PPI

# Separation of meat meal into components
# M.745

## 1996

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ISBN: 1 74036 153 9
Published: April 1996




MEAT & LIVESTOCK
AUSTRALIA

## Executive Summary

Experimental investigations involving screening, air-tabling and air-classification, supported by constituent analyses for protein, ash, fat and moisture, have been carried out to characterize the composition of meatmeal, and the behaviour of its components during separation operations. Both Press Cake and Milled Meal were used.

There is evidence that there is a limit to the extent to which the components of meatmeal can be separated. It is thought that this is principally due to the fat in the meatmeal.
The fat content of the fractions produced in screening increased as the screen size decreased.
Air-classification resulted in some product enrichment but was not encouraging, and the internal surfaces of the classifier quickly fouled with cohesive dust.
Air-tabling fulfilled much of its promise, and it was shown that a product stream consisting of large bone particles, greater than 850 µm, could be produced from an unprepared meatmeal feed stock. But , in the limited tabling trials performed it was not possible to achieve this level of separation with the finer material, less than 850 µm, which constituted 70% by weight of the feed.

Process options based on a combination of screening and tabling have been suggested. A separation operation in which Press Cake is screened to produce a protein rich undersize and a bone rich oversize which is then milled and processed on air tables appears to be the most attractive of the options. It is noted that the fat content of the screened Press Cake is high, and that this will affect its handlability and may affect its value.

Severe difficulty was experienced in discovering price information that would permit the construction of a cost function for use in the full evaluation of the economic viability of the different process options. Also, it is noted that local conditions at a meat works, particularly with regard to the availability of air cleaning and product storage facilities, could have a significant influence on capital requirements.

The efficiency of a process for separating meatmeal into components is likely to be dependent on the behaviour of fat in the various process streams. It is recommended that this point is fully resolved in further work, which would also investigate the feasibility of scavenging the fat. The use of a recycle with bone, or possibly an inert material has been suggested as the basis of a process method for doing this.

# Acknowledgement

The work on the Chloroform sink float test was carried out as the result of a suggestion by Bruce Hamilton.

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# PART ONE

## Constituent Analyses and Laboratory Experiments

## 1.1. Introduction

This report outlines the experimental methods and techniques used in the physical characterization of meat meal by sieving, air classification and air tabling. A short section on attrition in a fluidized bed is included, although this approach is not now regarded as a process option. Results are presented in both table and graphical form.

Notes on auxiliary and supplementary tests carried out in the course of the physical characterization work are also given; these trials were exploratory only, and were not part of the main systematic investigation.

*Details* of the analytical methods and techniques for Nitrogen, protein, ash, fat and moisture are not included here.

Except where otherwise stated, the material used in the experimental work is a milled rendered product from Ngauranga, Wellington New Zealand; the term "as received" indicates an unprepared feedstock drawn from the bulk supply collected from Ngauranga at the start of the experimental programme. Ngauranga Press Cake is the material taken from the rendering process prior to milling. Five named Australian meals are all milled materials.

## 1.2. Constituent Analysis

The market value of meatmeal products is traditionally determined by the protein content which is gauged from Kjeldahl Nitrogen. An objective of this work is the enrichment of the protein content of the meal by selective removal of bone. Bone content is gauged by ash content. Accordingly extensive measurements have been made on the different product streams made in the course of this investigation. Though not of primary interest as an indicator of value, the fat content of meatmeal products affects flow properties, and is known to influence screenability. Some measurements of fat content have also been made. Moisture accounts for a small percentage of the product mass, and in some cases has been measured to provide benchmark figures for general characterization of the meal.

All the constituent analyses reported in this work were carried out by the Analytical Services Team at Industrial Research Limited.

### 1.2.1 Nitrogen / Protein

As only 100 mg of sample are required for a Kjeldahl Nitrogen test, special care must be taken to ensure that this is representative. Accordingly, a representative sample of several grams of meat meal was prepared in a Tema mill to attempt to improve repeatability and to eliminate bias in the results that could arise from the inclusion of large discrete particles of bone or protein. Approximately 6 g of meat meal were weighed and milled for one minute. The sample was removed and the sides of the mill scraped down. All this material was returned to the mill for a further minute, before being brushed out into a labelled sample jar. The samples for Kjeldahl analysis were taken from this homogeneous milled product. A Tema mill is a milling device consisting of a shallow cylindrical chamber with a close fitting lid; the sample is placed in the chamber along with a hard cylindrical puck. The chamber containing the sample and puck are subjected to intense mechanical agitation from a dedicated mechanism, and the sample is comminuted by the action of the free moving puck inside the chamber.

### 1.2.2 Ash

Approximately 1g of sample was used in the analysis. Samples were ashed at 650°C for a minimum of 4 hours.

### 1.2.3 Moisture (Water)

Approximately 25 g of meat meal were placed in a Vacuum oven at 40 °C overnight.

### 1.2.4 Fat

Fat analysis was carried out via soxhlet extraction using Pegasol according to the AOAC method, Fat in Meat - 960.39. Approximately 25g of meat meal were ground in the Tema mill before analysis; refer to Tema mill grinding in Nitrogen method. Only a few analyses on selected meat meal samples were carried out.

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## 1.3. Particle Size Distribution

The notes here refer to screening trials with the meatmeal designated "Ngauranga Meatmeal". Quarantine regulations prevented the importation of samples from rendering plants in Australia, but some sieve analyses were carried out at University of New South Wales, and the results are also reported below.

### 1.3.1 Batch sieving

20 to 40 g of meat meal were used in obtaining a particle size distributions on Laboratory Test Sieves from Endecott Limited, London (BS 410). A grab sample of the meat meal was taken and reduced down to the required amount using a Riffle box. The meat meal was weighed and then placed on the top sieve. The sieves were hand shaken until a good separation had been achieved (i.e. the majority of material having passed through its mesh.) Sieving below 850 μm was difficult as the mesh blinds easily. Regular cleaning of these sieves was required.

An 'as received' sample took up to 45 mins to sieve due to difficulty in sieving below 850 μm. For a sample containing less fines, the particle size distribution was quicker to obtain.

N.B. Mechanical shaking resulted in the meat meal blinding the sieves.

### 1.3.2 Continuous Sieving with Sweco sieve

A Sweco Vibro-Energy Separator was used to obtain larger quantities of the various meat meal size fractions. The sieve sizes tried were 2360 μm, 1400 μm, 850 μm and 598 μm

A vibratory feeder, with an adjustable speed control, was used to feed the meat meal on to the sweco sieve. 'As received' meat meal was used as the feed material for all the sieves. The

2360 µm , 1400 µm and 850 µm sieves were initially stacked together in sequence. However, problems occurred with blinding of the 850 µm sieve and so this sieve was used on its own.

A very slow feed rate was required when using the 850 µm sieve. The mesh required constant light brushing to ensure that it did not blind. Complete cleaning of the sieve was also required at regular intervals when the brushing was no longer effective. The cleaning consisted of removing the sieve and blowing it down with compressed air.

Sieving below 850 µm was not feasible as the sieve immediately blinds. Brushing of the sieve was ineffective.

### 1.3.3 Results

#### 1.3.3.1 Size Distributions

The results of the sieve analyses for *Ngauranga Milled Meal, Ngauranga Press Cake* and Australian meals, *Herd, AMH Beaudesert, AMH Dinmore, Midco, and Mudgee,* are given respectively in Tables 1.1, 1.2, and 1.3. These are also plotted in Fig 1.1 to facilitate comparison between the different materials.. With the exception perhaps of the material "Herd", there is not much difference between the size distributions of the various meals. Because they are the subject of quite extensive investigation, Ngauranga Milled Meal and Ngauranga Press Cake are also plotted singly in Fig 1.2 and Fig 1.3.

**Table 1.1: Size distribution of Ngauranga Meal Milled - 'As Received'.**

| Mesh Size (µm) | 2360 | 1400 | 850 | 600 | 0355 | pan |
|---|---|---|---|---|---|---|
| wt % on Mesh | 2.91 | 11.6 | 18.06 | 14.01 | 18.88 | 34.53 |

**Table 1.2: Size distribution of Ngauranga Press Cake.**

| Mesh Size (µm) | 12500 | 6350 | 2360 | 1400 | 850 | 600 | pan |
|---|---|---|---|---|---|---|---|
| wt % on mesh | 6.58 | 20.02 | 28.87 | 6.36 | 12.18 | 14.42 | 11.57 |

**Table 1.3: Size distribution of Australian Meals.**

| Sample ID | Herd | AMH Beaudesert | AMH Dimore | Midco | Mudgee |
|---|---|---|---|---|---|
| Seive Size (µm) | wt % on mesh | wt % on mesh | wt % on mesh | wt % on mesh | wt % on mesh |
| 1000 | 13.1 | 18.90 | 14.90 | 19.30 | 24.90 |
| 853 | 2.90 | 7.10 | 3.30 | 4.50 | 3.20 |
| 699 | 5.70 | 10.90 | 8.60 | 8.50 | 7.90 |
| 500 | 9.30 | 16.50 | 20.50 | 15.10 | 18.00 |
| 300 | 20.00 | 24.20 | 18.70 | 28.80 | 30.00 |
| 150 | 28.30 | 22.20 | 29.60 | 22.60 | 15.90 |
| 90 | 17.80 | 0.10 | 4.30 | 1.20 | 0.10 |
| pan | 2.90 | 0.10 | 0.10 | 0.00 | 0.00 |

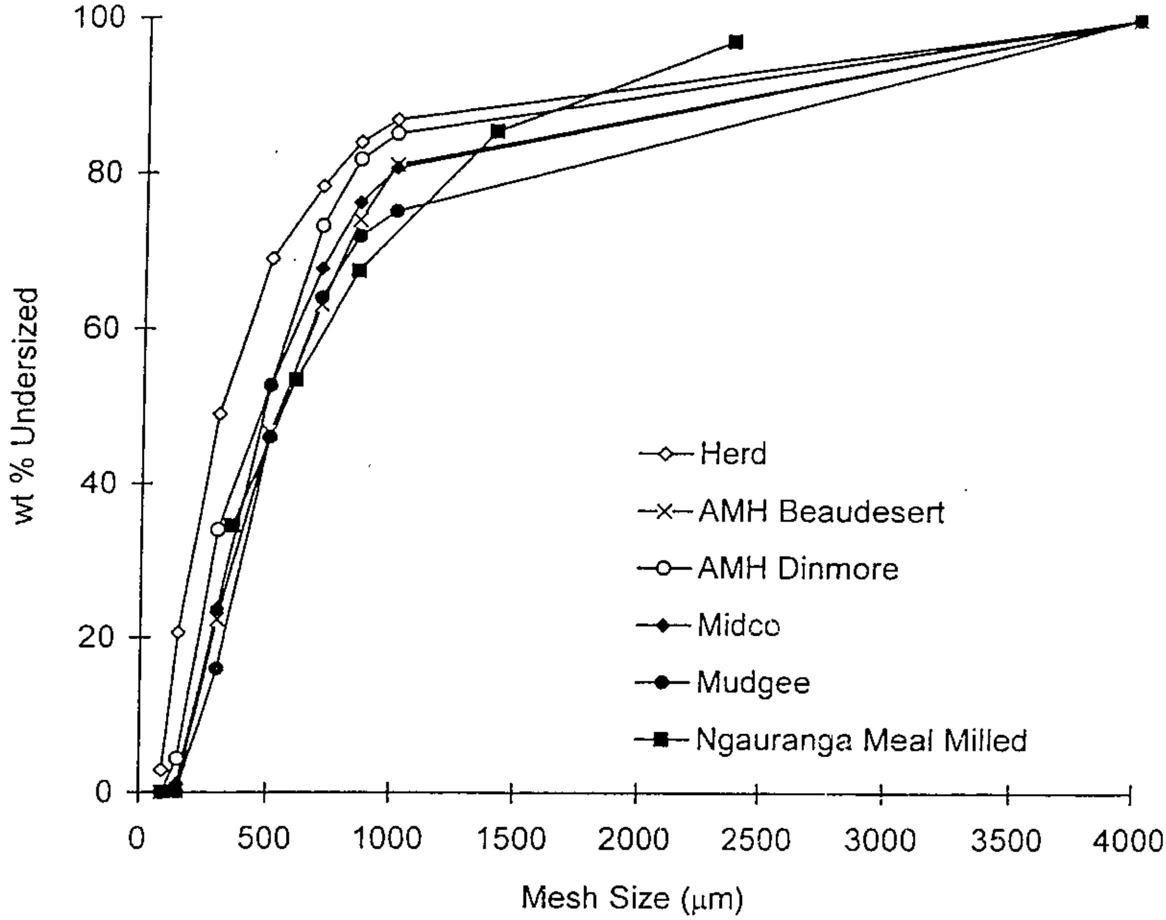


**Figure 1.1:** Particle Size Distributions of Australian Meals and Ngauranga Milled Meal .

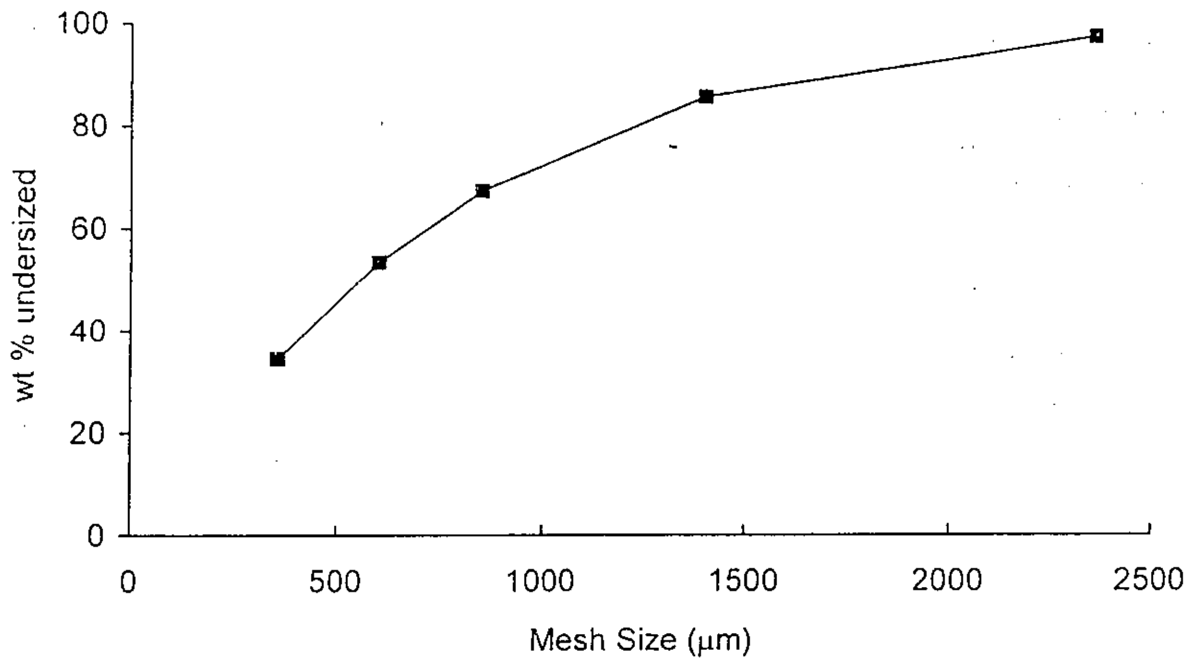


**Figure 1.2:** Size Distribution of Ngauranga Milled Meal.

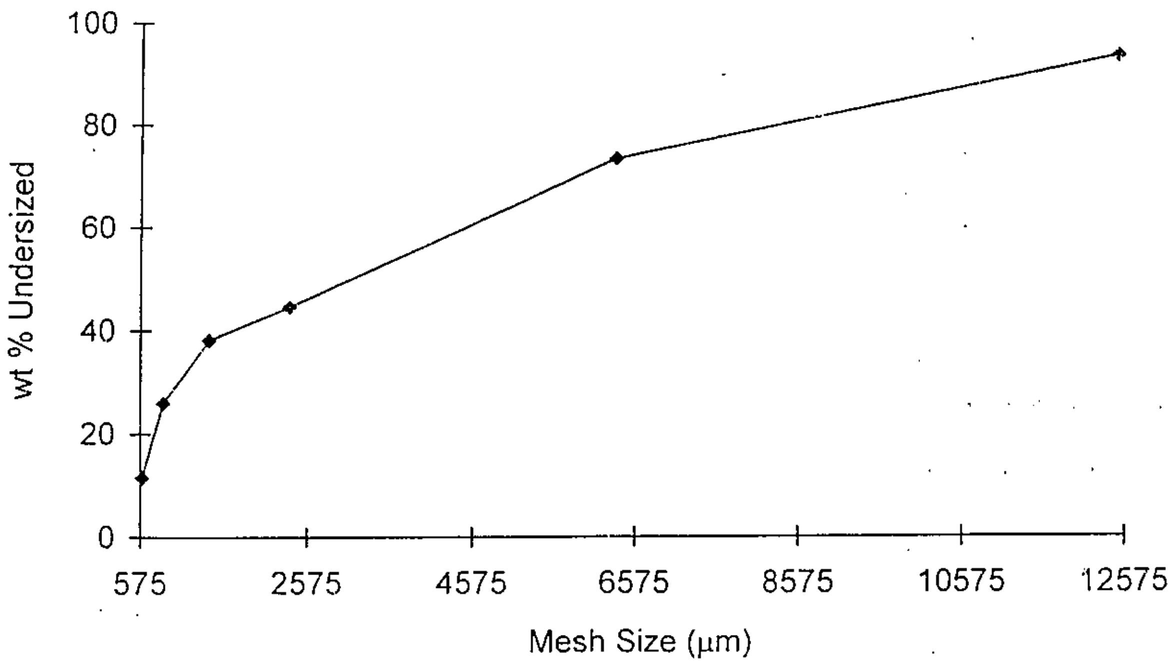


**Figure 1.3:** Size Distribution of Ngauranga Press Cake.

#### 1.3.3.2 Constituent Analyses of different size fractions

Because the Australian meatmeals could not be brought into New Zealand, the analyses reported here are for Ngauranga Milled Meal only. Table 1.4 gives Ash, protein, fat and moisture for the different size fractions. There is a small systematic decrease in ash content as size decreases; protein content shows some scatter, and moisture is of the order of 4% for all samples. The fat content of the two smallest size fractions of meal assayed is significantly larger than for the "as received" meal. Results for Press Cake are given in Table 1.5. For this material the change in protein content with size is significant, and is accompanied by an equally striking increase in the fat content which rises from 9.5% in the "as received" meal to 19.3% for the size fraction smaller than 600 μm. It is thought possible that the protein result for press cake in the range 850 μm > PC ≥ 600 μm is a result of the difficulty in obtaining a representitive sample.

**Table 1.4: Constituent Analysis of Ngauranga Meal Milled.**

| Size (μm) | % Ash | % Protein | % Moisture | % Fat |
|---|---|---|---|---|
| as received | 37.9 | 45.0 | 3.6 | 9.5 |
| M ≥ 2360 | 27.7 | 45.6 | - | - |
| 2360 > M ≥ 1400 | 44.9 | 43.8 | - | - |
| 1400 > M ≥ 850 | 41.8 | 42.5 | - | - |
| 850 > M ≥ 600 | 39.7 | 43.1 | 4.1 | 9.4 |
| 600 > M ≥ 355 | 39.0 | 41.9 | 3.9 | 13.4 |
| 355 > M | 33.7 | 43.8 | 4.6 | 14.4 |

**Table 1.5: Constituent Analysis of Ngauranga Press Cake.**

| Size (μm) | % Ash | % Protein | % Moisture | % Fat |
|---|---|---|---|---|
| 2360 > PC ≥ 1400 | 31.4 | 38.8 | - | - |
| 1400 > PC ≥ 850 | 27.5 | 58.8 | - | - |
| 850 > PC ≥ 600 | 21.0 | 43.8 | 4.2 | 16.9 |
| 600 > PC | 17.5 | 54.4 | 4.1 | 19.3 |

### 1.3.4 Photomicrographs of different size fractions

Samples obtained by screening were photographed under a Leica-wild MC3 microscope with a Minolta X-300s camera. Photographs, at a 10 x magnification, of the Ngauranga Milled Meal having the same size range as in Table 1.4, are shown as Plates One to Six in Appendix I. Plate Seven shows the fraction, 1400 μm > M ≥ 850 μm, at a magnification of 16 x. Plate Eight is for 600 μm > M ≥ 355 μm at 40 x. Plate Nine shows presscake in the range 1400 μm > PC ≥ 850 μm at a magnification of 40.

These photographs show fine particles adhering to larger ones, and also provide evidence of clustering in the fractions in the range 600 μm > M ≥ 355 μm, and 355 μm > M

### 1.3.5 Miscellaneous Analyses

Table 1.6 shows the results of analysis of bone fragments hand picked from bulk samples, and one analysis of the material constituting the sink fraction in the sink/float chloroform test discussed below.

Table 1.7 lists various physical properties of meatmeal and bone.

**Table 1.6: Constituent Analysis of Bone Fragments.**

| Preparation Method | % Ash | % Protein | % Moisture | % Fat |
|---|---|---|---|---|
| Hand picked | 57.7 | - | - | - |
| Hand picked | 60.6 | - | - | - |
| Hand picked | - | 26.9 | - | - |
| Hand picked | - | 28.8 | - | - |
| Hand picked | - | - | 4.2 | - |
| Hand picked | - | - | - | 3.8 |
| sink product in Chloroform Test* | 60 | 30 | - | - |

*See also Table 1.12

**Table 1.7 : Miscellaneous Physical properties of Meal and Bone.**

| | |
|---|---|
| Particle density of hand picked bone | 1994 $kgm^{-3}$ |
| Bulk density of Ngauranga milled meal | 592 $kgm^{-3}$ |
| Bulk density M ≥ 850 µm | 670 $kgm^{-3}$ |
| Bulk density of bone fragments prepared on Oliver 80 gravity table | Approximately 910 $kgm^{-3}$ |

## 1.4. Air Classification

It was outside the scope of this investigation to compare different types of air classifier, and all experimental work to assess the viability of air classification as a means of separating bone and protein from a meatmeal feedstock was carried out using an Alpine MultiPlex® Laboratory Zigzag Classifier. This device was available in our laboratories and as a result of previous experience was known to be efficient and effective with a variety of materials.

In many of the experiments the feedstock was prepared to attempt to improve separation efficiency. An air classifier makes a separation on the basis of differences in the drag forces on the particles in a moving air stream. Differences in drag may arise from differences in size, or density. So, if a feedstream is prepared so that the particles are uniformly sized the performance of an air classifier can be signifiicantly enhanced. Figure 1.4 has been drawn to illustrate this approach to the processing of dry non-cohesive feed streams. (The effectiveness of air tabling processes is also improved by preparing a closely sized feedstock).

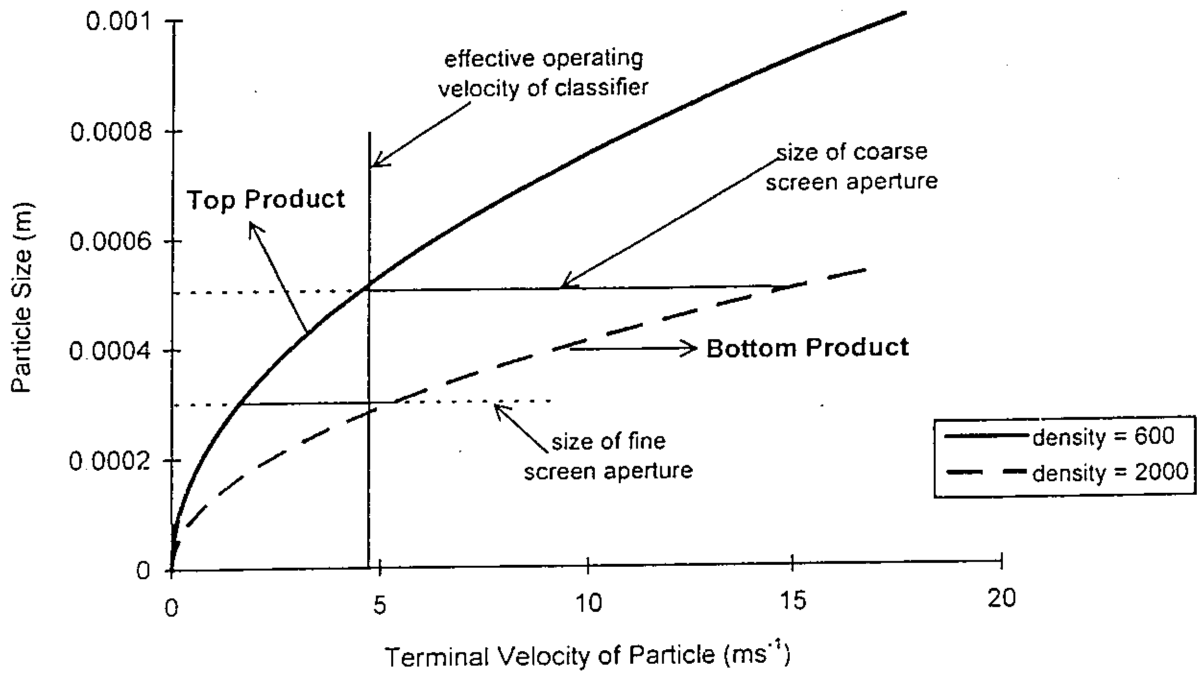


**Figure 1.4:** Diagram to illustrate separation achievable using combination of screen and air classifier.

### 1.4.1 The Alpine Multiplex® Zigzag Classifier

The Alpine MultiPlex® Laboratory Zigzag Classifier B1-40 MZM, is a high efficiency proprietary device manufactured by Alpine AG of West Germany. The principal features of the classifier can be seen in Plate Eleven in Appendix I. The Zig-zag classifier consists of a classifying channel with the characteristic zig-zag shape from which it derives its name. There are only two adjustable parameters, the air rate and the feed rate. The feed enters the column from an air tight hopper, at a rate controlled by a vibratory feeder. Air is sucked through the column, and metered by a rotameter. Air flow rate can be adjusted by a butterfly valve. The feed entering the column is split into two fractions. A "heavy" fraction migrates downwards against the rising air, and is collected in a glass bin at the bottom of the column. The "light fraction is swept out of the column and is removed from the air by a cyclone, and collected in another glass bin.

### 1.4.2 Method

200 g of meat meal were weighed out and all the lumps in the sample were broken down into discrete particles. The sample was then placed in the feed hopper. The vacuum cleaner, which drew the classifying air through the system, was turned on and the air flow rate adjusted to the desired value. The vibratory feeder speed control was set before turning on the feeder and timing how long the meat meal took to pass from the feeder into to zigzag tube. Once all the material had been fed into the system, the vibratory feeder was stopped. The vacuum cleaner was left on for a few more minutes to ensure all the fines in the system had been removed. The zigzag tube and connecting tubing were gently tapped to remove loose fines build up in the system. In order to stop any fines held up in the zigzag tube from falling into the coarse jar when the air was stopped, the lid on the jar containing the coarse meat meal was removed before turning off the air (vacuum cleaner). The lid on fines jar was then carefully disconnected to ensure that no fine material hold up in the tube was lost. The jars were emptied into appropriate containers and weighed. The material held up in the classifier was collected by brushing out the system so a rough mass balance could be calculated. The zigzag classifier was thoroughly cleaned using compressed air.

'As received' meat meal and three Sweco sieve size fractions, M > 850 μm, M < 850 μm and 1400 μm > M > 850 μm, were used in a number of experiments as the feed materials into the Zigzag classifier. Four experiments were also carried out where the fines product from the previous experiment became the feed material.

N.B. Problems occurred with the vibratory feeder. Feed rates were not completely constant throughout a run. The feed setting used was 4, on the arbitrary scale on the feed rate controller, but this was often increased to 5 towards the end of the run. Feeding problems occurred when the meat meal sample contained a lot of fines. Large build up of fines could occur in the zigzag tube but this only affected experiments where a lot of fines were present in the feed sample.

### 1.4.3 Results

An extensive suite of experiments was carried out, for a range of operating air rates and with the feed prepared to several different size specifications. Ash and protein analyses were obtained for most of these tests as well as the relative proportions of Coarse and Fine product. It is apparent from relatively cursory inspection that separation efficiencies are not good. While it is unlikely that these results will have any further use in the design of process plant for meat meal products, they provide evidence of the difficulty of separating a meat meal feedstock into components.

Plates Twelve and Thirteen are photomicrographs of coarse and fine product respectively. Fine particles are clearly visible adhering to larger ones, and there is evidence of clustering in the fine material.

Perhaps the most important result to emerge from the experiments with air classification is the qualitative finding that the internal surfaces of the classifier quickly become fouled. This can be seen in Plate Fourteen in Appendix I. This is regarded as a real impediment to the use of air classification equipment, or indeed any process equipment with internal surfaces that are not easily accesible for cleaning.

Table 1.8 shows the constituent analysis of the fine and coarse products, and Table 1.9 their relative proportions The most encouraging result is for Experiment zz#15 in which the Coarse product contains 55.7% ash. However as can be seen from Table 1.9, this is only 10.8% by weight of a feedstock which is itself only 18.6 % of the "as received"meal; i.e. the Coarse product with 55.7% ash is only 2% of the "as received meal"; see also Table 1.1 for the size distribution of the "as received"meal. The results in Table 1.8 have been plotted in Figs. 1.5 and 1.6

It is noted that apparent anomalies in the trends in the constituent analyses of the fine and coarse products are believed to be the result of dust losses, and losses from the overall product inventory due to fouling. This was not pursued in detail because of the decision to exclude air classification from the prime focus of *this* investigation.

Table 1.8: Constituent Analysis of Zigzag® Classifier Products.

| Sample No. | Feed Meat Meal (μm) | Air Flow rate ($m^3h^{-1}$) | Product | % Ash | % Protein |
|---|---|---|---|---|---|
| zz#5 | as received | 8 | coarse | 40.6 | 43.1 |
| | | | fines | 30.03 | 48.1 |
| zz#6 | as received | 10 | coarse | 41.5 | 42.5 |
| | | | fines | 32.0 | 47.5 |
| zz#2 | as received | 16 | coarse | 43.5 | 41.3 |
| | | | fines | 34.3 | 46.9 |
| zz#4 | as received | 20 | coarse | 46.5 | 40.6 |
| | | | fines | 34.6 | 45.6 |
| zz#8 | M < 850 | 8 | coarse | 37.8 | 43.1 |
| | | | fines | 30.4 | 48.1 |
| zz#7 | M < 850 | 10 | coarse | 40.2 | 41.3 |
| | | | fines | 31.7 | 47.5 |
| zz#9 | M < 850 | 12 | coarse | 43.8 | 37.5 |
| | | | fines | 33.8 | 46.3 |
| zz#10 | M < 850 | 14 | coarse | 45.7 | 34.4 |
| | | | fines | 34.5 | 46.3 |
| zz#11 | M > 850 | 14 | coarse | 40.6 | 41.9 |
| | | | fines | 28.0 | 48.1 |
| zz#12 | M ≥ 850 | 18 | coarse | 47.1 | 43.8 |
| | | | fines | 33.7 | 49.4 |
| zz#13 | M ≥ 850 | 22 | coarse | 49.6 | 36.9 |
| | | | fines | 36.7 | 45.0 |
| zz#14 | M ≥ 850 | 26 | coarse | 43.1 | 40.6 |
| | | | fines | 35.9 | 46.9 |
| zz#16 | 1400 > M ≥ 850 | 22 | coarse | 53.2 | 33.1 |
| | | | fines | 35.6 | 45.6 |
| zz#15 | 1400 > M ≥ 850 | 26 | coarse | 55.7 | 30.6 |
| | | | fines | 40.0 | 43.8 |
| zz#17 | as received | 22 | coarse | 44.0 | 41.3 |
| zz#18 | fines from zz#17 | 18 | coarse | 44.2 | 36.9 |
| zz#19 | fines from zz#18 | 14 | coarse | 42.2 | 41.3 |
| zz#20 | fines from zz#19 | 10 | coarse | 39.6 | 43.2 |
| | | | fines | 33.0 | 46.3 |
| zz#21 | 1000 > M ≥ 850 | - | - | 40.8 | 41.9 |
| zz#21 | 1000 > M ≥ 850 | 17 | coarse | 51.6 | 43.1 |
| | | | fines | 32.8 | 49.4 |

Table 1.9: Fine and Coarse Yields in Zigzag® Classifier separations.

| Sample Number | Feed Material (μm) | Weight Feed In (g) | Air Flow Rate ($m^3/h$) | % Coarse Out | % Fines out | % Coarse Out of as received meal | % Fines out of as received meal |
|---|---|---|---|---|---|---|---|
| zz#1 | as received | 400 | 16 | 23.9 | 76.1 | 23.9 | 76.1 |
| zz#2 | as received | 400 | 16 | 25.6 | 74.4 | 25.6 | 74.4 |
| zz#3 | as received | 400 | 12 | 37.2 | 62.8 | 37.2 | 62.8 |
| zz#4 | as received | 400 | 20 | 16.2 | 83.7 | 16.2 | 83.7 |
| zz#5 | as received | 400 | 8 | 63.8 | 36.2 | 63.8 | 36.2 |
| zz#6 | as received | 400 | 10 | 50.5 | 49.5 | 50.5 | 49.5 |
| zz#7 | m < 850 | 200 | 10 | 37.3 | 62.7 | 25.2 | 42.3 |
| zz#8 | m < 850 | 200 | 8 | 63.6 | 36.4 | 42.9 | 24.5 |
| zz#9 | m < 850 | 200 | 12 | 11.9 | 88.1 | 8.0 | 59.4 |
| zz#10 | m < 850 | 200 | 14 | 3.1 | 96.9 | 2.1 | 65.3 |
| zz#11 | m ≥ 850 | 200 | 14 | 81.4 | 18.6 | 26.5 | 6.1 |
| zz#12 | m ≥ 850 | 200 | 18 | 64.4 | 35.6 | 21.0 | 11.6 |
| zz#13 | m ≥ 850 | 200 | 22 | 36.5 | 63.5 | 11.9 | 20.7 |
| zz#14 | m ≥ 850 | 200 | 26 | 23.5 | 76.5 | 7.7 | 24.9 |
| zz#15 | 1400 > m ≥ 850 | 200 | 26 | 10.8 | 89.2 | 2.0 | 16.1 |
| zz#16 | 1400 > m ≥ 850 | 200 | 22 | 33.4 | 66.6 | 6.0 | 12.0 |
| zz#17 | as received | 400 | 22 | ~17.2 | ~82.8 | ~17.2 | ~82.8 |
| zz#18 | fines from zz#17 | ~330 | 18 | ~8.2 | ~91.8 | ~6.8 | ~76.0 |
| zz#19 | fines from zz#18 | ~305 | 14 | ~12.5 | ~87.5 | ~9.5 | ~66.7 |
| zz#20 | fines from zz#17 | ~265 | 10 | 22.4 | 77.6 | ~14.8 | ~51.4 |
| zz#21 | 1000 > m ≥ 850 | 200 | 17 | 46.7 | 53.3 | ~2.4 | ~2.8 |

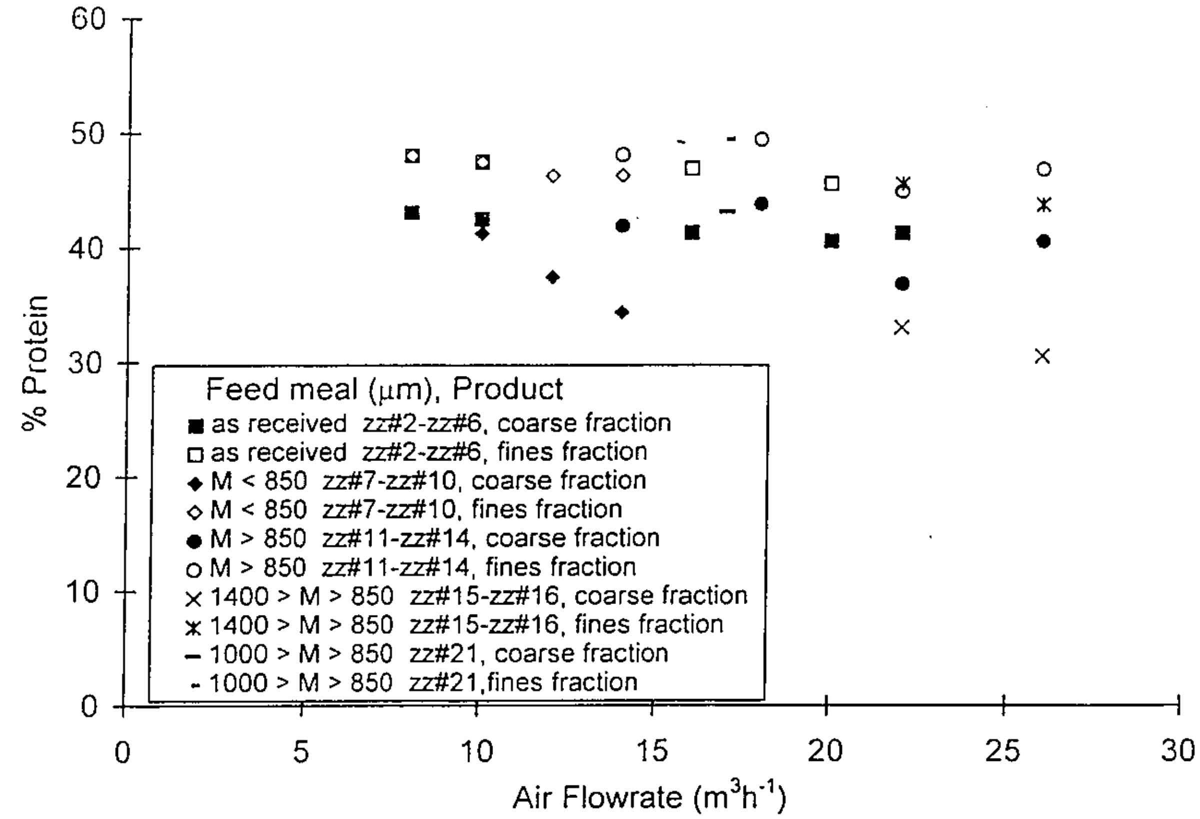


**Figure 1.5:** Protein contents for the coarse and fine fractions of meat meal produced in the Zigzag Classifier for various air flow rates.

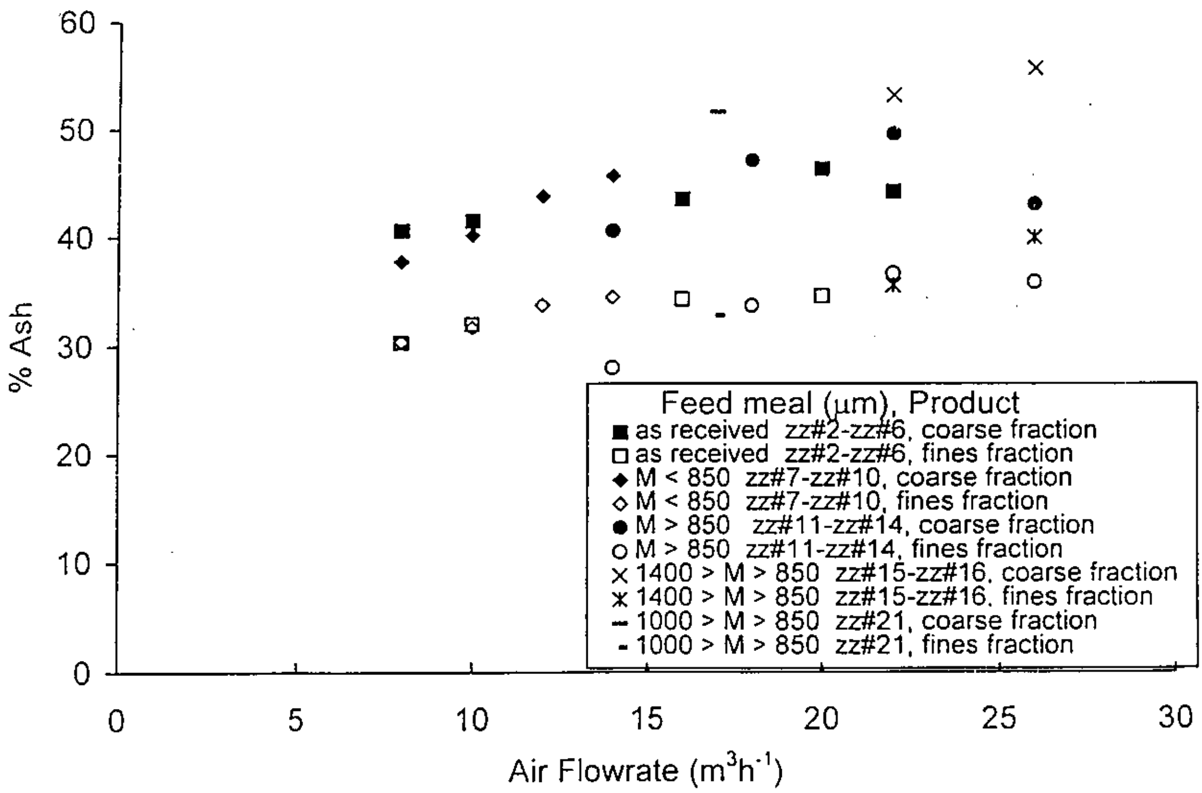


**Figure 1.6:** Ash contents for the coarse and fine fractions of meat meal produced in the Zigzag Classifier for various air flow rates.

## 1.5. Densometric Gravity Separation by Air Table

### 1.5.1 Westrup (LA-K) gravity separator (Laboratory scale)

The Westrup gravity separator was a small laboratory scale air table approximately 1m wide by 1/2m in length at the longest point. See Plate Seventeen. The fluidizing air, table vibration and the vertical and horizontal tilts were all adjustable. The feed rate was controlled by hand feeding the meat meal on to the table to ensure that the whole table was covered with a thin layer of meat meal at all times.

Initial tests were carried out to determine approximate settings for the fluidizing air, table vibration and tilt angles. Quantitative experiments were then carried out using 'as received' meat meal as the feed material for all but one experiment where the meat meal feed was greater than 710 μm.

Experience with this table was useful but quantitative information was not obtained.

### 1.5.2 Oliver 80 Air Table (Commercial Scale)

The Oliver 80 air table was a commercial size table approximately 0.84 m wide at the base by 1.76 m in length at its longest point. See Appendix I, Plate Fifteen.

Initially, qualitative experiments were carried out to determine the best table settings for a feed flow rate arbitrarily chosen as nominally 1 tonne per hour of 'as received' meat meal. The optimum settings included a $6^0$ tilt angle of the table and a minimum setting for the fluidizing air. The table vibration was fixed. The meat meal collected from the end of the table was split into three products which were labelled as the top (coarse), middle and bottom (fine) fractions. It is noted that it was not possible to exercise precise control over the feed rate.

In a quantitative test carried out to obtain information on the separation performance of the table, 65 kg of "as received" meat meal was fed at ~1.3 tonnes per hour. The fine product fraction was then recycled to try to obtain a further spilt of the bone and protein fraction in the fines. The vibration was increased for this fines feed. Three samples were again obtained.

The "as received" feed produced three distinct products; see Appendix I, Plate Sixteen. Inspection of the top (coarse) fraction suggested that it contained only bone particles; the middle fraction appeared to contain bone and a small quantity of large protein particles; the fines fraction visually contained smaller bone fragments mixed in with protein.

Approximately 10 kg of the coarse product was obtained, ie approximately 15 % of the total product. Recycling the fines produced no visible difference in the three product splits.

### 1.5.3 Results

Table 1.10 shows the analysis for the ash and protein content in each of the product fractions. The coarse fraction shows a high ash content equivalent to a product which consists almost entirely of bone. The middle fraction shows only a small increase in the ash content when compared with the "as received" meat meal feed. Recycling the fines fraction shows little improvement in the separation of the bone and protein fractions.

Table 1.11 gives the size distribution of the Coarse product, showing that almost all of it is larger than 600 µm.

**Table 1.10: Constituent Analysis of Oliver 80 Gravity Table Products.**

| Sample No. | Feed Meat Meal | Product | % Ash | % Protein |
|---|---|---|---|---|
| AT1 | as received | Top Fraction, coarse | 58.1 | 28.8 |
| AT1 | | Middle Fraction | 41.1 | 40.0 |
| AT1 | | Bottom Fraction, Fines | 34.3 | 45.6 |
| AT1 | Bottom Fraction Fines | Top Fraction, coarse | 38.6 | 44.4 |
| AT1 | | Middle Fraction | 33.2 | 46.5 |
| AT1 | | Bottom Fraction, Fines | 32.1 | 46.9 |

**Table 1.11: Size distribution of the Top Fraction (Coarse) Product from the Oliver 80 Gravity Table.**

| Mesh Size (µm) | 2360 | 1400 | 850 | 600 | 0355 | pan |
|---|---|---|---|---|---|---|
| % on Mesh | 5.59 | 63.86 | 28.95 | 1.20 | 0.35 | 0.05 |

## 1.6. Attrition in a Fluidized Bed

Two series of experiments were conducted. First of all, trials were carried out to determine the minimum air requirements for fluidization and to assess the fluidization behaviour of the various size fractions. Secondly, a series of experiments was conducted in which an air-jet was used to attempt to selectively break up and remove (soft) protein particles

### 1.6.1 Minimum Fluidization

All experiments were carried out in an 80 mm diameter perspex fluidized bed having a height of 550 mm. The distributor plate was a perforated perspex plate with 61 x 1 mm diameter holes drilled into the plate on a triangular pitch. Fluidizing air was taken from high pressure mains supply, dried, and metered into the bed via a Matheson mass flow meter with a 400 lpm capacity. See Fig 1.7.

Three meat meal samples, 'as received' meat meal, 2360 µm > M > 1400 µm and M > 850 µm, were initially tested to determine their suitability for fluidization. The fluidizing air was turned to a maximum flow rate and approximately 300g of meat meal was poured slowly into the bed. Observations on the fluidizing properties of the material were noted.

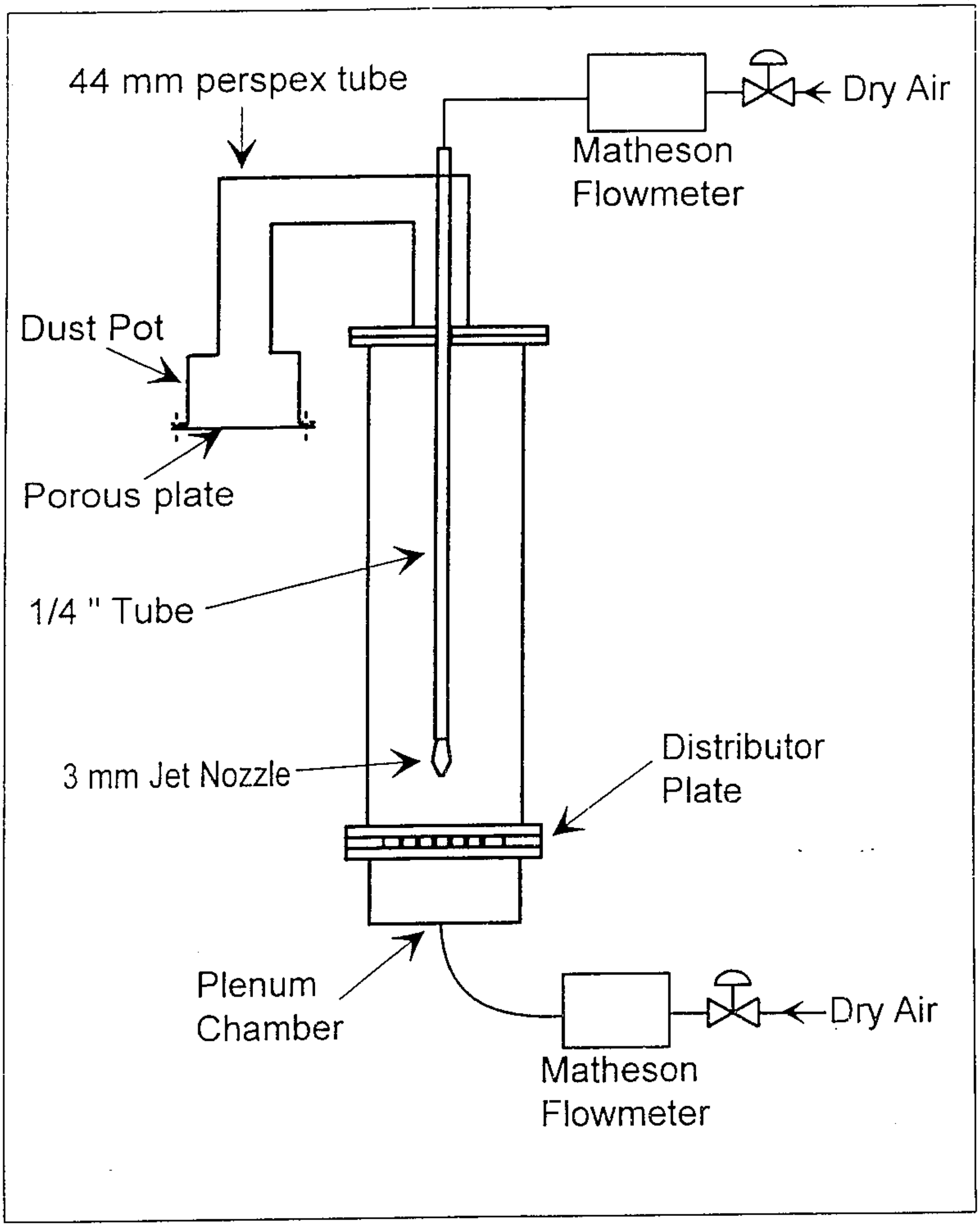


**Figure 1.7:** Schematic diagram of Attrition apparatus

- 'as received' meat meal - This sample does not fluidize even at a superficial velocity of 1.33 $ms^{-1}$, which was the maximum tested. Sample tends to 'Rat Hole' i.e. develops vertical rising channels in the material where the air exits.
- 2360 µm > M > 1400 µm - This meat meal sample fluidizes at high superficial velocities of over 1.06 $ms^{-1}$. However, dead or still patches of meat meal can be seen in the fluidized bed even at the high flow rates. Hair and fine material is carried out of the bed and the meat meal bubbles half way up the sides of the bed (approximately 300 mm). Large pieces of bone are carried half way up the bed with the smaller, and lighter, protein particles.
- M > 850 µm - This meat meal sample fluidizes as well as the closer sized meat meal fraction as described above.

### 1.6.2 Attrition Experiments

The 80 mm perspex bed described above was adapted for use in the attrition experiments. Air was fed into the bed up through the plenum chamber and also to a jet nozzle via two separate air lines. See figure 1.7. The air was metered by two Matheson flow meters, model numbers 8166, connected to a multiple flow controller. A dust collection system was set up consisting of a 120 mm diameter "dust pot" made from 2.5 mm thick perspex. A removable porous plate was attached to the bottom of the pot. The top of the pot was connected to 44 mm I.D. perspex tubing shaped into a U that lead back and bolted to the top of the fluidized bed. A 3 mm nozzle was placed 80 mm above the distributor plate. It was attached to a 750 mm long stainless steel tube, 6.25mm in diameter, which was fed into the bed through the perspex tubing leading to the dust pot. The nozzle was held steady using a burette stand and two clamps. The feed in all experiments was meat meal, M ≥ 850 µm.

The air flow rates were set using the control valves and the air then turned off. 500 g of meat meal was weighed out and poured into the fluidized bed. The dust pot attachment was bolted into place. The experiment was started when the air was turned on and the time was recorded. At regular intervals, the air to the bed was turned off so that the dust pot could be removed and weighed to determine the attrition rate.

### 1.6.3 Results

It became apparent that an attrition based process could be useful in preparing clean samples of bone, but was likely to be far too slow to be useful as a method of separating a meat meal feedstock into protein and bone components. Accordingly the programme was terminated sooner than anticipated and the samples taken over the course of the experiments were not analysed.

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## 1.7. Sink-Float Tests with Chloroform

### 1.7.1 Background

Both ash analysis and Kjeldahl Nitrogen analysis are relatively expensive, and do not provide immediate results. A rapid test method would be helpful in investigative laboratory work aimed at identifying optimal process conditions, and one technique considered worthy of evaluation was sink-float separation. Chloroform was immediately identified as a promising medium, and a comprehensive series of trials carried out.

### 1.7.2 Experimental

The meat meal sample was placed in a dense liquid medium - the 'heavy' components sinking and the 'light' components floating. Chloroform was used as it gave a good separation between white bone particles, which sank to the bottom, and the protein, which floated on the surface of the chloroform.

Approximately 25g of meat meal was weighed out and placed in a conical flask or measuring cylinder. Sufficient chloroform was added so all the meat meal was covered. The flask was then well shaken. The contents of the flask were allowed to settle before the chloroform and the "protein", floating on top of the chloroform, were decanted off.

Chloroform was then added twice more and the procedure repeated. The sample was air dried to remove most of the chloroform and then oven dried at 50°C until all of the chloroform had dissipated. The remaining "bone" was weighed.

N.B. For a sample containing a lot of fines more than three rinses in chloroform were required. The chloroform was fairly clear in colour for the final rinse.

### 1.7.3 Results

Table 1.12 shows analytical results; where a protein analysis is not recorded, it was not measured. The sink fraction, which had the appearance of clean bone consistently returns a value of about 60% ash. The protein content of the single sink sample analysed is 30% suggesting a combined assay of 10% for water and fat. A reading of 4.6% to 7.8% for the ash content of the float fraction is indicative of the presence of small particles of bone, as protein has an ash content of ~1%. While this result effectively negates the use of the sink-float test as a quick assay method, it is consistent with the presence of finely divided bone in close association with the soft protein in the meat meal.

Table 1.13 records the results of size distributions made on the sink product for various sized feeds. These results, plotted in Fig 1.8, provide evidence that a meatmeal mixture, sized using screens, contains particles of bone smaller than the screen aperture.

**Table 1.12: Constituent Analysis of Chloroform Sink -Float Products.**

| Feed Meat Meal | Product | % Ash | % Protein |
|---|---|---|---|
| as received | sink | 58.8 | 30.0 |
| as received | sink | 62.7 | - |
| | float | 7.0 | - |
| as received | sink | 62.0 | - |
| | float | 7.8 | - |
| as received | sink | 62.0 | - |
| | float | 4.6 | - |
| as received | sink | 62.0 | - |
| | float | 4.8 | - |
| as received | sink | 62.1 | - |
| | float | 5.8 | - |

Table 1.13: Particle Size Distributions on Sink Product from Chloroform Tests.

Table 1.13a: Sink Fraction; Feed - as received meat meal.

| Mesh (μm) | 2360 | 1400 | 850 | 600 | 355 | PAN |
|---|---|---|---|---|---|---|
| % wt. on Mesh | 1.89 | 9.55 | 15.79 | 14.35 | 23.78 | 34.65 |
| % undersized | 98.12 | 88.57 | 72.78 | 58.43 | 34.65 | 0 |

Table 1.13b: Sink Fraction; Feed - M ≥ 2360 μm.

| Mesh (μm) | 2360 | 1400 | PAN |
|---|---|---|---|
| % wt. on mesh | 91.35 | 7.28 | 1.37 |
| % undersized | 8.65 | 1.37 | 0 |

Table 1.13c: Sink Fraction; Feed - 2360 μm >M ≥ 1400 μm.

| Mesh (μm) | 1400 | 850 | PAN |
|---|---|---|---|
| % wt. on mesh | 86.21 | 11.49 | 2.30 |
| % undersized | 13.79 | 2.30 | 0 |

Table 1.13d: Sink Fraction; Feed - 1400 μm >M ≥ 850 μm.

| Mesh (μm) | 850 | 600 | PAN |
|---|---|---|---|
| % wt. on mesh | 79.29 | 17.84 | 2.86 |
| % undersized | 20.70 | 2.86 | 0 |

Table 1.13e: Sink Fraction; Feed - 850 μm >M ≥ 600 μm.

| Mesh (μm) | 600 | 355 | PAN |
|---|---|---|---|
| % wt. on mesh | 41.72 | 55.46 | 2.82 |
| % undersized | 58.28 | 2.82 | 0 |

Table 1.13f: Sink Fraction; Feed - 600 μm >M ≥ 355 μm.

| Mesh (μm) | 355 | 250 | 150 | 90 | 63 | PAN |
|---|---|---|---|---|---|---|
| % wt. on mesh | 31.75 | 12.10 | 32.43 | 14.62 | 7.07 | 2.03 |
| % undersized | 68.25 | 56.15 | 23.72 | 9.10 | 2.03 | 0 |

Table 1.13g: Sink Fraction; Feed - 355 μm >M.

| Mesh (mm) | 250 | 150 | 90 | 63 | PAN |
|---|---|---|---|---|---|
| % wt. on mesh | 4.42 | 41.34 | 30.7 | 14.46 | L |
| % undersized | 95.58 | 54.24 | 23.54 | 9.08 | 0 |

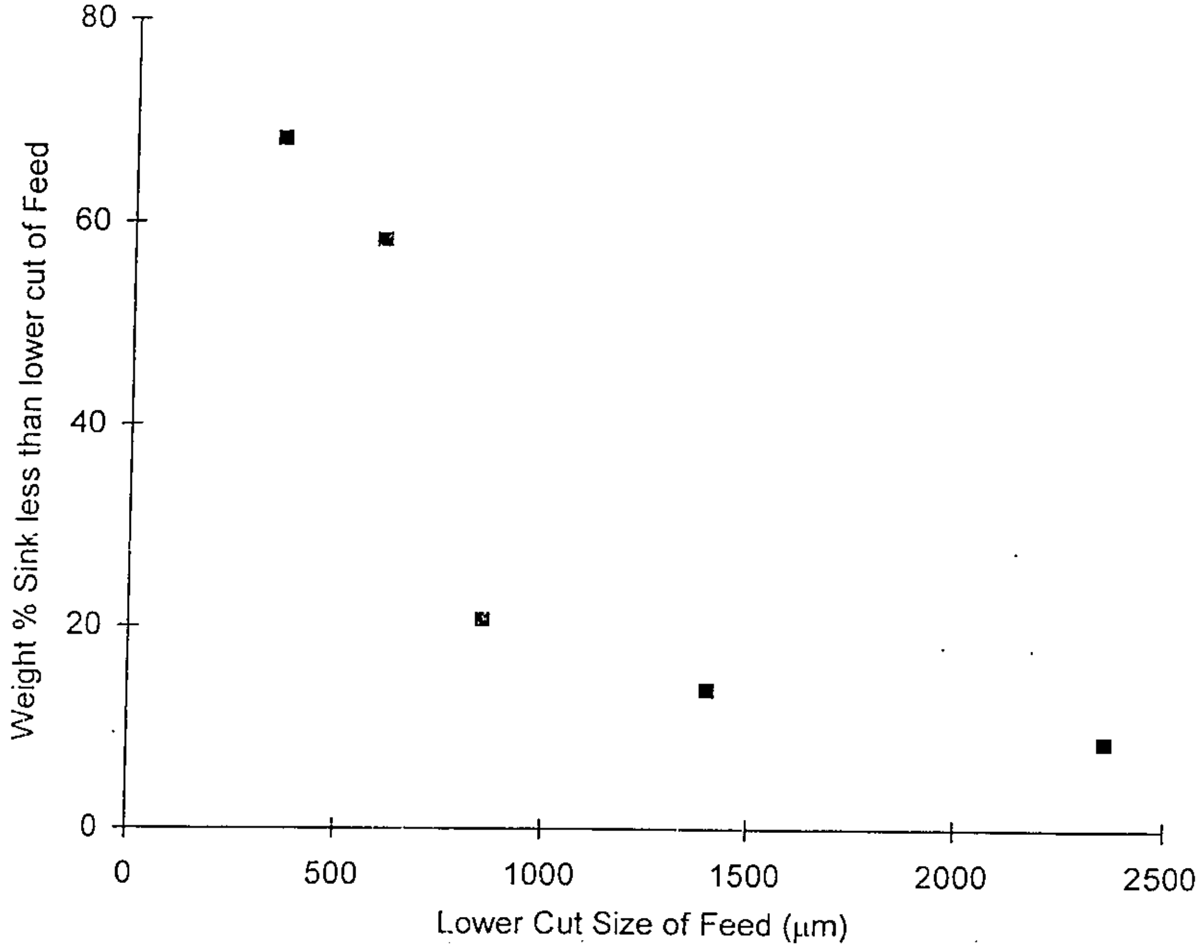


**Figure 1.8:** Weight % undersized of sink product from chloroform tests for various sized feeds.

## 1.8. Supplementary Experiments

### 1.8.1 Addition of a fine powder to sample

Further sieving trials were carried out to determine if a fine powder added to a meat meal sample would make the sieving easier. Approximately 1 g of Silica dust was sprinkled over 100g of 'as received' meat meal. The powder was mixed in thoroughly with a spatula before a particle size distribution was carried out. 1 g of Fumed Silica was also tried. No effect, and test discontinued.

### 1.8.2 Drying and then sieving test - 100g overnight at 105 C

100g of as received meat meal were placed in an oven at 105 °C overnight. A particle size distribution was then carried out on the dried sample to see if sieving was easier. No discernible effect.

### 1.8.3 Different mediums for sink/float test

Different mediums were tried in the sink-float test to try and improve the separation efficiency. Bromoform (density = 2.91 $gml^{-1}$) and carbon tetrachloride (density = 1.58 $gml^{-1}$) were tried. Three mixtures of bromoform and carbon tetrachloride with densities of approximately 2.02 $gml^{-1}$, 1.91 $gml^{-1}$ and 1.71 $gml^{-1}$ were also tried. No improvement over chloroform.

### 1.8.4 Salt solution test

A salt solution, of a similar density to that of chloroform, was made up to determine whether a separation of the protein and bone fraction in meat meal would occur. A saturated solution of calcium chloride hexahydrate, which had a density of 1.4 g $ml^{-1}$, was used. Ineffective.

## 1.9. Discussion

### 1.9.1 Constituent Analysis

The behaviour of the meatmeal feedstock in the physical separations discussed above is ascertained from the various constituent analyses performed on the feed and products of a separation operation. The meatmeal is assumed to be completely characterized by its analysis for protein, ash, fat and water. While every care has been taken to ensure that representative samples were used, inspection of those few results tabulated above for which all four constituents have been assayed, reveals a consistent shortfall of the order of 5 % in the mass balance. The possible reasons are thought to include variance in the appropriate factor used as a multiplier for the Kjeldahl nitrogen, and possibly the existence of some bound water not picked up in the moisture assay. This small discrepancy is not regarded as significant in the context of this investigation, and as it is outside the scope of this work to discover the reasons, it will not be discussed further. However, as it is necessary to close the mass balance for the quantitative assessment of the various process options developed in Part Two of this report, the missing mass will be arbitrarily assigned to the protein fraction.

### 1.9.2 Screening

The laboratory apparatus used in preparing the various sieve fractions used both to characterize the meatmeal and to prepare sized feeds for the air classification experiments was unsuitable for quantitative estimates of screening rates. However, it was clear that screening with mesh apertures smaller than 850 µm was very slow, and that the screen quickly blinded, necessitating frequent cleaning. For process applications, a 1000 µm (1 mm) aperture is probably the smallest that should be considered. Screening rate data, which are essential for sizing process equipment were provided by the manufacturers of industrial screeners and are presented in Part Two, in Table 2.3.

### 1.9.3 Air Classification

As pointed out above, there are sound theoretical reasons for pursuing the possibility of a process based on a combination of sizing by screening, followed by a densometric classification process such as air classification or tabling. The relative mechanical simplicity of air classifiers is appealing, and the availability of the Alpine Multiplex® Zigzag classifier enabled a thorough and systematic investigation. However, the zigzag performed poorly with meat meal, and this is attributed to the formation of agglomerates. There is visual evidence in the photographs of the product material that the meatmeal is cohesive, particularly the smaller size fractions, and it is highly likely that this is due to fat. As well as performing at low efficiency, the internal surfaces of the classifier were quickly fouled by deposits of cohesive dust. It is well known that fatty materials can cause severe problems in pneumatic conveying systems, and it now appears that a tendency for fat content to increase as particle size decreases may prohibit the use of air classification in this work. As will be seen when process options are discussed in Part Two, air cleaning equipment which is essential for legislative reasons is expensive and is yet another impediment to the use of air classification technology in the separation of meatmeal into components.

Notwithstanding the comments above, we are reluctant to completely dismiss air classification as a processing option in meatmeal beneficiation, for several reasons. Air classifiers are made to many different designs and function well in a wide variety of industries with a wide variety of products having a broad spectrum of properties. The effectiveness of process equipment is often determined as much by design as by the underlying operating principle, and it is intuitively reasonable to expect that some classifiers may promote and maintain dispersions that are sufficiently insensitive to the cohesive tendencies of fatty products to achieve acceptable separations. However, caution should be exercised in selecting and operating air classification equipment with products containing fat, and particular regard should be given to the potential for build up of cohesive dust on process surfaces.

### 1.9.4 Air Tabling

Qualitative and general statements circulating in industry circles acknowledge the potential effectiveness of air tabling in the separation of meat meal feedstocks into protein-rich and bone-rich streams. Some information on approximate feed rates for a specified table have been suggested by supply firms and are given in Part Two, in Table 2.1. The significance of the results listed here is the establishment of a figure of 15% for the proportion of a meatmeal feed that can be removed as "pure" bone. It is now thought likely that this would be a worst case for the Ngauranga meal used because the flow rate of ~1.3 tonnes per hour is significantly larger than the figure of 500 kg $^{-1}$ suggested by a supply firm for the Oliver 80; this information was not available when the experimental trials were carried out.

Tabling trials were necessarily restricted in scope for reasons of cost and logistics, but there is evidence in the results that there may be difficulties associated with the preparation of fine fractions of pure bone. It has been noted above that there was evidence of agglomeration in the fine fractions produced in the air classifier, probably because of the presence of fat. Bone particles have a fat content of ~4%, see Table 1.6, and removal of a pure bone stream will effectively increase the mean fat content of the remaining material. An increase in fat content as mean size decreases is likely to reduce the effectiveness of the air table in separating the finer part of the feed into its components.

### 1.9.5 Chloroform sink float test

The sink-float tests with chloroform were initiated in an attempt to find an assay method for bone or protein that would return indicative concentrations more quickly and for less cost than standard ashing or Nitrogen tests. In qualitative terms the separations achieved in the limited trials performed were good. However, material balances on several tests, showed that some of the bone was remaining associated with the float (protein) fraction, and this reduced the usefulness of the chloroform test, at this stage of its development, as a quantitative analytical guide. However, the potential has been demonstrated, and it is considered likely that further attention to the method of agitating the meatmeal sample in the chloroform separation medium, and to the relative quantities of chloroform and meatmeal, could result in the development of a quantitative test method.

### 1.9.6 Model for Meatmeal Mixture Structure

Implicit in the foregoing presentation of analytical results and the discussion of observed behaviour, is a model for the structure of meatmeal mixtures. This model is useful in assessing the effects of changing the relative proportions of the various constituents of the meal, and in the development of process options.

#### 1.9.6.1 Model

Meatmeal can be thought of as a mixture of three materials. These are **bone** particles, a second proteinaceous phase termed **meat**, and mobile **fat**. The **bone** particles are distributed over a range of sizes and are composed of protein, ash, water and fat in fixed proportions.

The meat is composed of protein, water, and a small amount of ash, in fixed proportions and consists of particulate proteinaceous animal matter distributed over a range of sizes.

The fat is a mobile phase, distinct from the fat in the bone. The proportion of fat in a meat meal is determined by the processing methods used to make the meat meal.

An empirical observation is that the fat tends to associate with the meat, so the removal of large bone particles as in a tabling process has the effect of increasing both the protein content and the fat content of the remaining meatmeal.

Using the measured composition of bone, and a meatmeal sample, the effect of selectively removing bone particles can be gauged from a material balance, and this approach will be used in the determination of the product streams in the development of meatmeal separation processes.

### 1.9.7 Constraints on Separation of Meatmeal into Components

In section 1.4, it was pointed out that with proper feedstock preparation by correctly chosen screens, it is possible in principle to achieve a very good, perhaps perfect, separation of a mixture of two components of different density, using air classification, or air tabling; see also Fig. 1.4. The screening step produces a closely sized feed which is then separated into components on the basis of differing behaviour in a drag based device such as an air classifier or air table. If, however, the effectiveness of the screening step is constrained, it will not be possible to surpass certain characteristic overall separation limits. This appears to be the case in the current investigation.

There are three pieces of experimental evidence, as well as visual indications in some of the photographs. First of all, the float fraction in the sink-float tests with chloroform had an ash content between 4.6% and 7.8 %, indicating the presence of bone particles in association with the protein. The test method involved shaking the meatmeal vigorously in chloroform; it was not possible in the limited number of trials undertaken to reduce the ash content of the float fraction below 4%, suggesting an extremely strong association between this bone and the protein matrix. These particles are thought to be very small. It is considered virtually certain that agitation and dispersion of meatmeal in an air environment, as in an classifier or table , without the benefit of the solvent action of the chloroform to loosen adhesion caused by fat, would also see the retention of some of the bone in the protein matrix.

Secondly, it was shown in Section 1.7.3, that in Chloroform tests, the sink product (bone) obtained from meatmeal fractions prepared to close size limits before testing, contained bone particles smaller than the nominal screen size. The proportion of this undersized bone increased as the nominal screen aperture limits decreased, reaching almost 70% for meal in the range $600 > M \geq 355$ µm; see Table 1.13 and Fig 1.8. This behaviour suggests the presence of agglomerates on the screen rather than discrete particles. There is insufficient information available to gauge the likely make up of an agglomerate.

Thirdly, the experimental work with the Zig-zag classifier and the Oliver air table, which formed much of the backbone of this programme, revealed difficulties in making clean separations, particularly of the smaller particles. While some improvement may come with experience and better operating practice, our results are thought to reflect a real processing difficulty, related to the fat content of the feedstock. Budget constraints prevented fat analysis of the many Zig-zag and air table samples taken in the course of the work, but these have been retained for analysis at a future date if required.

## 1.10. Conclusions

Air classsification is not regarded as a promising operation in a process for meatmeal separation, and is not considered further in this investigation.

About 15% of an unprepared meatmeal feedstock was separated as a pure bone stream, without much difficulty, and this will be used as a worst case figure for the separation efficiency of an air table in the development of process options.

The effects of selective removal of bone, protein or fat on the composition of a meatmeal can be gauged using a material balance, and this will be used in assessing the performance of process options.

The fat in the meat meal feed is likely to accumulate in the fine fractions produced in screening and tabling operations, and will limit the achievable separation efficiency.

# PART TWO

## Evaluation of Process Options

## 2.1. Introduction

Part Two of this report describes the development of a number of processing options for the further refinement of meat meal by separation into its constitutive components and gives an indicative economic evaluation of the different options. By making use of the experimental analyses and conclusions in Part One the performance of each different option is assessed and recommendations made.

Factors relevant to the successful application of a separation plant are discussed. These include practical considerations in the handling of the product, limits on the achievable separation and costing of the equipment. A number of processing options are outlined with calculated estimates of the separation performance, the cost of the equipment, and the increased product value due to the separation.

## 2.2. Process design factors

As outlined in Part One, air classification is considered unsuitable for use with meat meal. The operations considered in the following include the combined use of screening (sieving) and gravity tables. Screening of the milled meal provides no separation of the components by itself but can be useful in improving the performance of gravity separation steps (see Section 1.4) by narrowing the size distribution of the feed to the table.

Screening of the meal before it has been milled, i.e. the press cake, can however provide some protein enrichment by taking off the larger components which are predominantly bone. This larger fraction can then be milled and further processed to remove more of the bone. Sieve analysis of sample Press Cake from Ngauranga, Section 1.3, has indicated to what degree protein enrichment is possible, as described below. No knowledge is available however on whether this sample is representative of the size range of press cake available from other rendering plants, or of variations in the product with day to day operation.

The overall composition of the products is evaluated assuming the meal consists of a **bone** fraction, a **meat** fraction, and a mobile **fat** fraction, as outlined in Section 1.9.5.1. Mass balances over each separation unit allows calculation of the relative proportions of the three fractions in each stream, as well as their composition for use in evaluating the products value.

The range of flowrates considered for design of the process is assumed to be between 1.5 and 3.5 tonnes per hour. Calculations are given for both extremes of this range. Annual plant capacity is estimated for a 16 hour day, running 365 days a year with a 10% down time.

### 2.2.1 Gravity Tables

Our preliminary testing of the performance of a typical industrial scale gravity table is outlined in Section 1.5. This testing was not extensive but provides a base estimate for the capabilities of an air table with meat meal. The tests showed a bone stream of 10 kg in a 65 kg feed could be removed and this has been used as a conservative base case for the following analysis. Further testing with larger inventories would be required to find the optimum performance achievable with a gravity table.

For costing and sizing purposes, information was obtained from several commercial suppliers. This is listed in Table 2.1.

### 2.2.2 Screens

The calculations for screening processes are based on size distributions calculated in Part One. Typical screen sizes and costs from a number of companies are listed in Table 2.2.

Some difficulty, as noted in Part One, was experienced with the sieving of the meals particularly for smaller sizes. The meat component of the meal is high in fat content and many of the handling and sieving difficulties have been attributed to this. As noted above, even in the sink float test there is evidence that fine bone fragments are held up in the meat fraction and this effectively defines a physical limitation to the separation achievable by mechanical means. Some typical screening rates for meat meal of different sizes are given in Table 2.3.

Sieving of the material through a 2.36 μm mesh yielded a small oversize fraction of about 3% consisting mainly of balled up hair and fluff. Removal of this material may add to the product value and is a simple process. It also improves the handling of the material in later processing steps, so a scalping option has been included in the processing options below.

### 2.2.3 Air Cleaning

Depending on requirements for the exhaust air from the processing equipment and the availability of existing plant air cleaning facilities, additional equipment may be required. The cost of an air cleaning unit was based on the air requirements for the gravity tables and on an estimate by a New Zealand supplier of air cleaning equipment, with experience in Australia.

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## 2.3. Product value

For any additional separation steps to be viably added to existing rendering plants, the value of the separated products must obviously be greater than that of the original meal. The meal can, ideally, be separated into two basic products with commercial value. As outlined in the previous section the first is a protein product consisting largely of meat and blood, or soft component of the meal, the second is a stream of mostly pure bone - the hard component of the meal.

Table 2.1: Capacity and Indicative cost of Gravity Separators*

| Deck Area ($m^2$) | Capacity* ($kgh^{-1}$) | Cost $ AUS | Remarks |
|---|---|---|---|
| 1.66 | 300 - 500 | 23 000 | - |
| 2.42 | 440 - 730 | 25 600 | - |
| 3.66 | 660 - 1100 | 30 000 | - |
| 3.72 | 670 - 1120 | 61 000 | Imported / hydraulic controls |
| 5.56 | 1000 - 1700 | 70 000 | Imported / hydraulic controls |
| 8.36 | 1500 - 2500 | 85 000 | Imported / hydraulic controls |

* Details provided by Company Y.
* Based on estimate of 300-500 $kgh^{-1}$ for meat meal on 1.66 $m^2$ deck provided by Company Y. Air requirements are estimated to be 2300 - 3700 $m^3 h^{-1} m^{-2}$ deck area for meat meal.

Table 2.2: Indicative Cost of Screeners.

| Number of decks (-) | Area per Deck ($m^2$) | Cost $ AUS | Source |
|---|---|---|---|
| 1 | 2.16 | 27 000 | B |
| 1 | 3.09 | 32 000 | B |
| 1 | 4.65 | 49 000 | B |
| 2 | 2.16 | 28 000 | B |
| 2 | 3.09 | 33 000 | B |
| 2 | 4.65 | 51 000 | B |
| 3 | 2.16 | 29 000 | B |
| 3 | 3.09 | 35 000 | B |
| 3 | 4.65 | 53 000 | B |
| 3 | 1.67 | 24 000 | C |

A New Zealand Agent Company X
B Australian Agent Company X
C Australian Agent Company Y

Table 2.3: Some Screening Rate data for Meat Meal.

| Mesh | Aperture (μm) | Screening rate ($kg\ h^{-1}\ m^{-2}$) | Source |
|---|---|---|---|
| 5# | 4040 | 15600 - 21600 | A |
| 6# | 3350 | 11000 | A |
| 8# | 2460 | 2700 | A |
| 10# | | | |
| 12# | 1650 | 1300 - 1500 | A,B,C |
| 14# | 1370 | 3600 | A |
| | "1000" | 1000 | B |

### 2.3.1 Protein

The value of the protein stream is predominantly due to its protein content. Typical meals have protein contents around 50%. The price for meat meal has some fluctuations but is nominally around AUD 400/tonne for a 50% meal. Consultation with those in the industry has suggested that protein contents higher than the baseline 50% hold a premium of around $8 per percentage point protein increase. This provides a gauge for evaluation of product value increase, particularly for small increases in protein content, although it is probably conservative for higher enrichment.

### 2.3.2 Bone Chips

Although extensive investigation, including a comprehensive internet search, was made into potential markets for bone products, very little information was available. It was also difficult to gauge a value directly from the value of existing products which typically have different specifications to the unrefined bone stream that would result from the separation processes considered here. It is likely that some post separation processing of the bone stream would be required to present a marketable product, but this is not part of the current study.

The primary use for bone is as a phosphorous source, but also for calcium and other trace elements, and is commonly used as an animal feed. A typical end product containing 21% P and 18%Ca, ground to a specific size and packaged, sells for $525 to $550 per tonne. Analysis of the Ngauranga bone was not carried out but literature suggests that cooked bone has Phosphorous contents of typically 15%.

For the purpose of the following analyses a nominal value for the bone stream was chosen to be the same as the value of the as-received meat meal, i.e around $400/tonne. As a result the economic analysis reflects improved product value solely through enrichment of the protein product. Discussion of the sensitivity of the analysis to changes in the price of the bone chips is also included.

## 2.4. Process Design Calculations

The assumptions used in the process separation calculations follow. In all cases the compositions are based on analytical tests carried out on Ngauranga meat meal.

(i) The composition of the meat meal and/or press cake to be separated is assumed to be as follows, based on analysis of the meat meal sample from Ngauranga, as given in Table 1.4. A mass balance indicates a missing 4% which is assumed to be protein. This gives a total protein content of 49% as in Table 2.4 below.

Table 2.4: **Constituent analysis of meatmeal : reference values for process calculations.**

| | |
|---|---|
| Ash | 37.9% |
| Protein | 49.0% |
| Fat | 9.5% |
| Water | 3.6% |

(ii) The composition of the bone , used in the process calculations, is taken both from analysis of the bone fraction in the sink/float test and from samples of hand picked bone and is listed in Table 2.5. Table 1.12, suggests an ash content of 62% and a protein content of 30%. Analysis of hand picked bone, in Table 1.6, suggests the remaining 8% is nominally 4% fat and 4% water. Note that by mass balance with the data in Table 2.4, the bone constitutes 60% of the feed meat meal.

**Table 2.5: Constituent analysis of bone : reference values for process calculations.**

| | |
|---|---|
| Ash | 62% |
| Protein | 30% |
| Fat | 4% |
| Water | 4% |

(iii) Gravity table separation performance is conservatively based on values obtained in the preliminary trials using an Oliver 80 air table. These trials showed 10kg of a 65kg feed could be removed as a pure bone stream. This represents removal of 26% of the bone in the feed, effectively reducing the bone content in the protein product from 60% to about 53%.

(iv) The composition of the products after sieving the press cake through a 1400 μm mesh is based on size distribution analysis, in Table 1.1, and on the composition analysis of the different size fractions, Table 1.5. The composition of the undersize fraction (that passing through the 1400 μm sieve) has been estimated from an average of the composition of the fractions less than 1400 μm in Table 1.5. The average was weighted according to the distribution of particle sizes and values scaled slightly where necessary to close the mass balance. The composition calculated is given below in Table 2.6.

**Table 2.6: Constituent analysis of undersize presscake : reference values for process calculations.**

| | |
|---|---|
| Ash | 23.1% |
| Protein | 58.0% |
| Fat | 14.5% |
| Water | 4.4% |

(v) The gravity table sizes are chosen based on a capacity of 500 kg/hour for the 1.66m$^2$ table in Table 2.1. The required area for the screens was estimated from screening rate figures given in Table 2.3, for different size fractions. For multiple deck screens, the screen is sized on the lowest screening rate. Screens and gravity tables are selected from the available models from companies A,B,C, as in Tables 2.1 and 2.2.

## 2.5. Costing Calculations

The assumptions used in the costing calculations are summarised below;

(i) The price of the unprocessed meat meal is assumed to hold a nominal value of $400 per tonne for a protein content of 49%. For the purposes of analysis, a value per percentage point protein in the meal is calculated from $400/49%. i.e. $8.16 per percentage point. This is used as a conservative estimate for the increase in product value with protein enrichment.

(ii) The cost of capital items is taken from indicative estimates for a number of commercially available models. Costs for screens are given in Table 2.2, and costs for air tables in Table 2.1. A nominal estimate is made for the cost of installation and commissioning.

(iii) Annual operating costs are made from estimated labour costs of 1/8 person for operations involving only screen classifiers, and 1/2 person for operations involving gravity tables. One operator is costed at $50,000 per year. The cost for utilities is based on power consumption costs for the screening and air tables.

(iv) Operating hours at the nominated flow rate are assumed to be for 16 hour days, 365 days a year, with a 10% down time.

(v) A reliable source for a price for bone chips in an unprocessed form was difficult to find, so the price of the bone stream was assumed to be equal to the price of the raw feed meal, i.e. $400 per tonne.

## 2.6. Processing options

Four processing options are considered using combinations of screening and gravity table separation operations on both the pre-mill press cake and the post-mill meat meal. Figures 2.1 to 2.4 show schematic process diagrams for, respectively, process options #1 to #4 for a flow rate of 1.5 tonnes per hour. Figures 2.5 to 2.8 show the respective processes at 3.5 tonnes per hour.

A financial evaluation of the options is given for the two different flow rates in Tables 2.7 and 2.8, giving capital costs, annual running expenses, and an estimated nett increase in product value. These costings are indicative only. Options 2b, 3b, and 4b include costs for installation of an air cleaning unit if this is also required for operation of the plant. Figure 2.9 shows the sensitivity of the profitability of the separation process to changes in the price of the bone stream product. In Figure 2.10 the time taken for net income from product sales to equal capital investment is plotted as a function of the price obtained for the bone product.

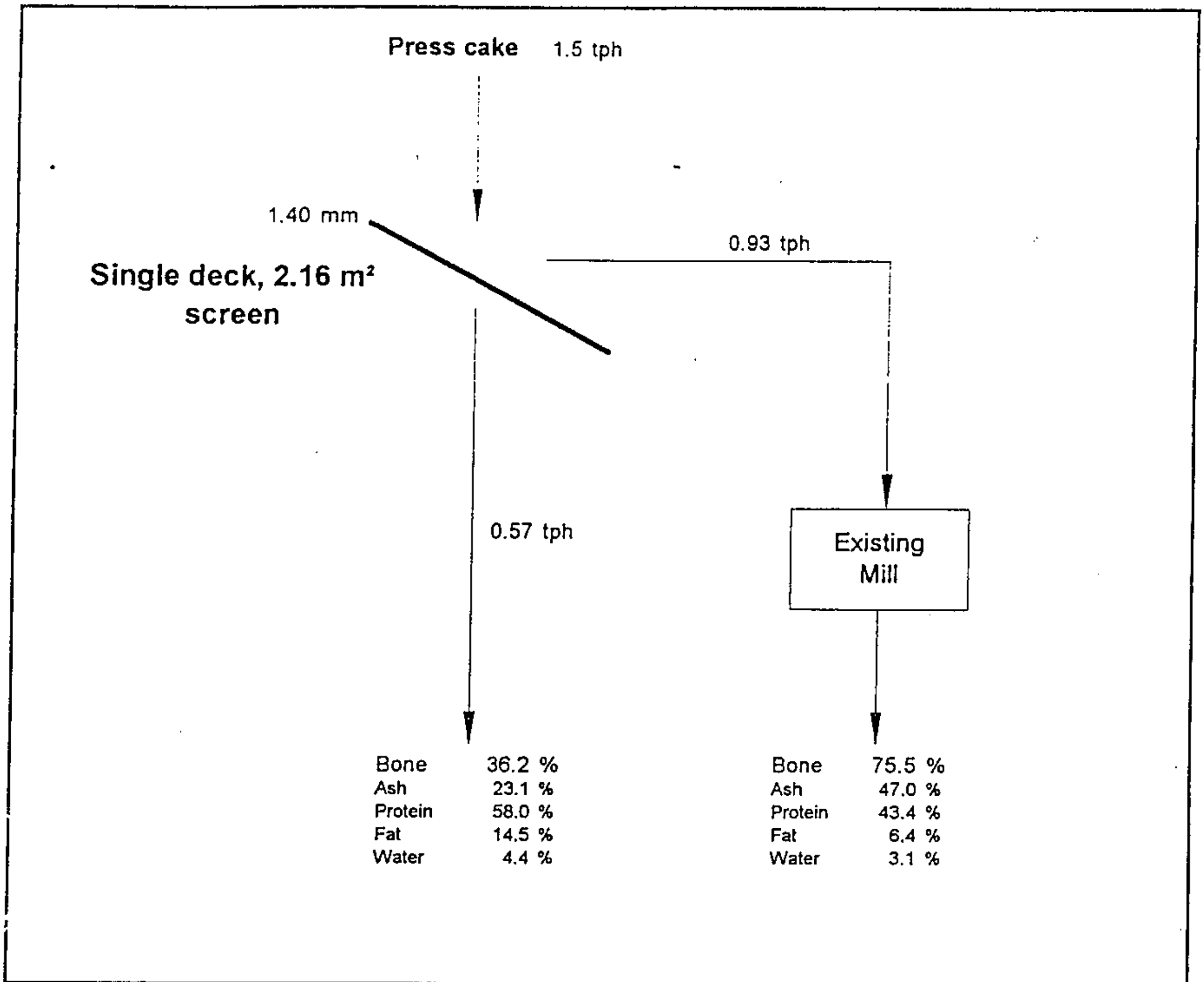
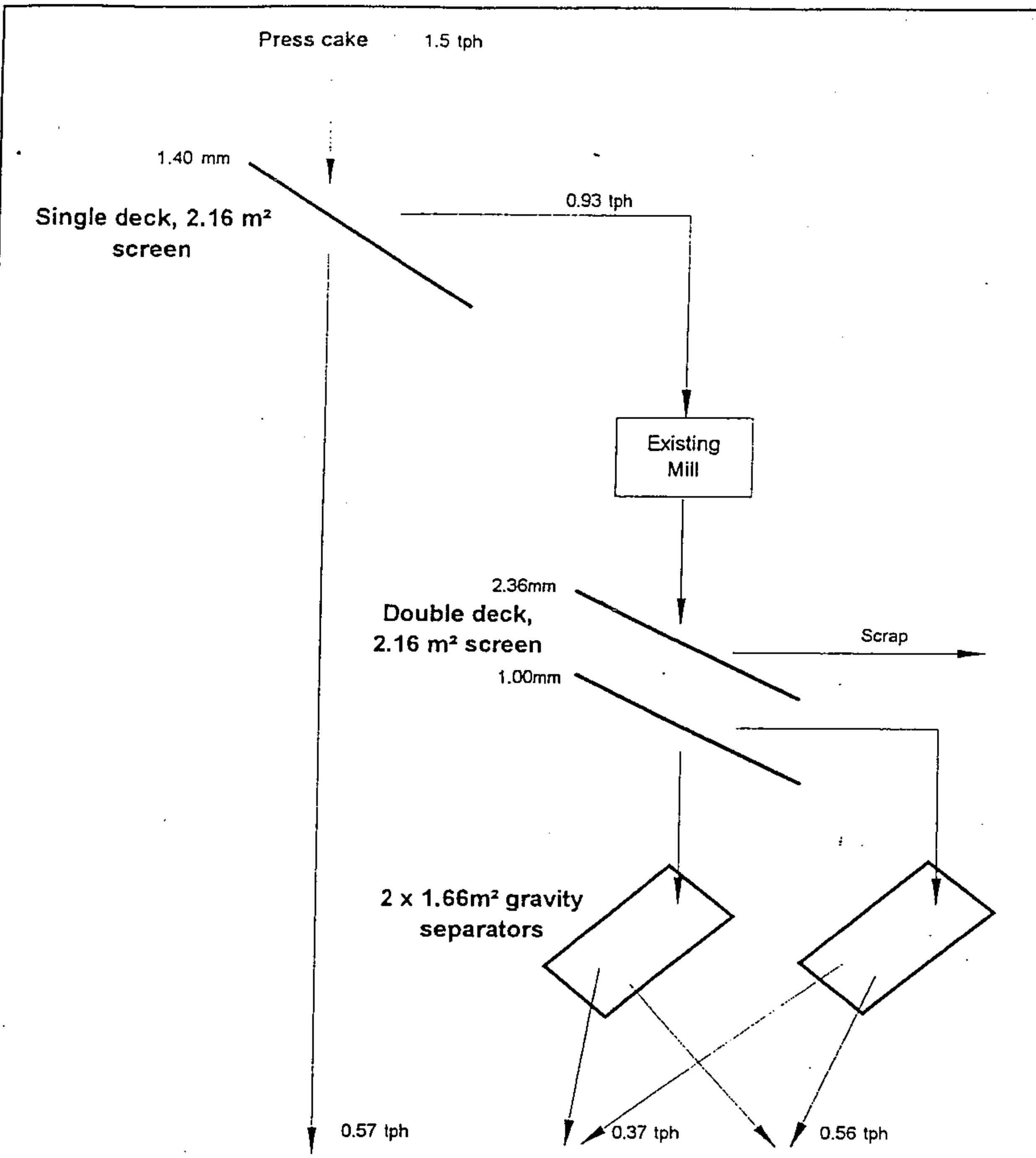



**Figure 2.1 - Process Option #1/$_{1.5}$, Flowrate 1.5 tonnes per hour**




| | | | |
|---|---|---|---|
| Bone | 36.2 % | 100.0 % | 53.2 % |
| Ash | 23 1 % | 62.0 % | 37 0 % |
| Protein | 58.0 % | 30.0 % | 52.5 % |
| Fat | 14.5 % | 4.0 % | 8 0 % |
| Water | 4.4 % | 4 0 % | 2.5 % |

**Figure 2.2 - Process Option #2/$_{1.5}$, Flowrate 1.5 tonnes per hour**

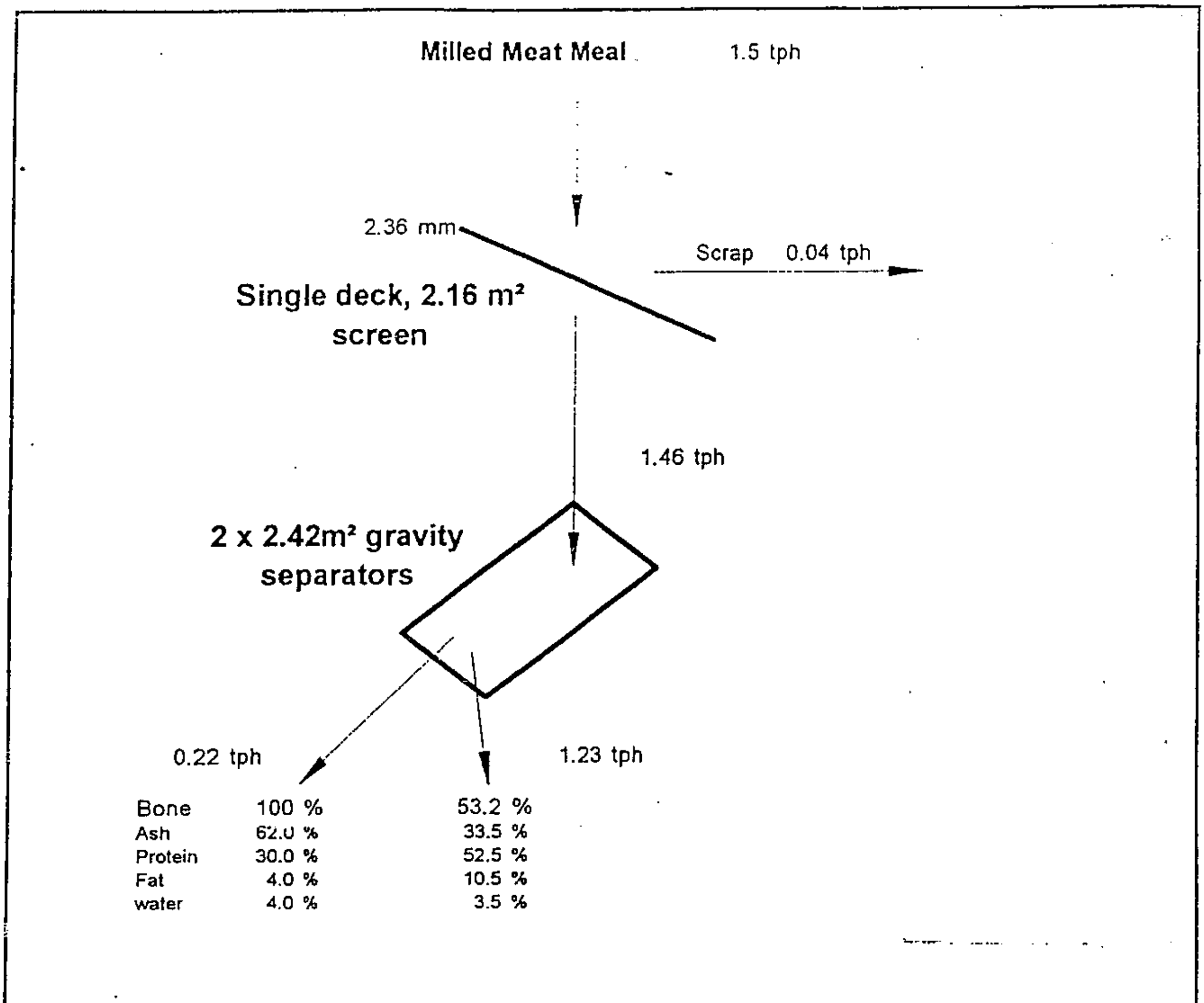



**Figure 2.3 - Process Option #3/$_{1.5}$, Flowrate 1.5 tonnes per hour**

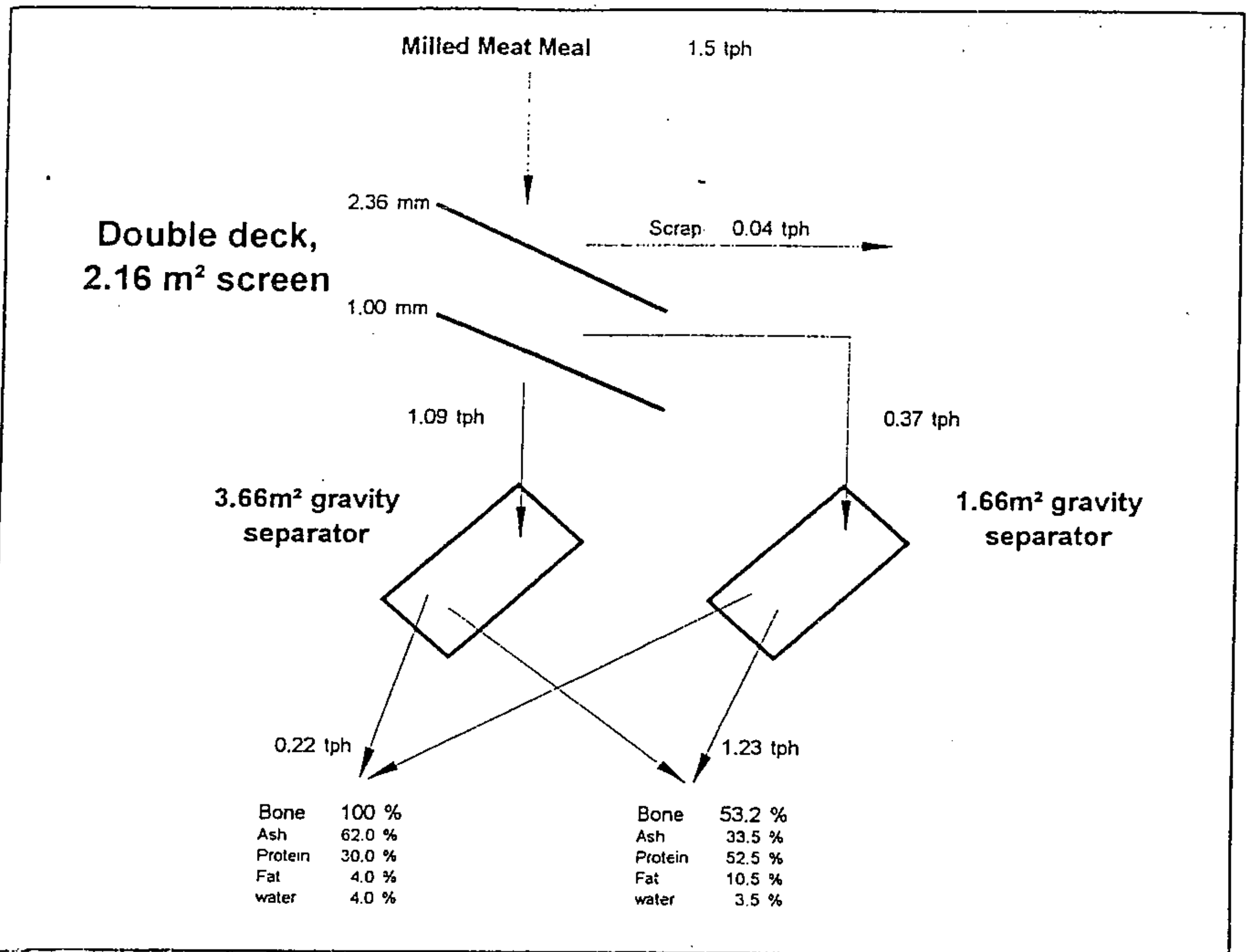



**Figure 2.4 - Process Option #4/$_{1.5}$, Flowrate 1.5 tonnes per hour**

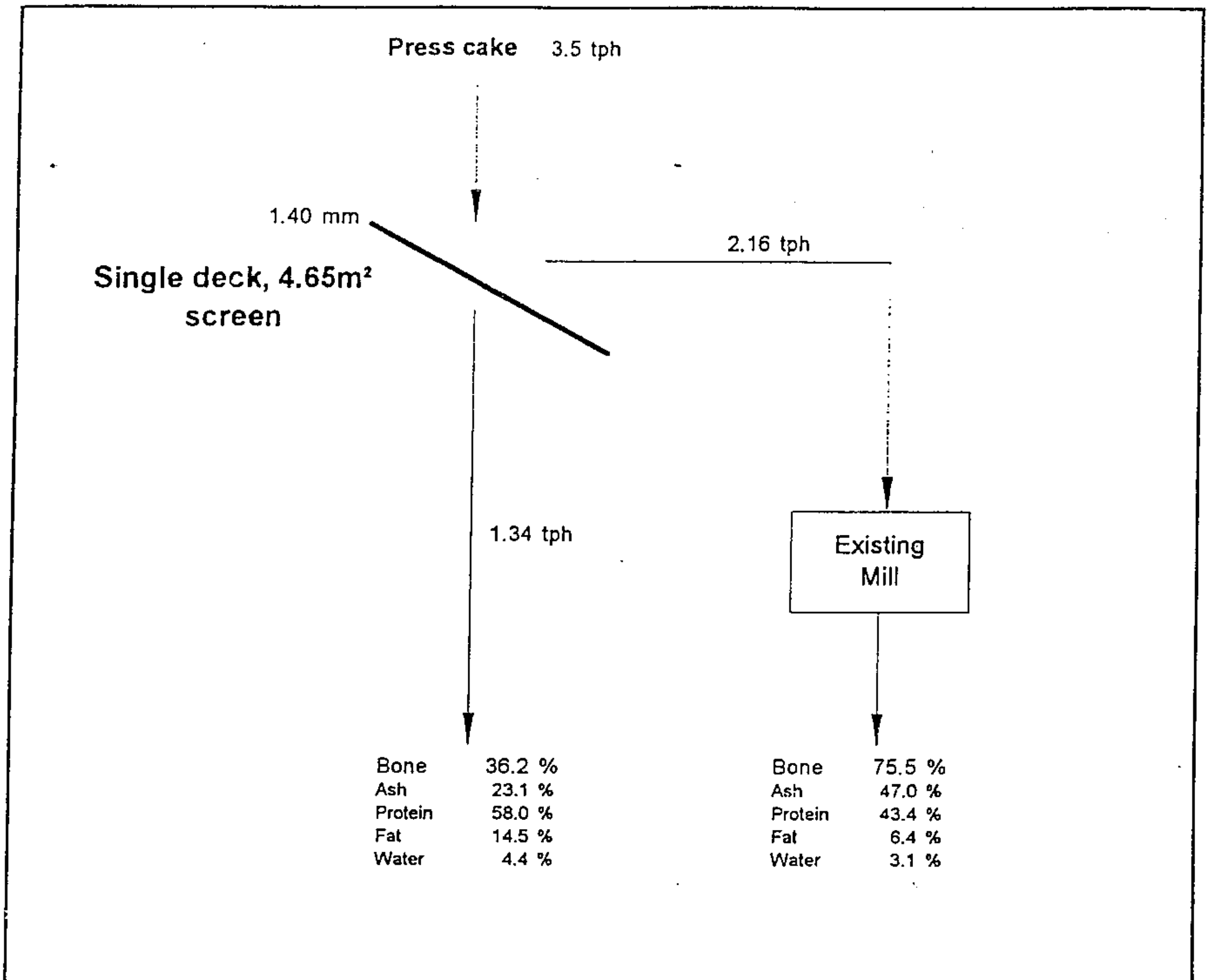
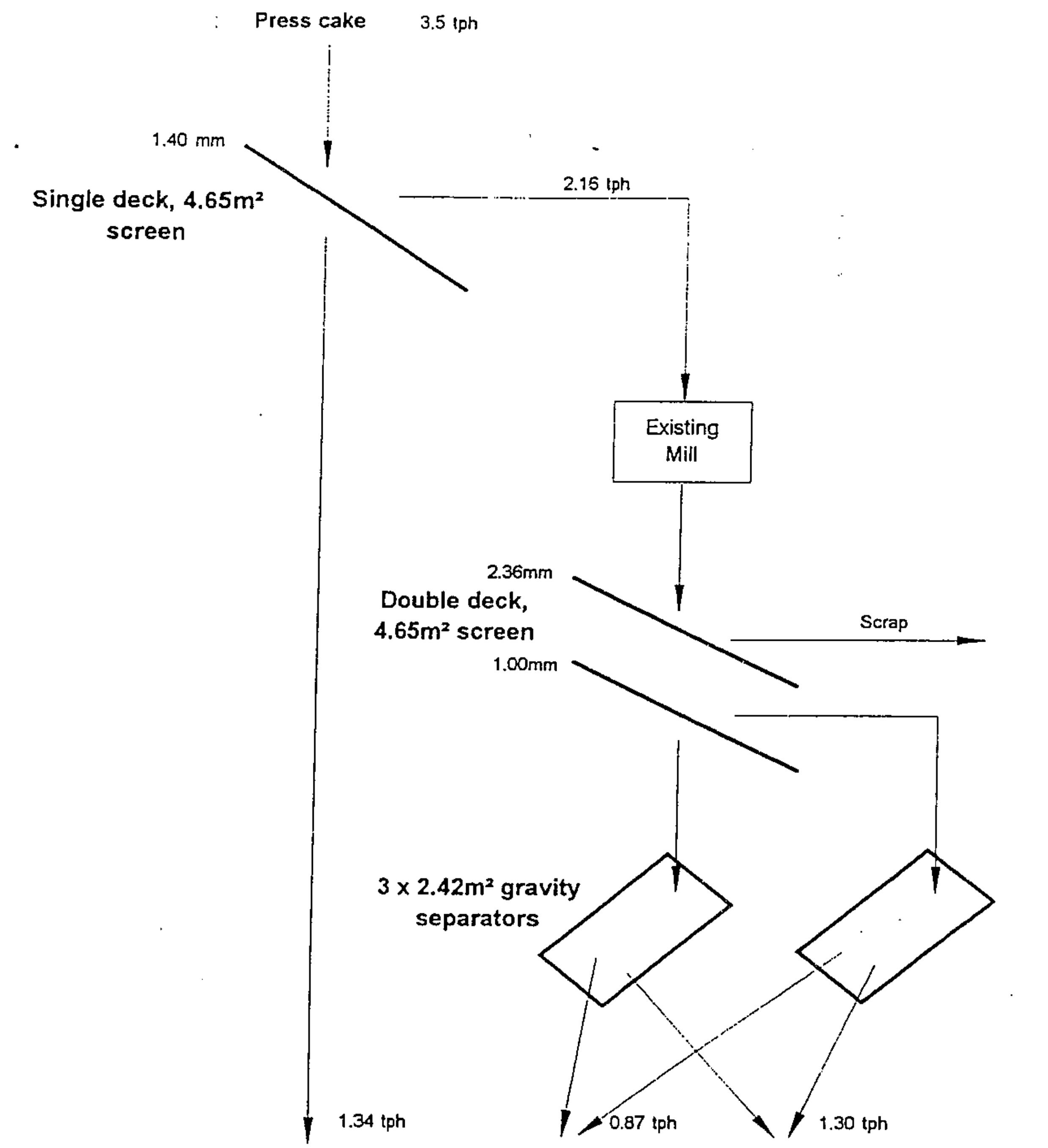



**Figure 2.5 - Process Option #1/$_{3.5}$, Flowrate 3.5 tonnes per hour**




| | | | |
|---|---|---|---|
| Bone | 36.2 % | 100.0 % | 53.2 % |
| Ash | 23.1 % | 62.0 % | 37.0 % |
| Protein | 58.0 % | 30.0 % | 52.5 % |
| Fat | 14.5 % | 4 0 % | 8.0 % |
| Water | 4.4 % | 4 0 % | 2.5 % |

**Figure 2.6 - Process Option #2/$_{3.5}$, Flowrate 3.5 tonnes per hour**

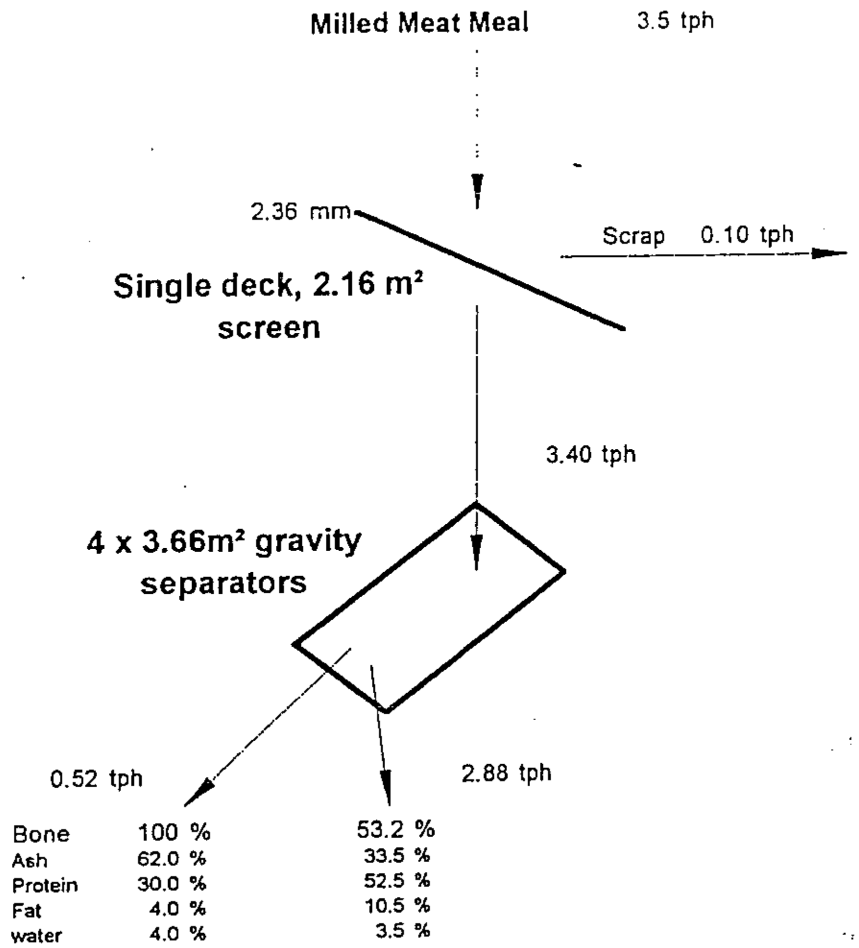



**Figure 2.7 - Process Option #3/$_{3.5}$, Flowrate 3.5 tonnes per hour**

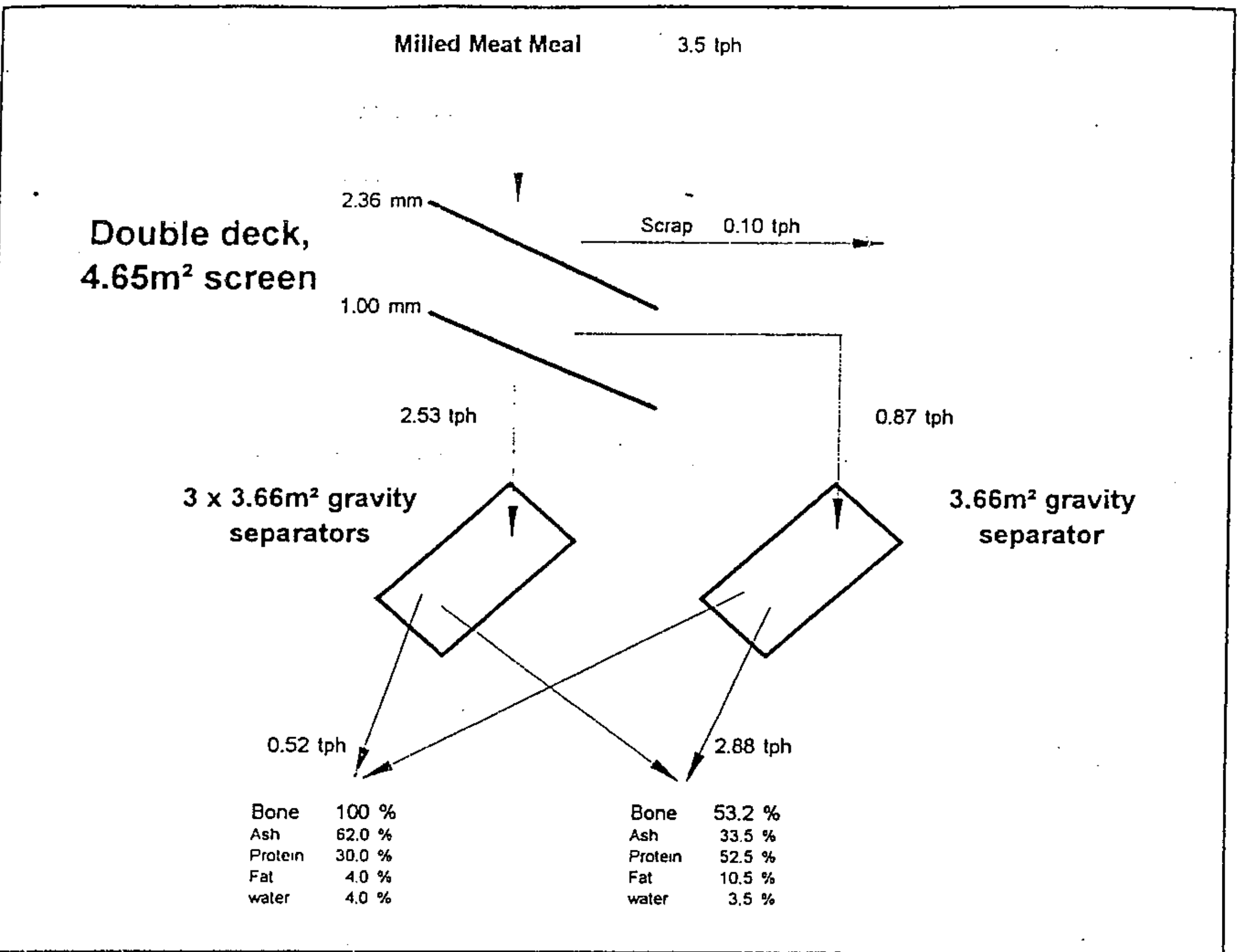



**Figure 2.8 - Process Option #4/$_{3.5}$, Flowrate 3.5 tonnes per hour**

## Table 2.7 - Costs for process options, flow rate 1.5 tonnes per hour

| Capital costs ($) | Option 1 | Option 2 | Option 2b | Option 3 | Option 3b | Option 4 | Option 4b |
|---|---|---|---|---|---|---|---|
| Screen(s) | 27000 | 55000 | 55000 | 27000 | 27000 | 28000 | 28000 |
| Tables | | 46000 | 46000 | 51200 | 51200 | 53000 | 53000 |
| Air Cleaning | | | 100000 | | 100000 | | 100000 |
| Installation | 20000 | 30000 | 40000 | 30000 | 40000 | 30000 | 40000 |
| **Total** | **47000** | **131000** | **241000** | **108200** | **218200** | **111000** | **221000** |
| **Annual costs** | | | | | | | |
| Labour | 6250 | 25000 | 25000 | 25000 | 25000 | 25000 | 25000 |
| Utilities | 1000 | 10000 | 10000 | 10000 | 10000 | 10000 | 10000 |
| **Total** | **7250** | **35000** | **35000** | **35000** | **35000** | **35000** | **35000** |
| **Revenue** | | | | | | | |
| Annual protein product (t) | 2996 | 5939 | 5939 | 6707 | 6707 | 6707 | 6707 |
| Annual bone product (t)[‡] | 4888 | 1945 | 1945 | 1177 | 1177 | 1177 | 1177 |
| Average protein increase (%) | 9 | 6.25 | 6.25 | 3.33 | 3.33 | 3.33 | 3.33 |
| Price of protein product ($/tonne) | 473.47 | 451.02 | 451.02 | 427.19 | 427.19 | 427.19 | 427.19 |
| Price of bone product ($/tonne) | 400 | 400 | 400 | 400 | 400 | 400 | 400 |
| Gross product value ($) | 3373708 | 3456603 | 3456603 | 3335968 | 3335968 | 3335968 | 3335968 |
| Price of feed meal ($/tonne) | 400 | 400 | 400 | 400 | 400 | 400 | 400 |
| Gross feed meal cost ($) | 3153600 | 3153600 | 3153600 | 3153600 | 3153600 | 3153600 | 3153600 |
| **Nett added product value ($)** | **220108** | **303003** | **303003** | **182368** | **182368** | **182368** | **182368** |
| **Added product value less annual costs ($)** | **212858** | **268003** | **268003** | **147368** | **147368** | **147368** | **147368** |
| **Time for capital return (yrs)** | **0.22** | **0.49** | **0.90** | **0.73** | **1.48** | **0.75** | **1.50** |

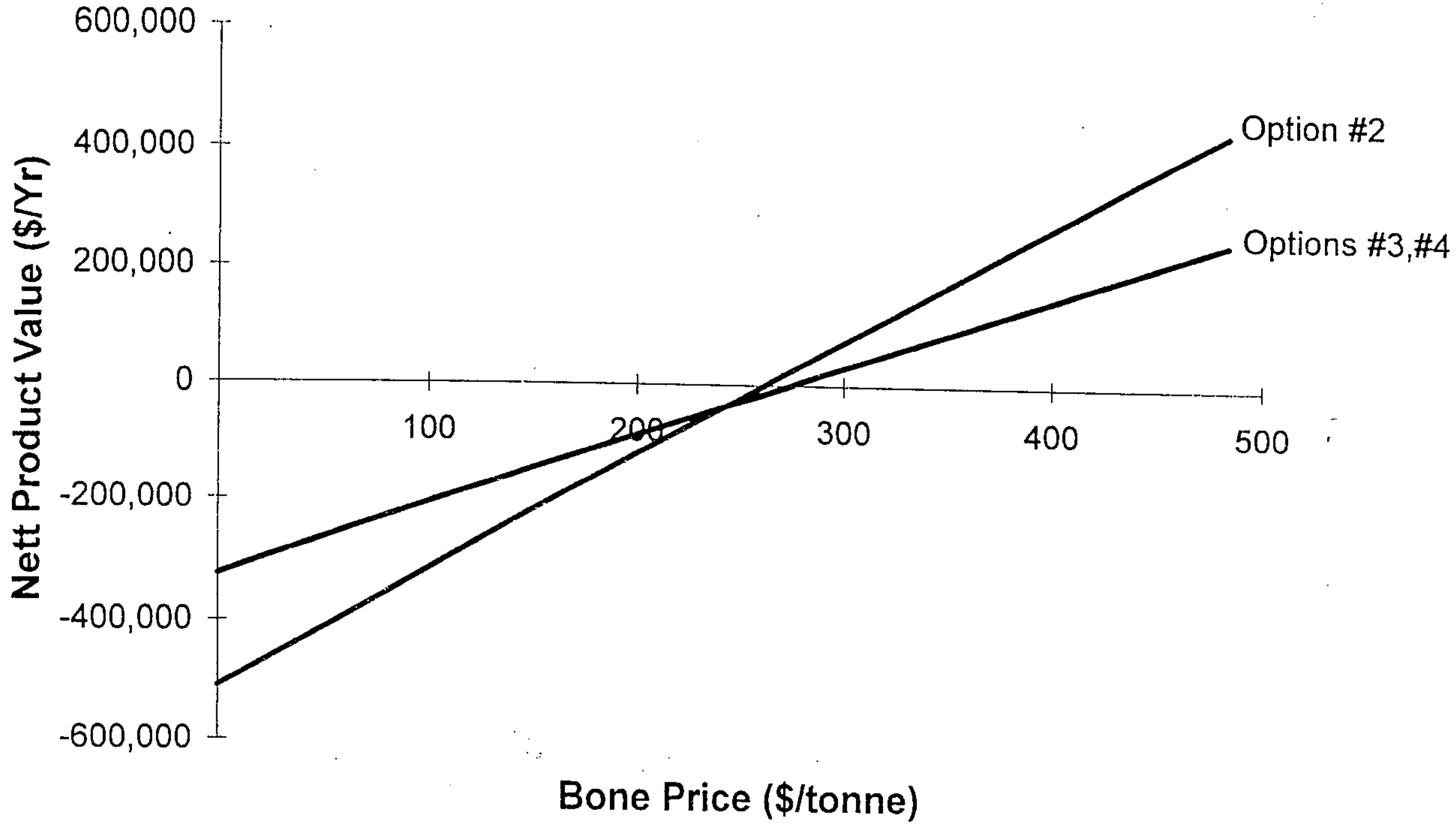
[‡] This is not a pure bone stream for option #1

## Table 2.8 - Costs for process options, flow rate 3.5 tonnes per hour

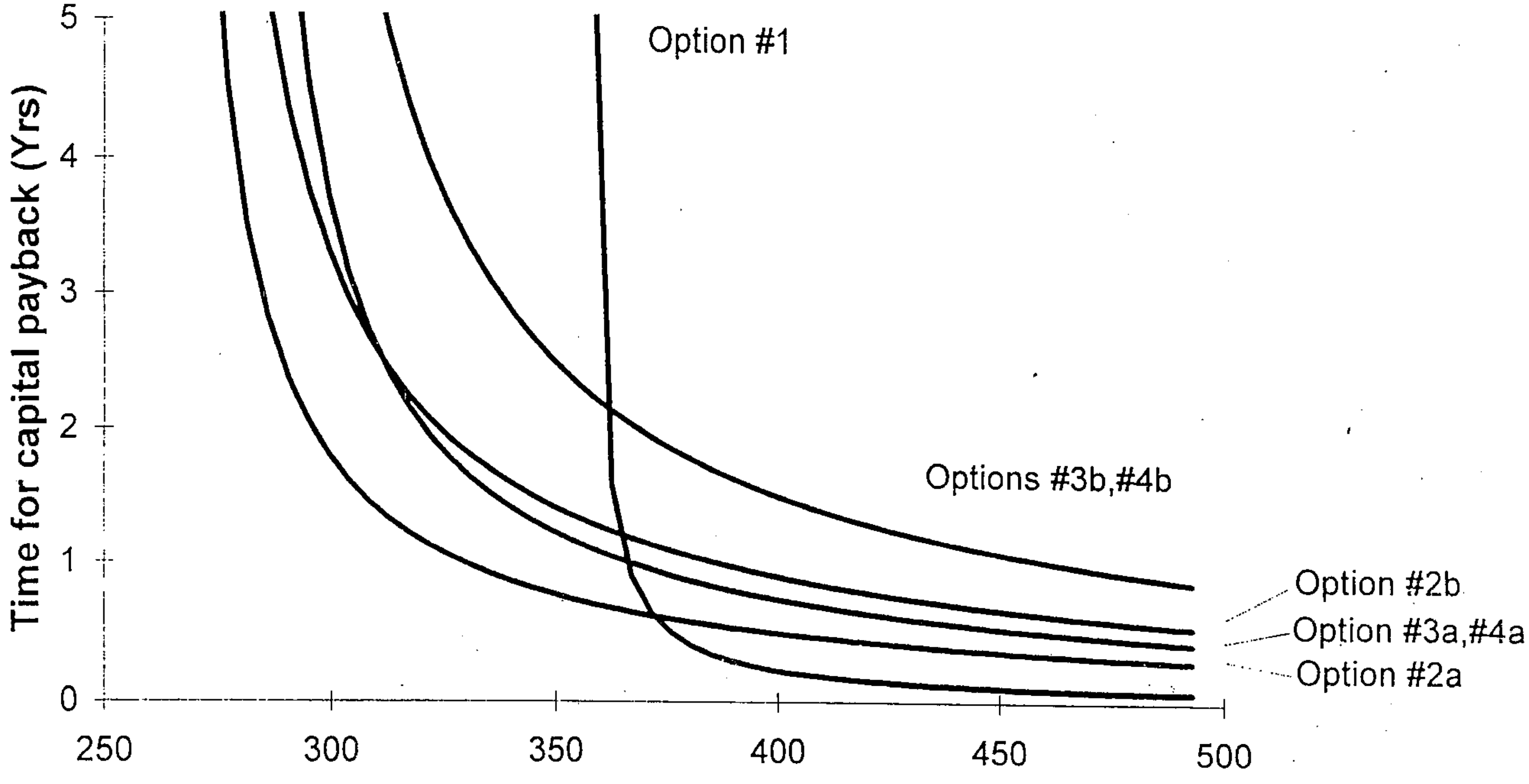
| Capital costs ($) | Option 1 | Option 2 | Option 2b | Option 3 | Option 3b | Option 4 | Option 4b |
|---|---|---|---|---|---|---|---|
| Screen(s) | 49000 | 77000 | 77000 | 27000 | 27000 | 51000 | 51000 |
| Tables | | 76800 | 76800 | 120000 | 120000 | 120000 | 120000 |
| Air Cleaning | | | 180000 | | 180000 | | 180000 |
| Installation | 20000 | 30000 | 40000 | 30000 | 40000 | 30000 | 40000 |
| **Total** | **69000** | **183800** | **373800** | **177000** | **367000** | **201000** | **391000** |
| | | | | | | | |
| **Annual costs** | | | | | | | |
| Labour | 6250 | 25000 | 25000 | 25000 | 25000 | 25000 | 25000 |
| Utilities | 1000 | 20000 | 20000 | 20000 | 20000 | 20000 | 20000 |
| **Total** | **7250** | **45000** | **45000** | **45000** | **45000** | **45000** | **45000** |
| | | | | | | | |
| **Revenue** | | | | | | | |
| Annual protein product (t) | 6990 | 13858 | 13858 | 15649 | 15649 | 15649 | 15649 |
| Annual bone product (t)‡ | 11406 | 4538 | 4538 | 2747 | 2747 | 2747 | 2747 |
| Average protein increase (%) | 9 | 6.25 | 6.25 | 3.33 | 3.33 | 3.33 | 3.33 |
| Price of protein product ($/tonne) | 473.47 | 451.02 | 451.02 | 427.19 | 427.19 | 427.19 | 427.19 |
| Price of bone product ($/tonne) | 400 | 400 | 400 | 400 | 400 | 400 | 400 |
| Gross product value ($) | 7871986 | 8065407 | 8065407 | 7783926 | 7783926 | 7783926 | 7783926 |
| Price of feed meal ($/tonne) | 400 | 400 | 400 | 400 | 400 | 400 | 400 |
| Gross feed meal cost ($) | 7358400 | 7358400 | 7358400 | 7358400 | 7358400 | 7358400 | 7358400 |
| **Nett added product value ($)** | **513586** | **707007** | **707007** | **425526** | **425526** | **425526** | **425526** |
| | | | | | | | |
| **Added product value less annual costs ($)** | **506336** | **662007** | **662007** | **380526** | **380526** | **380526** | **380526** |
| | | | | | | | |
| **Time for capital return (yrs)** | **0.14** | **0.28** | **0.56** | **0.47** | **0.96** | **0.53** | **1.03** |

‡ This is not a pure bone stream for option #1

Figure 2.9 - Nett Product Value vs Bone Price, 1.5 tph



## Figure 2.10 - Payback Time vs Bone Price, 1.5 tph



The reasoning behind the development of each option is given below.

### 2.6.1 Processing option #1

Process Option #1, Figs 2.1 and 2.5, shows the protein enrichment achievable using a 1.4mm screen split on the press cake. Just over a third of the product is protein enriched by about 9%, the remainder of the product is rich in bone and is fed through the existing mill. Note that the overall flow rate through the mill is now two thirds of what it used to be. The bone enriched stream is not a pure bone stream and may or may not hold a greater value than the pure bone resulting from the other options. This is the option with the lowest capital investment.

### 2.6.2 Processing option #2

Process Option #2, Figs 2.2 and 2.6, adds a gravity table separation step to Option #1. The bone enriched split of the press cake is fed to the mill, to a double deck screen, and then to a set of gravity tables in parallel. The double deck screen takes off a small fraction of scrap material such as hair and balls of fluff, and then divides the flow into two narrower size bands. Each of these bands is fed onto gravity tables.

The resulting product compositions shown in the figure are based on conservative estimates of the performance of a gravity table from experimental work, see section above. These experiments were not optimised but indicated that at least a minimum separation could be achieved separating a pure bone stream from the feed and enriching the protein stream nominally by 3.5%. This process yields two protein enriched streams and a pure bone stream. The pure bone stream makes up about 25% of the total flow.

It may be possible to operate the two screening options in a single screening unit which would give a nominal capital saving. A schematic diagram of this is given in Fig 2.11.

### 2.6.3 Processing options #3,#4

Process Options #3 and #4, Figs 2.3, 2 4, 2.7 and 2.8, are similar to Option #2 except the press cake is not screened. The meal from the mill is screened through a single screen for Option #3 and a double screen for Option #4, then passed over gravity tables. The larger mesh size on the single screen for Option #3 requires a significantly smaller screening area than is required for Option #4. The narrower size distributions resulting from use of the double screens however is expected to improve the performance of the tables, as outlined in Part One, and may justify the small additional capital investment required.

These two options, as shown in the figures, give a lower overall separation than Option #2. The performance of these processing options will however be more favourable than Options #1 or #2 if the gravity tables prove, with additional investigation, to give a better protein enrichment than that resulting from screening of the press cake (nominally 9%). It should also be noted though that the mean fat content of the milled material being fed to the gravity tables is lower if the press cake is screened. A lower fat content is expected to improve the handling and separation of the meal and favours Option #2 over #3 and #4.

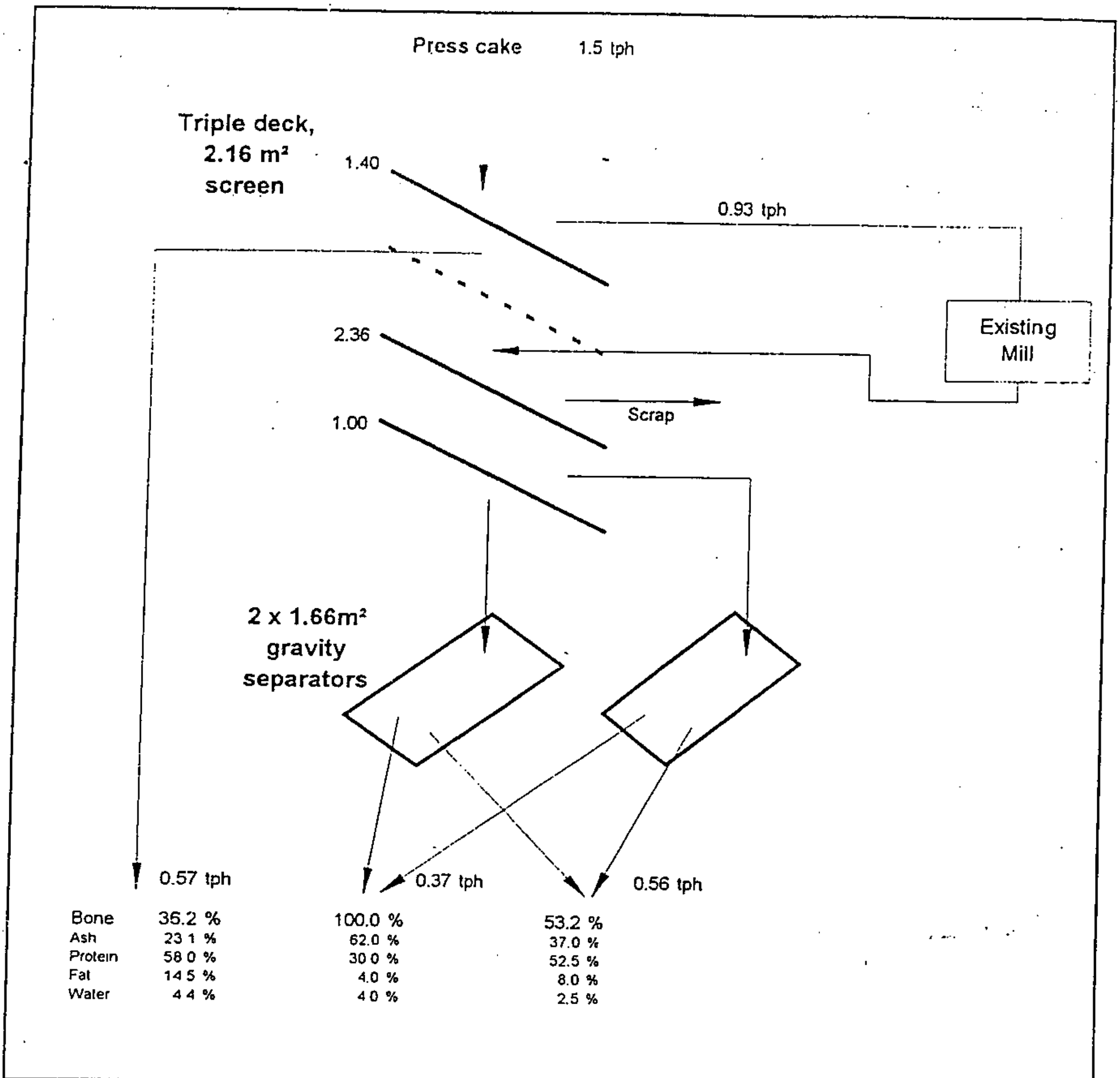



**Figure 2.11 - Alternative screen arrangement for Option #2/$_{1.5}$**

## 2.7. Discussion

The numbers in Tables 2.7 and 2.8 give compelling support to the selection of Option #2 as a sensible and preferred processing route. Furthermore, it is also likely that all screening could be carried out with a single three deck screen as shown in Figure 2.11 A screener supply firm has confirmed that this should be feasible, and discussions are continuing. This approach could result in capital savings of about $20,000. However, it is noted that these capital savings could be offset by costs associated with transporting the process streams between mill and screener. It is also noted that the high fat content of the press cake undersize screened product is likely to cause handling difficulties.

It is recognised that operating practices may differ from plant to plant, and that a financial analysis should be considered in conjunction with local conditions and constraints. It may not always be feasible or desirable to screen the press cake, and in this case the suggestions made as options #3 and #4 should be considered.

Likewise, Fig 2.10 shows the influence of bone price on the time taken for net product income to equal the capital investment in the plant; the figure was constructed using the assumptions detailed earlier in Section 2.5. It is encouraging to note that at bone prices around $400 per tonne, pay back times are about one year or less; see also table 2.8 for numerical values. Naturally calculations of this type are indicative only, and are affected by the particular assumptions made on capital equipment requirements, product prices running costs and other outgoings.

The development of economic pointers for assessment of the separation options has been severely hampered by the difficulty in obtaining information on a realistic price for the sale of the "pure" bone stream. Extensive inquiries were made throughout Australasia with no result; an internet search was also unrewarding. The quest for a cost function for gauging the effect of increases in protein content above the 50% benchmark was not completely satisfactory. Accordingly, Figure 2.9 has been included to emphasise the role of the price of the "pure" bone in determining nett product value.

As this investigation has progressed, it has become increasingly apparent that the behaviour of the fat in the various process options is likely to have a key role in deciding the success of a process for separating a meatmeal into its components. It is well known that the fat content of a meatmeal is important in screening operations, with 11% often quoted as an upper limit for trouble free operation. It now seems that fat will also influence the efficiency of tabling operations as well. Consideration has been given to ways of overcoming problems arising as fat content increases, and these will be detailed in a separate proposal. In outline, it is thought that the use of a recycle, consisting of suitably sized bone or perhaps an inert material, could be used to both scavenge the fat in a product stream, and effectively reduce its mean fat content. It would be necessary to clean the fat from the recycle stream.

## 2.8. Conclusions and Recommendations

This investigation has shown that the separation of large bone particles from a milled meatmeal feedstock can be achieved without difficulty using an air table. The large bone fragments in press cake are readily separated by screening. Also, it appears that the relatively small levels of beneficiation resulting from the removal of large particles only, could be sufficient to justify investment in separation plant. However, it is also shown that there may be constraints on the degree of separation that can be achieved, which may not be directly related to the performance of the equipment used, and the products resulting from even small separation efficiencies could have a high fat content, which will affect handlability and could affect product value.

It is recommended therefore that further work be undertaken to better understand the interaction of the **bone, protein** and **fat** in meatmeal processing. It is necessary to firmly establish and understand the existence of any limits on separation efficiency that may be an inherent part of the meatmeal system, rather than those imposed by the characteristics of processing equipment. Pivotal in this is the fate of fat in tabling and air classification; some information is already available on the behaviour of fat in screening. It is also important that before a commitment is made to a complete plant, a practical investigation of the capabilities of the combination of a screening operation and an air table is carried out. Consideration should be given to the development of techniques for mitigating the effects of increases in fat content, such as scavenging the fat as discussed above. It is not regarded as essential for pilot plant work that the capacities of equipment in the pilot plant are exactly matched and a combination of the smallest three deck screen in Table 2.2 and the smallest air table in Table 2.1, would be adequate, in conjunction with appropriate storage capacity for the process streams. Though confidentiality has been maintained throughout this report on the identity of the supply firms, details are available if needed; it will be necessary for the indicative price estimates listed here to be confirmed.

# Appendix I

Colour Plates

PLATE ONE - Meat Meal as received. Magnification x 10
Source: Ngauranga, Wellington, New Zealand.

PLATE TWO - Ngauranga Meal. Magnification x 10
Sieves: - 2360μm + 1400μm

PLATE THREE - Ngauranga Meal. Magnification x 10
Sieves: - 1400μm + 850μm

PLATE FOUR - Ngauranga Meal. Magnification x 10
Sieves: - 850μm + 600μm

PLATE FIVE - Ngauranga Meal. Magnification x 10
Sieves: - 600µm + 355µm

PLATE SIX - Ngauranga Meal. Magnification x 10
Sieves: - 355μm

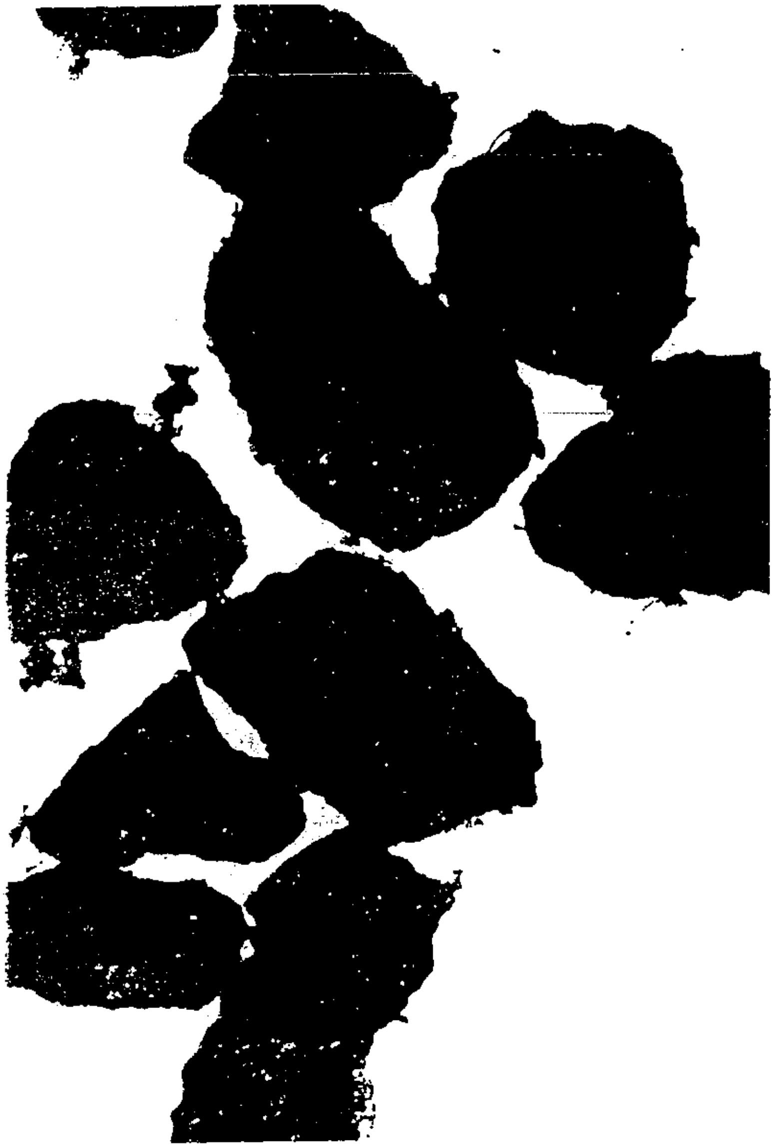


PLATE SEVEN - Ngauranga Meal. Magnification x 16
Sieves: - 1400μm + 850μm

PLATE EIGHT - Ngauranga Meal. Magnification x 40
Sieves: - 600μm + 355μm

PLATE NINE - Ngauranga Works. Press Cake
Magnification x 40
Sieves: - 1400μm + 850μm

PLATE TEN - Ngauranga Meal.
Sink Fraction in Chloroform Test.
Sieves: - 1400μm + 850μm

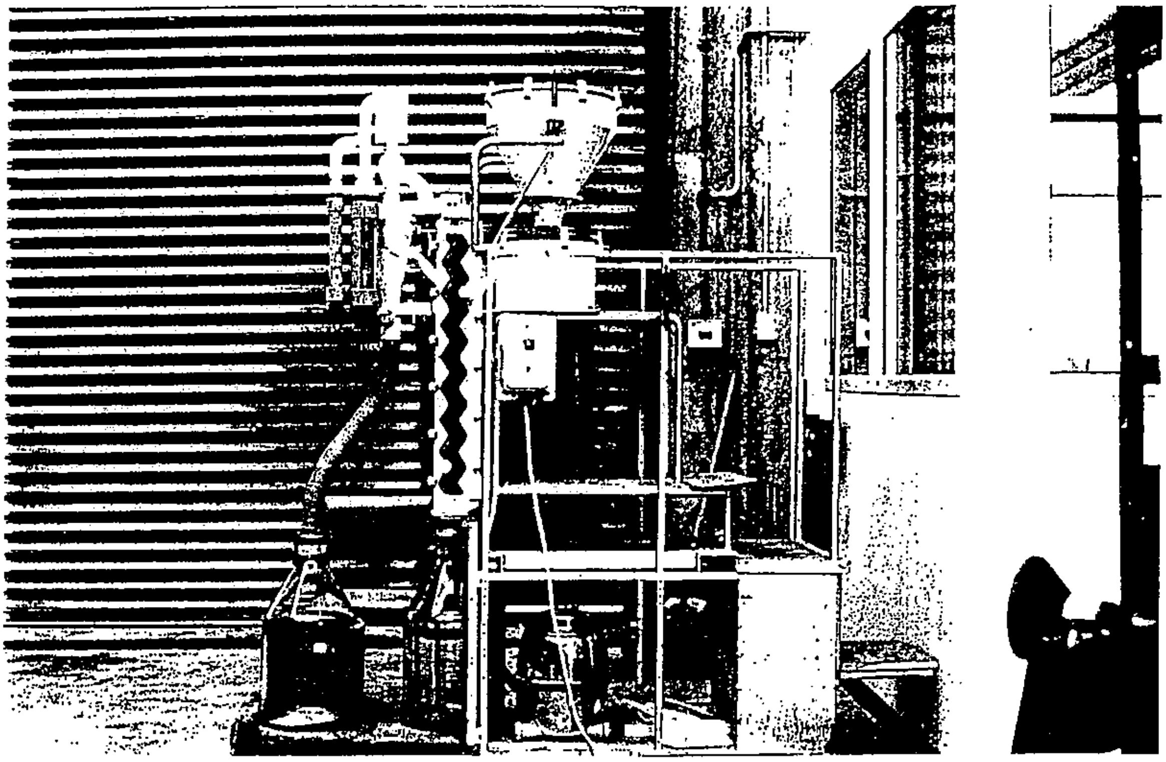


PLATE ELEVEN - Zig-Zag Classifier.

PLATE TWELVE - Zig-Zag Classifier Product.
Run zz#3 Coarse Fraction.

PLATE THIRTEEN - Zig-Zag Classifier Product.
Run zz#3 Fine Fraction.

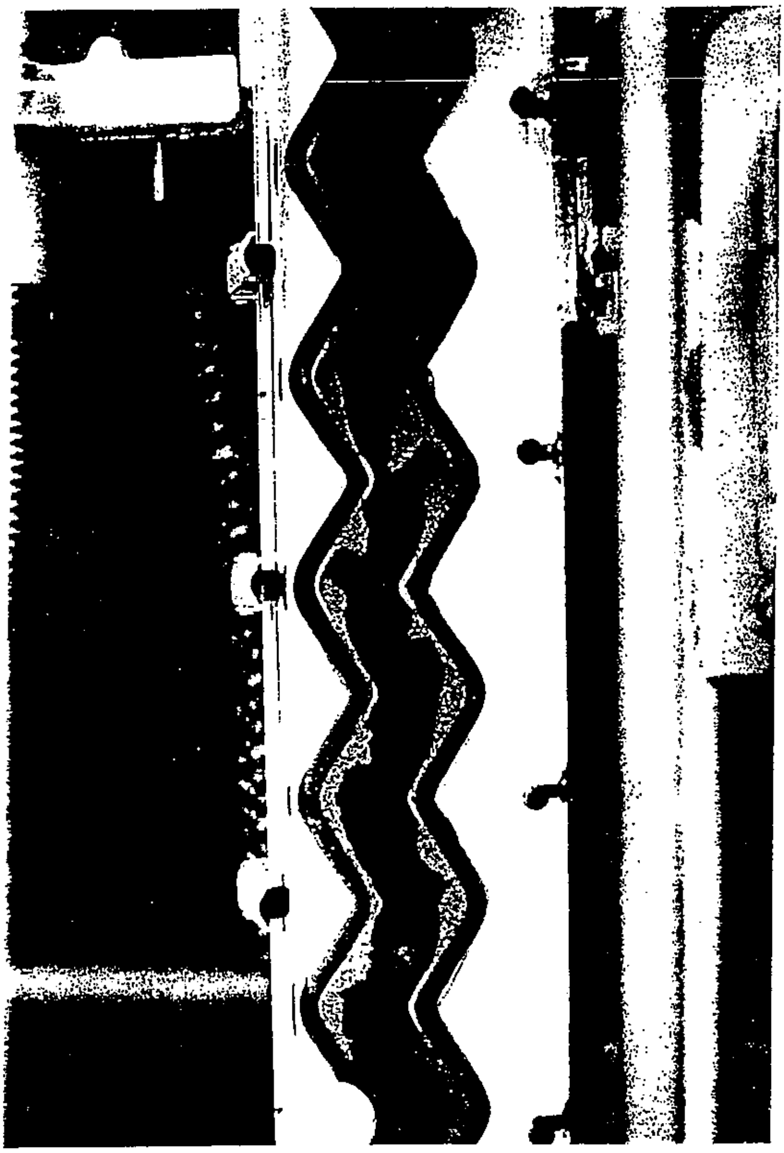


PLATE FOURTEEN - Zig-Zag Classifier.
Build up of Fine Material in
Separating Channel.

PLATE FIFTEEN: Oliver 80 Gravity Table.

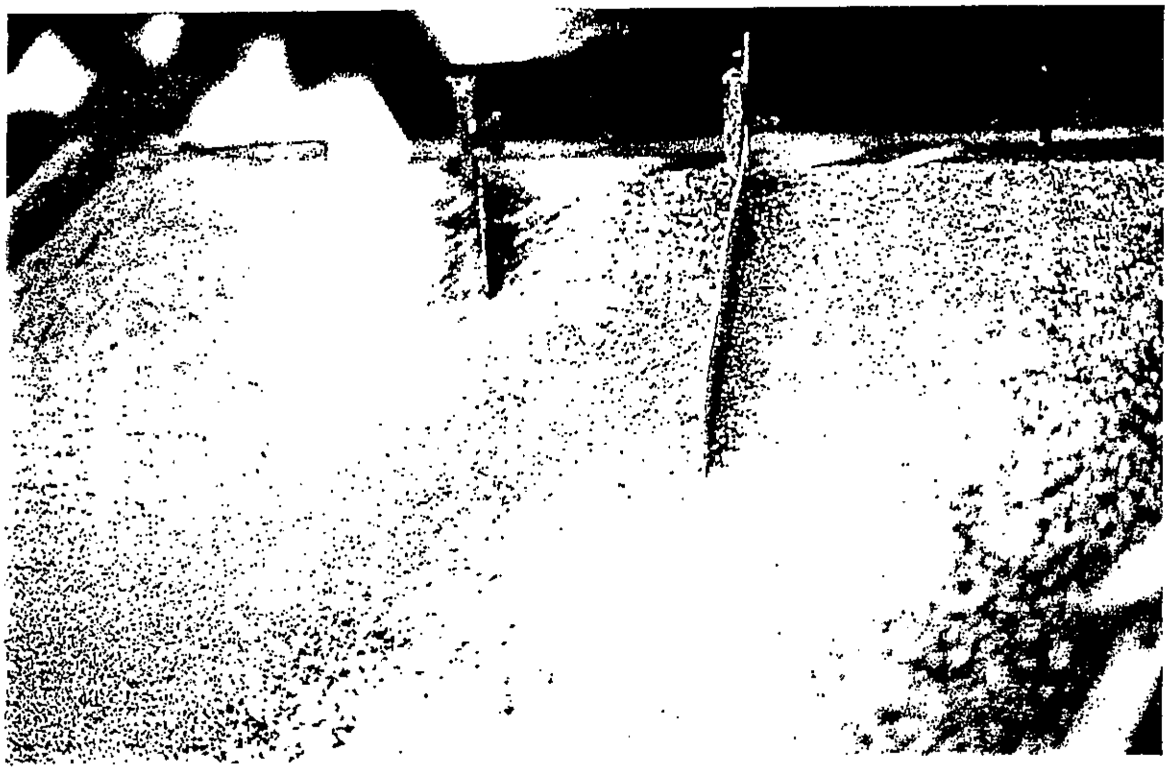


PLATE SIXTEEN: Bone Rich Take Off.
Oliver 80 Gravity Table.
Feed: As Received Ngauranga Meat Meal at approximately One Tonne per Hour.

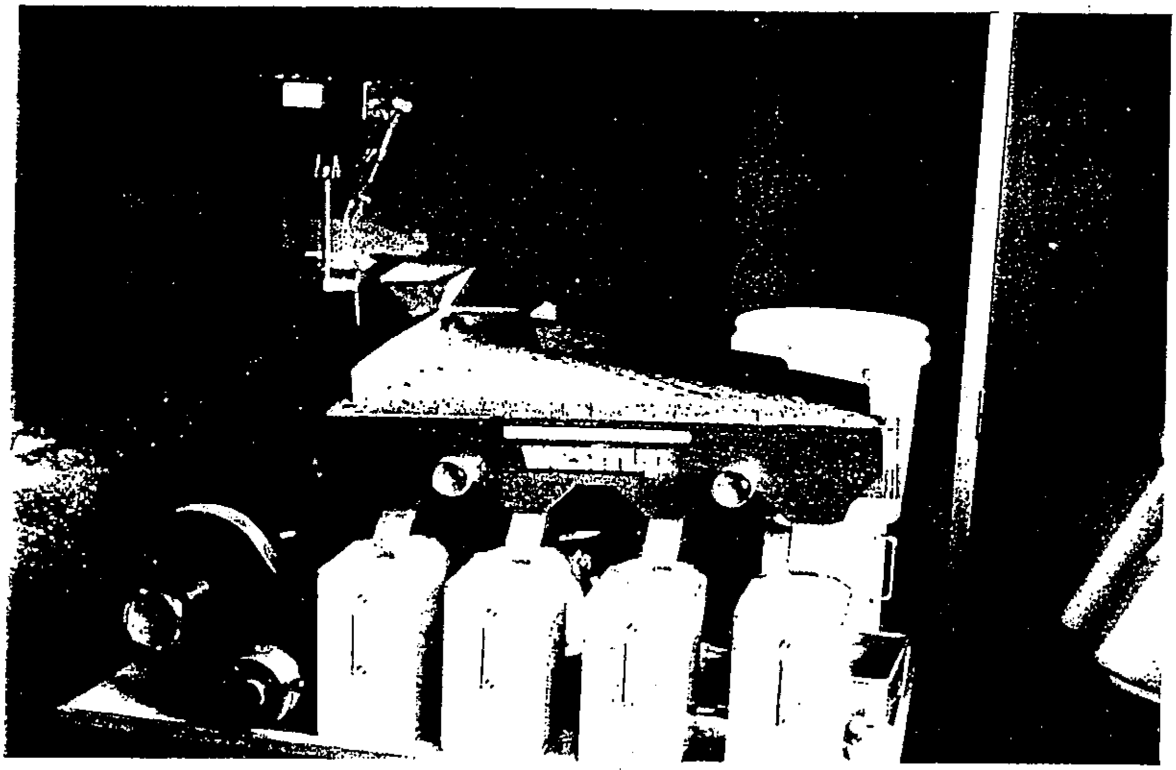


PLATE SEVENTEEN: Westrup Gravity Separator
(Laboratory Scale)