of chemical fertilizers?

Very Important	Fairly Important	Not Very Important	Not Important At All	NEUTRAL
46%	27%	15%	9%	3%

6. How important is it to you to obtain a pesticide free product?

Very Important	Fairly Important	Not Very Important	Not Important At All	NEUTRAL
37%	29%	20%	12%	2%

7. If commercial eggs cost $2.00 per dozen, how much more are you willing to pay for free range eggs that are produced by chickens that are fed certified organic grains, and have no chemical wash or sealants used while cleaning the eggs?

Will you be willing to pay more than $3.00 per dozen, less than $3.00 per dozen, or exactly $3.00 per dozen?

MORE	LESS	EXACTLY
11%	52%	36%

8. Will you be willing to pay more than $3.50 per dozen, less than $3.50 per dozen, or exactly $3.50 per dozen?

MORE	LESS	EXACTLY
41%	11%	48%

9. Will you be willing to pay more than $3.75 per dozen, less than $3.75 per dozen, or exactly $3.75 per dozen?

MORE	LESS	EXACTLY
74%	3%	23%

10. Will you be willing to pay more than $3.25 per dozen, less than $3.25 per dozen, or exactly $3.25 per dozen?

MORE	LESS	EXACTLY
37%	0%	63%

11. Will you be willing to pay more than $2.50 per dozen, less than $2.50 per dozen, or exactly $2.50per dozen?

MORE	LESS	EXACTLY
5%	56%	39%

12. Will you be willing to pay more than $2.75 per dozen, less than $2.75 per dozen, or exactly $2.75 per dozen?

MORE	LESS	EXACTLY
23%	17%	59%

13. Will you be willing to pay more than $2.25 per dozen, less than $2.25 per dozen, or exactly $2.25 per dozen?

MORE	LESS	EXACTLY
3%	76%	21%

14. If normal tomatoes cost $2.00 per pound, how much more are you willing to pay for tomatoes that are grown locally, pesticide free, using environmentally sustainable technology?

Will you be willing to pay more than $3.00 per pound, less than $3.00 per pound, or exactly $3.00 per pound?

MORE	LESS	EXACTLY
12%	49%	39%

15. Will you be willing to pay more than $3.50 per pound, less than $3.50 per pound, or exactly $3.50 per pound?

MORE	LESS	EXACTLY
39%	5%	56%

16. Will you be willing to pay more than $3.25 per pound, less than $3.25 per pound, or exactly $3.25 per pound?

MORE	LESS	EXACTLY
25%	0%	75%

17. Will you be willing to pay more than $3.75 per pound, less than $3.75 per pound, or exactly $3.75 per pound?

MORE	LESS	EXACTLY
70%	6%	24%

18. Will you be willing to pay more than $2.50 per pound, less than $2.50 per pound, or exactly $2.50 per pound?

MORE	LESS	EXACTLY
5%	56%	39%

19. Will you be willing to pay more than $2.75 per pound, less than $2.75per pound, or exactly $2.75 per pound?

MORE	LESS	EXACTLY
29%	12%	59%

20. Will you be willing to pay more than $2.25 per pound, less than $2.25 per pound, or exactly $2.25 per pound?

MORE	LESS	EXACTLY
3%	73%	24%

Appendix G

Review of the Current Market for Tilapia

July 2003 Summary to date

Jan Warren
AAFRD

Overall purpose or this report.

This review of the current quantities, value and state of the Alberta Tilapia market is intended to guide the industry in improving the probability of success of an Aquaponic fish and greenhouse based business, and to build the understanding of the Aquaponics Steering Committee with knowledge of consumer demand for tilapia.

The current quantities, values and state of the Alberta Tilapia Market, and like every existing market, - continues to fluctuate and can change. This information reports on the current opportunities, and some background for projecting potential demands and revenues for the future.

The method of collecting data was done by review of import data from CFIA, interview of tilapia producers, fish brokers and gathering data from federal aquaculture development studies. The list of contacts is found at the conclusion of my summary.

Worldwide, fisheries and aquaculture is at a turning point. Wild fisheries have peaked, and the producers who started into aquaculture as a re-circulating business 10 years ago, have developed their productivity, and have opened up attempts to market with varying degrees of temporary success. They have reached a stage where growth and expansion of the related value chain, which includes, industry efficiencies of production, feed manufacturing, a processing structure and market development for new markets which pull, must all come together quickly or we will with certainty have a market in crisis.

The consumer demand for fish continues to expand simultaneously with global population growth, and the demand for a fresh, safe, and healthy product rises at the predicted annual growth rate of 11% to 15%, as drawn from both aquaculture industry and consumer studies.

The Alberta Tilapia market

Currently, in Alberta, there are 3 recognized markets for tilapia.

LIVE Fresh market – Currently there are sales for 600,000 lbs of Live tilapia in Alberta annually, (This is 11,000 lbs or 7,000 fish per week.) The market is split basically between our two larger urban centers, with 40% of sales being in Edmonton, and related communities, and 60% in Calgary and area. This market is predicting a 10% growth. The size must be1.25-1.4 lbs (.57kg) and ready for tank sales. Tilapia sell wholesale for $3.50, and store in turn sells them for $4.88 to $5.49 as they explain- some are higher quality and therefore demand more value. The store price includes, the infrastructure costs, CFIA fees for slaughter on site, stocking and tank maintenance, labor and offal management feed. Focusing on the Chinese culture is very important.

The consumer of a Live tilapia is usually of oriental background, and purchases the live, whole fish as a symbol of Abundance and wholeness of life to them. Purchases of fish are for it's liveliness, freshness and during festive seasons will purchase for it's red markings. Quality and coloring are very influential. Branding these live fish is difficult, but there may be an opportunity around the "buying local quality".

Developing the customer knowledge of the firm flesh and flexibility in recipe development for alternative markets is needed for this unfamiliar, not native to AB product.

The producers for this market currently include 4 or more locations with 2 contact brokers attached directly to either Greenview or JK Farms own brokers. Brokers for the oriental stores work only with those who offer the best business potential; to them PRICE is everything, and they are not loyal or bound to repeat business arrangements (no connection to morality or business obligations) There have been market limiting price wars between these two in the past and any new entrants to this market will further limit sustainable business development. It is essential that the broker you work with can portray the Chinese Values in this Largely Oriental Market. The price to producer must be a minimum of $2.33 back to the producer to make a profit after production, shipping and brokerage costs. With these small margins, the CFIA records are currently reflecting an increase importation of fish nearly market size.

Food Service

Oriental restaurants in AB account for about 10% of all restaurant trade, and are the most likely purchasers of live tilapia, or frozen boneless fillets of tilapia. Of all Alberta restaurants 9% have a menu listing for tilapia

The Alberta restaurant breakdown for potential users of tilapia is as follows:

142 of 1689 in Calgary
129 of1311 in Edmonton
21 of 126 in Lethbridge
12 of 142 in Red Deer,
6 of 106 in Medicine Hat

The majority of the foodservice requires a fresh, boneless fillet in most incidences unless the chef has a particular need for the whole fish. Although most Alberta restaurants are served by the 2 major food brokerage companies, oriental restaurants usually also have an oriental food broker to access the unique and difficult to access inputs to their ethnic food preparations. Fresh fish are often held in tanks at the restaurant, and imported frozen fillets are used sparingly in fish cake. Imported tilapia come fresh from Idaho, and Vancouver or while the frozen tilapia comes from Indonesia. Foodservice and consumer studies reflect an 11% to 15% growth in fish sales annually.

Frozen Wholesale/Retail

In larger centers there are an average of 6 large marketplace oriental food stores, 4 fresh foodservice marketers, many wholesalers and bulk stores which carry tilapia either live in tanks or on ice, or frozen. At small centers which are distanced from the fresh market, you can access frozen tilapia fillets selling at $1.99/lb (which indicates about $1.33 to broker, and less than $1 to producer) These prices indicate why they continue to be imported from Thailand/Vietnam; the whole frozen tilapia retails at $.99/lb.

The Alberta producers

As of June 2003, the two main producers of live tilapia are: Greenview Aquaculture and Kim Diep of Red Deer. Greenview is currently providing up to 3,000 lbs weekly to the live, fresh market specifically targeted at the Calgary oriental market…They had been supplying right up to the top of the available 6,000 lb weekly market until the price wars caused by the flood of tilapia at production cost in the Edmonton area and have since, lost that market. (1,000 lbs weekly is shipped through the Greenview markets from

McNaughtons, and T &T sells this at a slightly higher price) Greenview has for 6 years been growing fish in harmony with plants, and has not been able to use this factor to increase the value of fish to the consumer, or cause them to increase their WTP. Good Question- (Does a gross profit of $3000 a week cover 4 shareholders ROI and $ fulltime staff? - it is unlikely) Issues still confronting this group include grading for market readiness- as there is no infrastructure in place to deal with fish too big or too small? There is no infrastructure available to slaughter, flash freeze, or value add.

Regulations and criminal charges have not been an issue for production at Kim Diep 's, and they are now building another barn, and because of this, Greenview is currently reviewing their feasibility; and their activities include the Brooks facility listed as for sale, are currently advertising for a partner to develop the wetlands u-fish, and are offering different grow out options for the purpose of seeing if they can remain viable.

Although not verified with Inspection, there is some potential new tilapia production coming on-stream in a warehouse in Calgary, which potentially could start a new Price war. (Qian)

The Alberta Fish Brokers

What they are looking for and how much potential there is/will be?

Citi Fish sales deals mostly in the fresh and frozen market of salmon, halibut and fish prepared for foodservice. There is a small demand for up to 20lbs of tilapia fillets weekly, brought in by special order from Ontario, and sells more Tilapia in Summer than in Winter, and has foodservice demand for Canadian fish, and sees a potential growth market(esp in Char and Trout, if he could obtain the size he wanted)

Billingsgate has some small markets for frozen tilapia and works with FPI or Tofin foods of Toronto when they need to fill a particular order,

Superstore Has their own buyers, and do sell fresh slaughtered and frozen tilapia on a small scale

Finns- has the foodservice contracts for most frozen products in northern Alberta,

does some fresh order buying and maintain a small fish market.

T&T Marketplace- are the largest and highest quality fish suppliers in both Edmonton and Calgary and work often with the Chinese Superstore in accessing their products

Classic Smokers- began their business by smoking salmon and fish for the upscale market and have now taken on a fresh fish direct to foodservice business

Alberta Tilapia Market requirements

Slaughter- identified by Alberta Economic Development as one of the resource/infrastructure supports that is missing in the links to provide growth opportunities

Processing- the processors want to know water, feed and fish qualities, and would proactively maintain food quality standards as in all food processing. The linkages and technology for this part of the chain does exist in Alberta.

Foodservice -will pay $1.99 per 4 oz fillet frozen and ready to prepare, and by comparison the foodservice profits at the end of the preparation is only 33% higher, and this covers the cost of wages and infrastructure costs.

Frozen Tilapia- are selling for $1.99 whole frozen as imported from the far East and Toronto. We cannot compete in this market because of the cost of production here in Alberta.

The Products that compete with Tilapia

Ling Cod- currently sells for $3.49/lb and is comparable to the Oriental customer. It has a season like lobster, and so out of season, the competition diminishes.

Buffalo fish, Yellowfish/catfish, orange roughy, and other imported fish are often found and the invoices are not followed closely.

Jason Munsch (AED) is collecting import numbers for fish and market value replacements, and the Aquaculture unit has all the import numbers of imported tilapia from CFIA.

Processing and profit Adding

Currently we have no processing which will produce the end product that we know both foodservice and direct demand customers would support.

There are presently at stake 2 tilapia recipes, which need developmental help and 3 foodservice opportunities at the door (Club 100, Harvest Gala and ICE 2005 requests have all been forwarded to the appropriate producer). We sit on a precipice decision as to what production level of tilapia will be available after this falls changes in the marketplace. We need a licensed slaughter facility to begin the opportunity to test market willingness, HAACCP strategies and connection of the value chain links to build this industry.

Fortified and Functional foods Opportunity

There is a consumer driven approach to choosing healthier foods, foods that have an appropriate added benefit as an anti-oxidant, a good source of calcium and essential fatty acids, or be useful for self-wellness management or health solutions.

This industry will need support both from Aquaculture Fish Producers Association and provincial resources to develop this awareness and the market building, as it is currently not able to do this without developmental support.

There needs to be 1. Industry Association development, 2. Linkage of this association to educational and nutritional marketing development, and 3, Support for education of the consumer and raising the awareness of nutrient (wellness) content and environmental freshness and local loyalty.

Issues and Regulations

The need to protect a sensitive industry from Illegal Business and Illegal Imports

Whether it be an illegal import trucker, an illegal fish or an illegally business management tactic, our industry suffers from lack of clear communication and responsibility. We are split between, CFIA food inspectors, Fish and Wildlife regulations, and Alberta Agriculture without a uniform and sequenced plan for managing these issues

The need to protect a fledgling opportunity against a promotion induced price war

Looking at the past 10 years of declining business growth (which has been noticed since we first tried to work with Greenview)- we should be aware that Tilapia production is currently in an insolvent position and will not continue business in the current economic environment.

Future Opportunities for Tilapia

*Price trends will not change much, so for industry growth in AB it is primary to develop new value added or bio nutrient trends to achieve a profit producing fish side for the industry. (NB

Foodservice development of new fish pack'n'go products, and snack foods)

•Expect some co-operative pricing or marketplace selling agreements, to establish current players in the marketplace, or value chain as it develops, as a positioning bargaining to protect each players market.

•Consumer driven health, longevity and pharmaceutical aids could become valuable development areas for bio nutrient development from fish. Watch the trends such as insulin derived from carp, collagen processing and pet food development

Future Trends that may affect fish production and therefore aquaponics

Feasible prices where production can meet market willingness to pay (also refer to Environmental scan where recommendation made for both "sides" of this industry should make a profit margin)

Protection in fair trading, this includes regulatory succession, and also awareness of trade competition/protection

Industry ability to support new product development- to broaden uses for the things produced and stabilize production (-this includes identified need priority and $ put toward a pilot slaughter and product development place, and it's relation to the # of industry players to support this)

The effect of promotion of new production opportunities in a flooded market

Knowledge of the future tilapia market. We need to set up and assess the parallel practices of aquaponics across Canada, and stay in touch with reality and trends that will increase the ability to profit add.

Watch for:

•Consumer perception of value to environment, health, WTP (willingness-to-pay), and how this relates to lifestyle needs

•Your infrastructure needs for slaughter, value adding, or processing facilities for whichever market you choose to position yourself for.

•The issues and regulations that affect, and to protect, a fledgling industry (everything form Fair Trading, Current Freshwater Fish Act regulations and Export Competition.)

Summary

The tilapia market in Alberta has reached the level of meeting the mass market, and there appears to be little further growth in sales, and some decline in profit due to energy and competitive costs. This is a difficult market to position in, because of the inability to differentiate yourself in the marketplace, and the price lowering wars of free trade and import replacement ease.

Whichever fish is chosen for your aquaponic business development, the re- statement from the overall scan that the fish should be a generating profit center, and an equal monetary producer on it's own, would be a positive reinforcement for insuring the probability of success for this business.

Resources upon request

Appendix H

Aquaponics and Food Safety

Gordon A Chalmers, DVM
Lethbridge, Alberta
April, 2004

You never really understand something unless you can explain it to your grandmother. **- Albert Einstein**

So I left him, and as I went away, I said to myself, 'Well, although I do not suppose that either of us knows anything, I am better off than he is. For he knows nothing, and thinks that he knows. I neither know nor think that I know. In this latter particular, I seem slightly to have the advantage of him'. **- Socrates**

On the antiquity of microbes: 'Adam had 'em'. - **Anon**

Introduction

Aquaculture provides approximately 20 million of the 140 million metric tons of fish and shellfish consumed in the world annually. The remaining 120 million metric tons are harvested from naturally existing populations, principally from marine fisheries, many of which are at their maximum sustainable yields, are in decline, or have completely collapsed. China dominates the world in the aquacultural production of fish and shellfish, of which more than half by weight are raised in China. However, several countries in Europe and North America are among the top 10 producers. Total global production by aquaculture is expected to grow from 20 to 55 million metric tons by 2025, with no increase, and possibly even declines, in harvests from the capture fisheries (Georgiadis et al, 2000).

In North America, the three principal species of fish reared by aquaculture are salmon (Oncorhynchus spp.), rainbow trout (O. mykiss) and channel catfish (Ictalurus punctatus). In 1999, the total production for both Pacific and Atlantic salmon in Canada and the USA was about 72,000 metric tons, for a value of $450 millions; for rainbow trout, production was 24,000 metric tons valued at $85 millions; for channel catfish, production was 271,000 metric tons valued at $424 millions.

In the USA in 2002, the consumption of seafood had increased 7.1%, with Americans eating 4.5 billion pounds of domestic and imported seafood (Anon, 2003d)(Table 1).

Table 1. Top Ten Seafoods in the USA, 2000-2002– Consumption per Person

Aquaponics

Aquaponics is a refined branch of aquaculture. The word ‘aquaponics’ is derived from a combination of ‘aquaculture’ (fish farming) and ‘hydroponics’ (growing plants without soil), and refers to the integration of hydroponic plant/vegetable production with aquaculture[*]. It is a bio-integrated system linking recirculating aquaculture with hydroponic production of plants such as vegetables, ornamental flowers, and culinary or medicinal herbs, etc.. A brief history of aquaponics and its evolution have been provided by Jones (2002). Helfrich (2000) also examined food production through hydroponics and aquaculture.

2000	2001	2002
Canned tuna/3.50 lb	Shrimp/3.40 lb	Shrimp/3.7 lb
Shrimp/3.200 lb	Canned tuna/2.90 lb	Canned tuna/3.1 lb
Pollock/1.595 lb	Salmon/2.023 lb	Salmon/2.021 lb
Salmon/1.582 lb	Pollock/1.207 lb	Pollock/1.13 lb
Catfish/1.050 lb	Catfish/1.044 lb	Catfish/1.103 lb
Cod/.752 lb	Cod/0.577lb	Cod/.658 lb
Clams/.473 lb	Clams/.465 lb	Crabs/.568 lb
Crabs/.375 lb	Crabs/.437 lb	Clams/.545 lb
Flatfish/.423 lb	Flatfish/.387 lb	Tilapia/.401 lb
Scallops/.269 lb	Tilapia/.348 lb	Flatfish/.317 lb
Tilapia/.264 lb	Scallops/.342 lb	Scallops/.313 lb

A variation of the aquaponic process as proposed by Nuttle (2003a) involves algalculture, aquaculture and aquaponics. In this system, quail provide the manure to supplement nutrients needed for algalculture, as well as supplying some eggs and meat. Tilapia (Oreochromis spp.) are used to consume surplus micro-algae and to supplement diets. Manure from the fish, effluent and algal water may be used to fertilize and irrigate (‘fertigate’) nearby aquaponic crops. A tank system is used to produce a manure effluent that is filtered by sand before being used in algalculture or aquaponic systems; manure solids are used to make an organic compost. To date, no disease problem has occurred in this system (Nuttle, 2003b). Algae are harvested weekly, sun-dried and crushed into algal powder, blended with bread flour and/or soup to add proteins, vitamins, minerals, omega-3 oils and multi-nutrient supplements ('nutraceuticals') for end users. Since one third of the 2.3 billion people in the world are known to be impoverished, such a combination of algalculture, aquaculture and aquaponics has the potential to help resolve many health problems caused by poverty.

In Australia, aquaculture is a fast-growing industry that utilizes low-density pond-rearing systems that, to a great extent, are limited by the lack of freshwater resources because of recent severe drought – hence, these systems are becoming increasingly wasteful of a precious resource. Because of these concerns, the aquacultural industry in Australia is evolving toward the use of the more efficient (in terms of water use) indoor re-circulating systems. As well, increasingly stringent environmental regulations make aquaponics a major answer to these critical problems (Lennard, 2004).

Although the word 'aquaponics' tends to imply the use of freshwater systems, there is ongoing work in Israel and Australia on saltwater aquaponics in the production of saltwater algae and seaweed as the plant elements, and sea finfish, sea crustaceans (shrimp), sea urchins and sea mollusks (shellfish such as abalone) as the animal element (Wilson, 2003). In Israel, saltwater aquaponics provide a 'holistic but profitable approach based on algal sunlight-dependent assimilation of excess nutrients and their conversion into microalgal …. biomass. The algae produced can be sold either as a primary commodity (the world wide seaweed market handles annually around nine million metric tons) or fed on-site to saltwater algivores such as fish, crustaceans, mollusks or echinoderms (sea urchins) that feed on algae.' (Wilson, 2003).

The science of aquaponics helps agricultural production through the implementation of certain principles:

•the products from one system serve as food or fuel for a second biological system;

•the integration of fish and plants is a type of polyculture that increases diversity and by this means, enhances stability of the system;

•biological water filtration removes nutrients from the water before it leaves the system;

•the sale of greenhouse products generates income that supports the local economy.

Nutrient wastes from tanks are used to fertilize production beds via the water. The roots of plants and associated rhizosphere bacteria remove nutrients from the water. These nutrients, generated from the feces of fish, algae and decomposing feed, are contaminants that could otherwise increase to toxic levels in the tanks. Instead they act as liquid fertilizer for hydroponically grown plants. In turn, the hydroponic beds function as biofilters, and the water can be recirculated to the tanks. Bacteria in the gravel and associated with the roots of the plants have a critical role to play in the cycling of nutrients; without these organisms, the system would stop functioning (Rakocy, 1999a,b; Diver, 2000).

A number of advantages of aquaponics for greenhouse managers include:

•water carrying feces from fish is a source of organic fertilizer that allows plants in the system to grow well;

•hydroponics is viewed as a method of biofiltration that facilitates intensive recirculating aquaculture;

•aquaponics is seen as a method to introduce organic hydroponically-grown products into the market place, because the only fertility introduction is feed, and all of the nutrients pass through a biological process;

•food-producing greenhouses, yielding two products from one production unit, are naturally appealing for niche marketing and green labeling;

•in arid regions where water is scarce, aquaponics is an appropriate technology that allows food production with re-used water;

•aquaponics is a working model of sustainable food production in which plant and animal systems are integrated, and the recycling of nutrients and water filtration are linked;

•in addition to its commercial applications, aquaponics has become a popular training aid in integrated bio-systems in vocational agriculture and biology classes (Rakocy, 1999a ; Diver, 2000).

An additional advantage of aquaponics includes improved efficiency in the use of water, especially in areas with a limited supply of water (McMurtry et al, 1997). Some methods of aquaponic production have been described at: www.aquaponics.com/infohydromethods.htm ; attra.ncat.org/attra-pub/aquaponic.html.

Graham (2003a) has examined aquaponics in Alberta from a business perspective.

Plants

Common plants that do well in aquaponic systems include any leafy lettuce, pak choi, spinach, arugula, basil, mint, watercress, chives, and most common house plants, etc.. Species of plants that have higher nutritional demands and will do well only in heavily stocked, well established aquaponic systems include tomatoes, peppers, cucumbers, beans, peas, and squash, among others (Rakocy, 1999a).

Aquaponic plants are subject to many of the same pests and diseases that affect field crops, although they seem to be less susceptible to attack from soil-borne pests and diseases. Because plants may absorb and concentrate therapeutic agents used to treat parasites and infectious diseases of fish, these products cannot be used in aquaponic systems. As an example related to pond culture, Avault (2001) reported the catastrophic loss of crawfish in an integrated rice-crawfish facility, after the use of the pesticide fipronil (ICON®) for the control of the rice water weevil. Even the common practice of adding salt to treat parasitic diseases of fish or to reduce nitrate toxicity would be deadly to plants. Instead, non-chemical methods are used, ie, biological control (resistant cultivars, predators, antagonistic organisms), barriers, traps, manipulation of he environment, etc.). It also seems that plants in aquaponic systems may be more resistant to diseases that affect those in hydroponic systems. This resistance may be due to the presence of some organic matter in the water, creating a stable, ecologically balanced growing environment with a wide diversity of microorganisms, some of which are antagonistic to pathogens that affect the roots of plants (Rakocy, 1999a).

Adler et al (2000) discussed the economics of an aquaponic system in the production of lettuce, sweet basil and rainbow trout, but did not indicate temperature levels for the growth of plants or fish.

In aquaponic environments, one of the concerns in the growth of plants is the effect of insect pests. For reasons mentioned previously, pesticides are not a practical answer in dealing with problems with insects in aquaponic environments. Some control strategies include the use of the bacterium *Bacillus thuringiensis israelensis* and insecticidal soaps.

In addition, phage therapy (page 69) has been suggested for the control of some diseases such as bacterial spot on tomatoes and Erwinia sp. infections of fruit trees (fire blight) and root crops (soft rot) (Brabban et al, 2003).

Bacillus thuringiensis

As noted, one of the concerns in the aquaponic systems is the control of insect pests of plants. However, the use of man-made chemical pesticides to control these insects is not a viable option in aquaponic systems. A practical method to aid in the control of insect pests on aquaponic plants may be through the use of strains of the *Bacillus thuringiensis* (*Bt*). This bacterial organism occurs naturally in the environment and has been isolated from insects, soil and the surfaces of plants. Its value lies in the fact that it produces substances that are toxic to insects. In 1961, it was registered as a pesticide in the USA and later, in 1998, it was re-registered (Anon, 2000).

The classification of *Bt* is difficult because of the close genetic relationship among *B. thuringiensis, B. cereus, B. anthracis* (the cause of anthrax), and *B. mycoides*. *Bacillus thuringiensis* is a Gram-positive, spore-forming rod that often has insecticidal properties. It belongs to the '*Bacillus cereus* complex' which includes those species mentioned previously. The taxonomic relationships among members of the *B. cereus* group are not clear, and are the cause of some concern, since the differences between *B. cereus* and *Bt* are small and possibly plasmid-based. The main characteristic separating *Bt* from the other *Bacillus* spp. listed is the formation of insecticidal crystalline proteins (Glare and O'Callaghan, 1998).

During sporulation, some strains of *Bt* produce one or more inclusions or parasporal bodies within a sporangium. The parasporal body is often toxic to specific groups of insects, and many different insecticidal crystal proteins (δ-endotoxin) can be found in different strains and subspecies of *Bt*.

For example, products of *Bacillus thuringiensis israelensis* israelensis (*Bti*) contain the spores and parasporal crystals of *Bti* H-14 serotype that must be ingested by the larval stage of the insect to cause mortality. Following ingestion, the parasporal crystals are solubilized in the alkaline midgut of the larvae, followed by proteolytic activation of the soluble insecticidal crystalline proteins. The toxin binds to a receptor on the cell membrane of the midgut, and results in pore formation in the cell, and death of the larvae. Insecticidal effect is caused by the parasporal crystal, which for *Bti* usually contains four major proteins (27, 65, 128, 135 kDa). The crystalline toxins of *Bti* are designated Cry4A, Cry4B, Cry11Aa and Cyt1Aa (Glare and O'Callaghan, 1998).

The toxicity of *Bt* is insect-specific. There are subspecies of the organism that affect different organisms, eg, subspecies *aizaiwa* and *kurtstaki* affect moths, israelensis affects mosquitoes and flies, and tenebrionis affects beetles, etc.. These organisms are applied to food and non-food crops, green houses, forests and outdoor home use. As well, researchers have inserted genes from *Bt* in some crops (called *Bt* crops), such as corn, cotton and potatoes (Anon, 2000).

Summarizing their study on *Bt*, and *Bti* in particular, Glare and O'Callaghan (1998), commented as follows:

Strains and varieties of Bt are pathogenic to a number of insect pests, including Lepidoptera and Diptera. In 1978, the discovery of Bti, a variety specific to Diptera, especially mosquitoes and black flies, has led to the development of many products based on this species of bacteria.

There is a well-documented history of environmental safety of strains of Bt used in pest control. This fact, coupled with the nature of its toxicity and level of specificity for target hosts, has led to the use of Bt in many pest control programs in environmentally sensitive areas.

The mode of action of Bti involves the synergistic interaction of four toxic proteins; toxicity to insects is related to the crystalline proteins formed during sporulation. The organism rarely recycles in natural environments.

Aspects of the environmental impact that need to be considered include mammalian and non-target safety, effect on the environment, persistence and occurrence in the natural environment, and possible resistance of the host. For microbial-based pesticides, such as Bt, gene transfer has to be considered.

The close genetic relationship among Bt, B. cereus (an occasional human pathogen) and B. anthracis has raised concerns about possible implication of Bt in human gastrointestinal illnesses and other health problems caused by B. cereus. However, after extensive field use, no such ill effect has been detected. A specific identification system for strains of Bt would assist monitoring of future applications.

After application, Bti does not persist in the environment. In general, reports of activity after application show a decline in efficacy within days, and little residual activity after several weeks. (On plant surfaces, Bt products degrade rapidly; they are moderately persistent in soil but their toxins degrade rapidly; Bt is not native to water, and is not likely to multiply in water; Bt is practically nontoxic to birds and fish; there is minimal toxicity of most strains to bees [Anon, 2000]).

Some of the toxic proteins of Bt are encoded by genes residing on extra-chromosomal DNA (plasmids) which can be exchanged among strains and species by conjugation and/or transformation. Although genetic transfer between Bt and other soil bacteria has been demonstrated in the laboratory, it hasn't been shown in the field. Unexpected pathogens have not resulted from extensive application of Bt, which suggests that, although gene transfer may have implications for genetically modified strains, it is a lesser concern for wild-type strains.

•Some insects, especially Lepidopterans, have become resistant after constant application of strains of Bt. However, resistance has not occurred after the application of Bti, possibly as a result of the complex mode of action involving synergistic interaction among up to four proteins. The use of Bti for over 10 years in Africa, USA and Germany has not resulted in the development of resistance.

Over 40 tons of Bti were applied in west Africa alone, without reports of safety or non-target concerns.

Glare and O'Callaghan (1998) listed a wide range of acari, amphibians, fish, crustaceans and insects, etc. that are not susceptible to *Bti*. Numerous references are also provided in this publication.

Insecticidal Soaps

Compared with traditional pesticides, insecticidal soaps control many targeted pests with fewer potentially adverse effects to the user, beneficial insects, and the environment – important factors in aquaponic systems. Insecticidal soaps are effective only on direct contact with the pests. The most common soaps are made of the potassium salts of fatty acids, which disrupt the structure, and permeability of cell membranes in insects. The contents of injured cells are able to leak from these cells, and the insect dies quickly. There is no residual insecticidal activity once the soap spray has dried.

Insecticidal soaps function best on soft-bodied insects such as aphids, mealybugs, spider mites, thrips, and whiteflies. It can also used for caterpillars and leafhoppers, though these large bodied insects can be more difficult to control with soaps alone. The addition of horticultural oils can increase the effectiveness of soap for harder to kill insects. Adult lady beetles, bumble bees and syrphid flies are relatively unaffected. Soap can be used with many beneficial insects, however predatory mites, larvae of green lacewing, and small parasitic wasps (such as the Encarsia, Trichograma and Aphidius spp. wasps) can be harmed with soap. Once the spray has dried, beneficial insects can be reintroduced safely into the treated area.

Soaps have low toxicity for mammals. However, they can be mildly irritating to the skin or eyes. Insecticidal soaps are biodegradable, do not persist in the environment, and they do not contain any organic solvents. It is less likely that resistance to insecticidal soaps will develop as quickly as it will to the more traditional pesticides. Resistance within the insect tends to develop more quickly with materials that have a very specific mode of action. There is a greater chance that resistance will develop to a material that affects the nervous system of an insect, for example, in a shorter period of time. Mixtures with foliar nutrients or pesticides containing metallic ions, such as zinc or iron, may be physically incompatible or phytotoxic.

Once an insecticidal soap spray has dried, there is no residual activity because soaps are effective only on contact. Therefore, if an insect has not been coated with the spray, it will not be affected by contact with or ingesting plant material that has been treated with soap.

Insecticidal soaps should be applied when conditions favor slow drying to provide maximum effectiveness, e.g., in the early morning hours with dew coverage or in the early evening. Treating with soaps on hot sunny afternoons promotes rapid drying of the material. Thorough coverage is vital for the soap to be effective. All soaps are long chain fatty acids, but not all soaps have insecticidal properties. Insecticidal soaps are specifically formulated to have high insect-killing properties, while being safe for most plant species. The soaps have no residual activity toward insects, but repeated applications may have damaging effects on some types of plants.

Hard water reduces the effectiveness of insecticidal soaps. Calcium, magnesium and iron precipitate the fatty acids and render them useless against the insects. Good spray coverage is essential for adequate results.

Insecticidal soaps may cause signs of phytotoxicity, such as yellow or brown spotting on the leaves, burned tips or leaf scorch on certain plants. In general, some crops and certain ornamentals are sensitive to burn caused by soaps. Multiple applications in a short time interval can aggravate phytotoxicity. In addition, water-conditioning agents can increase phytotoxicity. A precipitate may be formed when the metallic ions (e.g., calcium, iron or magnesium) found in hard water bind to the fatty acids in the soap (Anon, 2004b).

Some operators of aquaponic systems simply use a mixture of ordinary soap and water, and find it to be effective in controlling insects. One recipe is: one teaspoon of liquid soap such as mild Dove®, Pure Ivory Soap®, Sunlight® or pure castille soap, per quart of water.

Fish

In Canada as well as other areas of the world today it is common to grow Nile tilapia (*Oreochromis niloticus*), a warmwater species, and in some cases, rainbow trout (*Oncorhynchus mykiss*), a coldwater species, in aquaponic systems. Tilapia appear to be one of the most popular species of fish reared in aquaponic systems.

Selection of a desirable Tilapia sp. depends on the rate of growth and their tolerance to cold. Rankings for the growth rate of *Tilapia* sp. in ponds are: *T. nilotica >T. aurea >T. rendalli >T. mossambica> T. hornorum.* Tolerance to cold becomes increasingly important, especially for pond-rearing in more northern latitudes. *Tilapia aurea* is generally regarded as the most cold-tolerant of *Tilapia* spp.. The geographic range for culturing tilapia in outdoor ponds depends on temperature. The preferred temperature range for optimal growth of tilapia is 28-30^{o}C (82-86^{o}F). Growth diminishes significantly below 20^{o}C (68^{o}F), and death will occur below 10^{o}C (50^{o}F). Thus, Tilapia spp. are ideal for indoor aquaponic systems because the warm temperatures are also needed for the growth of plants (Rakocy and McGinty, 1989).

Other species of fish that are reared in aquaponic systems in other countries include largemouth bass (*Micropterus salmoides*), sturgeon (*Acipenser* spp.), hybrid and koi carp (*Cyprinus* spp), and baramundi (*Lates calcarifer*), etc.. Other common species used in aquaponic systems include sunfish (Family Centrarchidae), bream (*Abramis brama*), crappie, pacu (Family Characidae), red claw lobster or crayfish, and ornamental fish such as angelfish (*Pterophyllum scalare*), guppies (*Poecilia reticulata*), tetras (Family Chiracidae), gouramis (Family Belontiidae), swordfish (Family Xiphiidae), mollies (Family Poeciliidae), etc..

Water

From the perspective of food safety, the source of water used in aquaponic systems has the potential to have a significant bearing on the quality of the final products, whether they are fish or plants. In Alberta, deep wells or municipal supplies of water are the most common sources of water for experimental or commercial aquaponic systems, all of which are currently indoor facilities. According to Hutchings (2003), at least two of the deep-well sources of water for privately owned aquaponic systems in the province have a high total-salt content and generally, are not suitable for the growth of plants or freshwater fish.

In terms of water quality, and the concentrations of salts and minerals needed for the production of sweet basil (or general guidelines), Racozy (2003b) noted: 'Our general guideline is to feed fish at a ratio of 57 grams per m^2

of plant growing area per day. This ratio provides good nutrient levels. We supplement with equal amounts calcium hydroxide and potassium hydroxide to maintain pH near 7.0. Every three weeks we add 2 mg/L of iron in the form of a chelated compound.

In a commercial-scale aquaponic system at UVI (University of the Virgin Islands) that was to produce lettuce continuously for 2.5 years, nutrient concentrations varied within the following ranges (mg/L) that would have produced excellent sweet basil growth':

Calcium - 10.7-82.1	Phosphate P - 0.4-15.3	Copper - 0.01- 0.11
Magnesium - 0.7-12.9	Sulfate S - 0.1-23.0	Zinc - 0.11-0.80
Potassium - 0.3-192.1	Iron - 0.13-4.3	Boron - 0.01-0.23
Nitrate N - 0.4-82.2	Manganese - 0.01-0.19	Molybdenum - 0.00-0.17

Tests for water quality by the producer have been outlined by Mitchell (1998). Other papers relevant to effluent, waste management, and standards of water quality in aquaculture in general include those of Buttner et al (1993), Chen (1998), Boyd and Gautier (2000), Negroni (2000), and Lutz (2001).

Water can be a carrier of many microorganisms including pathogenic strains of bacteria, such as Escherichia coli, Salmonella spp., Vibrio cholerae, Shigella spp., and the microscopic parasites Cryptosporidium parvum, Giardia lamblia, Cyclospora cayetanensis, Toxoplasma gondii, and the Norwalk and hepatitis A viruses. Even small amounts of contamination with some of these organisms can result in foodborne illness in humans. The quality of water, how and when it is used, and the characteristics of the crop influence the potential for water to contaminate produce. In general, the quality of water in direct contact with the edible portion of produce may need to be of better quality compared to uses where there is minimal contact.

Other factors that influence the potential for contact with waterborne pathogens, and their likelihood of causing food-borne illness, include the condition and type of crop, the amount of time between contact and harvest, and post-harvest handling practices. Produce that has a large surface area (such as leafy vegetables) and those with topographical features (such as rough surfaces) that foster attachment or entrapment of organisms may be at greater risk from pathogens if they are present, especially if contact occurs close to harvest or during post-harvest handling. Some sectors of the produce industry use water containing antimicrobial chemicals to maintain water quality or minimize surface contamination (Anon, 1998c).

The quality of agricultural water will vary -- particularly surface waters that may be subject to intermittent, temporary contamination, such as the discharge of waste water or polluted runoff from livestock operations located upstream. Ground water that is influenced by surface water, such as older wells with cracked casings, may also be vulnerable to contamination. Practices to help ensure adequate water quality may include ensuring that wells are properly constructed and protected, treating water to reduce microbial loads, or using alternative methods of application to reduce or avoid water-to-produce contact. The feasibility of these and other practices will depend on available sources of water, the intended use of the water, and the needs and resources of the particular produce operation (Anon, 1998c).

Water supplies for onshore facilities have a very much higher risk of being contaminated by intestinal bacteria than do those for offshore operations. Feces from birds, animals and humans can enter bodies of water directly or from runoff from the land. For example, Strauss (1985) (cited by Howgate, 1998) reported the results of a global health-related environmental monitoring program of 110 rivers in four regions, namely, North America, South America, Europe, and Asia-Pacific. The median fecal coliform count in these rivers was in the range of 10^3–10^4 organisms/100 mL of water.

There are very few reports concerning the presence of pathogenic intestinal bacteria in farmed fish cultivated in unfertilized systems. Some studies have reported Salmonella spp. in ponds holding catfish, and on the skin and in the intestines of these harvested fish; the incidence was higher in samples taken in the summer compared with those collected in the winter. In Japan, this organism was found at low level in ponds holding eels, and in the intestines of fish in one pond. Several organisms including Listeria monocytogenes, Plesiomonas shigelloides, and Shigella dysenteriae (but not Salmonella spp.) were cultured from hybrid striped bass (Morone saxitalis x M. chrysops) reared in three freshwater systems in Maryland, USA. Two of the sites used well water, and the third used river water (Howgate, 1998).

The few data reported come from countries with temperate climates, and indicate a very low incidence of intestinal pathogens in fish cultured in unfertilized surface waters. However, the data point to an increased hazard during warm seasons. Of greater concern are the widespread practices of using human and animal waste as fertilizers in pond aquaculture, and of raising fish in waste waters. A number of studies cited by Howgate (1998) point up the health hazards of this practice.

An extensive microbiological study of water in, and fish cultured in, ponds filled with a mixture of waste waters found that bacterial loads were very high in these waters (Buras et al, 1987). Numbers of fecal organisms were in the order of 10^6 MPN (most probable number)/100mL of water, and those of Salmonella spp. were in the order of 10^2 MPN/100mL of water. At the end of the growing season, carp and tilapia in one pond had fecal coliforms in their tissues, including the muscle. Salmonella spp. were not detected in any tissue from these fish, but were detected in the digestive tract of tilapia from other ponds on other sampling occasions. The authors compared the bacterial counts in the tissues of fish and those in the water, and concluded that, in the water, there was a limiting count of 10^4/mL (standard plate count), below which bacteria of any kind did not penetrate tissues of the fish.

Other workers showed that in pond water, there is a ‘threshhold’ of about 10^3 organisms/mL above which the enteric organisms, E. coli and Salmonella typhi, will be found in the muscle of exposed fish (Pal and Dasgupta, 1991, cited by Howgate, 1998). Although the data were limited, there was evidence indicating that fish can be cultured in wastewater-treated ponds, without a significant risk to public health, as long as some safeguards are in place.

The bacterial load on/in contaminated fish can be reduced by allowing them to ‘depurate’ in clean water for a number of days, but the rate of reduction of the bacterial counts is very slow, and ‘depuration’ is likely not practical under commercial conditions. Some authors have proposed maximum counts of some bacterial species as guidelines for the management of aquacultural products from wastewater systems (Howgate, 1998).

In its ‘Guide to Minimize Microbial Food Safety Hazards for Fresh Fruits and Vegetables’ (Anon, 1998c), the USDA recognizes certain basic principles and practices associated with minimizing hazards of microbial contamination of food from the field through the distribution of fresh fruits and vegetables. However, it is important to note that these recommendations focus primarily on the common field methods of production, and NOT those of aquaponic/aquacultural methods. Nevertheless, they provide some useful guidelines.

Some of the general principles recommended by the USDA include:

Principle 1. Prevention of microbial contamination of fresh produce is favored over reliance on corrective actions once contamination has occurred.

Principle 2. To minimize microbial food safety hazards in fresh produce, growers, packers, or shippers should use good agricultural and management practices in those areas over which they have control.

Principle 3. Fresh produce can become microbiologically contaminated at any point along the farm-to-table food chain. The major source of microbial contamination with fresh produce is associated with human or animal feces.

Principle 4. Whenever water comes in contact with produce, its source and quality dictate the potential for contamination. It is important to minimize the potential of microbial contamination from water used with fresh fruits and vegetables.

Principle 5. Practices using manure from animals or municipal biosolid wastes should be managed closely to minimize the potential for microbial contamination of fresh produce.

Principle 6. Hygienic measures and sanitation practices during production, harvesting, sorting, packing, and transportation play a critical role in minimizing the potential for microbial contamination of fresh produce.

It is important to note that infected employees may transmit a wide range of communicable diseases and infections through food or utensils. A partial list of infectious and communicable diseases that may be transmitted through produce include (Table 4):

*The symptoms of diarrhea, fever, and vomiting are also those of several other pathogens transmitted occasionally by food contaminated by infected employees.

Plumb (1999) noted that cyprinids (which include various species of carp, as well as minnows indigenous to Alberta) are extremely susceptible to infections by columnaris organisms, the cause of Bacterial Gill Disease in a variety of species of fish. Both mortality and acuteness of disease increase with temperature (Noga, 1996). In general, water from pond or irrigation sources would not likely be good sources for aquaponic systems because of the potential of introducing minnows and other species of fish, along with a variety of disease-causing agents, ie, viral, bacterial, parasitic, fungal, etc..

Algae

Pathogens Often Transmitted by Food Contaminated by Infected Employees*	
1. Hepatitis A virus	Fever, Jaundice
2. Salmonella typhi	Fever
3. Shigella spp.	Diarrhea, Fever, Vomiting
4. Norwalk and Norwalk-like viruses	Diarrhea, Fever, Vomiting
5. Staphylococcus aureus	Diarrhea, Vomiting
6. Streptococcus pyogenes	Feve; Sore throat with fever

In the context of suitable sources of water for aquaponic systems, certain species of cyanobacteria (blue-green algae)-like bodies (CLB) have been reported to cause a prolonged syndrome of diarrhea, loss of appetite and fatigue lasting a range of 4 –107 days in humans in Chicago, USA and in the country of Nepal (Kocka et al, 1991). In this study, analysis of water from various sources, raw vegetables and cow manure detected CLB on one head of lettuce from which an affected patient had eaten two days before the onset of illness. Analysis of 184 stool samples submitted from affected patients at the end of an outbreak in Nepal, detected CLB in six (3%) patients.

Cyanobacteria are a diverse collection of primitive unicellular to multicellular photosynthetic bacteria usually found in water or very moist environments. In Alberta, species of cyanobacteria (commonly called blue-green algae) are well known for their role in poisoning cattle and other species when they ingest algal blooms that are concentrated by prevailing winds in areas of shoreline frequented by these animals when they come to drink.

When nutrients are in rich supply, some species of cyanobacteria may grow without light. The CLB are so named because they possess some morphological and reproductive characteristics similar to those of the Order Chroococcales of cyanobacteria. However, CLB don't have all the characteristics of any known type of cyanobacteria. These bodies may be seen on light microscopic examination of fresh stools as nonrefractile hyaline cysts measuring 8-9 µm in diameter (Kocka et al, 1991).

In 1989, the salmon farming industry in the Sechelt Inlet, BC, a well-protected but poorly flushed fjord, was heavily affected by algae (*Heterostigma and Chaetocero*s spp.). It is believed that, as the plume of the Fraser river turns northward, it has several effects: it tends to prevent water from leaving Sechelt Inlet, thereby reducing flushing action and creating the stability favorable to the growth of algae, as well as supplying nutrients that support the growth of these algae. In particular, the damaging effects of Chaetoceros sp. are better understood than those of Heterostigma sp.. In response to gill damage caused by algal spikes, even small numbers of Chaetoceros sp. (5 organisms/mL of seawater) were sufficient to stimulate the production of massive amounts of mucus, which inhibited the uptake of oxygen. This process caused the fish to convert to anaerobic metabolism, and ultimately led to death caused by one of three factors: 1) microbial infections of damaged gills, 2) hemorrhage of capillaries in the gills, or 3) suffocation as the result of the production of excess mucus. As well, damage to the gills allowed for the introduction of bacterial pathogens such as those of bacterial kidney disease and vibriosis that killed the affected fish (Stewart, 1997).

In another study, the blue-green alga, Lyngbya sp., was found to be abundant in several ponds in which catfish had an extreme off-flavor (Brown and Boyd, 1982).

However, the most significant public health problems caused by harmful algae are:

•Amnesic Shellfish Poisoning, caused by Pseudo-nitzschia sp. (domoic acid),
•Ciguatera Fish Poisoning, caused by a variety of algal species including *Gambierdiscus toxicus, Prorocentrum* spp., *Ostreopsis* spp., etc. (ciguatoxin, maitotoxin),
•Diarrhetic Shellfish Poisoning, caused by Dinophysis sp. (okadaic acid),
•Neurotoxic Shellfish Poisoning, caused by *Gymnodinium breve* (brevetoxins),
•Paralytic Shellfish Poisoning, caused by *Alexandrium* spp., *Gymnodinium catenatum* (saxitoxins).

Anamnesic shellfish and paralytic shellfish poisonings can be life-threatening, whereas the others listed cause illnesses from which recovery does occur. Recovery time following ciguatera fish poisoning may take weeks, months and even years. These toxicities occur in various coastal waters of the USA and around the world (Anon, 2003g).

Contaminants in Water

Hormones

In 2003, a study at St Mary's College of Maryland, USA, showed that minnows located immediately downstream from a large cattle feedlot in Nebraska had significant alterations in their reproductive biology. Male fish had one-third less testosterone and their testes were about half as big as those of unexposed fish; females had 20% less estrogen and 45% more testosterone compared with females from an uncontaminated stream. These findings indicated that effluent from feedlots is hormonally active, whether from natural or synthetic hormones injected into the cattle (Anon, 2003e).

The feeding of methyl testosterone (MT) in tilapia fry to produce a uniformly male population could suggest the presence of residues of this hormone. However, since these fish are fed MT for only a few days early in life, residues of this hormone are unlikely to be of concern in these fish at the time of marketing.

The injection of hormones such as human chorionic gonadotropin (HCG), a glycoprotein, in the spawning of fish has raised questions about residues in the tissues of these fish. However, Kelly and Kohler (1994) showed that in fish injected with HCG to induce ovulation and sperm production, heating (such as in cooking), as well as human digestive enzymes, will destroy residues of this hormone. In addition, these authors found that HCG was not detected in fish injected with this hormone after an average of 19 days (range 14-35 days) post-injection, depending on the species. It is interesting to note that tests for HCG in hybrid tilapia (O. mossambicus xO. niloticus) used in these experiments were negative at 14 days post-injection.

Drugs

A study from Oslo, Norway found that marine fish near an Arctic city had been receiving a mix of caffeine and painkillers from a local sewer. As well, samples taken from a sewer outlet near a psychiatric hospital had measurable amounts of anti-epileptic drugs and anti-depressants. Also found was ibuprofen, an anti-inflammatory drug often used to treat arthritis (Anon, 2003f). Hirsch et al (1999) cited a number of papers dealing with medications, including antibiotics, antiphlogistics (anti-inflammatory drugs), lipid regulators and beta-blockers found in aquatic environments in a number of countries. These studies would appear to represent 'the tip of the iceberg'.

A study to be released by the government of Alberta into levels of drugs and antibiotics in the Bow river reflects current concerns about the safety of sources of water in this province.

Polychlorinated biphenyls

Not only biological agents, but also pollutants are of great concern (Arkoosh et al, 1998). As we live in a virtually inescapable worldwide sea of polluted air, water and soil, it seems impossible to guarantee that our food supplies are completely free of contaminants. For example, it has been reported that seven of 10 farmed salmon purchased at grocery stores in Washington DC, San Francisco, California, and Portland, Oregon were contaminated with polychlorinated biphenyls (PCBs) at levels that raise health concerns. The report, released by the Environmental Working Group (EWG), has claimed that farmed salmon are likely the most PCB-contaminated protein source in the US food supply, and contain 16 times the amounts found in wild salmon, four times the level in beef, and 3.4 times the amount found in other seafood. The source of these PCBs is believed to be the fishmeal (most supplies are from Iceland, Peru, Chile and Denmark) fed to these salmon, although the origin of these salmon was not indicated (Anon, 2003b). However, Whelan (2003) discounted these claims and questioned the credibility of the EWG as a shadowy, non-scientific group.

Despite these objections, a report in early 2004 from CBC-TV indicated that there are definite risks to human health from the consumption of more than one meal of farmed salmon every two months, because contaminants such as PCBs are 10 times higher in these fish than in wild salmon (Anon, 2004d). In a subsequent press release, Health Canada reported that levels of PCBs in farmed (and wild) salmon are within the 2 ppm safety guideline, and thus, are safe for human consumption (Anon, 2004).

In a scientific publication however, Krümmel et al (2003) showed that wild stocks of sockeye salmon (*Onchorhynchus nerka*) returning from the sea to spawn in pristine lakes in Alaska can act as bulk-transport vectors of PCBs. When these fish die after spawning, PCBs are released into the sediment of these lakes and increase in concentration by more than seven-fold in some instances when the density of returning salmon is high. The source of PCBs in this case is believed to be distant industrial activities that release these pollutants into the atmosphere and oceans.

In an experimental study, Arkoosh et al (1994) found that B-cell mediated immunity was suppressed in juvenile Chinook salmon (O. tshawytsha) after exposure to either a polycyclic aromatic hydrocarbon or to PCBs. Johnson et al (2003) provided a detailed document on the public health implications of human exposure to PCBs: the finding of elevated levels of PCBs in human populations, plus the presence of developmental and neurological problems in children whose mothers ate PCB-contaminated fish, have serious implications in public health.

Organic Pollutants -- Pesticides, Herbicides, etc.

Aquacultural systems can be affected by acute and chronic discharges of organic pollutants. Acute pollution results from single, short-lived discharges such as accidental spillages from chemical plants into water supplies or by the grounding of sea vessels. Most industrial and agricultural chemicals are readily degraded by chemical and biological processes in soil and water, and do not accumulate to any large extent, and are rapidly eliminated from fish. Some studies have measured the uptake and loss of several agricultural chemicals by/from fish, and showed that these chemicals had low accumulation co-efficients and short half-lives of the order of hours. In one study, a single dose of parathion was added to a pond. Within two days, the fish concentrated this pesticide about 100-fold compared with the concentration in water, but 'depurated' it to very low levels by a month after exposure (Howgate, 1998).

More difficult to control is chronic contamination. In aquaculture, the main routes of chronic contamination are the use of polluted water, leaching of agricultural or industrial chemicals from treated or contaminated soil into surface waters, and deposition from the atmosphere. Many chlorinated compounds are discharged into, or are present in, the aquatic environment, but three groups in particular are of concern: 1) chlorinated insecticides such as DDT, dieldrin, lindane and their degradative products, 2) PCBs and 3) polychlorinated dibenzo-p-dioxins (PCDDs) and –difurans (PCDFs). Summaries and reviews of environmental impacts and the fate and significance to human health, of chlorinated organic compounds and other contaminants in the aquatic environment have been provided by several authors cited by Howgate (1998).

According to Howgate (1998), a hazard that apparently hasn't been investigated in aquacultural products is the presence of persistent organochlorines. High concentrations of these contaminants have been found in fish from some freshwater environments. For example, there is official advice against consuming fish from some parts of the Great Lakes because of high levels of organochlorines. By analogy, it is possible that fish in freshwater aquaculture could be affected similarly. There are theoretical reasons related to the physical properties of these contaminants and to aquacultural practices, for fish from freshwater aquaculture to pose only a low risk of harm to humans – however, measurements are needed for confirmation of this point. The flux of organic contaminants in aquatic ecosystems, their distribution among different compartments of the system, and their accumulation through trophic chains have been modeled and applied successfully to field situations (several references, cited by Howgate, 1998). It would be useful to apply these models to some representative aquacultural systems in order to predict how persistent chlorinated hydrocarbons, if present, would be distributed in these systems.

Kennish and Ruppel (1996) found contamination by chlordane (1,2,4,5,6,7,8,8-octachloro-3α-tetra-hydro-4,7-methanoindane) that is used in formulations of pesticides, at levels ranging from 5-2150 ppb wet weight in the tissues of four species of finfish and one of shellfish from estuarine and coastal marine waters of New Jersey, USA. In terms of contamination of water by pesticides and herbicides, several studies have been conducted by Agriculture Canada and/or AAFRD, and have shown levels of these products in a number of samples from Alberta (Hill et al, 1996; Hill et al, 2000; Ontkean et al, 2000; Hill, 2001). As well, Miller et al (1992) and Olson et al, (2003) reported on the effects of agricultural practices on water quality in Alberta.

A joint study by Agriculture Canada and AAFRD on the effects of agricultural management practices on water quality in southern Alberta detected the presence of selected herbicides at significant concentrations in surface runoff, effluent from subsurface drainage and ground water, under surface and sprinkler irrigation. As well, significant concentrations of nitrate were found in ground water under irrigated soils subjected to high applications of manure from feedlots (Miller et al, 1992).

In a more recent study on the Crowfoot Creek watershed near Strathmore, Alberta, Ontkean et al (2000) determined that levels of total phosphorus, total coliform bacteria and total dissolved solids often exceeded both Alberta and Canadian guidelines for water quality. In addition, levels of several pesticides often exceeded guidelines. Five pesticides were detected in this study; MCPA exceeded guidelines at least 50% of the time, and Dicamba met the irrigation guideline less than 30% of the time.

Manure

A study on the application of manure and its effects on the quality of soil and ground water under irrigation in southern Alberta, found that repeated application of manure, especially at high annual rates (60-120 mega grams/ ha/year) significantly affected the quality of soil and ground water, with a buildup of nutrients in the soil, and the movement of nitrate and chloride into ground water. The report also indicated that even at low rates of application, phosphorus will concentrate in soil at the surface, a concern for potential contamination of surface water by phosphorus through surface runoff (Olson et al, 2003).

Metals

Many metals and metalloids of concern for human health exist in a number of forms and valency states, and the chemistry of their fate in water is complex. The pH of water plays a large part, and for metals, solubility decreases with increasing pH. Fresh waters tend to be alkaline, and aquacultural systems in ponds are usually maintained at a pH above 8.0. As well, ponds usually have an aerobic, organic-rich sediment, conditions under which metals tend to precipitate in the sediment as insoluble sulfides or hydrated oxides.

The concentration of metals in edible portions of aquacultural products rather than in the water in which fish are reared, is relevant to public health. Although metals can enter fish by absorption through the gills or by absorption from feed, the latter is the more important route of the two. Metals are accumulated in tissues in which their concentrations are greater than in water or feed. In vertebrate species of fish, concentrations of metals are lowest in muscle, and tend to concentrate in kidney and liver. Sewage often contains high levels of heavy metals, but measurements in farmed fish, even those in sewage-fertilized systems, with the possible exception of mercury, are below regulatory or recommended limits (Howgate, 1998).

The significant exception to the regulation of metals in muscle by vertebrate fish is mercury in its organic form of methylmercury. Inorganic mercury can be methylated by biological, predominantly microbiological, processes. This organic form is taken up by aquatic organisms, and as a result, the concentration in tissues can be orders of magnitude greater than that in the water. Because methlymercury accumulates up the trophic chain, the highest concentrations are found in predatory fish. More than 95% of the total mercury in the edible portions of fish and invertebrates is in the form of methylmercury (Howgate, 1998; Gorski et al 1999). Ward and Neumann (1999) described seasonal variations in concentrations of mercury in the axial muscle of largemouth bass (Micropterus salmoides).

Odors, Off Flavors, etc..

As a point of interest, an examination of the strong odor of freshly chopped cucumbers in the Australian grayling (Prototroctes maraena) correlated it with trans-2-cis-6-nonadienal, an organic compound known to have the intense fragrance of cucumbers. The authors of this study also noted that the natural odor of cucumbers is shared by a number of identified salmoniform fish. There would not appear to be an issue of food safety in this finding (Berra et al, 1982).

Off-flavor in pond-reared channel catfish has been reported to be a frequent problem for farmers and has been viewed as a water quality-related phenomenon. Results of experiments conducted by Brown and Boyd (1982) indicated several possible causes that included a high rate of feeding. Although correlations between chlorophyll-α and chemical oxygen demand (COD) were not significant, ponds with the lowest concentrations of chlorophyll-α and COD contained the best-tasting fish. The blue-green alga, Lyngbya sp., was abundant in several ponds in which fish had an extreme off-flavor.

The aforementioned studies represent a sample of many investigations to determine the presence of pollutants of various kinds in water in southern Alberta and other sites; they indicate that, indeed there are pollutants present in water for agricultural use. A more detailed examination of several other published studies on pollutants in water is beyond the scope of this document. Pertinent citations of environmental and experimental studies on pollutants/toxins may be found in several of the references in this section and in the Supplementary References section.

Over all, it would seem that the best sources of water for aquaponic operations are likely to be treated municipal water supplies, or those from drilled wells or springs. All such supplies of water, especially those from wells, should be analyzed prior to use for their levels of chemical constituents and contaminants, to determine their suitability for both plants and fish (Mitchell, 1998).

Feed

In human food supplies, hazards that may be related to feed for animals may include salmonellosis, mycotoxicosis (toxins from molds), and the ingestion of unacceptable levels of veterinary drugs and agricultural and industrial chemicals. The link between BSE and variant Jakob-Creutzfeldt disease in humans is another example of contamination from livestock feeds (Orriss, 1997.)

Mycotoxins are secondary metabolites produced by various genera of fungi that grow on agricultural products before or after harvest, or during transportation or storage. Some species such as Aspergillus and Penicillium can invade grain after harvest and produce toxins, whereas others such as Fusarium spp. typically infest grains and produce toxins before harvest. In some cases, Aspergillus spp. can grow and produce toxins before the crop is harvested (Orriss, 1997).

Mycotoxins may be carcinogenic (ie, aflatoxins B_1, ochratoxin A, fumonisin

B_1), estrogenic (zearalenone, and I and J zearalenols), nephro (kidney) toxic (ochratoxins, citrinin, oosporeine), dermo (skin) necrotic (trichothecenes), or immunosuppressive (aflatoxin B_1, ochratoxin A and T-2 toxin). These toxins are regularly found in ingredients for animal feeds – maize (corn), sorghum grain, rice meal, cottonseed meal, peanuts, legumes, wheat and barley. Most are relatively stable and aren't destroyed by processing, and may even be concentrated in screenings. For humans, the main source of mycotoxins is contaminated grains and cereal, rather than animal products. Hence, the hazard is much greater in developing countries in which maize and other grains form the staple diet (Orriss, 1997). Experimental studies on the effects of aflatoxin in channel catfish have been reported by Jantrarotai et al (1990), and by Jantrarotai and Lovell (1990).

According to Tacon (2000), aquaculture consumes about 35% of the world supply of fishmeal, and the expectation is that by 2010, this level will rise to 56% of the entire supply. The use of commercial feeds containing fish meal seems to be a subject of current concern, given the findings of contamination with polychlorinated biphenyls (PCBs) in farmed (Anon, 2003b) and wild salmon (Krümmel et al, 2003). Most supplies of fishmeal, which is the suspected source of PCBs for farmed salmon, originate from Iceland, Peru, Chile and Denmark.

Prior to the introduction of pelleted, expanded and extruded feeds for fish, Salmonella spp. could be recovered from feeds. At present, given the high cooking temperature used in modern processes, these bacteria are rarely, if ever, detected in feed.

Feed is an ideal vehicle for the delivery of various 'neutraceuticals' in support of the immune system of fish and other species (de Wet, 2002).

Massie (2003) discussed the commercial production of environmentally friendly feeds for aquaponic systems.

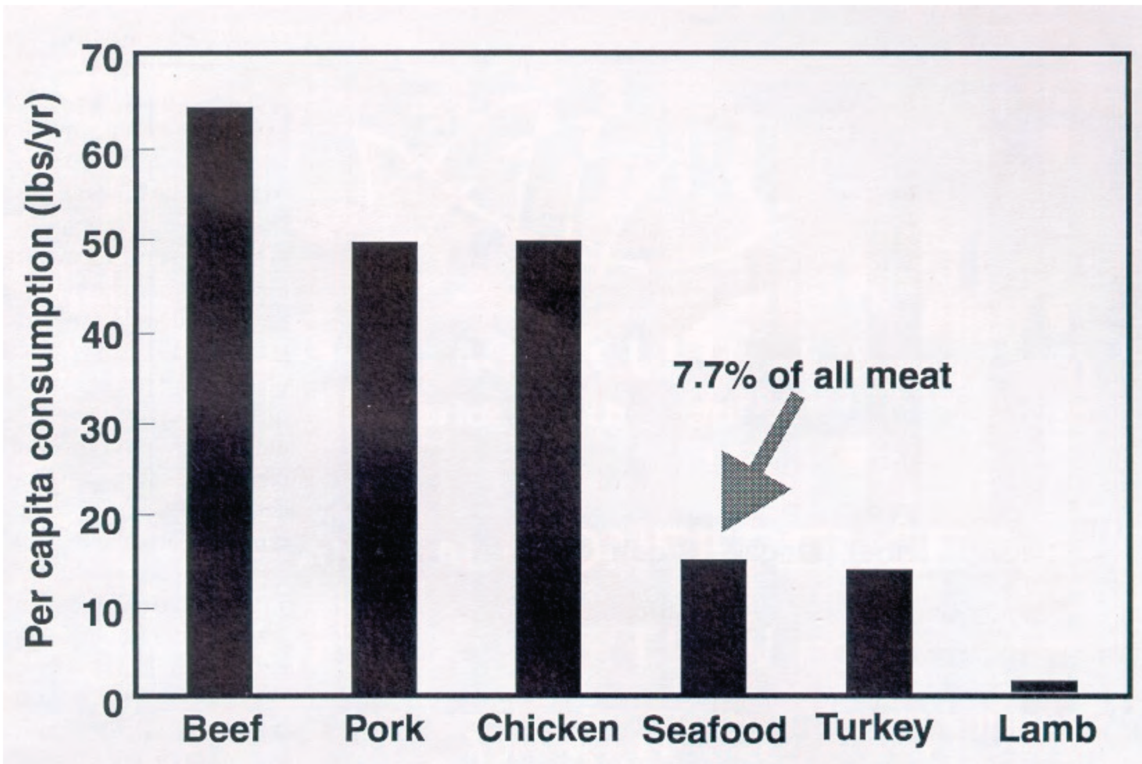
Food Safety

The safety of food for human consumption is becoming increasingly important/significant on a worldwide level. The recent, devastating industry-wide problems associated with the discovery of a single case of *Bovine Spongiform Encephalopathy* (BSE, 'Mad cow') that occurred in Alberta, plus the discovery in late 2003 of an Alberta-born *BSE*-affected Holstein cow in Washington state, USA, are only two examples. Another is the reverberations that continue to this day in connection with human illness and deaths caused by exposure to suspected animal-origin, water-borne *E. coli* serotype O157:H7 in Walkerton, Ontario in 2000. As well, among other examples, this bacterial serotype was the cause of serious illness in Japanese school children (Nickelson, 1998), in addition to illness associated with unpasteurized apple cider produced from fallen apples (ie, apples that had fallen from the trees prior to harvest) contaminated with livestock manure (Mshar et al, 1997). *Cyclosporiasis*, caused by a coccidia-like parasite that appears to be specific to humans, in raspberries imported into the USA (Hofmann et al, 1996; Nickelson, 1998; Anon, 1998a,b; Sterling and Ortega, 1999), and cryptosporidiosis (Mshar et al, 1997) associated with fallen apples, are further examples of the growing issue of the safety of the food supply in a shrinking world.

In spite of the many positive aspects of aquaculture/aquaponics -- such as the nutritional benefits of farmed fish (Hardy, 1998) -- in terms of food safety, it is important to examine the subject to determine the possible impact of factors that can adversely affect the final product.

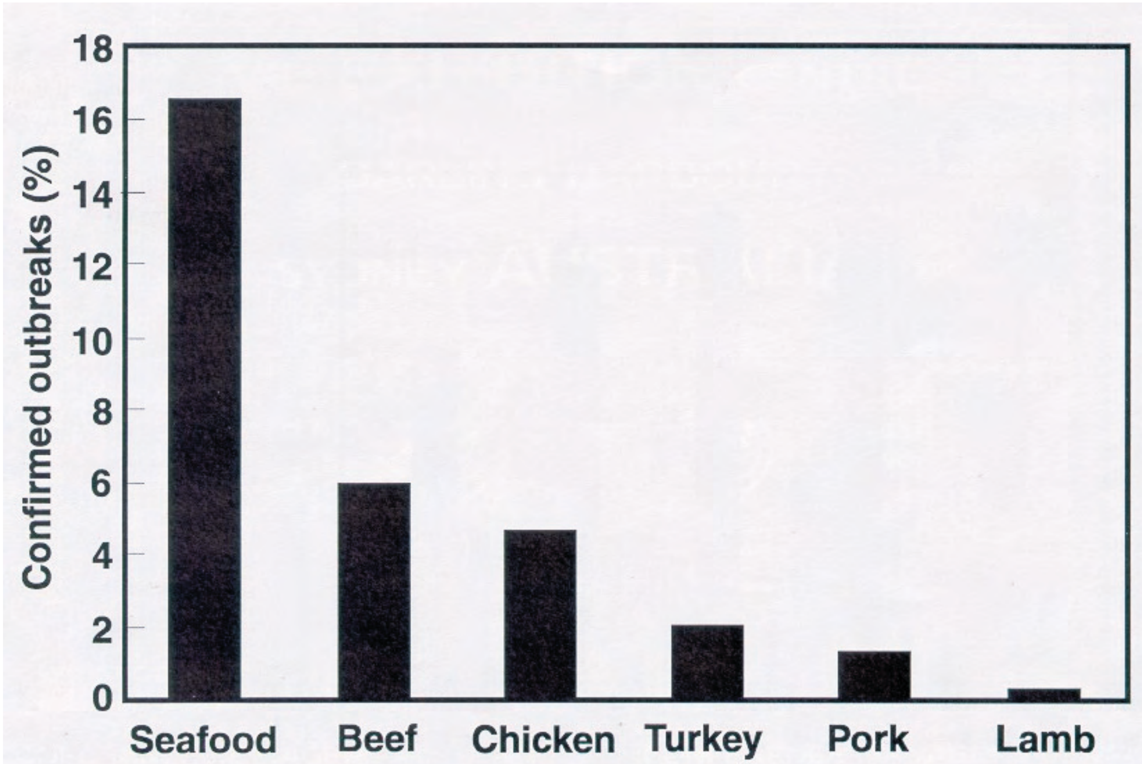
Nickelson (1998) noted that the per capita consumption of seafood (a combination of salt-and-freshwater fish) in the USA in 1998 was only 7.7% of all meat (Table 2).

Table 2. Per capita consumption of meat, poultry and seafood in the USA (From: Nickelson, 1998).



However, the percentage of c**onfirmed outbreaks of food-borne disease was highest in seafood** at almost 17%, compared with approximately 6% for beef, 5% for chicken, 2% for turkey, and just over 1% for pork, [even though the per capita consumption of seafood was much lower than it was for beef, pork and chicken (Table 3)

Table 3. Percentage of confirmed outbreaks of food-borne disease from meat, poultry and seafood (From: Nickelson, 1998).



Garrett et al (1997) examined public, animal and environmental implications of aquaculture (of which aquaponics is one component), and made the point that although most seafood is safe for human consumption, it is not entirely without risk. For example, of the seafood-borne illnesses reported to the Centers for Disease Control and Prevention (CDC) in the USA, more than 90% of the outbreaks and 75% of the individual cases were associated with ciguatoxin from a few reef species, and scombrotoxin from tuna, mackeral (Family Scombridae), bluefish (Pomatomus sp.), and the consumption of mainly raw mollusks etc.. However, none of these outbreaks was associated with aquacultural products (MacMillan, 2001).

Garrett et al (1997) noted that in many developing countries, it is a common practice to create numerous small fish ponds, an approach that can have a greater adverse effect on human health than the use of a single large pond. Small ponds increase the overall aggregate shoreline of ponds and produce higher densities of mosquito larvae and cercariae (intermediate stages in the life-cycle of flukes), which in turn, can increase the incidence and prevalence of human diseases such as filariasis and schistomoniasis, respectively.

The improper or illegal use of chemicals such as tributyl tin to control pests such as snails in ponds in some parts of the world can result in hazards to human health (Garrett et al, 1997; Howgate, 1998).

A number of reviews related to the safety of fishery products (cited by Howgate, 1998) relate to products harvested from the wild, and are heavily weighted toward the hazards of fishery products consumed in technologically more advanced countries. Most information on these hazards and on incidents of food poisoning is derived from these countries. By contrast, there is only scant literature related to food poisoning from fishery products consumed in developing countries, which are located mainly in tropical climates.

Reviews of bacteriological hazards associated with fish often separate the food-poisoning organisms into two main groups: those that are indigenous to the aquatic environment from which fish/shellfish are harvested, and those that are present on the fish/shellfish as a result of contamination of the water by human or animal feces. A third group is sometimes considered and is comprised of bacteria introduced to the product during handling and processing (Howgate, 1998).

Bacterial Diseases that may affect Fish and/or Humans

Like other animals raised for food, fish reared in aquaculture/aquaponic facilities have the potential to be affected by a variety of viral, bacterial, parasitic, and mycotic (fungal) agents, and also may be contaminated by antibiotics, mycotoxins (toxins produced by molds), pesticides, etc..

Several food-borne pathogens (parasites, bacteria, viruses, dinoflagellates) and toxins are associated with aquatic species (Harper, 2002). Because aquaponics is one component of the broader field of aquaculture, and food safety is always paramount, a look at some examples of the bacterial diseases that fish and humans may share in common seems to be in order.

Infectious disease does not happen in isolation. In order for disease to begin, the classical configuration of the interaction of the host, the agent and the environment must come into play. This idea suggests that it is the opportunity for exposure (or lack of) to these various agents and the susceptibility of the host that determine whether these specific infections will occur. The interplay of the host, the infectious agent and the environmental conditions certainly affects the final outcome of these biological encounters (Hedrick, 1998; Reno, 1998).

Topically (skin) acquired zoonotic diseases (diseases transmitted from animals to humans) including those caused by bacterial species such as *Aeromonas, Edwardsiella, Erysipelothrix, Mycobacterium, Streptococcus* (iniae), and *Vibrio* spp. have also been discussed by Harper (2002b,c). These topical infections usually occur as the result of injuries from the spines of fish or through contamination of open wounds. Although most humans have a strong natural immunity to wounds infected by marine bacteria, more serious infections are often associated with immune-compromised individuals, deep puncture wounds, and highly virulent strains of bacteria (Harper, 2002b).

The association between disease in fish and the health of in-contact humans is dramatically exemplified not only by reports of tuberculosis caused by *Mycobacterium marinum*, but also by Crayfish Handlers' disease caused primarily by *Erysipelothrix* and *Vibrio* spp. bacteria, and by infection with *Anisakis* spp. nematodes (Anon, 1997a; Alderman and Hastings, 1998). Graphic photos of human infections caused by *M. marinum* (fish tank granuloma, swimming pool granuloma) may be seen at http://tray.dermatology.uiowa.edu/MMarin01.htm . Hu and Koberger (1983) reported the isolation of *Vibrio cholerae*, the human intestinal pathogen, from 11 of 19 (58%) non-diseased American eels (*Anguilla rostrata*) from the estuary of the Suwannee river in Florida. Additional references of the occurrence of this pathogen in other identified marine species are listed in the report by Hu and Koberger (1983).

Human infections caused by the bacterium *Listeria monocytogenes* (Anon, 2002a, 2002b, 2003a), which is often associated with the ingestion of mayonnaise-based seafood and other deli salads and smoked seafood, and those caused by Salmonella spp. and E.coli, are of importance and concern (Penner, 2003).

Ignorance of the microbial profile of aquacultural products can also affect human health and has led to the transmission of streptococcal infections from tilapia to humans (Weinstein et al, 1996). As well, a change in marketing strategies to sell live fish in small containers instead of ice packs, has resulted in human infections with Vibrio spp. bacteria originating in tilapia in Israel (Garrett et al, 1997).

The abuse and misuse of raw chicken manure as fertilizer for ponds may result in the transmission of Salmonella spp. to the cultured product, and hence, to humans (Garrett et al, 1997). Several species of aquatic animals, including snails, clams, oysters, newts, frogs, crayfish, turtles, alligators, crocodiles and fish, have been known to carry Salmonella spp. (several references cited by Bocek et al, 1992). Souter et al (1976) found enteric (intestinal) bacteria in a study of common carp (Cyprinus carpio) and white suckers (Catostoma commersoni) from five locations, four in Ontario and one in Quebec. As well, these authors cultured Salmonella enteritidis serotype Montevideo from the intestines of fish netted in the St Lawrence river at Montreal. It is notable that in 1975, the International Joint Commission reported that four of the five areas sampled did not meet water quality objectives in 1974 (Souter et al, 1976).

Because of the foregoing findings, especially the observations of Garrett et al (1997), some concerns about food safety related to the use of quail in aquaponic systems, as proposed by Nuttle (2003a), arise because of the use of these birds in an aquaponics system. However, to date, Nuttle (2003b) has not reported any disease problem in this system. Nevertheless, in the absence of quality-control measures the potential for disease issues to arise continues to exist in this system.

An experimental study by Bocek et al (1992) determined that silver carp (Hypophthalmichthys molitrix) could retain a streptomycin (antibiotic)-resistant strain of Salmonella typhimurium in their intestines. However, other internal organs such as kidney were not affected. Isolations of this organism from the intestine occurred for 14 days after exposed fish were placed in clean water. These findings and those of Souter et al (1976) indicate the potential for the contamination of aquatic environments, and the transmission of Salmonella spp. and other enteric pathogens of humans to other species of fish in the same environment, and by extension, to humans consuming these fish. Many species of Salmonella may infect humans. However, other biological factors may mitigate the possibility of such transmission (MacMillan, 2001).

Ignorance of the hazards associated with the use of untreated animal or human waste in ponds has huge implications in human health. For centuries, those engaged in food production have cultured species of fish in wastewater-fed ponds and have grown secondary vegetable crops in waste water and sediment material in integrated aquacultural operations. Under these conditions, the potential for the transmission of human pathogens to cultured species of fish is seldom considered (Garrett et al, 1997).

Rice et al (1984) conducted a controlled study in Malaysia where four species of fish, (silver, bighead [*Aristichthys nobilis*], grass [C*tenopharyngodon idella*] and common [*Cyprinus* carpio] carp, and shrimp (*Macrobrachium rosenbergii*) were reared in ponds that received swine manure as fertilizer. These workers showed that although the (worm) parasites Ascaris and *Trichuris* spp. were present in the manure from hogs, and in pond water and sediments, human parasites were not found in the digestive tract of necropsied fish or shrimp. Ponds enriched with swine manure generally supported more pathogenic bacteria as well as more total bacteria, compared with control ponds.

Different species of bacteria including Aeromonas, Pseudomonas, *Corynebacterium* spp. and several species of *Enterobacteriaceae* were isolated in relatively low numbers from the scales of fish grown in swine manure. These authors concluded that since low numbers of pathogenic bacteria and human parasites were seen in/on these carp and shrimp, potential infections of processors or consumers would be reduced by proper handling and processing.

In aquaculture, despite the potential for the transfer of pathogenic bacteria from fish to humans, there are several natural barriers to the transfer of resistance factors among bacterial species and the occurrence of enteric bacteria that infect humans. These barriers include temperature, itinerant (transitory) microbial flora, and important physiological and evolutionary differences. Various physical factors may also decrease the probability of the transfer of resistance.

Likely the most obvious natural barrier is that of body temperature. Farmed aquatic species are all poikilothermic, with a labile body temperature that is dependent on environmental temperature. In poikilotherms, body temperature is generally too low to be considered optimal for the proliferation of most intestinal bacteria likely to infect humans. Most human food-borne pathogens prefer the comparatively warm temperatures of homeotherms (MacMillan, 2001). However, the rearing of a species such as tilapia could allow for the proliferation of an introduced human pathogen, since the warm temperatures required for optimal growth of this species approach those that are also suitable for the growth of bacterial pathogens (Rakocy and McGinty, 1989).

Streptococcus spp.

Streptococcal septicemia (invasion and multiplication of bacteria in the bloodstream) has occurred sporadically and as epizootics (outbreaks) among cultured freshwater and saltwater fish in many parts of the world. For example, Kusuda et al (1978) described the isolation of a *Streptococcus* sp. from an epizootic in cultured eels. However, the streptococcal species most commonly involved is *Streptococcus iniae*. It is mainly a disease of tilapia, hybrid striped bass (*Morone* saxatalis x *M. chrysops*) (Stoffregen et al, 1996), and rainbow trout. The known cyprinid species that are affected include golden shiner and blue minnow (*Fundulus grandis*) (experimental). Some species that **don't** appear to be affected by this agent include common carp, big-mouth buffalo (*Ictiobus cyprinellus*), goldfish, and certain species of tilapia (eg., *Sarotherodon mossambicus, Tilapia sparrmanii*) (Inglis et al, 1993). However, Johnson (2003) noted that S. iniae is a serious problem in some operations rearing Nile tilapia (*T. nilotica*), and equally importantly, it can be an important disease of humans. Because of these facts, infections caused by *S. iniae* in humans and tilapia will be discussed in some detail, as follows.

Tilapia spp. are common food fish reared in aquacultural/aquaponic settings. It seems that one of the most serious diseases with which producers may be faced in the rearing of tilapia is infection by S. iniae, a β-hemolytic bacterial species that was first reported in 1976 as the cause of 'golf ball disease' in Amazon freshwater dolphins (*Inia geoffrensis*) housed in aquaria in the USA. The first streptococcal infection in fish was reported from rainbow trout in Japan, and in tilapia in 1970. Outbreaks of this disease in tilapia were reported later from Japan in 1981, Taiwan in 1985, Israel in 1986, and the USA and Saudi Arabia in 1992. The species was renamed *S. shiloi* in Israel in 1986, but following taxonomic validation in 1995, the name S. iniae was retained because it was published before *S. shiloi* (George, 1998). Worldwide, streptococcal infections have been reported from about 22 species of fish. The most seriously affected species include yellowtail (*Seriola quinqueradiata*), eel (*Anguilla* spp.), tilapia, striped bass (*M. saxitalis*), rainbow trout and turbot (*Scophthalmus* maximus). The countries in which fish are most affected by this disease include Japan, Israel, the USA, South Africa, Australia and Spain (George, 1998).

Infection by S. iniae in humans was first recorded in Texas, USA in 1991 (George, 1998), and in Ottawa, Ontario in 1994 (Weinstein et al, 1996). In the initial report from Ontario, *S. iniae* was isolated from four individuals who had a history of preparing fresh, whole aquaculturally-reared fish purchased locally. Three of these individuals had a history of injury to their hands during preparation of these fish. While she was preparing tilapia, one individual punctured her hand with a bone, the second had lacerated the skin over her finger with a knife that had just been used to cut and clean an unidentified freshwater fish, and a third punctured her finger with the dorsal fin of a tilapia she was scaling. The period from injury to the onset of symptoms ranged from 16-48 hours. At the time of hospitalization, these patients had fever and cellulitis (inflammation of the connective tissues beneath the skin), with spread of the infection above the point of injury. Blood cultures from all three patients were positive for S. iniae. Treatment with beta-lactam antibiotics (*penicillins* or *cephalosporins*, etc.) or clindamycin resulted in complete resolution of the illness.

The fourth patient, a male, had a week's history of increasing pain in a knee, intermittent sweating, fever, difficult breathing, and confusion. About 10 days before he was admitted to hospital, he had prepared a fresh tilapia, but there was no indication that he had injured himself at that time. Blood cultures from this patient were positive for S. iniae. He was diagnosed with valvular endocarditis (infection of the heart valves) and meningitis caused by *S. iniae*. Treatment with beta-lactam antibiotics and erythromycin resulted in recovery. Later, surface cultures from four fresh tilapia collected from selected fish markets by health authorities yielded *S. iniae* from three fish; however the strains of S. iniae isolated were different from those involved in the outbreak.

The source of fresh whole tilapia sold in Ontario was fish farms in the USA. As a result, samples of live aquacultured fish imported into Canada were to be collected and cultured for *S. iniae.* Additional human cases of the disease have been identified both in Canada and the United States, and further isolations have been made from several species of fish (CMPT, 1997).

Streptococcus iniae is also known to cause disease in tilapia. The organism is transmitted horizontally from fish to fish. It may colonize the surface of the fish or it can cause invasive disease that may result in mortalities of 30-50%. Affected fish may swim erratically and display a whirling motion at the surface of the water, as a result of meningitis. Externally there may be darkening of the affected fish, dorsal rigidity, swollen abdomen, bulging eyes (exophthalmos), corneal opacity, rupture of the eyes, as well as hemorrhage of

the lower jaw, abdomen, opercula, anus and the base of fins. Internally, bloody fluid (ascites) may be found in the body cavity, along with a pale liver and enlarged spleen; affected fish die within several days of infection (Perera et al, 1994; George, 1998). In tilapia, signs of infection may be absent, or the disease may cause losses of 30-50% in affected fish.

Edwardsiella spp.

Two members of the *Edwardsiella* spp. group of bacterial organisms infect fish: *Edwardsiella tarda* [formerly called *E. anguillimortifera* and *Paracolobactrum anguillimortiferum* (Noga, 1996)] and *E. ictaluri*. These bacteria produce two different diseases.

Edwardsiella tarda causes septicemia (invasion and multiplication of bacteria in the bloodstream) in warmwater fish, particularly in eels and catfish (*Ictaluris punctata*), but is also known to cause disease in tilapia (Alceste and Conroy, 2002). This organism is widely disseminated in aquatic animals, pond water and mud, occurrences that provide ready opportunities to re-infect cultured fish. Infected fish processed for human consumption are a source of this organism, which can cause gastroenteritis in humans.

Edwardsiella ictaluri causes a septicemia in catfish, and is a highly contagious disease with serious effects on the commercial culture of catfish (losses from 10-50%) in the southern USA (Inglis et al, 1993; Noga, 1996).

Edwardsiella sp. septicemia is a mild to severe systemic disease of mainly warmwater fish in the USA and Asia. It is caused by *E. tarda* and is also called fish gangrene, emphysematous putrefactive disease of catfish, and Red Disease of eels. Catfish and eels, notably Japanese eels (*Anguilla japonica*) [but not reported from American (Anguilla rostrata) or European eels (*Anguilla anguilla*)], and catfish, are the most commonly infected species. However, the organism has been isolated from a variety of species of fish, including goldfish (*Carassius auratus*), common and grass carp, tilapia, etc. (Noga, 1996;).

In the USA, *E. tarda* has been isolated from 75% of water samples holding catfish, 64% of mud samples from ponds holding catfish, and 100% of frogs, turtles and crayfish from ponds containing catfish. The source of this organism is likely intestinal contents of carrier animals. Catfish and eels, as well as amphibians and reptiles, are likely sources of infection. Although environmental stressors don't appear to be essential for infection to occur, high temperature, poor water quality and crowding are likely contributing factors. Infections caused by *E. tarda* are not confined to fish, but are also found in snakes, alligators, sea lions, birds, cattle, swine and humans (Inglis et al, 1993; Noga, 1996).

Edwardsiella tarda is an important zoonotic disease of humans in which it is a serious cause of intestinal disease. In humans, it has also been implicated in meningitis, liver abscesses, and wound infections; most commonly, however, this organism causes gastroenteritis. Catfish fillets in processing plants are often contaminated with this organism that may spread to humans by the oral route (Noga, 1996). In an earlier study, Brady and Vinitnantharat (1990) injected live catfish with *E. tarda* or *E. ictaluri, Aeromonas hydrophila,* and

Pseudomonas fluorescens, and when the injected fish died or were moribund, they were frozen at –20°C. These workers found that *E. tarda* could be recovered on culture for 50 days, *E. ictaluri* for 30 days, *A. hydrophila* for 20 days, and *P. fluorescens* for 60 days, in these frozen fish.

Aeromonas spp.

Aeromonas spp. bacteria occur widely in fresh water and sewage. For example, Henebry et al (1988) found that the most common bacterium in the gut of young silver carp fed alternately on manure-silt and algal sources of food was *A. hydrophila*. Some species of Aeromonas are pathogenic for fish, and occasionally, to humans.

According to Noga (1996), motile aeromonad infection (MAI) is likely the most common bacterial disease of freshwater fish, all of which are probably susceptible. Motile aeromonads can also inhabit brackish water, but they decrease in prevalence with increasing salinity.

By far the most important bacterial pathogen of fish is *Aeromonas hydrophila* (synonyms: *A. liquefaciens*, *A. formicans*). This group of organisms is often described as the *A. hydrophila* complex. Motile aeromonads are common on the mucosal surfaces and internal organs of clinically normal fish, and are often secondary invaders in infections such as those caused by A. salmonicida. Kumar and Dey (1985) reported on septicemia (invasion and multiplication of bacteria in the bloodstream) caused by *A. hydrophila* in silver carp.

Davis and Hayasaka (1983) found that during the first nine months of culture, glass eels and elvers of the American eel (*Anguilla rostrata*) were affected by only a small number of bacterial pathogens and diseases. *Aeromonas* hydrophila accounted for 98.3 % of the *Aeromonas* spp isolated from these eels. In the next several months, only *Aeromonas* spp. were found to be associated with disease in these eels.

Aeromonas salmonicida causes a fatal outbreak of disease called furunculosis in salmonids. ‘Furunculosis’ is a term borrowed from a human condition. However, the changes seen in salmonids affected by this condition do not resemble the pus-filled swellings on the skin of humans affected by classical furunculosis. Despite these differences, the designation persists because it is too well established in scientific literature to be changed (Inglis et al, 1993; Cipriano and Bullock, 2001). Further information on this genus can be found in Cipriano et al (1996) and Cipriano et al. (1996a).

As a point of interest, it is useful to be aware that infections caused by Aeromonas spp. in humans have been known since the early 1950s (Mathewson and Dupont, 1992). The most common manifestation of Aeromonas spp. infections in humans is bacteremia (the presence of bacteria circulating in the bloodstream). As well, wound infections in humans are becoming more commonly reported in the scientific literature. The importance of these infections in humans is related to the fact that they can have fatal or seriously debilitating results, such as the amputation of affected limbs (Musher, 1980). Accordingly, wound infections should not be washed in river or pond water!

Erysipelothrix rhusiopathiae

Although this bacterial organism is not a pathogen of fish, it has been isolated from a number of different farmed species of fish such as cod (Family

Gadidae and herring (Family Clupiedae), etc.. It can survive for long periods of time in the mucous layer of fish, and is transmitted to humans through skin injuries from scales, teeth, bones or spines. In humans, the organism can cause three different types of lesions. Firstly, it can cause what is known as 'fish rose', a localized red-purple lesion on the hand or fingers. Secondly, it can cause a more diffuse skin lesion. Although rare, the last form is a septicemia that can lead to endocarditis (infection of the heart valves or the inner wall of the heart). Mortality rates for endocarditis can be 50%. Those at highest risk of infection by this organism are fish producers, handlers and fishermen (Harper, 2002b).

Vibrio spp.

Vibriosis is a common disease in freshwater and marine fish, and can cause localized ulcers of the skin, inappetance, darkening of the fish, abdominal distention, anemia, subdermal cavitation, plus lesions in muscle and eyes. Several different Vibrio spp. cause disease in marine fish, but not all of them are human pathogens. The known zoonotic pathogens include *V. cholerae*, *V. damsela*, *V. vulnificus*, and *V. parahaemolyticus*. Human disease associated with *Vibrio* spp. is most often associated with the ingestion of raw or improperly cooked fish and shellfish. Clinical signs in humans can include mild gastroenteritis, diarrhea, fever, septicemia, and may even lead to death (Harper, 2002b). As an example of the potential seriousness of rare *Vibrio* spp. infections in humans, in late 2003,*V. vulnificus* was confirmed to have caused the death of an individual working with hybrid tilapia (*O. mossambicus*, *O. nilotica* and *O. aureus*) in Israel, where tilapia are reared in brackish water (600-3000 ppm salt) (Lenoir, 2003).

Mycobacterium Spp.

Mycobacteria, consisting of a single genus, Mycobacterium, are currently represented by at least 54 recognized species of organisms. Most of these agents are free-living in soil and water; some species cause disease in animals and humans. Mycobacterial infections of fish are, in fact, tuberculosis of a number of species. The disease affects a wide range of freshwater and marine species of fish, and particularly aquarium fish, especially the freshwater families Anabantidae (climbing gouramies), Characidae (piranhas, tetras, etc.) and Cyprinidae (Noga, 1996). However, it seems likely that any species of fish may be infected. Mycobacteriosis is a chronic systemic disease, with lesions (granulomas) developing externally and throughout internal organs.

The species of Mycobacterium that are pathogenic for fish are *M. marinum*, *M. fortuitum* and *M. chelonae*. Treatment is not satisfactory, and diseased stock should be destroyed, especially since these agents can infect humans as well as fish (Inglis et al., 1993).

Mycobacterium marinum represents the largest proportion of all mycobacteria isolated from fish. Tropical freshwater and tropical marine fish may be infected, but natural infection in a temperate-water species has not been reported (Inglis et al, 1993).

The isolation of *M. fortuitum* has been documented less frequently than that of *M. marinum*, but the prevalence of infection by *M. fortuitum* is likely more widespread than is suspected. This organism infects fish from both tropical and temperate waters, but is most common in freshwater fish, although infection is known to occur in marine species (Inglis et al, 1993).

So far, infection by *M. chelonae* has been identified only in coldwater salmonid species. This infection has been specifically linked to freshwater hatchery environments, but once established, it seems to persist throughout both fresh and saltwater phases of the life cycle (Inglis et al, 1993).

The main signs of this illness depend on the species of fish involved and the existing ecological conditions (Inglis et al, 1993). The common findings are listlessness, lack of appetite, emaciation, difficult respirations, exophthalmia, skin discoloration and external lesions that range from loss of scales to nodules, ulcers and necrosis of fins as signs of advancing infection (Inglis et al, 1993). In coldwater salmonids, there may be no external sign of the disease other than mortality, or variable degrees of skin coloration. Internally, lesions are similar in tropical and coldwater fish. Visible or microscopic tiny gray-white lesions may be found scattered in any tissue, but especially in spleen, liver and kidney.

Mycobacteria that are pathogenic for fish can infect humans, in which the lesions are usually localized, non-healing ulcers (fish tank granuloma, swimming pool granuloma) that may be difficult to treat because of resistance by the causative organisms to most anti-tuberculosis drugs. For photos of lesions in humans, see http://tray.dermatology.uiowa.edu/MMarin01.htm. Although the risks to healthy humans are low, infections caused by M. marinum have been reported from HIV-infected individuals. Accordingly, gloves should be worn by individuals who are at risk when cleaning aquaria or handling fish (Noga, 1996). Johnson (2003) too has warned of the zoonotic dangers of this organism to individuals working with species of carp.

Listeria Spp.

Listeria spp. are widespread in soil and water. This species has been isolated with high frequency from both fresh and marine waters and from sediments. Several surveys of fishery products (raw and processed fish collected at the retail level or during processing) for *Listeria* spp. have recovered this organism with frequency: often, it has been recovered from one quarter of the samples examined (Howgate, 1998). It is notable that in their review of *Listeria* spp. in seafoods, Dillon and Patel (1992) did not cite any reference to the presence of this species on freshly harvested fish, either from the wild of from aquacultural sources. The organism has been found in a variety of raw foods such as uncooked meats and vegetables, as well as in processed foods that are contaminated after processing – ie, soft cheeses and cold cuts. Vegetables can become contaminated from the soil or from manure used as fertilizer (Anon, 2003h).

In humans, listeriosis is a serious infection caused by the ingestion of food contaminated with the bacterium *Listeria monocytogenes*. This disease affects primarily pregnant women, newborn infants, and adults with weakened immune systems. Pregnant women are about twenty times more likely than other healthy adults to be infected with this bacterium; persons with AIDS are almost three hundred times more likely to be infected compared with those with normal immune systems (Anon, 2003h). It has been estimated by the CDC that up to 2,500 cases of listeriosis resulting in 500 deaths (20% mortality!) occur annually in the USA (Anon, 2002c). In 2002, the CDC reported an outbreak of listeriosis attributed to contaminated poultry from a processing plant in the northeastern USA, and resulted in the recall of 27.4 million tons of ready-to-eat poultry products (Anon, 2002a, b).

Infected pregnant women may have only a mild influenza-like illness that can lead to miscarriage or stillbirth, premature delivery, or infection of the newborn infant.

Although several of these zoonotic diseases are self-limiting or uncommon, accidents can happen while gutting or handling fish. Immunodeficient patients (ie, those on steroid therapy, HIV patients) are at high risk. Good personal hygiene and proper sanitation during work with fish will help to prevent infections. As well, the assistance of proper medical care in treating abrasions or cuts, especially if healing seems delayed, progresses in size, forms a nodule, or if other signs arise (Harper, 2002b).

Clostridium botulinum

In freshwater environments, a high incidence of the bacterial organism *Clostridium botulinum* has been found in fish and in sediments in trout farms in Britain and Denmark, but given the widespread occurrence of this organism on the land and in water, it is very likely much more widespread in other farms (Howgate, 1998). The causative organism is not infective but produces potent toxins. There are seven toxigenic types of *Clostridium botulinum* (A to G) that produce potent neurotoxins. Type E has been incriminated in each recorded case in fish. Spores of the organism are very heat-resistant, and can withstand moist heat at 100^{o}C for several hours, but are destroyed at 120^{o}C in five minutes (Inglis et al, 1993).

Botulism causes a severe illness in humans and other animals; in humans, headache, disorders of vision, weakness and respiratory distress, vomiting, abdominal pain and diarrhea may be followed by neurological signs within one to six days. Resulting partial paralysis may persist for months; if the outcome is fatal, death usually occurs in the first 10 days of the illness (Inglis et al, 1993.)

In fish, the neurotoxin causes progressive muscular paralysis that affects all but the caudal fin. As a result, fish swim erratically and lose equilibrium; affected fish float on the surface, sink to the bottom, apparently recover and repeat the cycle until death intervenes (Inglis et al, 1993).

The presence of the organism in farmed trout has caused considerable debate about the risks of botulism in processed fishery products. The risk factors are more associated with aspects of processing, packaging and storage of the product than with the presence of the organism in fish. In any analysis of the public health hazards of farmed fish, it must be assumed that fish will carry spores of C. botulinum (Howgate, 1998). According to Inglis et al (1993), the risk to human health from botulism associated with seafood is real but not huge. In a review by the CDC in the USA, it was found that fish or fish products were implicated in 4.4% of outbreaks of botulism. Most of these involved canned, smoked or vacuum-packed seafood of the kind usually consumed without further cooking (which ordinarily would have inactivated the toxin).

The incidence of botulism is low and is associated with bad husbandry. The major reservoir of toxin and disease is fish that have died or are dying of the disease. Stock in contaminated systems must be slaughtered, pond debris removed and all buried in quicklime. Ponds holding affected fish can be returned to use within a month, but improvements in flow rates of water and reduced stocking densities must be made (Ingis et al, 1993.)

In Hawaii, in tilapia affected by the Hawaii Tilapia Rickettsia-Like Organism (HTRLO), blood vessels become blocked by large aggregates of inflammatory cells that damage the gills and diminish or block the transport of oxygen. The disease seems to be a seasonal event and occurs primarily during the winter, leading to speculation that it is the result of a complex interaction between the organism and one or more environmental factors, particularly low temperatures. Affected fish have pale streaks in the gills or they appear pale in color. Research continues (Anon, 1996).

As exemplified in the information on *Streptococcus iniae*, a few published reports that reviewed safety or health and farm-reared fish, suggest that it is only by puncture wounds associated with tilapia or catfish, or the consumption of raw fish, that any human disease has occurred (MacMillan, 2001).

In a UK study on *Campylobacter* spp. infections, a cause of gastrointestinal illness in humans, Evans et al (2003) found three major factors that contributed to these infections: eating chicken, eating salad vegetables such as tomatoes and cucumbers, and drinking bottled water. The study suggested that vegetables could be contaminated either before or after the point of sale. Contamination at the source could occur through contaminated soil or water during harvesting. As an example of the latter, these authors cited a report (Long et al, 2002) of imported lettuce as a vehicle for outbreaks of infection with Salmonella and Shigella spp. bacteria in the UK. However, they made the point that such infections derived from fruit and vegetables are rare. Further, the study showed that the *Campylobacter* spp. infections were mainly the result of cross-contamination in the kitchen, and that the association with tomatoes and cucumbers was the result of the need for extensive handling of these vegetables during preparation, and often the use of a chopping board.

Public Health and Bacteria Associated with Fish

Mankind is more comfortable with both laws and sausages when he doesn't know how they're made. Cross-Country Checkup, 2003

Human infections that may be caused by bacteria in fish include food poisoning and gastroenteritis (*Salmonella*, *Vibrio*, Clostridium spp., *Campylobacter jejuni*, etc.), wound infections and mycobacterial infections (tuberculosis).

Table 5 lists significant human pathogens isolated from fish or their environment (Inglis et al , 1993):

Salmonella spp.	Food poisoning
Vibrio spp.	Food poisoning
Campylobacter spp.	Gastroenteritis
Plesiomonas shigelloides	Gastroenteritis
Edwardsiella tarda	Diarrhea
Aeromonas hydrophila	Diarrhea, septicemia
Pseudomonas spp.	Wound infection
Mycobacterium marinum	Tuberculosis
Erysipelothrix rhusiopathiae	Erysipeloid, septicemia
Leptospira interrogans	Leptospirosis
Clostridium botulinum	Botulism

Food poisoning caused by pathogens in the aquatic environment

Fish-borne bacterial food poisoning may be caused by the bacteria naturally present in the aquatic environment, those derived from aquatic pollution, or those introduced during handling and processing. Bacteria naturally present in the aquatic environment and implicated in food poisoning include *Vibrio* spp. and *C. botulinum* type E. Twenty-three of 272 samples of seafood and water taken off southwest India contained *Vibrio cholerae* non-01; the pathogenicity of strains of *V.cholerae* non-01, *V. parahaemolyticus*, *V. vulnificus*, and *V. mimicus* isolated in the same region has been confirmed (Malathi et al. 1988, cited by Inglis et al, 1993). Sporadic cases of tropical diarrhea have been attributed to consumption of freshwater fish carrying *Edwardsiella tarda* and *Plesiomonas shigelloides*, with species such asTilapia providing the natural habitat of these bacteria.

If fish contaminated with these pathogens are harvested and stored at temperatures conducive to bacterial multiplication and then consumed, gastroenteritis may result. In humans, the symptoms associated with V. parahaemolyticus are characterized by abdominal pain, vomiting, watery diarrhea, fever, chills and headache. The incubation period is 12-48h and recovery occurs commonly within 5 days. Usually cooking or heat processing kills V. parahaemolyticus but low temperature storage only reduces multiplication, and organisms have been detected after two days storage at 4^{o}C from fish contaminated with about 103 cells per gram. Vibrio vulnificus causes septicemia, chills, fever, sometimes vomiting and diarrhea, and cutaneous lesions and ulcers may occur at the extremities. The onset of symptoms occurs within 24 hr of exposure. Individuals with impaired function of liver or stomach are particularly vulnerable.

Bacterial spoilage of fish

As noted by Inglis et al (1993), bacterial spoilage in fish is a complex process involving microbiological and non-microbiological processes. Nonmicrobiological deterioration is caused by endogenous proteolytic enzymes that are concentrated particularly in the head and viscera; such enzymes attack these organs and surrounding tissues after death. Activity is particularly great in fish that recently had been feeding heavily, leading to early rupture of the gut with dissemination of general contents including enzymes and micro-organisms. Enzymatic spoilage may be compounded by deterioration resulting from oxygenation of unsaturated fatty substances that cause loss of flavor and the development of rancidity.

During life, micro-organisms are present on the external surfaces of the fish and in the gut, but the muscle is normally sterile. After the death of fish, microbiological organisms diffuse into the muscle and increase in number, slowly at first, and then more rapidly, and cause a sequence of changes in odor and flavor. The rate of deterioration related to all processes can be slowed by immediate storage at low temperature, and by rapid removal of the viscera, skin and head. In regard to aquaculture, most of the global production occurs in Asia and the Pacific where refrigeration and other processing facilities may be limited. Several methods of preservation are available – icing, canning, chemical preservation, etc. – to delay these effects.

The bacterial flora of fish is derived essentially from the aquatic environment and varies with seasonal and environmental factors. Further, it is affected by the type of storage and processing following capture. Fish from subtropical waters have a high percentage of mesophilic bacteria, whereas in fish caught in cold waters, psychrophiles such as *Pseudomonas*, *Achromobacter* and *Flavobacterium* spp. predominate. During low-temperature storage, numbers of Pseudomonas spp. increase substantially and in one study, were found to reach 60-90% of the total count of bacteria in coldwater fish. *Pseudomonas*, *Alteromonas* and related species are considered to comprise the major part of the spoilage flora. They grow actively at low temperatures near 0^oC, and attack thioamino acids and thioamines to produce hydrogen sulfide and other volatile sulfides. Microbiological safety and quality are usually determined using 'marker' organisms to indicate the presence of given pathogens or toxin formers at specified levels.

The bacteria which present a public health risk grow best at $35\text{-}37^oC$, whereas spoilage bacteria have a lower optimum temperature for growth. A total count of bacteria in a sample incubated at the higher temperature gives an indication of the degree of contamination with potentially harmful bacteria. Determination of the incidence of E. coli and coliforms indicates fecal contamination, and sometimes it may be useful to investigate the presence of specific pathogens such as coagulase-positive Staphylococcus and Streptococcus spp.. Elevated levels of histamine are taken to indicate bacterial quality more generally and the risk of scombroid poisoning.

Antibiotics and Bacterial Resistance

Abuse of modern technology in aquaculture includes the willful misuse of therapeutic drugs, chemicals, fertilizers, and natural fisheries habitats. The widespread use and misuse of antibiotics to control diseases in agricultural and aquacultural species is worldwide and may well increase with increasing intensive livestock husbandry. For example, the illegal use of the antibiotic chloramphenicol in the culture of shrimp to control disease may result in residues of this antibiotic in the final product (Garrett et al, 1997; Rakocy, 2003a). The importance of chloramphenicol in humans is related to the occurrence of two types of depression of the bone marrow: 1) a reversible, dose-related interference with iron metabolism, and 2) an intractable anemia in some individuals (1:25,000 patients) after treatment with this antibiotic – hence the long-established ban on its use in humans and food-producing animals (Anon, 2004a).

In some countries, the availability or use of drugs for aquaculture is very limited, thus decreasing any potential impact on public health. In the USA, only two products are approved by the FDA for use in aquaculture: oxytetracycline (eg. Terramycin) and the potentiated sulfonamide, Romet-30 (a combination of sulfadimethoxine and ormetroprim) (Stoffregen et al, 1996). These two products are approved for use in channel catfish and salmonids, but only for certain diseases. In 2000, it was estimated that approximately 2.4×10^4 kg of antibiotics/year were delivered by feed mills in the production of over 600 million pounds of catfish held in ponds. It was also estimated that the industry rearing trout used $2\text{-}3 \times 10^3$ kg of antibiotics/year in medicated feed (MacMillan, 2001).

In Canada, approved antibiotics/chemotherapeuticals for use in cultured food fish include florfenicol, oxytetracycline, erythromycin, and trimethoprim-sulfadiazine (Anon, 2004c). In 1998, in British Columbia, the aquaculture industry used, and continues to use, three basic antibacterial compounds: oxytetracycline, two potentiated sulfonamides, and florfenicol. When each was considered in its use in fish, it was determined that 99.7% were approved for use in fish; the remaining 0.3% applied to fish were licensed for use in food-producing animals and were prescribed for fish under experimental protocols, or for fish not destined for human food (ie, brood stock). The majority of antibiotic-supplemented feed used in BC aquaculture was applied when fish were juveniles (smaller than 2 kg); between 72-94% of antibacterial drugs applied to salmon were fed to small fish. Such treatment of juvenile fish also created a drug-free clearance period of four to 12 months before fish were considered ready for harvest. None of the antibacterial agents used in farmed fish in BC has been used as growth promotants (Sheppard, 2000).

It has been stated that each farming company in BC applies considerable effort to minimize the need for, and use of, medicated feeds. The decision to use antibacterial products is made with care by the owner and attending veterinarian. Some farms are able to produce fish efficiently without the need for antibacterial agents. Others have a self-imposed 'no medication' period of six or 10 months before harvest. Some owners find that medication is essential to reduce the effects of bacterial diseases (Sheppard, 2000).

The use of antibiotics to treat disease in humans, and in various agricultural practices, has increased the worldwide prevalence of antibiotic-resistant bacteria. One example of many described illness associated with a cephalosporin-resistant *E. coli* among attendees affected as well with salmonellosis at a summer camp (Prats et al, 2003). There is concern that all uses of antibiotics select for bacteria that are resistant to antibiotics; the greater the use of antibiotics, the greater the selection pressure, and the more frequently are resistant pathogens encountered (Alderman and Hastings, 1998; MacMillan, 2001). For example, during epidemiological investigations of an epidemic of human cholera in Ecuador, it was discovered that the local shrimp industry might have contributed to an outbreak of antibiotic-resistant Vibrio cholerae in humans. It was suggested that there was improper use of antibiotics in the shrimp industry and that this led to the development of resistant V. cholerae. The counter argument was that poor public hygiene in affected areas was the major problem (Angulo, 2000).

Contamination in the kitchen or wound infections may be routes by means of which antibiotic-resistant organisms might cause illness that could be difficult to treat in humans. As noted earlier in this report, Aeromonas hydrophila, *Vibrio* and *Mycobacterium* spp. are organisms most likely to be involved (Alderman and Hastings, 1998). Recent information on human infections caused by *Streptococcus iniae* indicated that it too is such an agent (George, 1998). Persons involved could include food handlers, farm staff and fish processors; although these risks might be hazards of handling, it is also possible that the greater risk to humans in this area might arise, not from farmed fish reared for food, but from ornamental fish (Alderman and Hastings, 1998).

Antibiotic resistance is variably defined depending on specific needs. In terms of public health, resistance is often defined in a clinical context as an indicator of the likely outcome of therapy; it can also be defined in terms of bacterial patterns of growth in the presence of antibiotic-impregnated discs on agar media, the presence of certain genes for resistance, or as an epidemiological attribute. Resistance is either chromosomally or extra-chromosomally mediated. Resistance can be natural or a result of genetic mutation, or it can be induced by the transfer of genetic information among bacteria (Alderman and Hastings, 1998; MacMillan, 2001; Harper, 2002a).

Although all types of resistance may be clinically important, the possibility of extra-chromosomal resistance, such as the transfer of plasmids, etc. among different bacteria, is of great concern. For example, an *Aeromonas* sp. bacterium in the water or on a fish, and resistant to oxalinic acid, might transfer a resistance factor to an *E. coli* organism on fish or in the water. Such an organism might infect humans, or transfer the resistance to other human pathogens already present in humans (Bruun et al, 2003). The use of antibiotics in terrestrial animals may also cause antibiotic resistance in human pathogens, but it is hard to demonstrate cause and effect, and is considerably more controversial. Even so, some scientific reports support the idea that this is possible. Several reports support the contention that the presence of fluoroquinolone-resistant *Campylobacter jejuni* and *C. coli*, both human pathogens, has increased because of the use of these products in chickens and pigs. These worldwide bacteria can cause human gastrointestinal infections and diarrhea. It is known that *Campylobacter* spp. are spread mainly through the consumption of contaminated poultry. Although the significance of the *Campylobacter* data is in dispute, regulations to ban the use of fluoroquinolones from use in poultry have been instituted in the USA. (Incidentally, the CBC National news for January 15/04 showed a concerned Vietnamese farmer spraying antibiotics over his chickens in an attempt to prevent Avian Influenza that swept through Southeast Asia!) It seems, however, that there is no current report that proves that antibiotic contamination of the aquatic environment has caused human bacterial pathogens to become resistant (MacMillan, 2001).

Food-borne or zoonotic disease associated with aquacultural products including aquaponics, seems to be rare; for this reason it is assumed that that food-borne bacterial pathogens that are also resistant to antibiotics in these products are even more rare. As noted earlier in this report, most food-borne illnesses associated with fish in the USA were caused by non-bacterial conditions such as ciguatera and scombroid poisonings, but in none of these situations was an aquacultural product involved (MacMillan, 2001).

In aquaculture, there are several natural barriers to the transfer of resistance factors and the occurrence of enteric bacteria that infect humans. These barriers include temperature, itinerant (transitory) microbial flora, and important physiological and evolutionary differences. Various physical factors may also decrease the probability of the transfer of resistance. Likely the most obvious natural barrier is that of body temperature. Farmed aquatic species are all poikilothermic, with a labile body temperature that is dependent on environmental temperature. Generally, the body temperature of poikilotherms is too low to be considered optimal for the proliferation of most enteric bacteria likely to infect humans. Most human food-borne pathogens prefer the comparatively warm temperatures of homeotherms (creatures like humans that have a relatively stable temperature that is independent of the ambient temperature; warm-blooded) (Inglis et al, 1993; MacMillan, 2001).

The usual enteric bacteria of concern in debates on public policy are *E.coli, Campylobacter jejuni*, *C. coli*, *Shigella* and *Salmonella* spp, *Vibrio cholerae*, *V. paratyphi, Staphylococcus aureus*, Listeria *monocytogenes* and *Yersinia enterocolitica* (Inglis et al, 1993; MacMillan, 2001). Of these species, only *L. monocytogenes* is known to be capable of reproducing at low temperatures – in fact, usual refrigerator temperatures (4^{o}C) are ideal for the proliferation of these organisms, and are often used to encourage their growth in diagnostic material. However, the optimal temperatures for the proliferation of this organism are nevertheless in the range of 35-37^{o}C. Optimal incubation temperatures for all of the other species mentioned seem to be above 30^{o}C; these organisms are often isolated from clinical specimens that are incubated at temperatures of 35-37^{o}C. Because the preferred temperature range for the optimal growth of tilapia is 28-30^{o}C (82-86^{o}F) (Rakocy and McGinty 1989), it is possible that some of these organisms could proliferate in tilapia.

Cool and coldwater aquacultural production occurs at temperatures that are generally below 18^{o}C. Warmwater aquacultural production occurs at temperatures higher than 18^{o}C, and includes temperatures as high as 30 ^{o}C. In surveys of bacteria present under aquacultural conditions, Salmonella spp., E. coli and other potential enteric human pathogens, although rare or in very low numbers when present, are most often found in warmwater aquaculture rather than in coldwater environments. Vibrio cholerae, V. parahaemolyticus and other Vibrio spp. have been detected in estuarine and marine environments, including marine aquaculture. Vibrio spp. are generally the predominant bacterial genus in estuarine waters, and tend to have seasonal changes in abundance; their greatest abundance occurs during months of warm weather, which accounts, in part, for the seasonal occurrence of food-borne illness associated with the consumption of raw shellfish (MacMillan, 2001).

Present evidence suggests that psychrophilic and psychrotrophic bacteria (‘psychro’ is a combining form denoting a relationship to cold) naturally present in aquacultural environments have adapted to life at low temperatures, whereas human pathogens, which are mesophilic bacteria (‘mesophilic’ means preferring moderate temperatures), can be severely inhibited (MacMillan, 2001).

Another natural barrier to the transfer of resistance is related to the transitory nature of the microbial flora in fish. The presence of bacteria in the intestinal tract of fish appears to depend on their presence in the feed or in the water (MacMillan and Santucci, 1990). As the environment or the feed changes, so too does the microbial flora change. In contrast to homeotherms, fish don’t appear to have a permanent microflora. In partial support of this observation, Bocek et al (1992) found that silver carp living in water inoculated with an antibiotic-resistant strain of Salmonella typhimurium at the level of 10,000 bacterial cells per litre, retained the organism in their intestines for 14 days after they were transferred to clean water.

Earlier, Baker et al (1983) mixed S. typhimurium in waste from swine, and inoculated this mix into water stocked with tilapia (T. aurea). Salmonellae were recovered from the viscera of these fish for up to 16 days after inoculation, but other tissues were free of the organism. Since the flesh did not contain this organism, it was concluded that proper processing of the harvested product should provide an uncontaminated food for human consumption.

It is known that fish starved for a period of time may have an essentially sterile gastrointestinal tract (MacMillan and Santucci, 1990). Hence, contaminating enteric bacteria from terrestrial animals don’t necessarily establish residency in exposed fish, although they may occur temporarily in/on aquatic species. As well, depending on the ambient temperature, these organisms are unlikely to reproduce. Occasionally, various human bacterial pathogens may be recovered from fish or their environment, but it is doubtful that these bacteria have colonized or even reproduced under these conditions.

Temperature and physiological conditions in poikilotherms likely preclude the ability of most human pathogens from colonizing farmed aquatic animals; in fact, fish may be resistant to such colonization. Another important point is that because the bacterial flora of fish is transitory, the use of antibiotics as growth promotants does not appear to work, and in countries such as the USA, it is also illegal (MacMillan, 2001).

Generally speaking, the probability of contact between fish or their environment, and humans, is low. Fish processed for human consumption in the USA have very low numbers of potential human pathogenic bacteria. However, it is known that catfish fillets in processing plants in the USA are often contaminated with the bacterial organism, Edwardsiella tarda that may spread to humans by the oral route (Noga, 1996). In an FDA study in 1998, Salmonella spp. were detected in very low numbers from some farmed catfish and imported farmed tilapia; the source of the organism was not determined.

Rawles et al (1997) found that the performance of juvenile channel catfish was not improved by the inclusion of Romet-30 or oxytetracycline in the diet. Rather, compared with controls, performance of these fish tended to decrease when antibiotics were supplemented in the diet. Moreover, residues of antibiotics above the legal limit of 0.1 mg/kg were noted in most samples from fish medicated with antibiotics. A withdrawal period of three or four weeks effectively decreased the content of antibiotics in tissues to undetectable levels.

In a comparative study in Puget Sound, Washington, Herwig et al (1997) found that most antibiotic-resistant bacteria below pens holding salmon occurred at a site at which the most antibiotic was used, compared with the least resistance in pens where the least amount of antibiotic was used. On the farm at which most antibiotic was used, resistance to oxytetracycline and Romet-30 tended to parallel each other, and suggested either a common mechanism of resistance, or linkage of the genes responsible for the resistance.

The environmental fate of antibiotics used in aquaculture is generally unknown, however, waste management practices may diminish potential effects on public health. As noted, measurements have demonstrated the accumulation of antibiotics below net pens holding salmon (Smith et al, 1994; Herwig et al, 1997). Presumably, if sediments were removed from the system, less antibiotic would be present. Although more work is needed to determine the amount of antibiotic present in effluent, any impact on human health remains undocumented (MacMillan, 2001).

The lack of credible data provides grounds for speculation about the impact on public health, of pharmaceutical agents used by all animal industries, including aquaculture. It seems important to determine the total volume of antibiotics used in terrestrial and aquatic agricultural animals, and the prevalence of antibiotic-resistant bacteria on aquacultural products for human consumption. The origin of any recovered pathogenic bacteria, whether from the water, the farm, the processing plant or the retailer, would need to be determined. It would also be useful to determine the likelihood of the transfer of resistance factors from aquatic environments, including fish, and aquatic bacteria through to human pathogens. It would also help to determine the fate of antibiotics in the aquatic environment (MacMillan, 2001).

‘Neutraceuticals’ and Bacteriophages – Practical Alternatives to Antibiotics?

‘Neutraceuticals’

Many opportunistic disease-causing bacteria, viruses, fungi and other organisms exist within or on fish, or in the aquatic environment. Although these organisms are a normal component of all life, the immune system of fish can recognize, engulf and destroy pathogenic organisms. Because of the increased effects of crowding and associated stressors encountered in the rearing of fish, these animals are more susceptible to disease than are free-ranging fish. During periods of stress, the immune system may be overwhelmed or less efficient, and overt disease may be the result.

Since infections are usually opportunistic events, it is sometimes possible to control the spread of infection by correcting the management problems that precede an outbreak of disease. In severe situations, control of these infections may require the use of medicated feed. Alternatively, the feed may be a medium for therapy. Instead of the use (and abuse) of antibiotics, it is claimed that ‘functional’ feeds for fish can be given in an attempt to minimize or prevent disease. Claims for these ‘functional’ feeds indicate that they are enriched with specific natural feed ingredients with properties to reinforce the ability of the immune system to control pathogens. These ingredients are called ‘neutraceuticals’ that are purported to have specific protective functions, thereby offering a benefit beyond simple nutrition or basic fortification. According to claims for these products, proven ‘nutraceuticals’ include:

•Bioflavonoids that act as natural antioxidants, i.e. scavengers of active oxygen radicals that may adversely affect the health of fish.

•**Probiotics,** the first line of defense against intestinal disease, are health-promoting bacterial organisms that improve the microbalance by selectively suppressing harmful bacteria in the intestine.

•Prebiotics refer to a group of natural sugars such as oligosaccharides that are resistant to digestion by fish but can be utilized exclusively by specific probiotic organisms, allowing them to compete with and exclude pathogens in the gut (called ‘competitive exclusion’). Thus, prebiotics are nutrients for probiotic organisms.

•**Immunostimulants promote** the macrophage (= defence) system to eliminate pathogens in the bloodstream.

Additional claims for ‘neutraceuticals’ indicate that the use of functional feeds will aid in the control of pathogenic bacterial and fungal growth, as well as reducing the digestive problems that occur commonly after antibiotic treatment or prolonged stresses (de Wet, 2002).

From a practical point of view, there appears to be benefit in some of these alternate approaches to the control of disease, not only in fish, but also in other classes of animals, including humans (Fuller, 1989). Over time, such viable techniques could supplant many of the tons of antibiotics used today in the combined aquacultural and other livestock industries. Such replacement could reduce significantly, the number and species of antibiotic-resistant bacteria in the health of humans and livestock. Some examples of ‘neutraceuticals’ are listed herewith.

Probiotics

Alternative approaches to the use of antibiotics in the treatment and/or prevention of diseases affecting a variety of livestock, including fish, as well as those that affect humans, are gaining greater acceptance. One of these approaches involves the use of probiotics.

Several definitions of probiotics have been proposed. Fuller (1989) gave a precise definition, which continues to be widely used, i.e., 'a live microbial feed supplement which beneficially affects the host animal by improving its intestinal balance'. However, Verschuere et al (2000) have expanded this definition to allow for a broader application of the term, as follows: 'A probiotic is defined as a live microbial adjunct which has a beneficial effect on the host by modifying the host-associated or ambient microbial community, by ensuring improved use of the feed or enhancing its nutritional value, by enhancing the host response toward disease, or by improving the quality of its ambient environment.'

The means by which probiotics produce positive health benefits in aquaculture have been reviewed by Irianto and Austin (2002).

Numerous organisms, including a wide range of microalgae (*Tetraselmis* spp.), yeasts (*Debaryomyces, Phaffia* and *Saccharomyces* spp.), and Gram-positive (*Bacillus, Carnobacterium, Enterococcus, Lactobacillus, Micrococcus, Streptococcus* and *Weissella* spp.) and Gram-negative bacteria (*Aeromonas, Alteromonas, Photorhodobacterium, Pseudomonas* and *Vibrio* spp.), have been evaluated. The mode of action of the probiotic activities of these agents has not really been investigated, but possibilities include competitive exclusion, ie, the probiotic bacteria actively inhibit the colonization of potential pathogens in the digestive tract by antibiosis or by competition, and/or by the stimulation of immunity in the host. These products may stimulate appetite and improve nutrition by the production of vitamins, by the detoxification of compounds in the diet, and by the breakdown of indigestible components. There is accumulating evidence that probiotics are effective in inhibiting a wide range of bacterial and some viral pathogens in fish (Douillet, 2000; Tae-Kwang Oh [publication date not stated]).

A key point in the development of biological agents such as bacteria, for use in probiotic systems, is that they must be nonpathogenic for humans who consume the final product (Nikoskelainen et al, 2001).

A review of probiotic bacteria as biological control agents in aquaculture, including a table summarizing reports on this topic, has been provided by Verschuere et al (2000). Other selected references/reviews on the use of probiotics in aquaculture include those of Maeda et al, (1997), Xiang-Hong et al (1998), Gatesoupe (1999), Irianto and Austin (2002), Villamil et al (2002) and Abidi (2003), among many others.

Prebiotics

The official definition of prebiotics in humans is: 'Nondigestible food ingredients that beneficially affect the host by selectively stimulating the growth and activity of one species or a limited number of species of bacteria in the colon' (Duggan et al, 2002). Prebiotics refer to a group of natural sugars such as oligosaccharides [('oligo' means 'little, scanty or few'] (eg., lesser saccharides resulting from the partial hydrolysis of starch and known to contain a definite number of sugar molecules, such as maltose, a disaccharide), that are resistant to digestion by fish but can be utilized exclusively by specific probiotic organisms, allowing them to compete with and exclude pathogens in the gut (called 'competitive exclusion'). Thus, prebiotics are nutrients for probiotic organisms. Other examples of prebiotics include galacto-, fructo-, and isomalto-oligosaccharides used in the promotion of health. The use of prebiotics in aquaculture could add to the beneficial effects of probiotics in the prevention of infectious diseases, particularly bacterial diseases.

Immunostimulants

Immunostimulants are chemical compounds that aid in bolstering the immune system through the activation of white blood cells, and thereby may render animals more resistant to infections by a variety of biological agents (Raa, 2000). Included among these compounds are vitamins, trace elements, fatty acids, glucans, yeasts, nucleotides and others such as lactoferrin, chitin, levamisole, probiotics, etc. (Lall, 2003). It has been noted that vaccination is likely the best-known method of specific immunostimulation, and that activation of macrophages is an example of nonspecific immunostimulation (Zhou Jin, 2004). Reviews of immunostimulants in aquaculture have been provided by Sakai (1999) and Raa (2000).

It seems that the most promising immunostimulants are the β-1,3/1,6-glucans, because they have a well-defined chemical structure and mode of action on the immune system. In addition, these compounds are non-toxic universal 'alarm signals' that activate the immune system by the same basic mechanism in all groups of animals from the simplest invertebrates to humans. The β-glucans occur naturally in the bran of grasses (Gramineae) such as barley, oats, rye and wheat, generally in amounts of about 7%, 5%, 2%, and less than 1%, respectively (Chaplin, 2003), and in the cell wall of yeasts (Anon, 2003i). The β-1,3/1,6-glucans bind specifically to a receptor molecule on the surface of certain inflammatory cells called macrophages (macro = large; phage = to eat; hence, macrophages are large cells that engulf foreign material). These inflammatory cells play an essential and pivotal role in the initiation and maintenance of the immune response.

From an evolutionary point of view, macrophages are the oldest and most consistently preserved immunologically competent cell known. In order to function immunologically, macrophages must pass through a stage of activation that involves certain morphological changes but also, most importantly, an entire sequence of metabolic changes. Activation can be initiated by a variety of different stimuli, such as endotoxins, bacteria, viruses, or chemicals that can be too toxic or pathogenic to be useful. Beta-glucan is not only effective orally, it is also completely nontoxic and safe, but is one of the most potent stimulators of the immune response (Anon, 2003i).

The receptor for β-1,3/1,6-glucans on macrophages has been retained during evolution and is found in all animal groups from invertebrates to humans. When the receptor is engaged by β-1,3/1,6-glucans, these inflammatory cells become more active in engulfing, killing and digesting bacteria, and at the same time, they secrete signal molecules that stimulate the formation of new white blood cells. In animals that have specific immune mechanisms (fish and animals higher on the evolutionary scale), in addition to non-specific defences, the activated inflammatory cells produce cytokines that, in turn, also activate antibody-producing white blood cells (B [bone marrow-derived] and T [thymus-derived] cells). For this reason, β-1,3/1,6-glucans enhance the efficacy of vaccines. Because of the basic mode of action of β-1,3/1,6-

glucans, products in this category affect a number of different biological processes, including not only resistance to disease, but also growth, wound healing, repair of cells damaged by ultraviolet light, skin care, arthritis, etc.. The β-1,3/1,6-glucans are active not only when injected, but also when administered in the feed or on mucosal surfaces (Raa, 2000).

Duncan and Klesius (1996a) administered β-glucan and the yeast Saccharomyces cerevisiae, to channel catfish, and found that, although nonspecific immune responses were activated, the use of these producrts did not lead to enhanced nonspecific immunity to the bacterial pathogen, Edwardsiella ictaluri. By contast, Sahoo and Mukherjee (2002) compared four immunomodulating substances – β-1,3 glucan, levamisole and vitamins C and E -- in rohu (Labeo rohita Ham), a major species of carp in India. Although all four substances had significantly positive effects, β-glucan was found to be the most effective immunomodulator in these fish.

Among vitamins and minerals, vitamin C (ascorbic acid), and vitamins A and E, and the trace mineral selenium (Se) are important. Along with Se, vitamins C and E are key issues for fish; Se levels are often low in farmed fish (Lall, 2003). The biological importance of Se in the development and maintenance of the immune system of humans and other animals has been reviewed by Koller and Exon (1986).

Vitamin C is involved in specific and nonspecific immunity in fish and other animals. In its nonspecific role, vitamin C protects cells from the damaging effects of free radicals (oxygen), it is important in the production and secretion of interferon, it is required for the synthesis of collagen in the skin and skeleton (therefore important in wound healing), and it maintains the basement membrane of the epithelium of the oral cavity and intestines, etc.. Its role in specific immune responses includes the proliferation of B and T lymphocytes, and the antibody response. The requirement for vitamin C in fish is 25-50 mg/kg (Lall, 2003). Several other studies have examined the role of vitamin C in the nutrition of fish (Durve and Lovell, 1982; Li and Lovell, 1985; Liu et al, 1989; Hardie et al, 1991; Li et al, 1993; Li et al, 1998).

Blazer and Wolke (1984a) studied the effects of α-tocopherol (vitamin E) on the specific immunity and nonspecific resistance of rainbow trout fed a control and an α-tocopherol-deficient diet. Fish fed the deficient diet had significantly reduced immunological responses compared with those in the control group, although the deficient fish did not have any visible evidence of deficiency. Hardie et al (1990) studied parr of Atlantic salmon (Salmo salar) fed depleted, intermediate or high levels of vitamin E. Fish fed the depleted and high levels of vitamin E were then challenged with a virulent strain of Aeromonas salmonicida. Fish fed the depleted diet had significantly increased mortality compared with fish given the high-level diet. However, in contrast to the results reported by Blazer and Wolke (1984a) in rainbow trout, Hardie et al (1990) found that the function of white blood cells (specific humoral factors) in these salmon was not affected, whereas there were effects on certain nonspecific factors associated with immunity. Hardie et al (1990) also studied the effects of vitamin E on the immune response of Atlantic salmon (Salmo salar).

Blazer et al (1989) examined dietary influences on the resistance to disease in channel catfish, by comparing fish fed three different diets. Significant differences among the groups were observed but because the diets varied greatly, it was impossible to explain the observed differences. Deficiencies of vitamins C and/or E and trace minerals, and/or deficiencies of vitamins C or A were suggested as potential causes. A similar study conducted by Blazer and Wolke (1984b) in rainbow trout, resulted in findings generally similar to those observed in channel catfish.

The role of vitamin E in the immune response and resistance to disease is not so clear as that of vitamin C, however a combination of the two has appeared to be effective. The possible mechanisms of the action of Vitamin E on the immune response include 1) protecting the cellular membranes of white blood cells against the peroxidative damage induced by free radicals (such as oxygen) produced during the immune response, and 2) vitamin E aids in limiting the oxidation of arachidonic acid to prostaglandins PGE_2, $PGF_2\alpha$, TXB_2, and 6-keto $F_1\alpha$ in selected tissues. Since prostaglandins can depress the proliferation of lymphocytes (a species of white blood cell) and regulate the immune response, the inhibition of the synthesis of prostaglandins increases the number of lymphocytes, and as a result, increases cellular immunity (Lall, 2003).

Spirulina spp.

Spirulina spp. are blue-green algae that are rich in antioxidants, vitamins, minerals and other nutrients. This product has been used as a food supplement for more than 20 years. Spirulina spp. grow naturally in lakes with extremely high pH levels, but it is also harvested from large-scale commercial ponds, where purity is monitored before being dried and distributed in tablet and powdered form.

Several studies with animals have shown spirulina to be an effective immunomodulator (an agent that can affect the behavior of immune cells.) In rats, spirulina inhibited allergic reactions by suppressing the release of histamine in a dose-dependent fashion. In cats, spirulina enhanced the ability of macrophages to engulf bacteria, and in chickens, spirulina increased antibody responses and the activity of natural killer cells, which destroy infected and cancerous cells in the body. Research at the University of California, Davis, found that nutrient-rich spirulina is a potent inducer of interferon-γ (gamma) (a 13.6-fold increase) and a moderate stimulator of both interleukin-4 and interleukin-1β (a 3.3-fold increase). Increases in these cytokines suggest that spirulina is a strong proponent for protecting against intracellular pathogens and parasites and potentially, can increase the expression of agents that stimulate inflammation, which also helps to protect the body against infectious and potentially harmful micro-organisms. Additional studies with individuals consuming spirulina are needed to determine whether these dramatic effects extend beyond the laboratory. One study involving channel catfish fed Spirulina sp., showed that there were enhanced nonspecific cellular immune responses, but no specific protection against infection with Edwardsiella ictaluri (Duncan and Klesius, 1996b).

In the body, the preferential increase in the production of interferon-γ over interleukin-4 shifts the immune system towards mounting a cell-mediated immune response instead of a humoral response (ie, the production of antibodies). A cell-mediated response includes the activation of T-cells and antibodies that combine with macrophages to engulf invading micro-organisms – hence, the value of spirulina in protecting against intracellular pathogens and parasites. The moderate increase in the secretion of interleukin-1β, a cytokine that acts on nearly every cell of the body to promote inflammation, supports the overall immune response (Gan, 2000).

Bacteriophages

Since the advent of antibiotics, both the human health care and agricultural sectors have relied heavily (and continue to rely) on these products to control bacterial pathogens. However, increasing levels of resistance to antibiotics by pathogenic bacteria have reduced the efficacy of many current therapies. As a result, researchers have sought alternative methods to deal with these pathogens. One of these alternatives is the use of bacteriophages, a very old idea that continues to be used in human health in countries such as Russia, (reported in the CBC program, 'The Nature of Things') to deal with bacterial pathogens of the intestine (Stone, 2002).

Lytic bacteriophages are viruses that attach to specific receptors on the surface of bacteria, inject their DNA, and express genes that lead to the synthesis of new phages. This process ends with the programmed lysis (death) of the host bacterium, and the release of many more phages.

The therapeutic use of phages as antimicrobial agents has a number of advantages compared with other methods. Firstly, phages are highly specific and allow for the removal of the specifically targeted microorganisms from a mixed population. Secondly, unlike antibiotics that decay over time, numbers of phages actually increase and work their way more deeply into pockets of infection. Furthermore, phages are living entities that adapt and evolve; they can pass from host to host, and have the potential to establish an infectious cure.

Interest in agricultural applications of phages is now expanding rapidly in three major areas:

•phage control of plant diseases such as bacterial spot on tomatoes and *Erwinia* sp. infections of fruit trees (fire blight) and root crops (soft rot).

•phages to treat diseases of animals, eg, respiratory infections caused by *E. coli* in chickens, furunculosis (*A. salmonicida*) in fish, and mastitis in cattle.

•phages to control human food-borne pathogens such as *Salmonella* spp. in chickens, *E. coli* (O157:H7) in cattle, and *Listeria* spp. during the processing of food (Brabban et al, 2003).

In reference to humans, it has been reported that some investigators are attempting to use phages to control MRSA (methicillin-resistant *Staphyloccus aureus*), a bacterial organism that is responsible for the vast majority of serious infections that originate in hospitals (von Radowitz, 2003).

As an example in aquaculture, Park et al (2000) found two types of phages that were specific to the bacterial organism *Pseudomonas plecoglossicida*, the cause of bacterial hemorrhagic ascites of ayu fish (*Plecoglossus altivelis*). On the basis of their experimental work, the authors suggested that these phages might be used to control this disease; they also provided a number of references on phage control of several diseases in animals. Also, Grabow (2001) provided an update on the application of bacteriophages as models for viruses in water, along with numerous references on the subject.

Comments and Conclusions

Facts are hard….understanding is harder.…wisdom is hardest. **- Stephen Becker: A Covenant with Death, 1964**

The apparent scarcity of references attuned specifically to the topic of aquaponics and food safety has been a slight problem in this study, a finding with which Douillet (2003) agrees. Conversely, greater numbers of such references are more readily available for the larger topic of aquaculture in general. Hence, to a great degree, it has been necessary to focus on principles and facts applicable to aquaculture over all, and to try to extrapolate from them to aquaponics in particular.

It is significant that food-borne or zoonotic disease associated with aquacultural products, including aquaponics, seems to be rare; for this reason it is assumed that food-borne bacterial pathogens that are also resistant to antibiotics in these products are even more rare. From the perspective of food safety in aquaponic systems, there seems to be much less likelihood of contamination of vegetable and other aquaponic crops, and fish, with pathogenic bacteria of domestic animal origin, and with microscopic parasites such as *Cyclospora* sp. of human origin, and *Cryptosporidium* sp. of domestic animal origin, in aquaponic systems, especially in indoor systems, compared with the potential of such contamination in the traditional field methods of growing such crops.

It is positive and notable that a study by Robison and Byrne (2003), who collected water and various vegetables grown in the aquaponic facility rearing tilapia at the Lethbridge Community College, found that on unwashed produce, bacterial counts from the vegetables were within acceptable limits for ready-to-eat foods. Numbers of fecal coliforms increased between water entering the system and the water exiting the system, however numbers of fecal coliforms in both samples were very low.

By contrast, a report on a test-marketing study conducted by Choban and Frank (2004) showed that high levels of coliforms were found in unwashed bok choi, culantro roots and chives grown in an aquaponic system. These plants are low-growing and because their leaves are close to trays of recycled waste from fish, they are at greater risk of contamination. As a result, in order to market bok choi and culantro, investigators used a strict washing procedure. All other samples of vegetable produce in this study had no or presumptively negative levels of micro-organisms for which bacterial cultures were conducted. However, all aquaponically-grown produce was washed in 100 ppm chlorine and rinsed in potable water prior to sale. The results of this study indicated that all low-growing vegetables, and perhaps all vegetables produced in aquaponic systems may well require this procedure, in order to further the acceptance of such produce by the buying public.

Bearing on the last statement, it is interesting that in this study, although most feedback from customers at different markets in the province was positive, the feedback from those at a test market in Lethbridge tended to be negative. Customers at this site claimed that the tomatoes offered were not as flavorful as those grown in soil; they liked the taste of cucumbers offered; they felt that field-grown vegetables and herbs contained more soil micronutrients and were healthier and more flavorful; they were uncomfortable with the use of water holding fish for growing produce; some disagreed with the idea of using fish produced in a closed environment. As a result of such comments from customers, this market declined to have further aquaponically-grown produce delivered (Choban and Frank, 2004).

In outdoor systems, bacterial contamination could arise from the feces of rodents, birds and those from domestic animals and humans; in indoor systems, rodents are likely to be a potential source of bacteria pathogenic for humans. However, at the University of the Virgin Islands, where open-air aquaponics have been used in plant production for 20 years, it has been claimed that no one has become ill as a result of work in aquaponics (Rakocy, 2003a).

The inclusion in this document of the USDA 'Guide to Minimize Microbial Food Safety Hazards for Fresh Fruits and Vegetables' under the heading "water' was to highlight the potential for the contamination of fruits and vegetables by microbial agents in the broader context of agricultural production, not to arouse unreasonable or irrational fears about aquaponic/aquacultural production. To the contrary, as noted, information available to the present time indicates the relative safety of aquaponic/aquacultural production compared with the safety of traditional methods of producing fruits and vegetable, etc..

The protection of plants from insect pests in aquaponic systems may be accomplished through the selection of insect-resistant cultivars, the use of *Bacillus thuringiensis israelensis*, and/or the simpler use of insecticidal soaps.

Fish in aquaponic systems may be subject to the same disease conditions found in those reared in traditional aquacultural systems. ome of the organisms causing these diseases in fish may affect humans as well. For this reason, this writer has some concerns about the use of an aquaponic system such as that involving the use of quail to provide feces as a source of nutrient for algalculture, as proposed by Nuttle (2003a). The potential for the quail used in his proposed system to introduce a pathogen such as a *Salmonella* sp., etc. is possible, and without defined procedures to regulate and control (quality control) this and other potential pathogens, the system appears to have some potential weaknesses. Perhaps because the idea is so new, future refinements in methodology may well deal effectively with these concerns.

Since warm temperatures are required for the rearing of *Tilapia* spp. in this proposed aquaponic system, the possibility of introducing human bacterial pathogens, most of which also require warm incubation temperatures, is likely increased somewhat. Despite all too brief assurances from Nuttle (2003b) that food products derived from his proposed system are safe for human consumption, he did not provide current convincing evidence of quality control measures being used to assure safety of the final food products (algae and fish).

Hutchings (2003) has indicated the unsuitability for aquaponics, of some sources of water from deep wells in the province because of their high content of salt. Accordingly, it might be possible for some producers to explore the development salt-water aquaponics as described by Wilson (2003) and by Nuttle (2003a), or in a broader aquacultural, non-aquaponic endeavor, to rear fish such as tilapia in more brackish waters. In Israel, tilapia may be reared in brackish water (600-3000 ppm salt) (Lenoir, 2003).

It would seem practical that fish entering an aquaponic or any aquacultural facility should be obtained from a reliable (certified?) source in which routine (disease) surveillance procedures and diagnostic monitoring of brood stock are practiced. Such procedures are the most cost-effective method of avoiding the economic losses caused by pathogens. Ideally, operators of grow-out facilities should have samples of incoming stock examined, either at the source or within Canada, for evidence of infectious disease before they are admitted to the facility. Routine diagnostic monitoring of young fish is also valuable in detecting potential problems. When it is available, vaccination against specific diseases may be practical and cost-effective (Reddington, 2000).

Undoubtedly, in terms of attempting to prevent infectious diseases, the significant wave of the present and future for many species of animals, including humans (Salminen et al, 1996) and fish, may well be the use of so-called 'neutraceuticals' rather than the well-known use and abuse of antibiotics in the production of livestock. These 'neutraceutical' products include prebiotics, probiotics, immunostimulants and immunomodulators (β-glucans, selected vitamins and trace minerals, levamisole, etc.). As well, products containing bacteriophages that target specific bacterial pathogens – rather than the traditional and increasingly risky methods of simply 'throwing' antibiotics/chemotherapeutics at organisms that cause infectious diseases in livestock – may well be an additional, practical approach to food safety.

The use of 'neutraceuticals', either singly or in selected combination, plus vaccination where it is practical, would seem to be a realistic, rational approach to the prevention or amelioration of infectious disease in fish, other livestock, and in humans who consume them. Such a non-antibiotic approach to rearing food fish could be a major factor, both within Canada and internationally, in promoting and instilling consumer confidence in the quality of the edible product. Similarly, such approaches as an attempt to prevent infectious disease could be a positive factor in promoting aquaponically-grown fish and plants from the perspective of intra- and extra-Canadian trade.

For example, given the seriousness of infections caused by *Streptococcus* iniae in humans handling tilapia, it would be highly advantageous to develop an effective vaccine (more correctly, 'bacterin') against this organism in fish, ultimately to avoid human infections. Failing that, or in combination with it, as part of the routine management of aquacultural/aquaponic operations, the selective use of certain 'neutraceuticals' could be of immense benefit in terms of the safety and health of both humans and fish.

One issue that does not appear to have been addressed adequately in the literature to which this writer had access, relates to human safety in the use of live biological products such as probiotics and bacteriophages that are proposed for dealing with defined infectious diseases, especially bacterial diseases, of different species of fish and shellfish (Nikoskelainen et al, 2001). For example, some probiotics are derived from nonpathogenic strains of bacteria for which there are also pathogenic strains of the same organism. Reversion or mutation of a nonpathogenic organism to a pathogenic strain could have severe consequences not only for fish but also for humans consuming aquacultural/aquaponic products. Obviously, it is an important issue that needs to be examined, especially in the light of concerns about the threat of biological agents to incapacitate human populations. (Realistically, It may well be that this point is a 'given' in any studies on the use of probiotics in food-producing species of plants and animals.)

The excellent review of the safety to public health of aquaculturally-derived foods by Howgate (1998) concluded that the risks to public health from the consumption of aquacultural products are no greater, and in some instances, lower, than the risks from equivalent species caught from the wild. He makes the point that his review is an assessment of the relative risks; absolute risks from some hazards in aquacultural products are as high as they are in their wild counterparts. With the exception of veterinary residues, the nature of the hazards in aquacultural products is the same as those in fish from wild stocks. Epidemiological evidence shows that the major risks to public health from fishery products, both in nature and extent, arise from intrinsic hazards, ie, those present in the fish/shellfish at the time of harvest.

Other important points raised by Howgate (1998) include the following:

Producers of fish from wild stocks have little, if any, positive control over the intrinsic quality of the catch. The best that can be achieved is to be selective of the species caught, by choice of fishing grounds, and season of capture. One of the several advantages of aquaculture, and by extension, aquaponics as well, as a source of food fish is that the producer can exert control over the intrinsic quality, including safety, of the product.

Cultivation of fish in brackish or freshwater seems to present more hazards and greater risks than those reared in mariculture (fish reared in salt water). In either temperate or warmwater aquacultural facilities, there is a risk of contamination with enteric bacteria when waste water is used or when systems are fertilized with organic manure. There is evidence that these organisms can penetrate into the edible tissues of fish when there are high densities of bacteria in the water. As a result, more detailed studies into the bacteriological risks associated with fish reared in waste water and in systems fertilized by human and animal feces are needed. On a practical level, it would seem advisable to avoid the use of waste water from animals other than fish in aquacultural or aquaponic production.

Finally, inorganic chemical contaminants that arise from natural or human sources can have an impact on aquacultural systems involving fresh and brackish water. There are well-based theoretical considerations for the belief that the risk to human health from these contaminants would be very low in these systems. Hence, there is likely no need for guidelines on maximum limits for inorganic contaminants in supplies of water for aquaculture, in terms of safeguarding human health. One exception might be mercury which is likely the only metal of real concern, since it is absorbed from feed – hence there could be a basis for establishing maximum levels in feed.

Addendum

Hazard Analysis Critical Control Points

Hazard Analysis Critical Control Points (HACCP) is an internationally recognized system for controlling food safety (Graham, 2003). It was developed originally in the USA to guarantee the safety of food for astronauts in space, and has now been adopted worldwide as a scientific, straightforward, effective approach to enhance food safety. Under HACCP, processors implement controls throughout production, which in turn allow the operator to react quickly to prevent safety hazards before they occur. The seven basic principles of HACCP are:

•Determine the critical control points;
•Establish limits at each critical control point;
•Identify the hazards and list preventive measures to control them;
•Establish procedures to monitor the critical control points;
•Establish corrective action to be taken in case of a deviation;
•Establish effective record-keeping.

The five steps of hazard analysis are:
•Review the incoming material, including ingredients and packaging material;
•Evaluate each step of the processing operation;
•Observe the actual operating practices;
•Take accurate measurements;

Analyze the measurements.

In each case, the analysis must consider all possible biological, chemical and physical hazards. Once the hazards have been identified and analyzed, the next stage of HACCP is to determine the critical control points (CCP) necessary to control the hazards.

In the manufacturing process, CCP are points or steps at which control can be applied, and a food safety hazard can be prevented, eliminated or reduced to an acceptable level. Determining CCP needed to control identified hazards is the second major principle of a HACCP system. In the food processing sequence, CCP are located at any point where biological, physical and chemical hazards can be eliminated or controlled. Thus, CCP can include cooking, chilling, sanitizing, formulation control, prevention of cross-contamination, employee hygiene and environmental hygiene. It is key that CCP are developed and documented carefully, since the success of controlling hazards depends on the care taken in determining the CCP, the critical limits that must be met at each point, the monitoring procedures used to control each CCP, and the corrective action taken when there is a deviation identified at a CCP. Verification of each CCP in a processing plant ensures that monitoring procedures are in place and that they are effective in controlling the potential hazard.

Acknowledgments

It is very much a pleasure to acknowledge the amount of assistance I have received in the preparation of this report, especially that provided by the following individuals: Daryl Loback, Safe Food Systems Specialist, for the opportunity and financial support to explore this subject; Eric Hutchings for his knowledge, advice, encouragement and good humor; Jennifer Fullen and Connie Hruday of the Neil Crawford Provincial Centre for their invaluable assistance with a myriad of references; Judy Chow, Rita Alexander and Bev McIlroy and for their considerable patience and assistance with editing aspects of the text and preparation of the final document; Brian Coffey for his help with scanning and graphics; Gerald Ontkean for references from his MSc thesis; Brent Paterson for information on the Oldman River Basin Water Quality Initiative; and to the many members of both the Aquaculture Section and Irrigation Branch for their continued fellowship and good humor.

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