# ECONOMIC FEASIBILITY OF PROCESSING FOOD WASTE AND INCORPORATING PROCESSED FOOD WASTE PRODUCTS IN LEAST COST DUCK FEEDS

By

Ben Asare Budu

Department of Agricultural Economics, McGill University
Montreal, Quebec, Canada

October 2001

A Thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements of the degree of Master of Science

0-612-77059-1

**Short Title:**

**ECONOMIC FEASIBILITY OF PROCESSING FOOD WASTE AND INCORPORATING PRODUCTS IN LEAST COST DUCK FEEDS**

# ABSTRACT

The focus of this thesis was to analyze the least cost of producing rations for ducks in three age categories from a mixture of conventional feed ingredients and three different processed food waste products and to examine the financial and economic feasibility of establishing an industrial plant to produce these food waste products in the Montreal region. The first part of the thesis was investigated through the use of a linear programming model. The effect of recognizing the variability of protein levels in the various feed ingredients was examined through the use of chance-constrained programming. The market prices determined for the three processed food waste products were $130.00, $117.00 and $104.00 for products 1,2 and 3 respectively for ducks aged 0-2 weeks and 2-7 weeks. For breeding ducks, the market price was $108.00 for each of the processed food waste products. Using these prices, meat and bone meal, and bakery by-product in addition to the processed food waste products were selected to be in duck rations for all duck ages. Canola meal was selected to be in the ration for ducks aged 0-2 weeks and 2-7 weeks. Minimum cost results obtained from chance-constrained programming were much higher than minimum cost results from linear programming due to higher costs associated with raising the likelihood of meeting the minimum protein requirement.

The second part of the thesis was examined using economic and financial analyses for the investment. The basic plant requirements to produce the three processed food waste products were the same, however energy costs were different for the three products. Revenue was generated from tipping fees and the sale of the three processed food waste products.

All Net Present Values (NPVs) for the investment were found to be positive. Producing product-1 to be used in rations for ducks aged 0-2 weeks and 2-7 weeks had an Internal Rate of Return (IRR) of 22% and an IRR of 18% for breeding ducks with the lowest IRR being 14% in producing rations for ducks aged 0-2 weeks and 2-7 weeks using product-3. Thus it would be expected that a plant producing a combination of the 3 products during the entire lifespan of the plant would generate an IRR ranging from 14% to 22 %. The IRR values were higher than average real returns on long-term Canadian bonds of 4.07% (Bank of Canada, 1999) and the average return on capital of 6.41% (Statistics Canada, 1999). These findings are sensitive to changes in the prices of the feed ingredients used in the ration formulation, tipping fees, taxes, operating and capital costs. Based on the calculations of the NPV and the IRR of the investment, it can be concluded that the project is financially feasible.

## Abrégé

L'objectif de cette étude était d'évalué le coût minimum des ratios nutritifs destinés à des canards de trois groupes d'âges différents. Cinq mélanges nutritifs ont été analysés. Le premier faisait appel à un mélange dit conventionnel. Les autres étaient dérivés de la transformation de déchets alimentaires. De plus l'étude mesurait la faisabilité économique d'un projet d'établissement d'une usine de transformation dans la région de Montréal pour transformer les déchets alimentaires. La variabilité du niveau de protéine contenu dans les différents mélanges a été pris en considération avec l'usage d'un programme mathématique appelé "chance-constrained programming".

Les prix du marché déterminés pour ces mélanges nutritifs faits à partir de déchets alimentaires ont été de $130.00, $117.00 et $104.00 pour les produits 1, 2 et 3, pour les canards dont l'âge se situe entre 0-2 semaines et 2-7 semaines. Pour les canards d'élevages le prix du marché était de $108.00 pour chaque produit transformé. En se basant sur ces prix, la viande et les farines d'os ainsi que les sous-produits des boulangeries et les déchets alimentaires transformés ont été inclus dans les ratios nutritifs des canards de toutes catégories. La farine de canola fut également incluse dans les ratios nutritifs des canards d'âge 0-2 semaines et 2-7 semaines. Les coûts minimums obtenus par le chance-constrained programme ont été plus élevés que ceux obtenus par l'utilisation d'un simple programme linéaire. Ceci est dut par l'augmentation des coûts liés à la nécessité d'accroître la probabilité de satisfaire le niveau de protéine requis.

La seconde partie de cette thèse arbore une analyse financière afin d'évaluer la faisabilité économique d'une usine de transformation. Les exigences requises par l'usine pour la transformation des trois classes de déchets alimentaires à des fins nutritifs ont été

supposés les mêmes. Les coûts d'énergie, par contre, sont différents pour les trois catégories en question. Les revenues dérivés par l'entreprise sont liés à la vente et la distribution des produits transformés.

Toutes les valeurs actuelles nettes ont (NPV) été calculés. Elles ont été toutes positives. En incorporant le produit-1 dans les ratios nutritifs pour les canards âgés de 0-2 semaines et 2-7 semaines, le taux de rendement interne (IRR) était de 22% et un taux de 18% pour les canards d'élevages. Le taux le plus bas étant de 14% pour les ratios destinés aux canards âgés entre 0-2 semaines et 2-7 semaines et utilisant le produit-3. Ainsi, durant toute la période de mise en fonction, l'usine de transformation des déchets nutritifs peut espérer un rendement interne entre 14% et 22%. Ces valeurs sont bien supérieurs aux rendements moyens des obligations à long terme du Canada de 4.07% (Banque du Canada, 1999) et aux rendements moyens sur capital investi de 6.07% (Banque du Canada, 1999). Ces chiffres sont bien évidement sensibles aux prix des ingrédients utilisés dans les ratios nutritifs, aux coûts de distributions, et aux coûts d'opérations et du capital. En se basant sur les résultats des taux de rendements internes et ceux des valeurs actuelles nettes, il est possible de conclure que l'investissement est financièrement faisable.

## ACKNOWLEDGEMENT

I would like to express my sincere thanks to my supervisor, Professor Henning, for his assistance in outlining the research procedure, patience, skillful guidance, constructive criticism and support during the study. My thanks also go to Professor Laurie Baker for his encouragement, sound advice, constructive criticism and suggestions.

A number of people have provided assistance during the study. Professor Chavez and Professor Touchburn, Department of Animal Science, Macdonald Campus, McGill University for information on the process involved in food waste processing and data on the pilot plant at the Macdonald Campus Farm. Mr. Ed Kroeker, Marketing Director of Thermo Tech Incorporated, Hamilton, Ontario for financial data on the operation of the plant.

I would like to give my appreciation to the graduate secretary, Mrs. Patricia Atkinson who always gave me her kindness and useful assistance when I had requests and problems. Throughout my stay in the Department of Agricultural Economics, I received help from fellow graduate students. It is difficult to credit each person in turn, but I am extremely grateful, especially to Frank Amankwah for his encouragement and suggestions and friendship. I thank Dr Samuel Aggrey, formerly of the Department of Animal Science, Macdonald campus for his advice and help and the members of the Church of Pentecost, Montreal especially Charles Yeboah for his support and help. To my family, Setorme and Ohene-Kofi, thanks for your encouragement and support which has enabled me to complete my studies.

## TABLE OF CONTENTS

## LIST OF TABLES

**LIST OF APPENDICES**

# CHAPTER 1

## 1.1 INTRODUCTION

Today's industrial world is a wasteful society in which garbage output continues to grow, as does the environmental damage from waste disposal (Young, 1991). When a waste disposal problem is mentioned, what comes to mind is toxic and radioactive waste, which is dangerous and therefore newsworthy, rather than food waste. Food processors produce a significant amount of waste from production or packaging problems, product spillage or products that have passed their shelf life (Top, 1991). This is in addition to food waste from the residential sector and the commercial sector such as restaurants and hospitals. Food waste therefore could be produced from four sources, raw material waste, food processing waste, post processing waste and post consumer waste (Lencki, 1995).

These food wastes must be disposed of in an environmentally and economically feasible manner. One of the main ways of disposal is to transport food waste to landfills. Due to its negative characteristics such as odors, attraction to animals, and creation of migrating gases, it is important to reduce the quantity of food waste that is going to landfills (Derr and Dhillion, 1997).

Pequenta (1975), examining the economics of waste residual accumulation, explained that mankind has considered the environment as an abundant and free good. Since there is no such thing in the long run, the result is a massive build up of waste in the environment, creating serious problems. The public response to this waste problem has been through intervention in the production and distribution of particular goods and services in a regulatory manner by establishing rules and guidelines. Formerly, without these rules and regulations, wastes from the industrial and residential sector were disposed of without any direct cost to the generators of such waste. Waste was therefore disposed off in the environment without due regard to the externalities that this caused society. An example of such externalities from waste is the odor from food waste. Such externalities force waste to take on a negative value. When waste resources become subjected to the forces and incentives of the market system, reduction of environmental impact takes place. Rules and regulations enforced by penalties serve to control the disposal of waste. Innovations are also introduced to control this waste. Those that are economically feasible and could be used at least cost are greatly sought after. Examples of some of the innovations are recycling of glass, paper and plastic. Another innovation being suggested is the recycling of industrial and residential food waste into animal feed. This is seen worldwide as a possible solution to the control of the negative environmental externalities from food waste. There is some recycling of food waste into animal feed but this is far from being fully exploited.

Industrial and residential food waste recycling that is technically and economically feasible would have tremendous economic significance in today's animal agriculture and to its future prospects. The long-term consequences of growing resource scarcity and concern for environmental quality dictate that food waste recycling is a positive step that will be increasingly profitable to animal agriculture and society. The present study attempts to examine the profitability of producing duck feed from processed food waste at the industrial level.

## 1.2 OBJECTIVES

The objectives of the study are:

1. To estimate the cost of industrial scale processing of food waste into three final products, in the Montreal region.
2. To identify the minimum cost of producing duck feeds using a mixture of processed food waste and commercial feed ingredients.
3. To examine the impact of variability in protein level in the feed ingredients on the cost of producing duck rations.
4. To estimate the market price for processed food waste products as ingredients in duck rations.
5. To evaluate the financial performance of a waste processing plant.

## 1.3 ORGANISATION OF THE STUDY

This study examines the profitability of producing duck feed from food waste and commercial feed ingredients at the industrial level. It was based on information supplied from laboratory studies of feeding recycled agro-industrial food waste to ducks from starter to finishing for the purposes of comparing the feed conversion efficiency to conventional feeding.

Chapter 2 provides an overview of current levels of waste production and the literature on waste and food waste generation. This also includes an inventory of the food waste situation in Montreal. This section also provides an overview of the literature concerning the use of mathematical programming models to solve least-cost feed mix problems, with particular attention to the case when technical coefficients are not deterministic. This provides the foundation for model specifications that follow.

Chapter 3 examines the method used to conduct the analysis in the study. The chapter begins with an examination of the programming models used and identifies the constraints. This chapter also includes descriptions of the industrial plant requirements and layout and goes on to discuss the methods used in the financial and economic profitability analysis of the plant. Chapter 4 presents the results of the study and discuses these findings. The final chapter summarizes the main findings and conclusions of the study.

## CHAPTER TWO

## LITERATURE REVIEW

### 2.1 INTRODUCTION

The purpose of this chapter is to provide a brief overview of waste with emphasis on food waste and review studies that concern the use of programming models in ration formulation. The first section reviews the extent of waste and food waste and the economics behind its management and disposal. This section describes some research done on the processing of food waste to convert it into animal feed. The types of food waste available in Montreal for processing are presented.

The second section reviews literature on ration formulation and the introduction of risk in ration formulation to account for nutrient variability. Literature on two programming models, linear programming model and chance constrained programming model are discussed.

### 2.2 WASTE GENERATION

Increasing urbanization and unsustainable patterns of production and consumption are increasing the quantity of waste globally and the cost of disposal has risen about10-20 % over the past 20 years (Trade and Environmental Case Studies, 1997).

According to a report prepared for the U.S Environmental Protection Agency, a total of 208 million tonnes of municipal solid waste were generated in 1995 in the US. This is an average of 1.8kg per person per day (0.66 tonne/year). Waste production was projected to increase to 226 million tonnes by the year 2000 and 257 million tonnes by the year 2010 (Franklin Associates Ltd., 1997). In 1999, residents of Seoul in South

Korea generated a total of 10,765 tonnes of residential waste a day representing 1.05kg per person out of which 30% was food waste (Seoul Metropolitan Government, 2001).

In 1998, Canadians generated an average of 1 tonne of waste per person with residents in Quebec producing the most waste at 1.21 tonnes and residents of Nova Scotia the least at 0.77 tonnes (The Globe and Mail, November 2000). The City of Toronto processes and disposes of more than 2.0 million tonnes of municipal, private, and recyclable waste annually (City of Toronto, 1999). The Saint-Michel Environmental Complex in Montreal has a 75-hectare landfill site that receives 550,000 metric tonnes of municipal waste each year and this amount is being added to about 33 million tonnes of waste already buried (Ville de Montréal, 1998; Sanisoft, 2000). A significant proportion of wastes generated are food waste.

### 2.2.1 FOOD WASTE GENERATION

Food Waste includes leftover portions of meals and trimmings from food preparation activities in kitchens, restaurants, fast food chains, and cafeterias. It also includes wastes from agro-industrial establishments. The following table shows the composition of municipal solid waste in selected countries.

Table 2.1 Composition of municipal waste by selected countries

| | **Paper & Paperboard** | **Food & garden waste** | **Plastics** | **Glass** | **Metals** | **Textiles & others** |
|---|---|---|---|---|---|---|
| **Canada** | 28% | 34% | 11% | 7% | 8% | 13% |
| **US** | 38% | 24% | 9% | 6% | 8% | 15% |
| **Mexico** | 14% | 52% | 4% | 6% | 3% | 20% |
| **Germany** | 41% | 23% | 3% | 22% | 8% | 3% |
| **France** | 25% | 29% | 11% | 13% | 4% | 18% |

All figures are for 1997.
Source: The Globe and Mail, October 2000.

The table indicates that food and garden waste is the first significant component of municipal waste in Mexico, Canada and France; and the second in the US and Germany. It is estimated that food waste in the US comprised about 14.2 million tonnes in 1995 and it is projected to increase to 15 million tonnes in 2000 and 16.3 million tonnes by 2010 (Franklin Associates Ltd., 1997).

Canadians produce an estimated 3.0 million tonnes of food waste annually (Chang, 1998). The Institute of Environmental Science at the University of Quebec in Montreal, in a one-year study collected and analyzed about 200kg of household waste per day in Montreal. In the study, they found that household garbage in Montreal was typically comprised of 31% paper and cardboard, 24% food waste and the rest comprised plastic, garden waste, metals and other waste materials (Daniel Gagnon, 1995).

A scientific committee made up of representatives from universities, the Ministry of Agriculture, feed companies and veterinarians was formed by the Centre Québécois de Valorisation de la Biomasse in 1993 to identify the agro-industrial waste generated in the province of Québec. The inventory demonstrated that the agro-industrial food sector in Quebec produces 296,738 tonnes of dry matter annually. The description of food waste includes uneaten food and food preparation wastes from households, commercial establishments like restaurants, hotels, institutions like hospitals, schools, food processors, grocery distributors and retailers (Centre Québécois de la Valorisation de la Biomasse, 1993).

Canadians therefore produce more food waste per household than US households. Residents in Quebec produce the most waste per person and are likely to produce much more food waste than residents in other parts of Canada. Recycling of food waste in

Quebec would reduce dumping in landfills and make available nutrients from the food waste to the society.

### 2.2.2 FOOD WASTE CHARACTERISTICS

Food waste could be grouped under the following headings.

a) Waste from plant origin- this is composed of fruits such as whole fruits, fruit peels, fruit juice and fruit purees; vegetables such as whole vegetables, vegetable peels, out of date vegetable juices and puree; cereal wastes.

b) Wastes of miscellaneous or mixed origin- this is composed of bakery wastes such as breads, cakes and pastries; manufactured goods such as beverages, prepared dinners, sauces and baby formula.

c) Waste from animal origin- this is composed of meat such as meat processing wastes and outdated consumer meat products; fish and fish products; dairy wastes and products.

Sources of these specific waste products are from the food service section of institutions, restaurants (all categories), food wholesale and retail outlets, food processing operations and food related operations such as feed mills and residential activities (Thermo-Tech Inc., 1999).

### 2.2.3 ENVIRONMENTAL REGULATIONS AND LAWS FOR WASTE DISPOSAL IN CANADA

The federal government of Canada provides federal environmental regulation for waste disposal with the Canadian Environmental Assessment Act (CEAA) in 1995 and the Canadian Environmental Protection Act (CEPA) in 1999. The CEAA requires an environmental assessment by federal authorities of the operations of industries in their disposal of waste and the environmental effects from such disposal. In addition, the CEAA issues a federal permit or approval for a new project to be carried out based on the report of an environmental assessment. The factors to be considered in an environmental assessment report include reports on the project's likely environmental effects (waste disposal), the significance of these effects, public comments and mitigation measures. The CEPA regulates waste being divided into toxic and non-toxic categories and the appropriate disposal of each type of waste. Non-toxic food waste is required under the act to be disposed of in landfills, through composting plants or to be recycled (Lexpert, 2000).

The provinces and territories have the constitutional authority to deal with most activities relating to solid waste disposal and have established their own legislation in general environmental rights and responsibilities. The Quebec Environmental Quality Act (EQA) prescribes standards for the location, maintenance and operation of waste disposal sites and waste management systems. Taxes are imposed on citizens by municipal authorities for the disposal of residential wastes. Waste collection companies require special permits issued by the provincial authorities to operate and charge tipping fees for the disposal of industrial waste (Canadian Institute for Business and the Environment, 1997). Food wastes in Montreal are disposed of at the Complexe Environemental de Saint-Michel, a landfill formerly known as the Miron quarry. The following are some management options that have been used to dispose of food waste and their effectiveness.

### 2.2.4 FOOD WASTE MANAGEMENT OPTIONS

Several options are available for the disposal or recycling of food waste. These include (1) landfilling; (2) incineration; (3) composting; (4) direct feeding to livestock; and (5) recycling (Derr and Dhillion, 1997).

Landfills are quickly becoming exhausted and the identification and acceptance of new landfill sites are becoming virtually impossible causing tipping fees to rise to discourage the use of landfills and promote recycling (Top, 1991). In addition there is a high cost associated with landfilling. Tipping fees in The Netherlands are about $300 per tonne (The Globe and Mail, November 2000). In North America, tipping fees for landfills are between $70-$200 per tonne (Daniel Gagnon, 1995). The Dan Mulroony Disposal landfill site in Kingston, charges $95 per tonne as tipping fees (City of Kingston, 1999). The annual cost to a household in Montreal for landfilling residential waste is estimated at about $58.98 per tonne (Local Government Institute, 1997).

Incineration causes air pollution and results in the loss of valuable nutrients in the food waste to society. Another option is composting or feeding the food waste directly to livestock. The compost serves as fertilizer for farms and there is a long history of feeding food waste to swine as the nutritional requirement for swine are very similar to humans.

Recycling is an attractive alternative as it adds value to the food waste, increases storage life, transportability and handling characteristics of food waste. Research undertaken has created the technology to process various food wastes into animal feed (Derr and Dhillion, 1997).

A Vancouver based Canadian company, Thermo Tech Technologies, has an operating plant in Hamilton, Ontario that takes in about 400 tonnes of wet food waste per day and produces about 100 tonnes of dry animal feed per day. Thermo Tech uses microbiology (thermophilic bacteria) to convert wet organic waste into a high protein animal feed (Chang, 1998).

In the years 1992-1994, a collaborative effort between the feed industry and McGill University with the financial support of le Centre Québecois de Valorisation de la Biomass (CQVB) was established to demonstrate the commercial feasibility of recycling food waste into animal feed. In preliminary work done at Macdonald Campus of McGill University, Normand, (1997) and Farhart, (1997) performed experiments to assess the potential of using processed food waste as duck feed. They carried out two experiments each with six treatments. The first treatment had the ducks being fed solely on commercial pelleted feed. The second treatment was to feed the ducks on chopped fresh vegetables. The third to the fifth treatments had the ducks being fed on a mix of fifty percent commercial feed and fifty percent processed food waste in wet or dry form. The sixth treatment was to feed the ducks solely on processed food waste. In the first experiment the ducks raised on commercial feed had a better feed-conversion ratio, but there was no significant difference between treatments in body weights of the ducks at maturity. In the second experiment the ducks fed on processed food waste had a better-feed conversion ratio and a higher live body weight. In both experiments, they discovered that the ducks receiving the processed food waste had higher body fat than feeding ducks with commercial feed. They concluded that it is possible to raise ducks to market weight using processed food wastes as the only source of feed. Thus, the results provide support for the formulation of duck diets using the processed food waste ingredients.

The pilot plant for these experiments was to serve as a model for a plant to be built at the industrial level to process food waste in Quebec. It was envisaged that output from the plant would be three intermediate products that could be used in ration formulations for ruminant and non-ruminant animals. As part of this project, a database of organic waste was constructed to obtain an estimate of the disposition of waste in the Montreal region.

#### 2.2.4.1 INVENTORY OF FOOD WASTE IN MONTREAL

451 companies were contacted, with 228 respondents providing estimates of their waste generation (Table 2.2). For each enterprise or institution in the database, the information available includes the type of the enterprise, number of places contacted, and the quantity of each waste.

Table 2.2 Profile of commercial food waste producers in Montreal

| Type of Enterprise | Number of places contacted | Number declaring waste | Quantity tonnes/ week |
|---|---|---|---|
| Abattoir | 9 | 5 | 50 |
| Army base | 2 | 2 | 306 |
| Bakery | 36 | 22 | 33.8 |
| Cafeteria | 13 | 6 | 19.6 |
| Dairy industry | 9 | 7 | 1630 |
| Food bank | 7 | 5 | 50 |
| Hotel | 20 | 11 | 125 |
| Hospital | 42 | 22 | 48 |
| Market | 6 | 55 | 157 |
| Prison | 3 | 3 | 3.4 |
| Produce retailer | 111 | 67 | 51 |
| Produce wholesaler | 19 | 9 | 303 |
| Hospital Association* | 1 | 1 | 100 |
| Processor | 149 | 45 | 918 |
| Restaurant | 8 | 2 | 18 |
| Restaurant chains* | 1 | 1 | 100 |
| School | 13 | 13 | 23 |
| School board* | 2 | 2 | 143 |
| **Total** | **451** | **228** | **4078.8** |

*These units are a collection of different waste generation sites.
Source: Chavez and Touchburn (1994), Normand (1997).

The table shows the distribution of 4078.8 tonnes of food waste reported by various sources in Montreal for recycling. Upon discarding moldy forms of the food waste and plastic materials from the sources above, Table 2.3 profiles the types food waste that could be available weekly for processing at the industrial level to feed ducks within Greater Montreal.

Table 2.3 Profile of available food waste

| Type of wastes | Number of locations | Quantity tonnes/week |
|---|---|---|
| Dairy by-products | 7 | 1599 |
| Fruits and vegetables | 31 | 888 |
| Mixed food | 40 | 397 |
| Grain | 1 | 163 |
| Bakery by-products | 21 | 34 |
| **Total** | **100** | **3081** |

Adapted from Chavez and Touchburn (1994).
Source: Normand (1997)

Samples of these waste products were collected and tested for their nutritional requirements. Based on the samples collected, chemical analysis of the waste was done to determine the nutrient composition of each food waste. Table 2.4 shows the proximate analysis that was done on the food waste. These results indicate that food waste available in Montreal contains nutrients that could be processed and converted into duck feed. Depending on the consistency of the food waste that arrives for processing, Chavez (2000), has proposed that three intermediate products (Appendix 1) could be developed and used in duck feed.

Table 2.4 Proximate analysis of food waste on dry matter basis.

| FOOD WASTE PRODUCT | DM (%) | FAT (%) | CP (%) | ASH (%) | GE Kcal/kg | ADF | Ca (%) | P (%) |
|---|---|---|---|---|---|---|---|---|
| Okra | 24.34 | 14.95 | 33.12 | 3.77 | 5134 | 12.93 | 0.27 | 0.46 |
| Shepherd's Pie | 37.01 | 22.45 | 40.65 | 5.55 | 5289 | 0.99 | 0.04 | 0.36 |
| Baked Beans | 35.28 | 3.4 | 19.33 | 4.85 | 4134 | 10.79 | 0.17 | 0.33 |
| Lentils | 23.33 | 1.16 | 26.35 | 9.82 | 3878 | 6.83 | 0.05 | 0.25 |
| Noodles | 44.9 | 4.45 | 15.47 | 0.32 | 4521 | 0.34 | 0.02 | 0.11 |
| Granola Bars | 88.36 | 9.6 | 6.51 | 1.31 | 4811 | 0.79 | 0.06 | 0.15 |
| Cookies | 84.92 | 3.49 | 11.47 | 1.34 | 4249 | 0 | 0.11 | 0.25 |
| Bread | 92.31 | 3.65 | 15.79 | 1.88 | 4387 | 1.01 | 0.02 | 0.17 |
| Pizza Pockets | 57.21 | 17.18 | 22.16 | 3.13 | 5048 | 0.99 | 0.25 | 0.3 |
| Pogo | 56.04 | 22.95 | 19.95 | 5.81 | 5068 | 0.78 | 0.29 | 0.26 |
| Mixed Vegetables | 17.73 | 1.86 | 14.44 | 3.93 | 4372 | 8.04 | 0.27 | 0.26 |
| Brewer's Grain | 30.14 | 5.92 | 19.43 | 4.22 | 4193 | 21.2 | 0.33 | 0.55 |
| Peanut Skin | 87.8 | 18.3 | 13.88 | 2.25 | 4864 | 34.1 | 0.33 | 0.09 |

Source: Analysis done at Crampton Nutrition laboratory, Macdonald Campus, McGill University. Normand (1997)

## 2.3 PREVIOUS STUDIES ON THE USE OF MATHEMATICAL PROGRAMMING IN RATION FORMULATION

### 2.3.1 LINEAR PROGRAMMING (LP)

Linear programming is a method of determining a profit maximizing or cost minimizing combination of activities that are feasible with respect to a set of constraints (Hazell and Norton, 1986). The general mathematical programming problem for feed formulation seeks to minimize the cost of producing one unit of a particular feed. It is of the form:

$$\text{Minimize } \Sigma_j C_j F_j \qquad (1)$$

Subject to:

$$\Sigma_j a_{ij} F_j \leq UL_i \qquad (2)$$

$$\Sigma_j a_{ij} F_j \geq LL_i \qquad (3)$$

$$\Sigma_j F_j = 1 \qquad (4)$$

$$F_j \geq 0 \quad \text{for all } j \qquad (5)$$

where

Index (i)- represents nutritional characteristics, which must fall within certain limits.

Index (j)- feed ingredients to be used to produce the poultry ration.

Fj - represents how much of each feed ingredient is used in the diet.

$C_j$ - cost of each feed ingredient.

The constraints are in the form of resource limits and minimum and maximum requirements. $UL_i$ and $LL_i$ are the maximum and minimum amount of the $i^{th}$ nutrient in the diet and $a_{ij}$ represent the amount of the $i^{th}$ nutrient in the $j^{th}$ feed ingredient (F).

The constraints in (5) are non-negative restrictions. If the objective function and the constraints are linear, then the problem is an LP problem. If the objective function and the constraints have nonlinear forms, then the problem is a Nonlinear Programming problem.

Waugh (1951), applied linear programming to the livestock feed formulation problem and it has become one of the most widely used linear programming applications. LP models have been used for about four decades in the feed manufacturing industry and offer many advantages such as speed of calculation and the comprehensiveness of the evaluation of prices and nutritional characteristics of feeds under consideration (VandeHaar and Black, 1991). VandeHaar and Black (1991), describe the application of linear programming for evaluating and formulating diets for a typical dairy farm. The LP provides a framework that is flexible in describing feeds and in formulating diets that are realistic and practical and relatively well balanced. However they recognize that it is also very easy to develop impractical diets with LP models. This is due to the fact that it is difficult to take into account nutrient variability in the feed ingredients that are used to formulate the overall diet. Variability comes about because nutritive content varies considerably from one batch of ingredients to the other. The response to these problems has been to introduce risk into linear programming problems.

### 2.3.2 RISK IN PROGRAMMING

The introduction of risk into the linear programming model of a firm was accomplished by describing risky outcomes as probability distributions and choosing from among alternate possible distributions on the basis of the expected utility hypothesis

(Freund, 1956). It is assumed that the money outcome of a unit of a process under risk conditions is a random variable, which follows some probability distribution. This distribution can be defined as representing some measure of the degree of belief that particular outcomes will occur. Due to distribution problems and lack of data to support or reject any assumed distribution, the normal was used in the development of a risk program. Freund (1956), examines risky outcomes in terms of net incomes as the objective function. The context of his formulation was;

$$Max \sum_j \overline{p} X_j - b \sum_j \sum_k s_{jk} X_j X_k \quad \text{.........................................(6)}$$

Subject to:

$$\sum_j X_j = 1 \qquad (7)$$

$$X_j \geq 0 \qquad (8)$$

where

$X_j$ & $X_k$ = net incomes from j and k.

$\overline{p}$ = expected value of the objective function coefficient.

b = risk aversion coefficient.

$s_{jk}$ = covariance between j and k.

Here the objective function maximizes expected income less a risk aversion coefficient, b, times the variance of total income.

### 2.3.3 RISK IN ANIMAL FEED FORMULATION

The general stochastic minimization problem in animal feed considers each $a_{ij}$ to be a random variable rather than as a constant as in the linear programming problem. The probability of formulating a diet, which must meet the nutrient requirement, can be increased to $P \geq \alpha_i$, in which case constraint (2) and (3) above can be converted to:

$$P\left\{\sum_j a_{ij} Fj \leq UL_i\right\} \geq \alpha_i \qquad (9)$$

$$P\left\{\sum_j a_{ij} Fj \geq LL_i\right\} \geq \alpha_i \qquad (10)$$

The P (A) symbolizes the probability of event A occurring i.e. the nutrient requirement for the animal will be met and $\alpha$ is the required probability that the requirement will be achieved.

By introducing risk to account for the variability of nutrients, it creates an analytical problem in which linear programming methods cannot address. In order to solve such problems, several methods have been suggested as discussed below.

### 2.3.3.1 APPROXIMATION THROUGH LINEARIZATION

Rahman and Bender (1971) suggested that in order to account for the variability of nutrient content and still be able to use commonly available linear programming algorithms, the non-linear equations could be approximated by linear functions. They used a Taylor series approximation to replace each non-linear stochastic constraint by a linear function.

Considering a constraint as it would appear in the original LP formulation;

$$\Sigma_j a_{ij} F_j = b_i \qquad (11)$$

where

$b_i$ = the required level of $i^{th}$ nutrient.

$a_{ij}$ = the amount of $i^{th}$ nutrient in the $j^{th}$ feed ingredient.

$F_j$ = the unknown quantity of the $j^{th}$ ingredient to be used in a unit of the final mix.

The mean and the variance of this linear function are as follows;

Mean: $$E(b_i) = \sum F_j\, E(a_{ij}) = \sum F_j \mu_{ij} \quad (12)$$

Variance: $$V(b_i) = E\,[\{b_i - E(b_i)\}^2] = \sum_j \sigma_{ij}^2 F_j^2 + \sum_j \sum_k \sigma_{ij,k} F_j F_k \quad (13)$$

where

$\sigma_{ij}^2$ = variance of ith nutrient in the jth feed ingredient.

$\sigma_{ij,k}$ = covariance between the jth and kth feed ingredients in their respective levels of ith nutrient.

Assuming that the nutrient contents of the ingredients are not correlated, their covariance is zero, and the variance reduces to;

$$V(b_i) = \sum_j \sigma_{ij}^2 F_j^2 \quad (14)$$

This is a quadratic expression. Through the use of a Taylor Series expansion, a linear approximation is given by;

$$V(b_i) = \sum_j \sigma_{ij} F_j \quad (15)$$

There is a mathematical error resulting from using this approximation and this error grows as the magnitude of the variance increases.

### 2.3.3.2 MAXIMIZATION

Chen (1973) argued that a solution found under the Rahman and Bender approach is not optimal in terms of the original stochastic programming problem. The result for the desired level of probability of success is likely to deviate greatly from the true optimal nonlinear programming result, because the solution obtained with the Rahman and Bender approach seeks to minimize $(\Sigma_j \sigma_{ij} F_j)^2$ instead of the true measurement of the total variance for any given cost and mean content restriction. She examines a revised stochastic programming problem in which the probability of success is maximized such that the cost and other linear inequality restrictions are satisfied. The cost of the ration will increase as the success rate increases, so that a nutritionist can set an upper bound on the cost of the ration. The revised stochastic programming problem to maximize the probability of success is;

$$\text{Maximize} \quad \text{Prob}\,(\Sigma_i \gamma_i UL_i + \Sigma_i \beta_i LL_i) \tag{16}$$

Subject to

$$\Sigma_i \gamma_i a_{ij} + \Sigma_i \beta_i a_{ij} \leq C_j \tag{17}$$

$$\gamma_i, \quad \beta_i \geq 0 \tag{18}$$

The dual variables are $\gamma_i$, the marginal value of the $i^{th}$ nutrient upper limit constraint, and $\beta_i$, the marginal value of the $i^{th}$ nutrient lower limit constraint. The problem then becomes a management decision, in which the success rate of meeting the variable nutrient requirement can be compared to the subsequent cost. She applied this maximization procedure to a numerical example to determine the least cost poultry ration. The computation was solved in an iterative manner. The cost was selected beginning from the least cost obtained from the LP formulation and gradually increased over a uniform range of values. The results from her analysis show that when cost increases, the probability of success increases at a decreasing rate and finally approaches one.

### 2.3.3.3 GOAL PROGRAMMING (GP)

Rehman and Romero (1984, 1986) examined the weakness of linear programming when applied to ration formulation. The ordinary least-cost approach may generate solutions that either cannot be implemented or supply nutritionally undesirable levels of various nutrients. The weaknesses were due to the exclusive reliance on cost as the only decision criterion. But the decision-maker may be interested in an economically optimal ration that achieves a compromise amongst several conflicting objectives such as minimization of cost, imbalances of nutrient supplies and the satisfaction of certain conditions like the calcium/phosphorus ratio. Their two papers introduced the applicability of multiple-criteria decision-making to ration formulation. The technique they used was goal programming and its variants such as weighted goal programming and multiple-objective programming to meet various objectives.

#### 2.3.3.3.1 WEIGHTED GOAL PROGRAMMING (WGP)

Weighted goal programming minimizes the deviations between desired levels of goals and the actual results. This is included in the model by converting inequality constraints into equalities through the addition of positive and negative deviation variables that permit either under, or over-achievement of each goal. These deviations become decision variables and are subjectively weighted according to the relative importance of each goal. The goals that were considered by Rehman and Romero were cost, nutritional imbalances, and the volume of the diet.

These goals are as follows;

$$\Sigma_j (a_{ij}F_j + p_j) = b_j \quad (19)$$

The decision variables of the objective function are expressed as percentage deviations from the target goals, and are given by;

$$\text{Min } \Sigma_j W_j p_j/b_j * 100 \quad (20)$$

where;

$W_j$ = weights attached to the deviational variables

$F_j$ = ration ingredients

$p_j$ = deviational variables representing under-achievement of the goal

bj = the goal to be achieved

To achieve the target goals, the $p_j$'s are minimized.

#### 2.3.3.3.2 MULTIPLE-OBJECTIVE PROGRAMMING (MOP)

MOP involves optimizing several objectives simultaneously. While WGP deals with several goals in the form of constraints, MOP deals with multiple objectives. In WGP, the objective is to minimize the sum of weighted deviations for a number of goals. MOP searches for the set of efficient or Pareto optimal solutions to a set of objectives and is given by;

$$\text{Min or Max } \Sigma_j W_j b_j(F) \quad (21)$$

Where $b_j(F)$ are the target goals set for each objective function. These goals consist of equations that are substituted in each objective function.

Lara (1993) used multiple-objective programming in a case study for dairy cow diets in Spain. He introduced a second objective, besides least-cost, the maximization of the inclusion in the diet of feeds available on the farm. He examined three models of the MOP. The first model had two objectives, the minimization of cost and the maximization of the use of stored feeds. The second model was made up of minimized cost, maximized use of on-farm feeds and minimized inclusion of off-farm feeds. The third model was a fractional form of MOP, which was made up of dividing the first model by the second model. The computations were done with the ADBASE software (Steur, 1993). His results found the fractional form of the MOP yielded the best solution for the farmer.

Rehman and Romero (1984, 1986), found that solutions to the GP problems are only efficient in a mathematical sense and can result in technically unacceptable solutions. The complexity of the analysis is in the choice of the weights, which if not selected with care can result in a large number of calculations.

### 2.3.3.4 CHANCE-CONSTRAINED PROGRAMMING

Chance-constrained programming was first developed and introduced by Charnes and Cooper, (1959). It is a well-known technique and has been applied to agriculture (Boisvert, 1976; Boisvert and Jensen, 1973; and Danok et al., 1980) and water management (Eisel, 1972; Loucks 1975; and Maji and Heady, 1978). It deals with variability assuming the decision-maker is willing to make a probabilistic statement about the frequency with which constraints need to be satisfied. Chance constrained programming requires a linear objective function but the constraints can be nonlinear.

The $a_{ij}$ are assumed to be independent and normally distributed random variables (Freund, 1956) with corresponding variances of $\sigma_{ij}^2$ (i.e. the variance of nutrient i for ingredient j). From constraint (11), the mean and the variance were given by equations (12) and (13). The covariance reduces to zero due to the independence of the $a_{ij}$ and the variance simplifies to;

$$V(b_i) = \Sigma_j \sigma_{ij}^2 F_j^2$$

Considering the stochastic constraint: $P(\Sigma_j a_{ij} F_j \geq b_i) \geq \alpha_i$, subtracting the expected value of $b_i$ from both sides and dividing by the standard deviation;

$$P\left[\frac{\sum_j a_{ij}F_j - \sum_j F_j E(a_{ij})}{(\sum_j \sigma_{ij}^2 F_j^2)^{1/2}} \geq \frac{b_i - \sum_j F_j E(a_{ij})}{(\sum_j \sigma_{ij}^2 F_j^2)^{1/2}}\right] \geq \alpha_i \text{.........................} (22)$$

if and only if:

$$\frac{b_i - \sum_j F_j E(a_{ij})}{(\sum_j \sigma_{ij}^2 F_j^2)^{1/2}} \geq Z_i \text{.........................................................} (23)$$

Where $Z_i$ is the number of standard errors that $b_i$ is away from the mean. This is restated as:

$$\Sigma F_j \mu_{ij} - Z(\Sigma_j \sigma_{ij}^2 F_j^2)^{1/2} \geq b_i \qquad (24)$$

Then constraints (9) and (10) are simplified to the form:

$$\sum_j \bar{a}_{ij} F_j + Z_i \sqrt{\sum_j \sigma_{ij}^2 F_j^2} \leq UL_i \text{.........................................................} (25)$$

$$\sum_j \bar{a}_{ij} F_j + Z_i \sqrt{\sum_j \sigma_{ij}^2 F_j^2} \geq LL_i \text{.........................................................} (26)$$

The term $Z_i$ is the standard normal deviate corresponding to the requested probability $\alpha_i$. The maximum nutrient constraints (≤ constraints) have nonnegative $Z_i$, while the corresponding minimum nutrient constraints have nonpositive $Z_i$. This can be explained as follows. If the desired probability of success is P≥ 0.95, then in the maximum constraint, the standard normal deviate is +1.645 because 95% of the standard normal distribution is less than or equal to +1.645. Similarly, if the desired probability of success is P≥ 0.95 in the minimum constraint, then the standard normal deviate is −1.645, because 95% of the standard normal deviation is greater that or equal to −1.645. This will ensure that that the probability of having a diet that meets the nutrient requirement is at least 95%. Changing the constraints into the form as above makes them nonlinear and must be solved using a non-linear algorithm.

### 2.3.3.4.1 APPLICATIONS IN ANIMAL FEED FORMULATION

In the animal diet formulation industry, Van de Panne and Popp (1963) used chance-constrained programming to take into account a varying protein content in ration formulation for a dairy farm. The resulting chance-constrained problem gave rise to a non-stochastic programming problem, which was linear in the objective function and quadratic in the constraints.

St-Pierre and Harvey (1986) investigated single chance-constrained programming, in which one nutrient requirement is probabilistic, and joint chance constrained programming, in which several minimum nutrient requirements are probabilistic. They used a general non-linear programming (NLP) computer program, MINOS (Modular In-core Nonlinear Optimization System), to solve the problem. Compared to other algorithms such as, the iterated Rahman and Bender algorithm, they concluded that the use of the NLP (MINOS) algorithm gave the best results in terms of least cost.

Black and Hlubick (1980) described the assumptions underlying LP and the resultant implications of incorporating biological knowledge into the LP framework. They also used chance-constrained programming in adjusting for variation in feedstuff nutrient values and in animal requirements. They concluded that if rations were formulated for average nutrient values, animal nutrient requirements would only be achieved 50% of the time, assuming symmetrical probability distributions. That is to say if rations are formulated using the nutrient requirements of the average animal, the nutrient requirements of 50% of the animals will not be met.

D'Alfonso et al (1992) compared the least-cost solutions for poultry rations formulated using linear programming, linear programming with a margin of safety and chance-constrained models. Each model was solved using GAMS (Brooke et al., 1988). The results indicated that chance-constrained programming achieved the best results in terms of satisfying the objective of least cost. The probability of formulating a diet that meets the desired nutrient requirements was more than 50 percent. Based on this research, an industrial poultry feed manufacturing company, Agway Incorporated, (Syracuse, New York) has been using chance-constrained programming in its formulations (Roush et al, 1994).

Chance-constrained has been applied in a wide variety of disciplines. Different computer software and algorithms have been developed to handle problems involving chance-constraints. Some other practical applications of chance-constrained programming are discussed below.

#### 2.3.3.4.2 OTHER APPLICATIONS OF CHANCE-CONSTRAINED PROGRAMMING

A key issue for credit unions is how the union manages the net income resulting from variations in operating costs and loan defaults. Smith (1988) presented a model of credit union loan and deposit rate decision making to consider the implications of uncertainty and taxation. The objective function in the model assumed that the credit union provides financial services to its members at rates that are better than elsewhere available. The objective function was based on differences between the credit union's deposit and loan rates and those from alternative sources. This was subject to a change in capital reserve of the credit union for a period and a change in a minimum level of capital that is required to enter the next period. The changes in capital reserve shows the variations in the net income due to the random nature of operating costs and default in loans i.e. the chance-constraint. Smith described the static properties of the model to draw conclusions. The credit union would prefer a larger increase in capital reserve to a small change in it. A higher level of capital reserves, a lower expected cost of operations and default rate on loans and less variance in the stochastic equation would all tend to improve the performance of the credit union by lowering loan rates and raising deposit rates (Smith, 1988).

Marti (1996) examined the application of chance constrained programming to the decision on the design of a mechanical structure in engineering. The parameters for the design of the structure (yield stresses, allowable stresses, moment capacities and specific gravity), external manufacturing errors and cost factors are not known at the planning stage and are considered to be random variables with a probability distribution. The correction of a design decision, if the random nature of the variables is not taken into account in the initial design, could be expensive and time consuming. By the use of chance-constrained programming, the objective function was replaced by the mean of its value and the random constraints replaced by chance constraints.

Wojciechowski et al (1999), used a chance constrained model to analyze several management decisions to determine if marketing tools used as substitutes for reduced government support, can be useful in managing revenue risk for cotton producers. The marketing tools used in the study were contracts and options. The random variables were price and yield distributions. The optimal marketing strategy depended on the level of future prices prior to planting. The results suggested that existing marketing tools could be used to reduce output and price uncertainty.

For this study linear programming and chance-constrained programming are used in the analysis. The wide application of the methods suggests that feed manufacturers can use it in ration formulations. There is also the existence of algorithms and software to solve such problems.

# CHAPTER 3

# RESEARCH METHODOLOGY

## 3.1 INTRODUCTION

The steps taken to determine the least cost feed mix for ducks and evaluate the investments in a food waste processing plant are outlined in this chapter. The first section presents a description of the general methodology used for the analysis, followed by a description of the programming models used to obtain the least cost feed mix. The linear and non-linear programming models have been designed to minimize the cost of rations for ducks. This was undertaken within the limits of nutritional requirements of ducks and the volume of ration to be produced.

The next section provides a description of the plant requirements and layout and examines the tools used in analysing the financial and economic viability of establishing and operating an industrial plant to process food waste. The description and design of the plant was used to estimate the cost of establishing a plant at the industrial level to process food waste into 3 final products. Data for the plant were obtained from Thermo Tech Inc in Ontario and the Department of Animal Science, Macdonald Campus, Hydro Quebec, and a real estate company (Royal Lepage, 2000) in Montreal and Ottawa.

## 3.2 DESCRIPTION OF METHODOLOGY

Depending on the type of waste that comes to the plant, three final products of different nutritional characteristics could be produced. These 3 processed food waste products were combined with 12 commercial feed ingredients in the programming analysis. The programming models were first analyzed using prices provided by Chavez

(2000), for the 3 processed food waste products (Product 1 --- $280.00 per tonne, Product 2 --- $200.00 per tonne, Product 3 --- $140.00 per tonne). Chavez proposed these prices based on expert advice from the Food Nutrition Department of McGill University. These prices were used in the programming analysis in order to estimate the level of market price the three products would be incorporated in the duck rations. The analysis estimated the least cost of producing duck rations when all values are deterministic and compared with least costs when some variability is introduced.

Revenue from the sale of the processed food waste products using the estimated prices from the programming models, revenue from tipping fees, investment and operating costs of the plant were used in estimating the Net Present Value (NPV) and the Internal Rate of Return (IRR). The NPV and the IRR were calculated based on the assumption that the plant receives food waste with consistent nutritional characteristics and produces either product 1, 2 or 3 within the year. In reality, the plant would be producing a combination of the three products within the year and the NPV and the IRR would range between producing products with the least returns to products with the most returns over the lifespan of the plant.

### 3.3 PROGRAMMING MODELS USED

The model building procedure in this study follows that of McCarl and Spreen (1997) and D'Alfonso et al (1992). The procedure included model construction and documentation and the determination of model coefficients from given data, market reports and private communication. The model minimized the cost of choosing feed ingredients (commercial feeds and processed food waste products) that meet the nutritional requirements of ducks in various stages of development. Three feeds were formulated for ducks between the ages of 0-2 weeks, 2-7 weeks, and breeding ducks. Two models were used, a linear programming model (LP) and a chance-constrained programming model (CC). Each of the models was solved with GAMS using the MINOS solver, a software package capable of solving both linear and non-linear programs.

### 3.3.1 DESCRIPTION OF THE LINEAR PROGRAMMING MODEL

The LP model requires some assumptions about the nature of the data and the products to be produced.

1) The prices of the commercial feed ingredients were the average 1999 market prices in Montreal per tonne (Agri-Food Canada, 1999).
2) The nutrient requirements for the duck rations were assumed constant and independent of the final product price. The nutrient characteristics of the feed ingredients used in the diet were assumed known with certainty. That is to say that different batches of the final diet were assumed to have the same nutrient content.
3) The duck rations formulated were assumed to depend on prices and nutrient requirements.

The objective function of the LP minimizes the cost of producing one tonne of the final duck ration by combining 12 commercial feed ingredients subject to nutritional constraints of ducks. Then the 3 processed food waste products were explicitly included with the commercial feed ingredients to run the model again.

The dietary constraints were formulated to meet the nutritional requirements of ducks in the 3 age categories as set by the National Research Council (NRC) in 1984 (Appendix 2). The nutritional requirements used in the analysis were dry matter (DM), fat, protein, crude fibre (CF), metabolizable energy (ME), calcium (C), phosphorus (P), and potassium (K). Appendix 1 shows the nutritional characteristics and prices of the 12 commercial feed ingredients and the 3 processed food waste products used in the ration formulation.

In mathematical terms, the LP model is written as:

$$\text{Minimize } \Sigma_j C_j F_j$$

Subject to:

$$\Sigma_j a_{ij} F_j \geq X_i$$

$$\Sigma_j F_j = 1$$

$$F_j \geq 0 \text{ for all } j$$

Where

Index (i) - represents nutritional characteristics of the feed ingredients used in the formulation.

Index (j) - feed ingredients.

$a_{ij}$ = the amount of the $i^{th}$ nutritional characteristic in the $j^{th}$ feed ingredient in kg/kg.

$X_i$ = the nutritional requirement of the duck ration in kg/kg.

Fj - represents how much of each feed ingredient is used in the diet.

$C_j$ - cost of each of the feed ingredients in dollars/tonne.

A representative diet for ducks of any age using only commercial feeds is shown in Table 3.1 and that with the inclusion of plant products is shown in Table 3.2. The commercial feed ingredients considered were Alfafa meal, Barley, Canola meal, Corn, Soybean, Oats, Wheat, Fish meal, Meat and Bone meal, Feather meal, Gluten meal, Bakery by-products, and the processed food waste products were Product 1, Product 2, and Product 3, which were represented by $F_1$, $F_2$, ..... $F_{15}$ respectively. $X_1$ ..... $X_8$ represents the nutritional ration requirements for ducks of a particular age.

Table 3.1 Framework for Linear Programming model (Commercial feed ingredients)

**Objective Function**

Min $210.00F_1 + 134.10F_2 + 168.16F_3 + 133.06F_4 + 282.82F_5 + 122.50F_6 + 151.00F_7 + 825.00F_8 + 303.00F_9 + 350.00F_{10} + 450.00F_{11} + 111.00F_{12} = Z$

**Subject to:**

**DM:** $92F_1 + 89F_2 + 93F_3 + 89F_4 + 90F_5 + 89F_6 + 88F_7 + 92F_8 + 93F_9 + 93F_{10} + 90F_{11} + 92F_{12} \geq X_1$

**ME:** $1630F_1 + 2640F_2 + 2000F_3 + 3350F_4 + 2440F_5 + 2550F_6 + 2568F_7 + 2830F_8 + 2150F_9 + 2360F_{10} + 3720F_{11} + 3862F_{12} \geq X_2$

**PROTEIN:** $20.0F_1 + 11.0F_2 + 38.0F_3 + 8.5F_4 + 48.5F_5 + 11.4F_6 + 15.3F_7 + 63.6F_8 + 50.4F_9 + 81.0F_{10} + 62.0F_{11} + 10.5F_{12} \geq X_3$

**FAT:** $3.6F_1 + 1.8F_2 + 3.8F_3 + 3.8F_4 + 1.0F_5 + 4.2F_6 + 3.3F_7 + 9.3F_8 + 10.0F_9 + 7.0F_{10} + 2.5F_{11} + 11.7F_{12} \geq X_4$

**CF:** $20.2F_1 + 5.5F_2 + 12.0F_3 + 2.2F_4 + 3.9F_5 + 10.8F_6 + 2.6F_7 + 0.5F_8 + 2.8F_9 + 1.0F_{10} + 1.3F_{11} + 1.2F_{12} \geq X_5$

**C:** $1.67F_1 + 0.03F_2 + 0.68F_3 + 0.02F_4 + 0.27F_5 + 0.06F_6 + 0.04F_7 + 1.23F_8 + 10.30F_9 + 0.33F_{10} + 0.50F_{11} + 0.13F_{12} \geq X_6$

**P:** $0.28F_1 + 0.36F_2 + 1.17F_3 + 0.28F_4 + 0.62F_5 + 0.27F_6 + 0.49F_7 + 1.63F_8 + 5.10F_9 + 0.55F_{10} + 0.14F_{11} + 0.24F_{12} \geq X_7$

**K:** $2.15F_1 + 0.48F_2 + 1.29F_3 + 0.30F_4 + 1.98F_5 + 0.45F_6 + 0.51F_7 + 0.69F_8 + 1.45F_9 + 0.30F_{10} + 0.35F_{11} + 0.35F_{12} \geq X_8$

**Volume:** $F_1 + F_2 + F_3 + F_4 + F_5 + F_6 + F_7 + F_8 + F_9 + F_{10} + F_{11} + F_{12} = 1$

Table 3.2 Framework for Linear Programming model (Commercial feed ingredients + Processed food waste products)

**Objective Function**

$$\text{Min } 210.00F_1 + 134.10F_2 + 168.16\,F_3 + 133.06F_4 + 282\,.82F_5 + 122.50F_6 + 151.00F_7 + 825.00F_8 + 303.00F_9 + 350.00F_{10} + 450.00F_{11} + 111.00F_{12} + 280.00F_{13} + 200.00F_{14} + 140.00F_{15} = Z$$

**Subject to:**

**DM:** $92F_1 + 89F_2 + 93\,F_3 + 89F_4 + 90F_5 + 89F_6 + 88F_7 + 92F_8 + 93F_9 + 93F_{10} + 90F_{11} + 92F_{12} + 86.16F_{13} + 87.00F_{14} + 85.50F_{15} \geq X_1$

**ME:** $1630F_1 + 2640F_2 + 2000\,F_3 + 3350F_4 + 2440F_5 + 2550F_6 + 2568F_7 + 2830F_8 + 2150F_9 + 2360F_{10} + 3720F_{11} + 3862F_{12} + 3310F_{13} + 3148F_{14} + 2880F_{15} \geq X_2$

**PROTEIN:** $20.0F_1 + 11.0F_2 + 38.0\,F_3 + 8.5F_4 + 48.5F_5 + 11.4F_6 + 15.3F_7 + 63.6F_8 + 50.4F_9 + 81.0F_{10} + 62.0F_{11} + 10.5F_{12} + 22F_{13} + 15F_{14} + 8F_{15} \geq X_3$

**FAT:** $3.6F_1 + 1.8F_2 + 3.8\,F_3 + 3.8F_4 + 1.0F_5 + 4.2F_6 + 3.3F_7 + 9.3F_8 + 10.0F_9 + 7.0F_{10} + 2.5F_{11} + 11.7F_{12} + 12F_{13} + 8.98F_{14} + 5.96F_{15} \geq X_4$

**CF:** $20.2F_1 + 5.5F_2 + 12.0\,F_3 + 2.2F_4 + 3.9F_5 + 10.8F_6 + 2.6F_7 + 0.5F_8 + 2.8F_9 + 1.0F_{10} + 1.3F_{11} + 1.2F_{12} + 1.92F_{13} + 8.61F_{14} + 15.29F_{15} \geq X_5$

**C:** $1.67F_1 + 0.03F_2 + 0.68\,F_3 + 0.02F_4 + 0.27F_5 + 0.06F_6 + 0.04F_7 + 1.23F_8 + 10.30F_9 + 0.33F_{10} + 0.50F_{11} + 0.13F_{12} \geq X_6$

**P:** $0.28F_1 + 0.36F_2 + 1.17F_3 + 0.28F_4 + 0.62F_5 + 0.27F_6 + 0.49F_7 + 1.63F_8 + 5.10F_9 + 0.55F_{10} + 0.14F_{11} + 0.24F_{12} \geq X_7$

**K:** $2.15F_1 + 0.48F_2 + 1.29F_3 + 0.30F_4 + 1.98F_5 + 0.45F_6 + 0.51F_7 + 0.69F_8 + 1.45F_9 + 0.30F_{10} + 0.35F_{11} + 0.35F_{12} \geq X_8$

**Volume:** $F_1 + F_2 + F_3 + F_4 + F_5 + F_6 + F_7 + F_8 + F_9 + F_{10} + F_{11} + F_{12} + F_{13} + F_{14} + F_{15} = 1$

### 3.3.2 DESCRIPTION OF THE CHANCE-CONSTRAINED PROGRAMMING MODEL

It is well known that the level of a nutrient in a particular feed ingredient will vary from lot to lot. Meanwhile, the nutrient content of feed ingredients is critical when developing rations to feed animals that are producing meat, milk or eggs (Shutze and Benoff, 1981). Thus, taking into account this variability could change the optimal feed mix. In this section the model is altered by relaxing assumption 2 for the LP. It had been assumed that the nutrient variance for each ingredient was known. Now this assumption is relaxed within the framework of a chance-constrained model.

Accounting for this variability is important to the feed manufacturer who needs to guarantee a minimum content of some nutritive elements in the feed mix. Although protein is not the only variable nutrient in duck diets, it is frequently the limiting factor in duck rations and protein supplements are relatively expensive. The variance of nutrients other than protein has little effect on least cost solutions (St-Pierre and Harvey, 1986).

The chance-constrained model was used to identify the least cost duck feed that was likely to meet a specified minimum protein requirement. That is, a probability is assigned to the likelihood that samples taken from different batches of the ration will have the required protein content. A chance-constraint was applied to the protein level and the probability set at 95%. Other variables are considered to be deterministic.

In mathematical terms, the chance-constrained model is written as:

$$\text{Minimize } \Sigma_j C_j F_j$$

Subject to:

$$\Sigma_j a_{ij} F_j \geq X_i$$

$$\sum_j \bar{a}_{ij} F_j + Z_i \sqrt{\sum_j \sigma_{ij}^2 F_j^2} \geq X_i$$

$$\Sigma_j F_j = 1$$

$$F_j \geq 0$$

where;

$a_{ij}$ = the amount of the $i^{th}$ nutritional characteristic in the $j^{th}$ feed ingredient in kg/kg.

$X_i$ = the nutritional requirement of ducks in kg/kg.

Fj = represents how much of each feed input is used in the diet.

$C_j$ = cost of each feed input in dollars/tonne.

$Z_i$ = standard normal deviate corresponding to a probability of 95%.

$\sigma_{ij}$ = standard deviation of protein for a feed ingredient.

The stochastic constraint in the model represents the probabilistic requirement for protein in the diet and accounts for the variability of protein in each feed ingredient. The desired probability of success was set at P≥ 0.95 corresponding to a standard normal deviate of −1.645, because 95% of the standard normal distribution is greater than or equal to −1.645. This ensured that that the probability of having a diet that meets the protein requirement is at least 95%. The stochastic constraint requires the mean and variance of protein in feed ingredients. The mean and variance of the nutritive content of feed ingredients were obtained from several sources and the values shown in Table 3.3. The variance for processed food waste products from the plant was not included in the programming model because these are manufactured products and the protein level could be controlled within a small margin of error to the stated protein content.

Table 3.3 Means and Variances of protein levels in feed ingredients.

| | Mean (% protein) | Variance |
|---|---|---|
| Dehydrated Alfafa meal | 20.0 | 1.08 |
| Barley | 11.0 | 0.61 |
| Canola Meal | 38.0 | 1.00* |
| Corn | 8.5 | 0.36 |
| Soybean meal | 48.5 | 1.00 |
| Oats | 11.4 | 0.78 |
| Wheat | 15.3 | 0.96 |
| Fish meal | 63.6 | 1.39 |
| Meat and bone meal | 50.4 | 3.24 |
| Feather meal | 81.0 | 3.16 |
| Gluten meal | 62.0 | 16.67 |
| Bakery by-products | 10.5 | 5.34 |

* Variance for canola meal was assumed to be the same as that for soybean meal.
Source: Shutze and Benoff, 1981; National Research Council, 1984; St-Pierre and Harvey, 1986

A representative stochastic programming model for ducks of any age is presented in Tables 3.4 and 3.5 below. Table 3.4 was used in analysing commercial feed ingredients only and Table 3.5 for commercial feed and the 3 processed food waste products. $X_1$....... $X_8$ represents the nutritional requirements for ducks of a particular age.

Table 3.4 Framework for Chance-constrained Programming model (Commercial feed ingredients)

**Objective Function**

Min $210.00F_1 + 134.10F_2 + 168.16\ F_3 + 133.06F_4 + 282\ .82F_5 + 122.50F_6 + 151.00F_7 + 825.00F_8 + 303.00F_9 + 350.00F_{10} + 450.00F_{11} + 111.00F_{12} = Z$

**Subject to:**

**DM:** $92F_1 + 89F_2 + 93\ F_3 + 89F_4 + 90F_5 + 89F_6 + 88F_7 + 92F_8 + 93F_9 + 93F_{10} + 90F_{11} + 92F_{12} \geq X_1$

**ME:** $1630F_1 + 2640F_2 + 2000\ F_3 + 3350F_4 + 2440F_5 + 2550F_6 + 2568F_7 + 2830F_8 + 2150F_9 + 2360F_{10} + 3720F_{11} + 3862F_{12} \geq X_2$

**PROTEIN**:** $20.0F_1 + 11.0F_2 + 38.0\ F_3 + 8.5F_4 + 48.5F_5 + 11.4F_6 + 15.3F_7 + 63.6F_8 + 50.4F_9 + 81.0F_{10} + 62.0F_{11} + 10.5F_{12} - 1.645\ \mathrm{SQRT}\ (1.082F_1^2 + 0.61F_2^2 + 0F_3^2 + 0.36F_4^2 + 1.00F_5^2 + 0.78F_6^2 + 0.96F_7^2 + 1.39F_8^2 + 3.24F_9^2 + 3.16F_{10}^2 + 16.67F_{11}^2 + 5.34F_{12}^2) \geq X_3$

**FAT:** $3.6F_1 + 1.8F_2 + 3.8\ F_3 + 3.8F_4 + 1.0F_5 + 4.2F_6 + 3.3F_7 + 9.3F_8 + 10.0F_9 + 7.0F_{10} + 2.5F_{11} + 11.7F_{12} \geq X_4$

**CF:** $20.2F_1 + 5.5F_2 + 12.0\ F_3 + 2.2F_4 + 3.9F_5 + 10.8F_6 + 2.6F_7 + 0.5F_8 + 2.8F_9 + 1.0F_{10} + 1.3F_{11} + 1.2F_{12} \geq X_5$

**C:** $1.67F_1 + 0.03F_2 + 0.68\ F_3 + 0.02F_4 + 0.27F_5 + 0.06F_6 + 0.04F_7 + 1.23F_8 + 10.30F_9 + 0.33F_{10} + 0.50F_{11} + 0.13F_{12} \geq X_6$

**P:** $0.28F_1 + 0.36F_2 + 1.17F_3 + 0.28F_4 + 0.62F_5 + 0.27F_6 + 0.49F_7 + 1.63F_8 + 5.10F_9 + 0.55F_{10} + 0.14F_{11} + 0.24F_{12} \geq X_7$

**K:** $2.15F_1 + 0.48F_2 + 1.29F_3 + 0.30F_4 + 1.98F_5 + 0.45F_6 + 0.51F_7 + 0.69F_8 + 1.45F_9 + 0.30F_{10} + 0.35F_{11} + 0.35F_{12} \geq X_8$

**Volume:** $F_1 + F_2 + F_3 + F_4 + F_5 + F_6 + F_7 + F_8 + F_9 + F_{10} + F_{11} + F_{12} = 1$

Table 3.5 Framework for Chance-constrained Programming model (Commercial feed ingredients + Processed food waste products)

**Objective Function**

$$\text{Min } 210.00F_1 + 134.10F_2 + 168.16\ F_3 + 133.06F_4 + 282.82F_5 + 122.50F_6 + 151.00F_7 + 825.00F_8 + 303.00F_9 + 350.00F_{10} + 450.00F_{11} + 111.00F_{12} + 280.00F_{13} + 200.00F_{14} + 140.00F_{15} = Z$$

**Subject to:**

**DM:** $92F_1 + 89F_2 + 93\ F_3 + 89F_4 + 90F_5 + 89F_6 + 88F_7 + 92F_8 + 93F_9 + 93F_{10} + 90F_{11} + 92F_{12} + 86.16F_{13} + 87.00F_{14} + 85.50F_{15} \geq X_1$

**ME:** $1630F_1 + 2640F_2 + 2000\ F_3 + 3350F_4 + 2440F_5 + 2550F_6 + 2568F_7 + 2830F_8 + 2150F_9 + 2360F_{10} + 3720F_{11} + 3862F_{12} + 3310F_{13} + 3148F_{14} + 2880F_{15} \geq X_2$

**PROTEIN**:** $20.0F_1 + 11.0F_2 + 38.0\ F_3 + 8.5F_4 + 48.5F_5 + 11.4F_6 + 15.3F_7 + 63.6F_8 + 50.4F_9 + 81.0F_{10} + 62.0F_{11} + 10.5F_{12} + 22F_{13} + 15F_{14} + 8F_{15} - 1.645\ \text{SQRT}\ (1.082F_1^2 + 0.61F_2^2 + 0F_3^2 + 0.36F_4^2 + 1.00F_5^2 + 0.78F_6^2 + 0.96F_7^2 + 1.39F_8^2 + 3.24F_9^2 + 3.16F_{10}^2 + 16.67F_{11}^2 + 5.34F_{12}^2) \geq X_3$

**FAT:** $3.6F_1 + 1.8F_2 + 3.8\ F_3 + 3.8F_4 + 1.0F_5 + 4.2F_6 + 3.3F_7 + 9.3F_8 + 10.0F_9 + 7.0F_{10} + 2.5F_{11} + 11.7F_{12} + 12F_{13} + 8.98F_{14} + 5.96F_{15} \geq X_4$

**CF:** $20.2F_1 + 5.5F_2 + 12.0\ F_3 + 2.2F_4 + 3.9F_5 + 10.8F_6 + 2.6F_7 + 0.5F_8 + 2.8F_9 + 1.0F_{10} + 1.3F_{11} + 1.2F_{12} + 1.92F_{13} + 8.61F_{14} + 15.29F_{15} \geq X_5$

**C:** $1.67F_1 + 0.03F_2 + 0.68\ F_3 + 0.02F_4 + 0.27F_5 + 0.06F_6 + 0.04F_7 + 1.23F_8 + 10.30F_9 + 0.33F_{10} + 0.50F_{11} + 0.13F_{12} \geq X_6$

**P:** $0.28F_1 + 0.36F_2 + 1.17F_3 + 0.28F_4 + 0.62F_5 + 0.27F_6 + 0.49F_7 + 1.63F_8 + 5.10F_9 + 0.55F_{10} + 0.14F_{11} + 0.24F_{12} \geq X_7$

**K:** $2.15F_1 + 0.48F_2 + 1.29F_3 + 0.30F_4 + 1.98F_5 + 0.45F_6 + 0.51F_7 + 0.69F_8 + 1.45F_9 + 0.30F_{10} + 0.35F_{11} + 0.35F_{12} \geq X_8$

**Volume:** $F_1 + F_2 + F_3 + F_4 + F_5 + F_6 + F_7 + F_8 + F_9 + F_{10} + F_{11} + F_{12} + F_{13} + F_{14} + F_{15} = 1$

## 3.4 INVESTMENT IN INDUSTRIAL PLANT

The proposed plant was designed to convert a broad range of food waste into 3 value added end products. Estimated market prices derived from the programming analysis that allows the processed food waste products to be included in the least cost duck rations were used in estimating the Net Present Value (NPV) and the Internal Rate of Return (IRR) in the investment analysis. The investment analysis estimated the maximum NPV and IRR before taxes.

## 3.5 PLANT REQUIREMENTS AND LAYOUT

Appendix 3 provides a list of major components and a material flow diagram for a typical food waste processing plant. These are based on the pilot project at Macdonald Campus and the industrial plant built in Hamilton by Thermo Tech Technologies Inc. Figure 3.1 shows the product flow at the industrial plant.

Arrival of food waste at the plant

↓

Weighing and conveying to holding tanks and refrigeration equipment

↓

Visual inspection and separation of non-organic waste

↓

Chopping, grinding and mechanical separation of non-organic waste

↓

Centrifuge to extract solid matter

↓

Evaporation of excess water

↓

Mixing and drying

↓

Cooling and blending

↓

Pelleting and packaging

↓

Distribution to wholesalers

**Figure 3.1 Product Flow Diagram: Food Waste Processing Plant**

### 3.5.1 PLANT DESCRIPTION

The land required for the plant is 65,000 square feet and the proposed building for the plant requires approximately 22,000 square feet of building space. It has a receiving area, a working area, and a place for the freezing system and a storage room. The working area lies in front of the pulper and is linked to the refrigeration equipment and the delivery dock by conveyor belts. Solid and liquid food wastes are received and stored separately. Food wastes that do not need to be used immediately are stored by refrigeration. The plant requires access roads for the delivery of supplies and transportation of finished products. There is enough space for trucks to be able to move in and out of the premises. The whole plant is linked to an odour combustor. The building is a one-storey type and contains sections for offices.

It has a processing capacity of 400 tonnes of food waste per day. The plant is designed to run on 3 shifts of 8 hours per day for 25 working days in a month. The average yield of the final product per tonne of each raw material is assumed to be 20% on a dry weight basis. The plant construction is completed in year zero and begins production in the first month.

## 3.6 PROCESSING COSTS AND REVENUES

The two types of cost considered are investment and operating costs. The following assumptions are made to simplify costing.

1) All costs are expressed in 1999 Canadian dollars.

2) The machinery used in the model is based on the machinery owned and operated at the Macdonald campus pilot plant and the industrial scale plant operated by Thermo Tech.

### 3.6.1 INVESTMENT COSTS

Investment costs of the plant include land, buildings, equipment, engineering design, and construction costs. There was also a provision for start up and contingency costs, and working capital. Together, these determine the total investment cost. Below is a brief description of some major investment items.

#### 3.6.1.1 LAND

The value of land differs from one location to the other. The total land area required was 65,000 square feet. The building for the plant and office space required 22,000 square feet with the rest used for parking lots, landscaping and other requirements. The value of industrial land in the West Island of Montreal was $27.00 per square foot (Royal Lepage, 2000) for a total investment of $1.76 million.

#### 3.6.1.2 BUILDINGS

The investment cost ($3.1 million) of the building was obtained from Thermo Tech. The building components included concrete floor, ventilation, ceiling, lighting, and construction materials. The sides of the building measured 230 feet with a height of 18 feet (Royal Lepage, 2000).

### 3.6.2 OPERATING COSTS

Operating variables consist of utilities, labour, and other charges such as repairs and maintenance on buildings and equipment. The cost of each item depended on the quantity needed and the market price. The design specifications and the operating size determine the operating costs.

#### 3.6.2.1 LABOUR

Labour requirements were obtained from the total number of employees required to operate the designed plant per hour (Thermo Tech Inc 1999, Macdonald Campus-pilot plant). The wage rate for each class of labour was estimated on the basis of the experience at the Macdonald Campus pilot plant and Thermo Tech. Total Labour costs are given in Appendix 4.

Table 3.6 Labour Requirements – 3 shifts (8hrs per shift)

| Job description | Number of Employees | Wage Rate |
|---|---|---|
| Shift Manager | 3 | \$13/hr |
| Assistant Shift Manager | 3 | \$10/hr |
| Equipment Operator | 3 | \$10/hr |
| Plant labour force | 6 | \$8/hr |
| Plant Manager | 1 | \$21.25/hr |
| Assistant Plant Manager | 1 | \$17.50/hr |
| General Office Clerk | 1 | \$11/hr |
| Total Number of employees | 18 | |

#### 3.6.2.2 ENERGY COSTS

The main source of power for operating equipment and machinery and providing heat for drying and other activities like lighting is electricity. The quantity of electricity required to process food waste to produce a tonne of final product was estimated. This was done by estimating the amount of energy required to operate the plant and to remove a kilo of water from the final product. Processing times for the 3 processed food waste products are different. Product 3 having more moisture content than product 1 and 2 will require more time to produce hence have greater energy costs. Hydro Quebec provided the electricity rate (3.72 cents/Kwh) for industrial establishments and this rate was used to determine energy cost required to produce a tonne of the processed food waste products (Appendix 4).

### 3.6.3 PER UNIT COST OF PROCESSING

In order to determine the unit cost of processing, investment and operating costs were estimated for a 400 tonne per day processing plant. Total investment costs provided the basis for the estimation of depreciation and interest. The average Canadian prime business interest rate of 6.44% in 1999 was used to calculate interest paid on capital. The unit cost was determined by dividing the total operating cost by the capacity of the plant (Appendix 4).

### 3.6.4 REVENUES

A tipping fee of $30.00 per tonne was assumed to be charged by the plant from establishments to collect their food waste for processing. The three plant products are sold at the estimated market prices determined by the programming models. These income flows are used together with estimated costs to construct a cash flow to evaluate the investment in the plant.

### 3.6.5 EVALUATING INVESTMENT

Capital budgeting was used to evaluate the financial and economic viability of the investment. The technique used involves calculating costs and revenues and present value discounting. After deriving the revenues and costs, a cash flow was calculated and used to estimate the Net Present Value (NPV) and the Internal Rate of Return (IRR). The NPV was calculated at a given discount rate over the 20-year lifetime of the plant (Thermo Tech Inc). The NPV was calculated using equation 3.1.

$$NPV = \sum_{t=0}^{n} PVB_t - \sum_{t=0}^{n} PVC_t \text{..........................................} Equation 3.1$$

Where

$PVB_t$ = present value of revenues

$PVC_t$ = present value of costs

t = time period (year)

n = project life

Using the same cash flow, the IRR was estimated using a spreadsheet simulation. The objective is to find the discount rate that gives a zero NPV.

#### 3.6.5.1 RATES USED IN ANALYSIS

The discount rate is the opportunity cost of an investment, such as the rate of return on money in the next best investment alternative. The discount rate used was the average long-term Canadian real return bond of 4.07% in 1999 (Bank of Canada, 1999).

# CHAPTER 4

# RESULTS AND DISCUSSION

## 4.1 INTRODUCTION

This chapter presents the results and discussion from the programming analysis and the economic evaluation of establishing a plant at the industrial level to process food waste. The first section describes the results of the base case scenario for the linear and non-linear programming using assumed prices for the three processed waste products. Other price scenarios were used to determine the maximum prices that would still allow the three processed waste products to be included in the ration. This provides an indication of the maximum market value for these products. The next section provides a description of the design and operation of the plant. This section also presents the results and discussions from using the determined market prices from the programming analysis to evaluate the economic viability of investing in the plant.

## 4.2 BASE CASE SCENARIO-LINEAR PROGRAMMING (LP) AND CHANCE-CONSTRAINED PROGRAMMING MODELS (CC)

Each of the models was run with the 12 commercial feed ingredients and re-run a second time with the addition of the three processed food waste products. For the first run of the model, prices of the processed waste products were assumed to be \$280.00, \$200.00 and \$140.00 for products 1,2 and 3 respectively. The CC model was used to analyze the stochastic aspect of the ration formulation by converting the deterministic protein constraint into a stochastic one. With this change, it was expected that the solution would shift towards ingredients in which protein variance is low.

An example of the GAMS/MINOS model and the output of the results for ducks 0-2 weeks old are presented in Appendix 5. Summaries of the least cost results and feed ingredients selected to be included in the ration are presented in tables 4.1 and 4.2.

Table 4.1 Summary of least cost for LP and CC ($/tonne).

| | 0-2 Weeks | 2-7 Weeks | Breeding |
|---|---|---|---|
| **LINEAR PROGRAMMING** | $138.27 | $126.62 | $160.46 |
| **CHANCE CONSTRAINED PROGRAMMING** | $141.94 | $131.65 | $160.46 |

Table 4.2 Amounts of feed ingredients selected to be included in duck rations (tonnes)

| **Feed Ingredients** | **Ducks (LP)** | | | **Ducks (CC)** | | |
|---|---|---|---|---|---|---|
| | 0-2 wks | 2-7 wks | Breeding | 0-2 wks | 2-7 wks | Breeding |
| Alfafa meal | | | | | | |
| Barley | | | | | | |
| Canola meal | 0.373 | 0.144 | | 0.452 | 0.252 | |
| Corn | | | | | | |
| Soybean meal | | | | | | |
| Oats | | | | | | |
| Wheat | | | | | | |
| Fish meal | | | | | | |
| Meat and bone meal | 0.031 | 0.038 | 0.258 | 0.027 | 0.033 | 0.258 |
| Feather meal | | | | | | |
| Gluten meal | | | | | | |
| Bakery by-product | 0.596 | 0.817 | 0.742 | 0.522 | 0.716 | 0.742 |
| Product 1 | | | | | | |
| Product 2 | | | | | | |
| Product 3 | | | | | | |

Formulating duck rations using chance-constrained programming showed a higher cost for ducks aged 0-2 weeks and 2-7 weeks than linear programming. The difference in cost in the two models was due to cost associated with raising the probability to meet protein requirement in chance constrained programming.

At the prices assumed for the formulation, the model rejected the three processed food waste products and only three feed ingredients were used in the rations (canola meal, meat and bone meal and bakery by-product). In all cases, meat and bone meal, and bakery by-product were selected to be in the ration. The selection of meat and bone meal may be due to their high protein content (Appendix 1). Fish meal and gluten meal have higher protein content than meat and bone meal, but were probably rejected due to higher costs (Appendix 1). Even though bakery by-product has lower protein content comparable to barley, corn, oats and wheat; greater amounts of it were selected than the other feed ingredients because it has the lowest price per tonne (Appendix 1). Canola meal was selected to be in the ration for ducks aged 0-2 weeks and 2-7 weeks. Even though the protein content of canola meal is lower than that for soybean meal, it was selected because of its lower price (Appendix 1). In the CC model, the variance for processed food waste products from the plant was not included in the programming because these are manufactured products and the protein level could be controlled within a small margin of error to the stated protein content.

## 4.3 RESULTS FROM OTHER PRICE SCENARIOS FOR EACH OF THE PROCESSED FOOD WASTE PRODUCTS

The results in the previous section indicate that the assumed prices for the processed food waste products were too high. This section determines the prices at which the processed food waste products would enter the formulation. Appendix 6 shows the marginal prices for the commercial feeds and processed food waste products. Marginal prices represent the amount by which each assumed price would have to change such that the corresponding ingredient would be included in the formulation. This refers to changing the price of one ingredient at a time in order to allow it to enter the model. The price for each of the processed food waste products was reduced with prices ranging from the lowest $28.45 to the highest $171.45 from their marginal prices (Appendix 6). Each of the processed food waste product together with the commercial feed ingredients was then run separately in the programming. This was to determine the price that allows each of the product to enter the model one at a time. The maximum price set that allowed each of the three processed food waste products to enter into the formulation one at a time was $130.00, $117.00 and $104.00 for products 1,2 and 3 respectively for ducks aged 0-2 weeks and 2-7 weeks. For breeding ducks, the maximum price set was $108.00 for each of the processed food waste products. The results obtained for breeding ducks were the same for LP and CC.

The price of product 1 was dropped just enough within the marginal price change to allow the product to enter the formulation. The same thing was done for product 2 and 3. This was done for all the rations formulated for ducks in various stages of growth. Table 4.3 shows the least costs obtained with the determined market prices for each of the processed food waste products. It shows the least costs obtained for the LP and the CC when the price of product 1, 2 and 3 was reduced to allow them to enter the model. Table 4.4 shows other feed ingredients selected with each of the processed food waste product in each duck ration formulation.

Table 4.3 Summary of least cost for each of the processed food waste products.

| | 0-2 Weeks | 2-7 Weeks | Breeding |
|---|---|---|---|
| **Product 1** | | | |
| **LINEAR PROGRAMMING** | $137.87<br>$0.40* | $126.41<br>$0.21* | $160.06<br>$0.40* |
| **CHANCE CONSTRAINED PROGRAMMING** | $139.39<br>$2.55* | $130.00<br>$1.65* | $160.06<br>$0.40* |
| **Product 2** | | | |
| **LINEAR PROGRAMMING** | $137.84<br>$0.43* | $126.27<br>$0.35* | $160.08<br>$0.38* |
| **CHANCE CONSTRAINED PROGRAMMING** | $139.68<br>$2.26* | $128.53<br>$3.12* | $160.08<br>$0.38* |
| **Product 3** | | | |
| **LINEAR PROGRAMMING** | $138.12<br>$0.15* | $126.22<br>$0.40* | $160.18<br>$0.38* |
| **CHANCE CONSTRAINED PROGRAMMING** | $141.30<br>$0.64* | $128.79<br>$2.86* | $160.18<br>$0.38* |

*Difference in cost between table 4.3 and table 4.1.

Table 4.4 Amounts of selected feed ingredients in combination with each processed food waste product (tonnes).

| **Feed Ingredients** | **Ducks (LP)** | | | **Ducks (CC)** | | |
|---|---|---|---|---|---|---|
| | 0-2 wks | 2-7 wks | Breeding | 0-2 wks | 2-7 wks | Breeding |
| Product 1 | 0.577 | 0.303 | 0.733 | 0.616 | 0.394 | 0.733 |
| Canola meal | 0.100 | 0.0009 | * | 0.114 | 0.036 | * |
| Meat and bone meal | 0.053 | 0.050 | 0.267 | 0.053 | 0.049 | 0.267 |
| Bakery by product | 0.270 | 0.647 | * | 0.217 | 0.521 | * |
| Product 2 | 0.554 | 0.447 | 0.708 | 0.387 | 0.533 | 0.708 |
| Canola meal | 0.264 | 0.056 | * | 0.333 | 0.089 | * |
| Meat and bone meal | 0.044 | 0.049 | 0.025 | 0.038 | 0.048 | 0.025 |
| Bakery by product | 0.138 | 0.448 | 0.267 | 0.242 | 0.310 | 0.267 |
| Product 3 | 0.187 | 0.462 | 0.519 | 0.085 | 0.379 | 0.519 |
| Canola meal | 0.388 | 0.181 | * | 0.446 | 0.227 | * |
| Meat and bone meal | 0.033 | 0.042 | 0.264 | 0.028 | 0.039 | 0.264 |
| Bakery by product | 0.392 | 0.315 | 0.217 | 0.441 | 0.355 | 0.217 |

* Not selected in the ration.

Comparing Table 4.4 to 4.2, similar feed ingredients plus the processed food waste products were selected to be included in the ration. In all cases, meat and bone meal, and bakery by-product were selected to be in the ration. Canola meal was selected to be in the ration for ducks aged 0-2 weeks and 2-7 weeks. The pattern of selection for canola meal and meat and bone meal were similar compared to Table 4.2 in that smaller amounts of these feed ingredients were selected to be in the ration as compared to bakery by-product. Higher amounts of product 1 and 2 were selected compared to the other selected feed ingredients for ducks 0-2 weeks and breeding ducks. In rations for ducks 2-7 weeks of age, higher amounts of bakery by-product were selected when combined with product 1 and smaller amounts when combined with products 2 or 3. The processed food waste products affected the selection of bakery by-product in the ration formulation. Higher amounts of products 1 and 2 were selected compared to bakery by-product because they contain greater protein content even though they have higher market prices (Appendix 1). The lower market price determined for product 3 makes it the preferred ingredient over bakery by-product even though it has lower protein content (Appendix 1).

Higher costs were obtained in formulating rations for ducks aged 0-2 weeks and 2-7 weeks from using CC than LP providing support to the reason that the increased costs could be due to cost associated with raising the probability to meet protein requirement in CC programming. The difference in costs between table 4.3 and 4.1 show the amount of cost savings from using a mixture of commercial feed ingredients and processed food waste products. Costs savings using chance-constrained programming were much higher than cost savings resulting from linear programming. In the chance-constrained model, there was no variance associated with the processed food waste products. This may have caused the solution for the programming to shift towards ingredients with the least protein variance i.e. to the processed food waste products.

Based on the market prices selected, significant amounts of the processed food waste products were selected to be included in duck rations. Cost savings were also achieved when the processed food waste products were allowed to enter the formulation at the determined market prices. The prices determined from the programming are therefore the best market prices for the processed food waste products and producers of duck rations at the determined market prices would purchase any of the products when they are available on the market. These market price results were used in the financial and economic analysis for investing in the project.

## 4.4 FINANCIAL AND ECONOMIC ANALYSIS OF THE PLANT

The calculation of NPV and IRR were based on the assumption that the plant will be producing either product-1 or product-2 or product-3 at a time. This is due to the fact that the a priori food waste content is unknown and the plant could receive food waste of consistent nutritional characteristics to produce either product 1 or 2 or 3 at a time. Producing a combination of the 3 processed food waste products will therefore be expected to have values ranging from the lowest to the highest NPV and IRR.

### 4.4.1 TOTAL COSTS AND REVENUES

The plant receives initial revenue of $300,000 per month form tipping fees operating at 400 tonnes of input per day. Final output from the plant per month is 2000 tonnes (20% of total input). Market prices for the three processed food waste products were estimated from the programming results. The prices per tonne for the three processed food waste products were Product 1- $130.00, Product 2- $117.00, and Product 3-$104.00 in preparing rations for ducks aged 0-2 weeks and 2-7 weeks. For breeding ducks the price per tonne for each of the three processed food waste products was $108.00. Table 4.5 shows the monthly revenues for the three products.

Table 4.5 Monthly Revenues

| **Processed Food Waste** | **Price Per tonne** | **Monthly output (tonnes)** | **Tipping fee (Monthly)** | **Total Revenue per month** |
|---|---|---|---|---|
| **Product-1** | $130.00 | 2000 | $300,000 | $560,000 |
| **Product-2** | $117.00 | 2000 | $300,000 | $534,000 |
| **Product-3** | $104.00 | 2000 | $300,000 | $508,000 |
| **Product 1,2 or 3** | $108.00 | 2000 | $300,000 | $516,000 |

Costs were estimated for the investment and operating variables. Appendix 4 shows the investment and operating cost structure of the plant. For the 3 processed food waste products, the basic plant requirements were the same in terms of land size, building and equipment and the operating costs were the same in terms of labour. Energy costs were different for the three products, due to different processing times. Food waste used in the production of Product-3 has higher water content and would take a longer time to process. Table 4.6 shows a summary of monthly operating costs for the three products.

Table 4.6 Monthly Operating Costs

| Plant | Labour Costs | Other Costs* | Energy Costs | Total Operating Costs |
|---|---|---|---|---|
| **Product-1** | $51,779 | $142,802 | $133,100 | $333,912 |
| **Product-2** | $51,779 | $142,802 | $157,300 | $358,112 |
| **Product-3** | $51,779 | $142,802 | $169,400 | $370,212 |

*Includes depreciation, interest on capital, office & general, vehicle expenses, insurance, marketing, maintenance, quality control and telephone (Appendix 4).

## 4.5 ECONOMIC ANALYSIS OF THE PLANT

Total costs and revenues for each year were discounted at a rate of 4.07% to give the yearly present value of costs and revenues and were added to derive the total present costs and revenues. The formulated cash flows were used in the estimation of Net Present Value (NPV) and Internal Rate of Return (IRR) using an electronic spreadsheet (Microsoft Excel Version 97). The NPV and the IRR calculations were formulated using the pre-programmed options of the spreadsheet (Appendix 7). A summary of the results is provided in Table 4.7.

Table 4.7 Summary of economic results

| **Using prices in producing rations for ducks aged 0-2 weeks and 2-7 weeks** | | |
|---|---|---|
| **Processed Food Waste** | **NPV*** | **IRR** |
| **Product-1 ($130)** | $30,389,399.34 | 22% |
| **Product-2 ($117)** | $22,253,099.00 | 18% |
| **Product-3 ($104)** | $16,077,938.79 | 14% |
| **Using prices in producing rations for breeding ducks** | | |
| **Processed Food Waste** | **NPV*** | **IRR** |
| **Product-1 ($108)** | $23,257,980.72 | 18% |
| **Product-2 ($108)** | $19,335,700.48 | 16% |
| **Product-3 ($108)** | $17,374,560.00 | 15% |

- At 4.07% discount rate.
- Prices for each of the processed food waste products are in brackets.

All NPVs were found to be positive. This suggests that the project is economically feasible. Producing product-1 to be used in rations for ducks aged 0-2 weeks and 2-7 weeks had an IRR of 22% and an IRR of 18% for breeding ducks. The lowest IRR of 14% was for producing rations for ducks aged 0-2 weeks and 2-7 weeks using product-3 in the least cost feed mix. This indicates that producing a combination of the 3 products for the entire 20 years of the plant would generate an IRR ranging from 14% to 22 %. The IRR values gave higher returns when compared to average real returns on long term Canadian bonds of 4.07% (Bank of Canada, 1999) and the average return on capital of 6.41% (Statistics Canada, 1999). The IRR of investment in the plant therefore indicates that the project is viable.

Charging a tipping fee is crucial to the viability of the project. If there is no tipping fee charged, the NPV turns negative and the project is not viable. To produce product 3, which generates the least IRR, a minimum tipping fee of $21.00 will have to be charged to make the project viable. The NPV and IRR calculated for product 3 with a tipping fee of $21.00 are $1,490,946.46 and 5% respectively making the project viable.

The NPV and the IRR were calculated before taxes, as it was difficult to predict what type of tax relief might be available to such a processing facility. Incorporating taxes in the analysis would raise the operating costs of the project and possibly affect the viability of the project. Taxes are charged on net profits. Profits from the cash flow are positive and charging taxes on them would lower the NPV and the IRR estimated. Using 1999 corporate tax rate of 44.6% (KPMG, 1999) for Canada, the IRR for product-1 reduces to 11%, product-2 to 8% and product-3 to 6%. The IRR would therefore range from 11% to 6%, reducing the viability of the project when compared to the average return on capital of 6.41% (Statistics Canada, 1999). The government in granting some amount of tax relief for the project would increase the IRR and the NPV after tax.

# CHAPTER 5

# SUMMARY AND CONCLUSIONS

## 5.1 INTRODUCTION

The main objectives of this thesis were to analyze the least cost of producing rations for ducks in three age categories from a mixture of conventional feed ingredients and three different processed food waste products. Further, the thesis examines the financial and economic feasibility of establishing an industrial plant to produce these food waste products in the Montreal region. A linear programming model was used to determine cost savings from using processed food waste and conventional feed ingredients instead of using conventional feed ingredients alone. The effect of recognizing the variability of protein levels in the various feed ingredients was examined through the use of chance-constrained programming.

Market prices for the three products were estimated using the programming models and then used to analyze the financial and economic feasibility of investing in an industrial plant to process food waste. Such a plant was designed to operate at a capacity of 400 tonnes of input per day, with 3 shifts per day. Net present value (NPV) and the internal rate of return (IRR) were used to assess the investment.

## 5.2 SUMMARY OF FINDINGS

The maximum price set that allowed each of the three processed food waste products to enter into the formulation one at a time was $130.00, $117.00 and $104.00 for products 1,2 and 3 respectively for ducks aged 0-2 weeks and 2-7 weeks. For breeding ducks, the maximum price set was $108.00 for each of the processed food waste products. Based on these price sets, meat and bone meal, and bakery by-product were selected to be in the duck ration for all duck ages. Canola meal was selected to be in the ration for ducks aged 0-2 weeks and 2-7 weeks. The use of processed food waste products affected the amount of bakery by-product in the rations. Higher amounts of products 1 and 2 were selected compared to bakery by-product because of their greater protein content even though they have higher market prices. The lower market price for product 3 makes it the preferred ingredient over bakery by-product even though it has lower protein content.

Minimum cost results obtained from chance-constrained programming were much higher than minimum cost results from linear programming due to higher costs associated with raising the likelihood of meeting the minimum protein requirement. However by using the chance-constrained approach, feed manufacturers would be more confident in their ability to sell feeds that meet their protein requirements.

In general, the findings suggest that it is economically feasible to use processed food waste products in duck rations. At the market prices estimated for the processed food waste products, producers of duck rations would be expected to purchase any of the processed food waste products when they are available. These market prices were then used in the financial analysis of the investment in the processing plant.

The basic plant requirements to produce the three processed food waste products were the same in terms of land, labour, buildings and equipment. Energy costs however were different for the three products, due to different moisture contents resulting in different processing times. Revenue was generated from tipping fees paid by generators of food waste, and the sale of the three processed food waste products. It was assumed that the plant sold everything it produced.

All NPVs for the investment were found to be positive. Producing product-1, to be used in rations for ducks aged 0-2 weeks and 2-7 weeks, had an IRR of 22% and an IRR of 18% for breeding ducks. The lowest IRR was 14% from producing rations for ducks aged 0-2 weeks and 2-7 weeks using product-3. Thus it would be expected that a plant producing a combination of the 3 products during the entire lifespan of the plant would generate an IRR ranging from 14% to 22 %. The IRR values were higher than the average real returns on long-term Canadian bonds of 4.07% (Bank of Canada, 1999) and the average return on capital of 6.41% (Statistics Canada, 1999). The NPV and IRR of the investment in the plant therefore suggest that the project is financially feasible.

## 5.3 IMPLICATIONS OF THE STUDY

Recycling of food waste in addition to generating value-added food waste products also reduces the dumping in landfills. Findings from the study indicate that feed manufacturers have an alternative in formulating duck feeds at a lower minimum cost when processed food waste products are incorporated. Even though the study was done for duck feeds, it could be easily extended to other animals. With increasing concerns for better environmental stewardship in Quebec, the government is inclined to support a feasible project that promotes recycling of food waste.

The findings were responsive to changes in the prices of the feed ingredients used in the ration formulation, tipping fees, operating and capital costs. Changing the plant location could also alter the results, as most of the operating and capital costs were specific to the Montreal area.

## 5.4 LIMITATIONS OF THE STUDY

There are several limitations to the analysis. Some of these relate to data problems, which have an impact on the depth and the relevance of the results obtained. In the chance-constrained model, the variance for processed food waste products from the plant was not included in the programming model because these are manufactured products and the protein level could be controlled within a small margin of error to the stated protein content. This may have had an impact on the optimal solution by shifting selection of the feed ingredients in the duck ration to favour the processed food waste products. Lack of data prevented nutrient values for calcium, phosphate and potash from being included in the analysis. However, improvements in data and estimation techniques may produce better results.

Data for the analysis were obtained primarily from Thermo Tech Inc in Ontario and the Department of Animal Science of Macdonald Campus. There was great reluctance on the part of the equipment industry to provide precise data and prices for equipment. As a result, the data used may not closely reflect actual prices in the industry. Thus the design and financial analysis of the plant should be interpreted as indicative of what could be expected from an investment in this type of processing facility.

Energy charges were adopted from the average electricity cost of operating a medium scale industry to produce a tonne of processed food waste product based on Hydro Quebec's rate for medium scale industries. These are theoretical estimates and may not be the best representation for the selected equipment. Charging a tipping fee is crucial to the viability of the project. If there is no tipping fee charged the project is not viable.

NPV and IRR were calculated before taxes. It is difficult to predict what type of tax relief might be available to such a processing facility. However accounting for taxes lower IRR and NPV and affect the financial viability of the project.

In addition, palatability of the proposed diet to ducks, which affects marketing of the products were not considered in the study and can play an important part in the decision making process.

## 5.5 RECOMENDATIONS FOR FURTHER RESEARCH

1. The three processed food waste products are new to Montreal. The potential market for the products needs to be studied in order to identify the best form of marketing. More information is required on the nutrient composition and variance of the processed food waste products in order to give better results.
2. Charging tipping fees is determined to be crucial to the viability of the project. More research needs to be done on raising revenue through other sources than tipping fees. One way of raising revenue is through governmental support for recycling of food waste, which may be through a tax or a levy on industrial and commercial generators of food waste. For residential locations, a portion of the tax collected for residential waste disposal could be used by the government for food waste recycling. Simply increasing dumping fees at landfill sites could have the desired result.

3. The NPV and the IRR were calculated before taxes, accounting for taxes affect the feasibility of the project. Research on the effect of tax relief for investors by the Quebec government needs to be undertaken, as it will have an impact on the feasibility report of the project.
4. The palatability issue will be of concern as it affects the marketability of the products and the taste of the duck carcass in human consumption. There is the potential for using the processed food waste products for other animals however further research needs to be done on the palatability and the taste of the carcass meat.

## REFERENCES


Agri-Food Canada, 1999. Selling Price of Feed Ingredients. Economic and Industry Analysis Division, Market Research and Analysis Section.

Bank of Canada, 1999. Government of Canada Bond Series. World Wide Web, Internet http://www.bank-banque-canada.ca/cgi-bni/famecgi-fdps

Black, R.J., and Hlubick, J. 1980. Basics of Computerized Linear Programs for Ration Formulation. Journal of Dairy Science. Vol 63, Pp 1366-1378.

Boisvert, R. 1976. Available Field Time, Yield Losses and Farm Planning. Canadian Journal of Agricultural Economics. Vol 24 Pp 21-32.

Boisvert, R. N., and Jensen, H. 1973. A Method for Planning Under Uncertain Weather Conditions, with Applications to Corn-Soybean Farming in Southern Minnesota. University of Minnesota Agricultural Experiment Station Tech. Bulletin No. 292, 1973.

Brooke, A., Kendrick, D., and Meeraus, A., 1988. GAMS: A User's Guide. The Scientific Press, Redwood City, CA.

Canadian Institute for Business and the Environment, 1997. Quebec Reducing Environmental Protection. The Gallon Environment Newsletter, Vol 1, no 9.

Centre Québécois de Valorisation de la Biomasse, 1993. Cahier technique on Waste Management Project. Ville de Montreal.

Chang, G., 1998. Going Brown-Recycling Food Waste into a Second Meal. World Wide Web. Internet. http://www.exn.ca/html/templates/printstory.cfm?ID=19980602-56.

Charnes, A., and Cooper, W. W. 1959. Chance Constrained Programming. Management Science. Vol 6 pp 73-79.

Chavez, E.R., and Touchburn, S.P., 1994. Inventory of Commercial Organic Waste in the Greater Montréal, Department of Animal Science, McGill University.

Chavez, 2000. Department of Animal Science, Macdonald Campus. Personal Communication.

Chen, J. T., 1973. Quadratic Programming for Least Cost Feed Formulations under Probabilistic Protein Constraints. American Journal of Agricultural Economics. Vol 55. Pp 73-79.

City of Kingston, 1999. Press Release on Waste Disposal in Kingston. World Wide Web. Internet.

City of Toronto, 1999. Garbage and Recycling Paper. City of Toronto. World Wide Web. Internet.

D'Alfonso, T. H., Roush, W. B., and Ventura, J. A., 1992. Least Cost Poultry Rations with Nutrient Variability: A Comparison of Linear Programming with a Margin of Safety and Stochastic Programming Models. Poultry Science. Vol 71, Pp 255-262.

Danok, A.B., McCarl, B. A., and White, T. K., 1980. Machinery Selection Modeling: Incorporation of Weather Variability. American Journal of Agricultural Economics. Vol 62, Pp 700-708.

Derr, D.A., and Dhillion, P.S., 1997. The Economics of Recycling Food Residuals. Biocycle Vol 38(4), Pp. 55-56. April, 1997..

Eisel, L. 1972. Chance Constrained Reservoir Model. Water Resources Research. Vol 8, Pp 339-347.

Farhart, G.A., 1997. Nutritional Evaluation of Industrial Food Wastes in Ducks Diets. M.Sc thesis, Department of Animal Science, Macdonald Campus of McGill University.

Franklin Associates Ltd., 1997. Characterization of Municipal Solid Waste in the United States, 1996 Update. Prepared for US Environmental Protection Agency (EPA), Municipal and Industrial Solid Waste Division.

Freund, R.J., 1956. The Introduction of Risk into a Programming Model. Econometrica. Vol 24(3), Pp 253-263.

Gagnon D., 1995. The 4 Rs of Garbage. Eco-column no. 3. Ville de Montreal. World Wide Web. Internet.

Hazell, P. B., and Norton, R. D., 1986. Mathematical Programming for Economic Analysis. MacMillan Publishing Company, New York. NY.

Hydro Quebec, 1999. Personal Communication. Montreal.

KPMG, 1999. KPMG Corporate Tax Rate Survey-January 1999. World Wide Web http://www.kpmg.ch/news/1-0199.htm#Anchor-global-56863

Lara, Pablo, 1993. Multiple Objective Fractional Programming and Livestock Ration Formulation: A Case Study for Dairy Cow Diets in Spain. Agricultural Systems Vol 41 Pp 321-334

Lencki, R.W., 1995. Issues and solutions for recycling food wastes. Pp 1-5 in Recycled Feeds for Livestock and Poultry Symposium, OMAF 1995.

Lexpert, 2000. Environmental Law. The Canadian Legal Expert Directory. Newsletter.

Local Government Institute, 1997. Residential Solid Waste Collection National Survey. Paper. World Wide Web. Internet

Loucks, D. 1975. An Evaluation of some Linear Decision Rules in Chance Constrained Models for Reservoir Planning and Operation. Water Resources Research. Vol 11, Pp 777-782.

Maji, C., and Heady, E. 1978. Intertemporal Allocation Of Irrigation Water in the Mayurakshi Project (India): An Application of Chance Constrained Linear Programming. Water Resources Research. Vol 14, Pp 190-205.

Marti, K. 1996. Stochastic Optimization in Engineering. In: Dolezal and Fiedler: Systems Modeling and Optimization. Chapman and Hall, London-NewYork 1996

McCarl, B. A., and Spreen, T. H., 1997. Applied Mathematical Programming using Algebraic systems. World Wide Web. Internet.
http://agrinet.tamu.edu/mccarl/regbook.htm

National Research Council, 1984. Nutrient Requirements of Poultry. 8th rev ed. National Academy Press, Washington, DC.

Normand, L. 1997. Recycling of Agro-industrial Food Waste into Feed for Pekin Duck Meat Production towards a Sustainable Agriculture in the Province of Quebec. M.Sc thesis, Department of Animal Science, Macdonald Campus of McGill University.

Pequenta, C., 1975. Economic Feasibility of Waste as Animal Feed. In Waste Recycling and Canadian Agriculture, Conference Proceedings: The Agricultural Economics Research Council of Canada. Toronto.

Rahman, S. A., and Bender, F. E., 1971. Linear Programming Approximation of Least Cost Feed Mixes with Probability Restrictions. American Journal of Agricultural Economics. Vol 53, Pp 24-32.

Rehman, T., and Romero, C., 1984. Multiple-Criteria Decision-Making Techniques and Their Role in Livestock Ration Formulation. Agricultural Systems Vol 15, Pp23-29.

Rehman, T., and Romero, C., 1986. Goal Programming with Penalty Functions and Livestock Ration Formulation. Agricultural Systems Vol 23, Pp 117-132.

Roush, W.B., Stock, R.H., Cavener, T. L., and D'Alfonso, T.H., 1994. Using Chance-constrained Programming for Animal Feed Formulations at Agway. Operations Research Society of America. Interfaces. Vol 24 Pp 53-58.

Royal Lepage 2000, Personal communication. Montreal and Ottawa.

Sanisoft, 2000, The Current Waste Disposal System in Montreal. World Wide Web. Internet. http://sanisoft.tripod.com/envstud/mongarb.html

Seoul Metropolitan Government, 2001. Environment Report. World Wide Web. Internet. http://english.metroseoul.kr/about/cityfacts/environment.cfm#top#

Shutze, J. V., and Benoff, F. E., 1981. Statistical Evaluation of Feed Ingredient Variation and Procedures for Determining Number of Samples needed for Laboratory Analysis. Pages 134-146 in: Proceedings Georgia Nutrition Conference for the Feed Industry, Atlanta, GA.

Smith, D. J. 1988. Credit Union Rate and Earnings Retention Decisions under Uncertainty and Taxation. Journal of Money, Credit and Banking. Vol 20 (1), Pp 119-131.

St. Pierre, N. R., and Harvey, W. R., 1986. Incorporation of Uncertainty in Composition of Feeds into Least Cost Ration Models. 1. Single Chance-constrained programming. Journal of Dairy Science. Vol 69, Pp 3051-3062.

St-Pierre, N. R., and Harvey, W. R., 1986. Incorporation of Uncertainty in Composition of Feeds into Least Cost Ration Models. 2. Joint Chance-constrained programming. Journal of Dairy Science. Vol 69, Pp 3063-3073.

Statistics Canada. Canadian Economic Observer, 1999. Statistics Canada. http://www.statcan.ca

Steur, R. E., 1993. Operating Manual for the Multiple Objective Linear Programming Computer Package. College of Business administration, The University of Georgia.

The Globe and Mail, November 18, 2000. Waste Not. Pp F4.

The Globe and Mail, October 14, 2000. Trash talking and garbage ideal. Pp A14.

Thermo-Tech Inc, 1999. Marketing Report of the Company. Vancouver, B.C.

Top, P.J., 1991. Food Waste Recycling Plant. In Industrial Waste Diversion Program Final Report #12. Waste Management Branch, Ontario Ministry of Environment. June 1991.

Trade and Environmental Case Studies, 1997. Poland Waste Imports. An Online Journal. Vol 7, no 1.

Van de Panne, C., and Popp, W. 1963. Minimum-Cost Cattle Feed under Probabilistic Protein Constraints. Management Science. Vol 9, Pp 405-430.

VandeHaar, M.J., and Black, J.R. July 1991. Ration Formulation Using Linear Programming. Veterinary Clinics of North America: Food Animal Practice. Vol 7 (2), Pp 514-556.

Ville de Montréal. Situation de la Récupération à la Ville de Montréal. 1998 http://www.ville.montreal.qc.ca/tp/environ/statist.htm. Last Modified/Reviewed: 1 February 1998.

Waugh, F.V. 1951. The Minimum-Cost Dairy Feed. Journal of Farm Economics. Vol 33, Pp 299-310.

Wojciechowski, J., Glenn, C. W., Turner, S. c., and Miller, B. R., 1999. Marketing of Cotton Fiber in the Presence of Yield and Price Risk. University of Georgia. Paper submitted at the Southern Agricultural Economics Association Meeting.

Young, J.E., 1991. Discarding the Throwaway Society. In 'World Watch' paper 101. Worldwatch Institute Washington U.S.A.

# APPENDIX 1

## FEED INGREDIENTS, CHARACTERISTICS AND PRICES

## CONVENTIONAL FEED INGREDIENTS COMPOSITION

| Ingredients | DM (%) | ME (Kcal/kg) | Protein (%) | Fat (%) | Crude Fibre (%) | Calcium (%) | Phosphate (%) | Potash (%) | Price $/tonne |
|---|---|---|---|---|---|---|---|---|---|
| **Alfafa meal** | 92 | 1630 | 20.0 | 3.6 | 20.2 | 1.67 | 0.28 | 2.15 | 210.00 |
| **Barley** | 89 | 2640 | 11.0 | 1.8 | 5.5 | 0.03 | 0.36 | 0.48 | 134.10 |
| **Canola Meal** | 93 | 2000 | 38.0 | 3.8 | 12.0 | 0.68 | 1.17 | 1.29 | 168.16 |
| **Corn** | 89 | 3350 | 8.5 | 3.8 | 2.2 | 0.02 | 0.28 | 0.30 | 133.06 |
| **Soybean** | 90 | 2440 | 48.5 | 1.0 | 3.9 | 0.27 | 0.62 | 1.98 | 282.82 |
| **Oats** | 89 | 2550 | 11.4 | 4.2 | 10.8 | 0.06 | 0.27 | 0.45 | 122.50 |
| **Wheat** | 88 | 2568 | 15.3 | 3.3 | 2.6 | 0.04 | 0.49 | 0.51 | 151.00 |
| **Fish meal** | 92 | 2830 | 63.6 | 9.3 | 0.5 | 1.23 | 1.63 | 0.69 | 825.00 |
| **Meat & bone Meal** | 93 | 2150 | 50.4 | 10.0 | 2.8 | 10.30 | 5.10 | 1.45 | 303.00 |
| **Feather meal** | 93 | 2360 | 81.0 | 7.0 | 1.0 | 0.33 | 0.55 | 0.30 | 350.00 |
| **Gluten meal** | 90 | 3720 | 62.0 | 2.5 | 1.3 | 0.50 | 0.14 | 0.35 | 450.00 |
| **Bakery by products** | 92 | 3876 | 10.5 | 11.7 | 1.2 | 0.13 | 0.24 | 0.35 | 111.00 |

Source: National Research Council, 1984.
Prices from Agriculture and Agri-food Canada, 1999

**PRODUCTS OF THE PLANT**

| | Product 1 | Product 2 | Product 3 |
|---|---|---|---|
| **DM (%)** | 86.16 | 87.00 | 85.50 |
| **ME (Kcal/kg)** | 3310 | 3148 | 2880 |
| **Protein (%)** | 22 | 15 | 8 |
| **Fat (%)** | 12 | 8.98 | 5.96 |
| **Crude fibre (%)** | 1.92 | 8.61 | 15.29 |
| **Market Price $/tonne** | 280.00 | 200.00 | 140.00 |

Source: Chavez 2000, Animal Science Department, Macdonald Campus. Values for Calcium, Phosphate and Potash were not available.

# APPENDIX 2

# NUTRIENT REQUIREMENTS OF DUCKS

## NUTRIENT REQUIREMENTS OF DUCKS

| | 0 – 2 Weeks | 2 – 7 Weeks | Breeding |
|---|---|---|---|
| **DM (%)** | ≥ 0 | ≥ 0 | ≥ 0 |
| **ME (Kcal/kg)** | 2900 | 3000 | 2900 |
| **Protein (%)** | 22 | 16 | 15 |
| **Fat (%)** | ≥ 1. 0 | ≥ 1.0 | ≥ 1.0 |
| **Crude fibre (%)** | ≥ 0 | ≥ 0 | ≥ 0 |
| **Calcium (%)** | 0.65 | 0.60 | 2.75 |
| **Phosphate (%)** | 0.45 | 0.35 | 0.30 |
| **Potash (%)** | 0.30 | 0.30 | 0.30 |

Source: National Research Council, 1984.

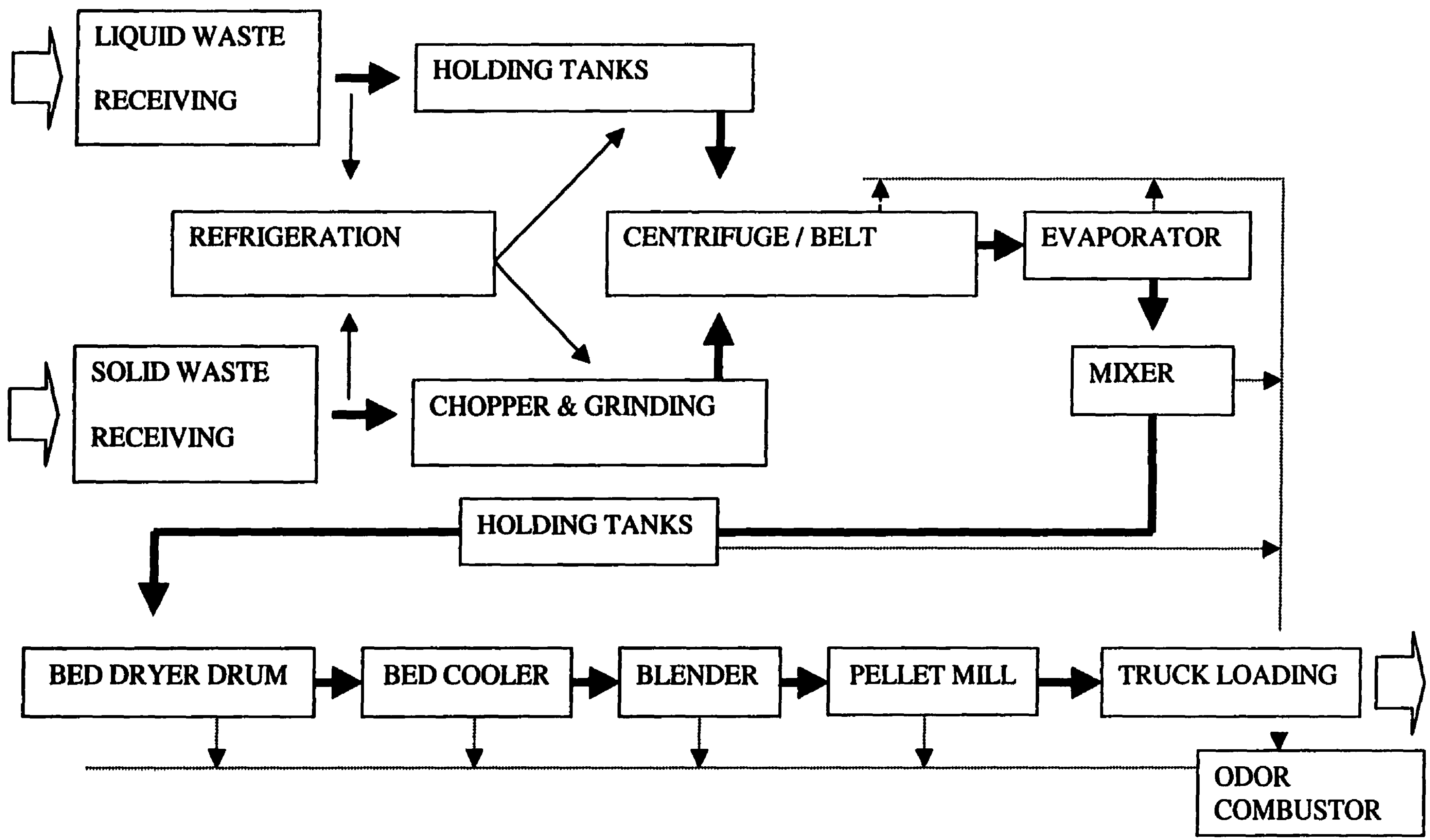
## APPENDIX 3

## LAYOUT OF PLANT

## MAJOR COMPONENTS OF THE FOOD WASTE PROCESSING PLANT

1. Land area in square meters.
2. Receiving areas.
3. Industrial building for the plant.
4. Refrigeration storage equipment.
5. Elevators to transport waste.
6. Chopper and grinding equipment / pulpers.
7. Belt conveyors.
8. Belt press and press extract / Centrifuge.
9. Evaporator.
10. Mixing machine.
11. Holding tanks.
12. Fluidized bed dryer or dryer drum with combustion chamber.
13. Fluidized bed cooler or cooling conveyor.
14. Storage bins.
15. Blender mill.
16. Pellet mill.
17. Final product storage bins.
18. Electrical control panel.
19. Odor combuster.
20. Fork lifts and loading trucks.

## DIAGRAM OF THE PLANT



## APPENDIX 4

## CAPITAL AND OPERATING COSTS OF PLANT

## ENERGY COST PER TONNE OF PROCESSED FOOD WASTE PRODUCT

Energy for the food waste processing plant was assumed to come from electricity. This is the main source of power for operating equipment and machinery and providing heat for drying and other activities like lighting to produce a tonne of processed food waste product. Using the Hydro Quebec electricity rate for medium scale industries, the energy cost was calculated for processing food waste to produce a tonne of final product. These costs were then used to estimate energy costs per year for a tonne of each of the 3 processed food waste products.

From experiments done at Macdonald campus, in order to produce a tonne of final product, the amount of energy required to operate the entire plant and to provide heat to dry the final product was 620 cal/g of water. i.e. 620 Kcal/kg. The industrial hydro rate for medium scale industries under the rate M plan is 3.72 c/KWH (Hydro Quebec, 1999).

Equivalence: 1 KWH = 860 Kcal

Processing of food waste could be achieved at the industrial level with pellets having 10% moisture content (Thermo Tech Inc). To process food waste to a tonne of final product with 90% of water removed from the final product is given by;

(620Kcal/Kg)*0.90 = 558 Kcal = 558/860 = 0.65 KWH/kg.

Energy cost = 3.72 c/KWH x 0.65 = 2.42 c/kg = $2.42/100kg water removed.

The 3 processed food waste products have different levels of moisture content and therefore would have different processing times. Product-3 having the highest moisture content would have the longest time to produce and therefore the highest energy costs. The energy costs required to produce a tonne of each of the 3 processed food waste products are given below.

- Product 1: premium quality; 550 kg of water removed per tonne = \$13.31 / tonne waste processed.
- Product 2: standard quality; 650 kg of water removed per tonne = \$15.73 / tonne of waste processed.
- Product 3: high fibre product; 700 kg of water removed per tonne = \$16.94 / tonne waste processed.

## INVESTMENT AND OPERATING COSTS OF PLANT

**Assumptions:**
400 tonnes per day processing capacity
25 working days per month
3 shifts of 8hrs per day

### COSTS OF THE PLANT-INVESTMENTS (YEAR 0)

| Description | Costs ($) |
|---|---|
| Land ($27/sq ft) | 1,755,000 |
| Buildings | 3,100,000 |
| Equipment | 6,900,000 |
| Engineering Design Package | 1,892,620 |
| Construction Costs | 983,355 |
| Start up & Contingency | 20,000 |
| Working Capital | 200,000 |
| **TOTAL INVESTMENT** | **14,850,975** |

### OPERATING COSTS (PER MONTH OF OPERATION)

| **Direct labour cost** | |
|---|---|
| Shift Managers ($13/hr) | 7,800 |
| Assistant Shift Managers ($10/hr) | 6,240 |
| Equipment operator ($10/hr) | 6,240 |
| Plant Labour Force ($8/hr) | 9,600 |
| Fringe Benefits (30%) | 8,964 |
| **SUB-TOTAL** | **38,844** |

| **Indirect Labour Costs** | |
|---|---|
| Plant Manager | 4,250 |
| Assistant Plant Manager | 3,500 |
| General Office Clerk | 2,200 |
| Fringe Benefits (30%) | 2,985 |
| **SUB-TOTAL** | **12,935** |

| **Other costs** | |
|---|---|
| Interest per month (6.44%) | 79,700 |
| Depreciation on equipment (6%) | 34,500 |
| Depreciation on Building (6%) | 15,500 |
| Office & General | 1,000 |
| Vehicle expenses | 1,000 |
| Insurance & Licenses | 2,500 |
| Marketing & Promotion | 5,000 |

| | | | |
|---|---|---|---|
| Repairs & Maintenance | | 6,666 | |
| Quality control | | 1,667 | |
| Telephone | | 1,500 | |
| **SUB-TOTAL** | | **149,033** | |

| | **PRODUCT 1** | **PRODUCT 2** | **PRODUCT 3** |
|---|---|---|---|
| Energy | 133,100 | 157,300 | 169,400 |
| **TOTAL OPERATING COST** | **333,912** | **358,112** | **370,212** |

Source: Thermo Tech Inc.
Work done on experimental plant at Macdonald Campus.
Interest rate on capital from Bank of Canada, 1999

## APPENDIX 5

## SAMPLE OF GAMS MODEL AND RESULTS OUTPUT FOR DUCKS 0-2 WEEKS

## SAMPLE OF LP MODEL FOR DUCKS 0-2 WEEKS

```
SET j NAMES OF THE AVAILABLE FEED INGREDIENTS
/DEHYDRATED-ALFAFA-MEAL, BARLEY, CANOLA-MEAL, CORN,  SOYBEAN,
OATS, WHEAT, FISH-MEAL, MEAT-AND-BONE-MEAL, FEATHER-MEAL,
CORN-GLUTEN-MEAL, BAKERY-BY-PDT/
SET i NUTRIENT REQUIREMENT CATEGORIES
/DRY-MATTER, MET-ENERGY, PROTEIN, FAT, CRUDE-FIBRE, CALCIUM,
PHOSPHORUS, ASH/
l TYPES OF LIMITS IMPOSED ON NUTRIENTS /MINIMUM, MAXIMUM/;
PARAMETER c(j)  FEED INGREDIENT COST PER TON PURCHASED
/DEHYDRATED-ALFAFA-MEAL 210.00, BARLEY 134.00, CANOLA-MEAL
168.16, CORN 133.06, SOYBEAN 282.82, OATS 122.50, WHEAT 151.00,
FISH-MEAL 825.00,
MEAT-AND-BONE-MEAL 303.00, FEATHER-MEAL 350.00,
CORN-GLUTEN-MEAL 450.00, BAKERY-BY-PDT 111.00/
TABLE  b(i,l)
                                  MINIMUM
         DRY-MATTER                 0
         MET-ENERGY                 2900
         PROTEIN                    22
         FAT                        1
         CRUDE-FIBRE               0
         CALCIUM                    0.65
         PHOSPHORUS                 0.45
         ASH                        0.30
```

```
TABLE  a(j,i) NUTRIENT CONTENT PER TON OF FEED
                                  DRY-MATTER  MET-ENERGY  PROTEIN     FAT
                                  CRUDE-FIBRE  CALCIUM   PHOSPHORUS    ASH
     DEHYDRATED-ALFAFA-MEAL          92        1630        20.0     3.6
                                    20.2       1.67      0.28        2.15
     BARLEY                          89        2640        11.0     1.8
                                     5.5       0.03      0.36        0.48
     CANOLA-MEAL                     93        2000        38.0     3.8
                                    12.0       0.68      1.17        1.29
     CORN                            89        3350         8.5     3.8
                                     2.2       0.02      0.28        0.30
     SOYBEAN                         90        2440        48.5     1.0
                                     3.9       0.27      0.62        1.98
     OATS                            89        2550        11.4     4.2
                                    10.8       0.06      0.27        0.45
     WHEAT                           88        2568        15.3     3.3
                                     2.6       0.04      0.49        0.51
     FISH-MEAL                       92        2830        63.6     9.3
                                     0.5       1.23      1.63        0.69
     MEAT-AND-BONE-MEAL              93        2150        50.4     10.0
                                     2.8      10.30      5.10        1.45
     FEATHER-MEAL                    93        2360        81.0     7.0
                                     1.0       0.33      0.55        0.30
     CORN-GLUTEN-MEAL                90        3720        62.0     2.5
                                     1.3       0.50      0.14        0.35
     BAKERY-BY-PDT                   92        3862        10.5     11.7
                                     1.2       0.13      0.24        0.35
```

```
41   POSITIVE VARIABLES
42   f(j) AMOUNT OF EACH INGREDIENT USED IN THE DIET;
43   VARIABLES
44   COST PER TON COST OF THE DIET;
45   EQUATIONS
46
47   OBJT                 OBJECTIVE FUNCTION (TOTAL COST OF THE
                          FEED)
48
49   MIND(i)              MINIMUM LIMITS ON EACH NUTRIENT IN THE
                          DIET
50   WEIGHT               REQUIREMENT THAT ONE TONNE OF FEED BE
                          PRODUCED;
51
52  OBJT..                COST =E= SUM(j,c(j)*f(j));
53
54  MIND(i)..             SUM(j,a(j,i)*f(j)) =G= b(i,'MINIMUM');
55  WEIGHT..              SUM(j,f(j)) =E= 1
56
57  MODEL DIET /ALL/;
58  SOLVE DIET USING LP MINIMISING COST;
```

## RESULTS FROM THE MODEL

```
MODEL STATISTICS

BLOCKS OF EQUATIONS        3     SINGLE EQUATIONS       10
BLOCKS OF VARIABLES        2     SINGLE VARIABLES       13
NON ZERO ELEMENTS        121
```

## SOLVE SUMMARY

```
     MODEL   DIET                  OBJECTIVE  COST
     TYPE    LP                    DIRECTION  MINIMIZE
     SOLVER  MINOS                 FROM LINE  58

**** SOLVER STATUS      1 NORMAL COMPLETION
**** MODEL STATUS       1 OPTIMAL
**** OBJECTIVE VALUE              138.2781

 RESOURCE USAGE, LIMIT          0.000      1000.000
 ITERATION COUNT, LIMIT         8          10000

                         LOWER     LEVEL     UPPER    MARGINAL

---- EQU OBJT              .         .         .        1.000

  OBJT  OBJECTIVE FUNCTION (TOTAL COST OF THE FEED)
```

---- EQU MIND MINIMUM LIMITS ON EACH NUTRIENT IN THE DIET

| | LOWER | LEVEL | UPPER | MARGINAL |
|---|---|---|---|---|
| DRY-MATTER | . | 92.404 | +INF | . |
| MET-ENERGY | 2900.000 | 3113.967 | +INF | . |
| PROTEIN | 22.000 | 22.000 | +INF | 1.846 |
| FAT | 1.000 | 8.698 | +INF | . |
| CRUDE-FIBRE | . | 5.281 | +INF | . |
| CALCIUM | 0.650 | 0.650 | +INF | 11.637 |
| PHOSPHORUS | 0.450 | 0.738 | +INF | . |
| ASH | 0.300 | 0.735 | +INF | . |

| | LOWER | LEVEL | UPPER | MARGINAL |
|---|---|---|---|---|
| ---- EQU WEIGHT | 1.000 | 1.000 | 1.000 | 90.106 |

WEIGHT REQUIREMENT THAT ONE TONNE OF FEED BE PRODUCED

---- VAR f AMOUNT OF EACH INGREDIENT USED IN THE DIET

| | LOWER | LEVEL | UPPER | MARGINAL |
|---|---|---|---|---|
| DEHYDRATED-ALFAFA-MEAL | . | . | +INF | 63.543 |
| BARLEY | . | . | +INF | 23.241 |
| CANOLA-MEAL | . | 0.373 | +INF | . |
| CORN | . | . | +INF | 27.032 |
| SOYBEAN | . | . | +INF | 100.050 |
| OATS | . | . | +INF | 10.653 |
| WHEAT | . | . | +INF | 32.188 |
| FISH-MEAL | . | . | +INF | 603.187 |
| MEAT-AND-BONE-MEAL | . | 0.031 | +INF | . |
| FEATHER-MEAL | . | . | +INF | 106.544 |
| CORN-GLUTEN-MEAL | . | . | +INF | 239.636 |
| BAKERY-BY-PDT | . | 0.596 | +INF | . |

| | LOWER | LEVEL | UPPER | MARGINAL |
|---|---|---|---|---|
| ---- VAR COST | -INF | 138.278 | +INF | . |

COST PER TON COST OF THE DIET

## APPENDIX 6

## MARGINAL PRICES OF FEED INGREDIENTS

MARGINAL PRICES FROM BASE CASE RESULTS

| | Linear programming ($/tonne) | | | Chance-constrained programming ($/tonne) | | |
|---|---|---|---|---|---|---|
| | **0-2 wks** | **2-7 wks** | **Breeding** | **0-2 wks** | **2-7 wks** | **Breeding** |
| Alfafa meal | 63.54 | 63.54 | 69.93 | 59.09 | 59.10 | 69.93 |
| Barley | 23.24 | 23.24 | 24.89 | 17.25 | 17.25 | 24.89 |
| Canola Meal | * | * | 46.78 | * | * | 46.78 |
| Corn | 27.03 | 27.03 | 24.14 | 20.47 | 20.47 | 24.13 |
| Soybean | 100.05 | 100.05 | 169.18 | 102.59 | 102.59 | 169.18 |
| Oats | 10.65 | 10.65 | 12.82 | 4.74 | 4.74 | 12.82 |
| Wheat | 32.18 | 32.19 | 41.69 | 27.18 | 27.18 | 41.69 |
| Fish meal | 603.19 | 603.19 | 693.23 | 608.89 | 608.89 | 693.23 |
| Meat & bone Meal | * | * | * | * | * | * |
| Feather meal | 106.54 | 106.54 | 235.22 | 116.52 | 116.52 | 235.22 |
| Gluten meal | 239.64 | 239.64 | 332.02 | 245.20 | 245.20 | 332.01 |
| Bakery by products | * | * | * | * | * | * |
| Product 1 | 149.29 | 149.29 | 171.45 | 145.83 | 145.83 | 171.45 |
| Product 2 | 82.20 | 82.21 | 91.45 | 77.14 | 77.14 | 91.45 |
| Product 3 | 35.13 | 35.13 | 31.45 | 28.46 | 28.45 | 31.45 |

*** Indicates that this ingredient was included in the diet.**

# APPENDIX 7

# FINANCIAL ANALYSIS

**COST ANALYSIS- PRODUCT ONE**

| Year | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***COSTS*** | | | | | | | | | | | | | | | | | | | | | |
| **INVESTMENTS** | | | | | | | | | | | | | | | | | | | | | |
| Land ($27/sq ft) | 1,755,000 | | | | | | | | | | | | | | | | | | | | |
| Buildings | 3,100,000 | | | | | | | | | | | | | | | | | | | | |
| Equipment | 6,900,000 | | | | | | | | | | | | | | | | | | | | |
| Engineering design package | 1,892,620 | | | | | | | | | | | | | | | | | | | | |
| Construction costs | 983,355 | | | | | | | | | | | | | | | | | | | | |
| Start up & Contingency | 20,000 | | | | | | | | | | | | | | | | | | | | |
| Working Capital | 200,000 | | | | | | | | | | | | | | | | | | | | |
| Sub-total (investment) | 14,850,975 | | | | | | | | | | | | | | | | | | | | |
| **OPERATING** | | | | | | | | | | | | | | | | | | | | | |
| Direct labour costs | | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 |
| Indirect labour costs | | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 |
| Interest | | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 |
| Energy costs | | 1,597,200 | 1,597,200 | 1,597,200 | 1,597,200 | 1,597,200 | 1,597,200 | 1,597,200 | 1,597,200 | 1,597,200 | 1,597,200 | 1,597,200 | 1,597,200 | 1,597,200 | 1,597,200 | 1,597,200 | 1,597,200 | 1,597,200 | 1,597,200 | 1,597,200 | 1,597,200 |
| Office & General | | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 |
| Vehicle expenses | | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 |
| Insurance & Licences | | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 |
| Marketing & Promotion | | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 |
| Repairs &Maintenance | | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 |
| Quality control | | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 |
| Telephone | | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 |
| Sub-total (operating) | | 3,406,940 | 3,406,940 | 3,406,940 | 3,406,940 | 3,406,940 | 3,406,940 | 3,406,940 | 3,406,940 | 3,406,940 | 3,406,940 | 3,406,940 | 3,406,940 | 3,406,940 | 3,406,940 | 3,406,940 | 3,406,940 | 3,406,940 | 3,406,940 | 3,406,940 | 3,406,940 |
| **TOTAL COSTS** | 14,850,975 | 3,406,940 | 3,406,940 | 3,406,940 | 3,406,940 | 3,406,940 | 3,406,940 | 3,406,940 | 3,406,940 | 3,406,940 | 3,406,940 | 3,406,940 | 3,406,940 | 3,406,940 | 3,406,940 | 3,406,940 | 3,406,940 | 3,406,940 | 3,406,940 | 3,406,940 | 3,406,940 |
| ***REVENUE*** | | | | | | | | | | | | | | | | | | | | | |
| **Sales** | | | | | | | | | | | | | | | | | | | | | |
| Product 1@ $130.00 per tonne | | 3,120,000 | 3,120,000 | 3,120,000 | 3,120,000 | 3,120,000 | 3,120,000 | 3,120,000 | 3,120,000 | 3,120,000 | 3,120,000 | 3,120,000 | 3,120,000 | 3,120,000 | 3,120,000 | 3,120,000 | 3,120,000 | 3,120,000 | 3,120,000 | 3,120,000 | 3,120,000 |
| Tipping fee @ $30.00 per tonne | | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 |
| **Salvage and Resale value** | | | | | | | | | | | | | | | | | | | | | |
| Land | | | | | | | | | | | | | | | | | | | | | 594,000 |
| Building | | | | | | | | | | | | | | | | | | | | | 155,000 |
| Equipment | | | | | | | | | | | | | | | | | | | | | 345,000 |
| **TOTAL REVENUE** | | 6,720,000 | 6,720,000 | 6,720,000 | 6,720,000 | 6,720,000 | 6,720,000 | 6,720,000 | 6,720,000 | 6,720,000 | 6,720,000 | 6,720,000 | 6,720,000 | 6,720,000 | 6,720,000 | 6,720,000 | 6,720,000 | 6,720,000 | 6,720,000 | 6,720,000 | 7,814,000 |
| ***Cash Flow*** | -14,850,975 | 3,313,060 | 3,313,060 | 3,313,060 | 3,313,060 | 3,313,060 | 3,313,060 | 3,313,060 | 3,313,060 | 3,313,060 | 3,313,060 | 3,313,060 | 3,313,060 | 3,313,060 | 3,313,060 | 3,313,060 | 3,313,060 | 3,313,060 | 3,313,060 | 3,313,060 | 4,407,060 |
| Present Value @ 4.07% | -14,850,975.00 | 3,183,401.86 | 3,058,980.96 | 2,939,358.04 | 2,824,406.72 | 2,713,940.04 | 2,607,818.18 | 2,505,823.16 | 2,407,824.70 | 2,313,648.78 | 2,223,175.84 | 2,136,230.94 | 2,052,686.80 | 1,972,409.53 | 1,895,271.98 | 1,821,151.11 | 1,749,929.00 | 1,681,492.26 | 1,615,731.97 | 1,552,543.45 | 1,984,438.54 |
| Net Present Value | $30,369,298.34 | | | | | | | | | | | | | | | | | | | | |
| Internal Rate of Return | 22% | | | | | | | | | | | | | | | | | | | | |

**COST ANALYSIS- PRODUCT TWO**

| Year | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **COSTS** | | | | | | | | | | | | | | | | | | | | | |
| **INVESTMENTS** | | | | | | | | | | | | | | | | | | | | | |
| Land ($27/sq ft) | 1,755,000 | | | | | | | | | | | | | | | | | | | | |
| Buildings | 3,100,000 | | | | | | | | | | | | | | | | | | | | |
| Equipment | 6,900,000 | | | | | | | | | | | | | | | | | | | | |
| Engineering design package | 1,892,620 | | | | | | | | | | | | | | | | | | | | |
| Construction costs | 983,355 | | | | | | | | | | | | | | | | | | | | |
| Start up & Contingency | 20,000 | | | | | | | | | | | | | | | | | | | | |
| Working Capital | 200,000 | | | | | | | | | | | | | | | | | | | | |
| Sub-total (investment) | 14,850,975 | | | | | | | | | | | | | | | | | | | | |
| **OPERATING** | | | | | | | | | | | | | | | | | | | | | |
| Direct labour costs | | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 |
| Indirect labour costs | | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 |
| Interest | | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 |
| Energy costs | | 1,887,600 | 1,887,600 | 1,887,600 | 1,887,600 | 1,887,600 | 1,887,600 | 1,887,600 | 1,887,600 | 1,887,600 | 1,887,600 | 1,887,600 | 1,887,600 | 1,887,600 | 1,887,600 | 1,887,600 | 1,887,600 | 1,887,600 | 1,887,600 | 1,887,600 | 1,887,600 |
| Office & General | | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 |
| Vehicle expenses | | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 |
| Insurance & Licences | | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 |
| Marketing & Promotion | | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 |
| Repairs &Maintenance | | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 |
| Quality control | | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 |
| Telephone | | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 |
| Sub-total (operating) | | 3,697,340 | 3,697,340 | 3,697,340 | 3,697,340 | 3,697,340 | 3,697,340 | 3,697,340 | 3,697,340 | 3,697,340 | 3,697,340 | 3,697,340 | 3,697,340 | 3,697,340 | 3,697,340 | 3,697,340 | 3,697,340 | 3,697,340 | 3,697,340 | 3,697,340 | 3,697,340 |
| **TOTAL COSTS** | 14,850,975 | 3,697,340 | 3,697,340 | 3,697,340 | 3,697,340 | 3,697,340 | 3,697,340 | 3,697,340 | 3,697,340 | 3,697,340 | 3,697,340 | 3,697,340 | 3,697,340 | 3,697,340 | 3,697,340 | 3,697,340 | 3,697,340 | 3,697,340 | 3,697,340 | 3,697,340 | 3,697,340 |
| ***REVENUE*** | | | | | | | | | | | | | | | | | | | | | |
| **Sales** | | | | | | | | | | | | | | | | | | | | | |
| Product 1@ $117.00 per tonne | | 2,808,000 | 2,808,000 | 2,808,000 | 2,808,000 | 2,808,000 | 2,808,000 | 2,808,000 | 2,808,000 | 2,808,000 | 2,808,000 | 2,808,000 | 2,808,000 | 2,808,000 | 2,808,000 | 2,808,000 | 2,808,000 | 2,808,000 | 2,808,000 | 2,808,000 | 2,808,000 |
| Tipping fee @ $30.00 per tonne | | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 |
| **Salvage and Resale value** | | | | | | | | | | | | | | | | | | | | | |
| Land | | | | | | | | | | | | | | | | | | | | | 594,000 |
| Building | | | | | | | | | | | | | | | | | | | | | 155,000 |
| Equipment | | | | | | | | | | | | | | | | | | | | | 345,000 |
| **TOTAL REVENUE** | | 6,408,000 | 6,408,000 | 6,408,000 | 6,408,000 | 6,408,000 | 6,408,000 | 6,408,000 | 6,408,000 | 6,408,000 | 6,408,000 | 6,408,000 | 6,408,000 | 6,408,000 | 6,408,000 | 6,408,000 | 6,408,000 | 6,408,000 | 6,408,000 | 6,408,000 | 7,502,000 |
| ***Cash Flow*** | -14,850,975 | 2,710,660 | 2,710,660 | 2,710,660 | 2,710,660 | 2,710,660 | 2,710,660 | 2,710,660 | 2,710,660 | 2,710,660 | 2,710,660 | 2,710,660 | 2,710,660 | 2,710,660 | 2,710,660 | 2,710,660 | 2,710,660 | 2,710,660 | 2,710,660 | 2,710,660 | 3,804,660 |
| Present Value @ 4.07% | -14,850,975.00 | 2,604,660.72 | 2,502,787.27 | 2,404,907.54 | 2,310,866.71 | 2,220,492.09 | 2,133,642.63 | 2,050,190.70 | 1,970,018.80 | 1,892,975.77 | 1,818,944.72 | 1,747,808.90 | 1,679,455.08 | 1,613,774.46 | 1,550,662.50 | 1,490,018.73 | 1,431,746.66 | 1,375,753.48 | 1,321,960.11 | 1,270,250.90 | 1,713,166.96 |
| Net Present Value | $22,253,099.00 | | | | | | | | | | | | | | | | | | | | |
| Internal Rate of Return | 18% | | | | | | | | | | | | | | | | | | | | |

COST ANALYSIS- PRODUCT THREE

| Year | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *COSTS* | | | | | | | | | | | |
| **INVESTMENTS** | | | | | | | | | | | |
| Land ($27/sq ft) | 1,755,000 | | | | | | | | | | |
| Buildings | 3,100,000 | | | | | | | | | | |
| Equipment | 6,900,000 | | | | | | | | | | |
| Engineering design package | 1,892,620 | | | | | | | | | | |
| Construction costs | 993,355 | | | | | | | | | | |
| Start up & Contingency | 20,000 | | | | | | | | | | |
| Working Capital | 200,000 | | | | | | | | | | |
| Sub-total (investment) | 14,860,975 | | | | | | | | | | |
| **OPERATING** | | | | | | | | | | | |
| Direct labour costs | | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 |
| Indirect labour costs | | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 |
| Interest | | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 |
| Energy costs | | 2,032,800 | 2,032,800 | 2,032,800 | 2,032,800 | 2,032,800 | 2,032,800 | 2,032,800 | 2,032,800 | 2,032,800 | 2,032,800 |
| Office & General | | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 |
| Vehicle expenses | | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 |
| Insurance & Licences | | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 |
| Marketing & Promotion | | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 |
| Repairs &Maintenance | | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 |
| Quality control | | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 |
| Telephone | | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 |
| Sub-total (operating) | | 3,842,540 | 3,842,540 | 3,842,540 | 3,842,540 | 3,842,540 | 3,842,540 | 3,842,540 | 3,842,540 | 3,842,540 | 3,842,540 |
| TOTAL COSTS | 14,860,975 | 3,842,540 | 3,842,540 | 3,842,540 | 3,842,540 | 3,842,540 | 3,842,540 | 3,842,540 | 3,842,540 | 3,842,540 | 3,842,540 |
| *REVENUE* | | | | | | | | | | | |
| **Sales** | | | | | | | | | | | |
| Product 1@ $104.00 per tonne | | 2,496,000 | 2,496,000 | 2,496,000 | 2,496,000 | 2,496,000 | 2,496,000 | 2,496,000 | 2,496,000 | 2,496,000 | 2,496,000 |
| Tipping fee @ $30.00 per tonne | | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 |
| **Salvage and Resale value** | | | | | | | | | | | |
| Land | | | | | | | | | | | |
| Building | | | | | | | | | | | |
| Equipment | | | | | | | | | | | |
| TOTAL REVENUE | | 6,096,000 | 6,096,000 | 6,096,000 | 6,096,000 | 6,096,000 | 6,096,000 | 6,096,000 | 6,096,000 | 6,096,000 | 6,096,000 |
| *Cash Flow* | -14,860,975 | 2,253,460 | 2,253,460 | 2,253,460 | 2,253,460 | 2,253,460 | 2,253,460 | 2,253,460 | 2,253,460 | 2,253,460 | 2,253,460 |
| Present Value @ 4.07% | -14,860,975.00 | 2,165,331.03 | 2,080,646.63 | 1,999,278.01 | 1,921,088.66 | 1,845,958.13 | 1,773,766.82 | 1,704,397.83 | 1,637,741.74 | 1,573,692.46 | 1,512,148.03 |
| Net Present Value | $15,077,938.79 | | | | | | | | | | |
| Internal Rate of Return | 14% | | | | | | | | | | |

| Year | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|
| *COSTS* | | | | | | | | | | |
| **INVESTMENTS** | | | | | | | | | | |
| Land ($27/sq ft) | | | | | | | | | | |
| Buildings | | | | | | | | | | |
| Equipment | | | | | | | | | | |
| Engineering design package | | | | | | | | | | |
| Construction costs | | | | | | | | | | |
| Start up & Contingency | | | | | | | | | | |
| Working Capital | | | | | | | | | | |
| Sub-total (investment) | | | | | | | | | | |
| **OPERATING** | | | | | | | | | | |
| Direct labour costs | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 |
| Indirect labour costs | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 |
| Interest | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 |
| Energy costs | 2,032,800 | 2,032,800 | 2,032,800 | 2,032,800 | 2,032,800 | 2,032,800 | 2,032,800 | 2,032,800 | 2,032,800 | 2,032,800 |
| Office & General | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 |
| Vehicle expenses | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 |
| Insurance & Licences | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 |
| Marketing & Promotion | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 |
| Repairs &Maintenance | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 |
| Quality control | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 |
| Telephone | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 |
| Sub-total (operating) | 3,842,540 | 3,842,540 | 3,842,540 | 3,842,540 | 3,842,540 | 3,842,540 | 3,842,540 | 3,842,540 | 3,842,540 | 3,842,540 |
| TOTAL COSTS | 3,842,540 | 3,842,540 | 3,842,540 | 3,842,540 | 3,842,540 | 3,842,540 | 3,842,540 | 3,842,540 | 3,842,540 | 3,842,540 |
| *REVENUE* | | | | | | | | | | |
| **Sales** | | | | | | | | | | |
| Product 1@ $104.00 per tonne | 2,496,000 | 2,496,000 | 2,496,000 | 2,496,000 | 2,496,000 | 2,496,000 | 2,496,000 | 2,496,000 | 2,496,000 | 2,496,000 |
| Tipping fee @ $30.00 per tonne | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 |
| **Salvage and Resale value** | | | | | | | | | | |
| Land | | | | | | | | | | 594,000 |
| Building | | | | | | | | | | 155,000 |
| Equipment | | | | | | | | | | 345,000 |
| TOTAL REVENUE | 6,096,000 | 6,096,000 | 6,096,000 | 6,096,000 | 6,096,000 | 6,096,000 | 6,096,000 | 6,096,000 | 6,096,000 | 7,190,000 |
| *Cash Flow* | 2,253,460 | 2,253,460 | 2,253,460 | 2,253,460 | 2,253,460 | 2,253,460 | 2,253,460 | 2,253,460 | 2,253,460 | 3,347,460 |
| Present Value @ 4.07% | 1,453,010.50 | 1,396,185.74 | 1,341,583.30 | 1,289,116.27 | 1,238,701.13 | 1,190,257.65 | 1,143,708.70 | 1,098,980.21 | 1,056,000.97 | 1,607,315.98 |
| Net Present Value | | | | | | | | | | |
| Internal Rate of Return | | | | | | | | | | |

COST ANALYSIS- PRODUCT ONE

| Year | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ***COSTS*** | | | | | | | | | | | |
| **INVESTMENTS** | | | | | | | | | | | |
| Land ($27/sq ft) | 1,755,000 | | | | | | | | | | |
| Buildings | 3,100,000 | | | | | | | | | | |
| Equipment | 6,900,000 | | | | | | | | | | |
| Engineering design package | 1,892,620 | | | | | | | | | | |
| Construction costs | 983,355 | | | | | | | | | | |
| Start up & Contingency | 20,000 | | | | | | | | | | |
| Working Capital | 200,000 | | | | | | | | | | |
| Sub-total (Investment) | 14,850,975 | | | | | | | | | | |
| **OPERATING** | | | | | | | | | | | |
| Direct labour costs | | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 |
| Indirect labour costs | | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 |
| Interest | | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 |
| Energy costs | | 1,597,200 | 1,597,200 | 1,597,200 | 1,597,200 | 1,597,200 | 1,597,200 | 1,597,200 | 1,597,200 | 1,597,200 | 1,597,200 |
| Office & General | | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 |
| Vehicle expenses | | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 |
| Insurance & Licences | | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 |
| Marketing & Promotion | | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 |
| Repairs &Maintenance | | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 |
| Quality control | | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 |
| Telephone | | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 |
| Sub-total (operating) | | 3,406,940 | 3,406,940 | 3,406,940 | 3,406,940 | 3,406,940 | 3,406,940 | 3,406,940 | 3,406,940 | 3,406,940 | 3,406,940 |
| **TOTAL COSTS** | 14,850,975 | 3,406,940 | 3,406,940 | 3,406,940 | 3,406,940 | 3,406,940 | 3,406,940 | 3,406,940 | 3,406,940 | 3,406,940 | 3,406,940 |
| ***REVENUE*** | | | | | | | | | | | |
| **Sales** | | | | | | | | | | | |
| Product 1 @ $108.00 per tonne | | 2,592,000 | 2,592,000 | 2,592,000 | 2,592,000 | 2,592,000 | 2,592,000 | 2,592,000 | 2,592,000 | 2,592,000 | 2,592,000 |
| Tipping fee @ $30.00 per tonne | | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 |
| **Salvage and Resale value** | | | | | | | | | | | |
| Land | | | | | | | | | | | |
| Building | | | | | | | | | | | |
| Equipment | | | | | | | | | | | |
| **TOTAL REVENUE** | | 6,192,000 | 6,192,000 | 6,192,000 | 6,192,000 | 6,192,000 | 6,192,000 | 6,192,000 | 6,192,000 | 6,192,000 | 6,192,000 |
| ***Cash Flow*** | -14,850,975 | 2,785,060 | 2,785,060 | 2,785,060 | 2,785,060 | 2,785,060 | 2,785,060 | 2,785,060 | 2,785,060 | 2,785,060 | 2,785,060 |
| Present Value @ 4.07% | -14,850,975.00 | 2,676,141.06 | 2,571,481.75 | 2,470,915.49 | 2,374,282.21 | 2,281,428.06 | 2,192,205.33 | 2,106,471.92 | 2,024,091.40 | 1,944,932.64 | 1,868,869.65 |
| Net Present Value | $23,257,990.72 | | | | | | | | | | |
| Internal Rate of Return | 18% | | | | | | | | | | |

| Year | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|
| Direct labour costs | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 |
| Indirect labour costs | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 |
| Interest | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 |
| Energy costs | 1,597,200 | 1,597,200 | 1,597,200 | 1,597,200 | 1,597,200 | 1,597,200 | 1,597,200 | 1,597,200 | 1,597,200 | 1,597,200 |
| Office & General | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 |
| Vehicle expenses | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 |
| Insurance & Licences | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 |
| Marketing & Promotion | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 |
| Repairs &Maintenance | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 |
| Quality control | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 |
| Telephone | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 |
| Sub-total (operating) | 3,406,940 | 3,406,940 | 3,406,940 | 3,406,940 | 3,406,940 | 3,406,940 | 3,406,940 | 3,406,940 | 3,406,940 | 3,406,940 |
| **TOTAL COSTS** | 3,406,940 | 3,406,940 | 3,406,940 | 3,406,940 | 3,406,940 | 3,406,940 | 3,406,940 | 3,406,940 | 3,406,940 | 3,406,940 |
| Product 1 @ $108.00 per tonne | 2,592,000 | 2,592,000 | 2,592,000 | 2,592,000 | 2,592,000 | 2,592,000 | 2,592,000 | 2,592,000 | 2,592,000 | 2,592,000 |
| Tipping fee @ $30.00 per tonne | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 |
| Land | | | | | | | | | | 594,000 |
| Building | | | | | | | | | | 155,000 |
| Equipment | | | | | | | | | | 345,000 |
| **TOTAL REVENUE** | 6,192,000 | 6,192,000 | 6,192,000 | 6,192,000 | 6,192,000 | 6,192,000 | 6,192,000 | 6,192,000 | 6,192,000 | 7,286,000 |
| ***Cash Flow*** | 2,785,060 | 2,785,060 | 2,785,060 | 2,785,060 | 2,785,060 | 2,785,060 | 2,785,060 | 2,785,060 | 2,785,060 | 3,879,060 |
| Present Value @ 4.07% | 1,795,791.34 | 1,725,551.40 | 1,658,060.03 | 1,593,223.82 | 1,530,918.56 | 1,471,044.07 | 1,413,514.05 | 1,358,233.92 | 1,305,115.72 | 1,746,580.28 |

**COST ANALYSIS- PRODUCT TWO**

| Year | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***COSTS*** | | | | | | | | | | | | | | | | | | | | | |
| **INVESTMENTS** | | | | | | | | | | | | | | | | | | | | | |
| Land ($27/sq ft) | 1,755,000 | | | | | | | | | | | | | | | | | | | | |
| Buildings | 3,100,000 | | | | | | | | | | | | | | | | | | | | |
| Equipment | 6,900,000 | | | | | | | | | | | | | | | | | | | | |
| Engineering design package | 1,892,620 | | | | | | | | | | | | | | | | | | | | |
| Construction costs | 983,355 | | | | | | | | | | | | | | | | | | | | |
| Start up & Contingency | 20,000 | | | | | | | | | | | | | | | | | | | | |
| Working Capital | 200,000 | | | | | | | | | | | | | | | | | | | | |
| Sub-total (investment) | 14,850,975 | | | | | | | | | | | | | | | | | | | | |
| **OPERATING** | | | | | | | | | | | | | | | | | | | | | |
| Direct labour costs | | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 |
| Indirect labour costs | | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 |
| Interest | | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 |
| Energy costs | | 1,867,600 | 1,867,600 | 1,867,600 | 1,867,600 | 1,867,600 | 1,867,600 | 1,867,600 | 1,867,600 | 1,867,600 | 1,867,600 | 1,867,600 | 1,867,600 | 1,867,600 | 1,867,600 | 1,867,600 | 1,867,600 | 1,867,600 | 1,867,600 | 1,867,600 | 1,867,600 |
| Office & General | | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 |
| Vehicle expenses | | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 |
| Insurance & Licences | | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 |
| Marketing & Promotion | | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 |
| Repairs &Maintenance | | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 |
| Quality control | | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 |
| Telephone | | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 |
| Sub-total (operating) | | 3,697,340 | 3,697,340 | 3,697,340 | 3,697,340 | 3,697,340 | 3,697,340 | 3,697,340 | 3,697,340 | 3,697,340 | 3,697,340 | 3,697,340 | 3,697,340 | 3,697,340 | 3,697,340 | 3,697,340 | 3,697,340 | 3,697,340 | 3,697,340 | 3,697,340 | 3,697,340 |
| **TOTAL COSTS** | 14,850,975 | 3,697,340 | 3,697,340 | 3,697,340 | 3,697,340 | 3,697,340 | 3,697,340 | 3,697,340 | 3,697,340 | 3,697,340 | 3,697,340 | 3,697,340 | 3,697,340 | 3,697,340 | 3,697,340 | 3,697,340 | 3,697,340 | 3,697,340 | 3,697,340 | 3,697,340 | 3,697,340 |
| ***REVENUE*** | | | | | | | | | | | | | | | | | | | | | |
| **Sales** | | | | | | | | | | | | | | | | | | | | | |
| Product 2@ $108.00 per tonne | | 2,592,000 | 2,592,000 | 2,592,000 | 2,592,000 | 2,592,000 | 2,592,000 | 2,592,000 | 2,592,000 | 2,592,000 | 2,592,000 | 2,592,000 | 2,592,000 | 2,592,000 | 2,592,000 | 2,592,000 | 2,592,000 | 2,592,000 | 2,592,000 | 2,592,000 | 2,592,000 |
| Tipping fee @ $30.00 per tonne | | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 |
| **Salvage and Resale value** | | | | | | | | | | | | | | | | | | | | | |
| Land | | | | | | | | | | | | | | | | | | | | | 594,000 |
| Building | | | | | | | | | | | | | | | | | | | | | 155,000 |
| Equipment | | | | | | | | | | | | | | | | | | | | | 345,000 |
| **TOTAL REVENUE** | | 6,192,000 | 6,192,000 | 6,192,000 | 6,192,000 | 6,192,000 | 6,192,000 | 6,192,000 | 6,192,000 | 6,192,000 | 6,192,000 | 6,192,000 | 6,192,000 | 6,192,000 | 6,192,000 | 6,192,000 | 6,192,000 | 6,192,000 | 6,192,000 | 6,192,000 | 7,286,000 |
| *Cash Flow* | -14,850,975 | 2,494,660 | 2,494,660 | 2,494,660 | 2,494,660 | 2,494,660 | 2,494,660 | 2,494,660 | 2,494,660 | 2,494,660 | 2,494,660 | 2,494,660 | 2,494,660 | 2,494,660 | 2,494,660 | 2,494,660 | 2,494,660 | 2,494,660 | 2,494,660 | 2,494,660 | 3,588,660 |
| Present Value @ 4.07% | -14,850,975.00 | 2,397,098.11 | 2,303,351.60 | 2,213,271.54 | 2,126,714.27 | 2,043,542.11 | 1,963,622.66 | 1,886,828.73 | 1,813,038.06 | 1,742,133.26 | 1,674,001.40 | 1,608,534.07 | 1,545,627.05 | 1,485,180.21 | 1,427,097.35 | 1,371,286.01 | 1,317,657.35 | 1,266,126.03 | 1,216,610.00 | 1,169,030.46 | 1,615,923.08 |
| Net Present Value | $19,336,700.48 | | | | | | | | | | | | | | | | | | | | |
| Internal Rate of Return | 18% | | | | | | | | | | | | | | | | | | | | |

COST ANALYSIS- PRODUCT THREE

| Year | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **COSTS** | | | | | | | | | | | | | | | | | | | | | |
| **INVESTMENTS** | | | | | | | | | | | | | | | | | | | | | |
| Land ($27/sq ft) | 1,755,000 | | | | | | | | | | | | | | | | | | | | |
| Buildings | 3,100,000 | | | | | | | | | | | | | | | | | | | | |
| Equipment | 6,900,000 | | | | | | | | | | | | | | | | | | | | |
| Engineering design package | 1,892,620 | | | | | | | | | | | | | | | | | | | | |
| Construction costs | 983,355 | | | | | | | | | | | | | | | | | | | | |
| Start up & Contingency | 20,000 | | | | | | | | | | | | | | | | | | | | |
| Working Capital | 200,000 | | | | | | | | | | | | | | | | | | | | |
| Sub-total (investment) | 14,850,975 | | | | | | | | | | | | | | | | | | | | |
| **OPERATING** | | | | | | | | | | | | | | | | | | | | | |
| Direct labour costs | | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 | 466,128 |
| Indirect labour costs | | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 | 155,220 |
| Interest | | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 | 956,400 |
| Energy costs | | 2,032,800 | 2,032,800 | 2,032,800 | 2,032,800 | 2,032,800 | 2,032,800 | 2,032,800 | 2,032,800 | 2,032,800 | 2,032,800 | 2,032,800 | 2,032,800 | 2,032,800 | 2,032,800 | 2,032,800 | 2,032,800 | 2,032,800 | 2,032,800 | 2,032,800 | 2,032,800 |
| Office & General | | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 |
| Vehicle expenses | | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 |
| Insurance & Licences | | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 | 30,000 |
| Marketing & Promotion | | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 |
| Repairs &Maintenance | | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 | 79,992 |
| Quality control | | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 |
| Telephone | | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 |
| Sub-total (operating) | | 3,842,540 | 3,842,540 | 3,842,540 | 3,842,540 | 3,842,540 | 3,842,540 | 3,842,540 | 3,842,540 | 3,842,540 | 3,842,540 | 3,842,540 | 3,842,540 | 3,842,540 | 3,842,540 | 3,842,540 | 3,842,540 | 3,842,540 | 3,842,540 | 3,842,540 | 3,842,540 |
| **TOTAL COSTS** | 14,850,975 | 3,842,540 | 3,842,540 | 3,842,540 | 3,842,540 | 3,842,540 | 3,842,540 | 3,842,540 | 3,842,540 | 3,842,540 | 3,842,540 | 3,842,540 | 3,842,540 | 3,842,540 | 3,842,540 | 3,842,540 | 3,842,540 | 3,842,540 | 3,842,540 | 3,842,540 | 3,842,540 |
| ***REVENUE*** | | | | | | | | | | | | | | | | | | | | | |
| **Sales** | | | | | | | | | | | | | | | | | | | | | |
| Product 1 @ $108.00 per tonne | | 2,592,000 | 2,592,000 | 2,592,000 | 2,592,000 | 2,592,000 | 2,592,000 | 2,592,000 | 2,592,000 | 2,592,000 | 2,592,000 | 2,592,000 | 2,592,000 | 2,592,000 | 2,592,000 | 2,592,000 | 2,592,000 | 2,592,000 | 2,592,000 | 2,592,000 | 2,592,000 |
| Tipping fee @ $30.00 per tonne | | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 | 3,600,000 |
| **Salvage and Resale value** | | | | | | | | | | | | | | | | | | | | | |
| Land | | | | | | | | | | | | | | | | | | | | | 594,000 |
| Building | | | | | | | | | | | | | | | | | | | | | 155,000 |
| Equipment | | | | | | | | | | | | | | | | | | | | | 345,000 |
| **TOTAL REVENUE** | | 6,192,000 | 6,192,000 | 6,192,000 | 6,192,000 | 6,192,000 | 6,192,000 | 6,192,000 | 6,192,000 | 6,192,000 | 6,192,000 | 6,192,000 | 6,192,000 | 6,192,000 | 6,192,000 | 6,192,000 | 6,192,000 | 6,192,000 | 6,192,000 | 6,192,000 | 7,286,000 |
| *Cash Flow* | -14,850,975 | 2,349,460 | 2,349,460 | 2,349,460 | 2,349,460 | 2,349,460 | 2,349,460 | 2,349,460 | 2,349,460 | 2,349,460 | 2,349,460 | 2,349,460 | 2,349,460 | 2,349,460 | 2,349,460 | 2,349,460 | 2,349,460 | 2,349,460 | 2,349,460 | 2,349,460 | 3,443,460 |
| Present Value @ 4.07% | -14,850,975.00 | 2,257,576.63 | 2,169,286.66 | 2,084,449.57 | 2,002,930.30 | 1,924,598.12 | 1,849,331.33 | 1,777,007.14 | 1,707,511.43 | 1,640,733.57 | 1,576,567.28 | 1,514,910.43 | 1,455,664.87 | 1,398,736.30 | 1,344,034.11 | 1,291,471.23 | 1,240,964.00 | 1,192,432.02 | 1,145,798.04 | 1,100,987.83 | 1,550,543.49 |
| Net Present Value | $17,374,560.36 | | | | | | | | | | | | | | | | | | | | |
| Internal Rate of Return | 15% | | | | | | | | | | | | | | | | | | | | |