# Economic feasibility of whey processing in South Africa

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# Summary

The dairy industry worldwide has acquired the capacity for extending the uses and derivates of milk, launching new products into the world market. By the segregation of the different milk components, protein, carbohydrates, minerals or fat concentrates, normally in powder form, may be manufactured. That is how a new milk ingredient or milk component industry has been created. Current technology even allows the extraction of micro-components of milk i.e., lactoferrin. Although their health and rheological properties make them interesting for the food and beverages industry, they are used at other industries like the pharmaceutical, paint, plastic or paper industries. Nevertheless, there are many countries, like South Africa, in which these technologies have not been implemented and they are net importers of such products. Ingredients are already been used there despite the necessary infrastructure has still not been achieved. Leader dairy processing companies in South Africa belong to multinational companies that import their ingredients from their branches at large milk-producer-countries, like New Zealand.

The objective of this MSc Thesis is to determine if a fraction of this ingredient industry, specifically that dedicated to the whey processing, could be viable in South Africa, at the same time that the impact of the scales of production is studied.

Therefore, a Gouda cheese factory has been considered with a production of whey as by-product. A decision tree approach has been designed to choose the most profitable option to produce from this whey. Four scenarios have been addressed reflecting the development of the whey processing industry in countries where this industry is already developed: 1) concentrate the resulted whey and sell it to the feed industry; 2) spray dry defatted whey to get whey powder; 3) ultrafiltrate defatted whey to extract WPC 80% (whey protein concentrate with 80% protein concentration) and sell the concentrated permeate (leftover components not retained by Ultrafiltration); 4) Crystallise the permeate to obtain lactose. Each of the scenarios adds a step in the decision tree. Scenarios 2, 3 and 4 are investment-intensive due to the high technology machinery they require. Four scales of production have been analysed: 400, 800, 1,200 and 1,600 Tons milk/d. Dairy products, energy, water and supplies (packaging and additives) prices and salary data applicable for South Africa have been used. Machinery prices have been derived from European prices. Building construction costs have been estimated from machinery installation costs. A spreadsheet model has been designed to study the profitability of the different scenarios based on their Return on Investment (ROI).

From the initial amount of milk of the different scales of production 10% turns cheese, 0.77% cream, 1.12% whey cream, 2.78% WPC 80% and 3.29% lactose. Despite these low percentages, ROIs appeared positive, even large (the lower was 18.22%), in all cases, maybe due to the high prices used in the calculations or the exclusion of information regarding the costs included in the model (i.e. land, financial or transport costs).

The finer the extraction is, the more expensive it becomes due to the high cost of machinery required and its related costs. The second scenario showed the highest ROI within each scale of production. The extraction of lactose seemed to be more advantageous than only protein extraction. Finally, the least profitable was the cheese factory that concentrates whey and delivers it to the feed industry. The fourth scenario involves 29.11% higher investment in machinery than the third one, which confirms the results found by other authors.

For the smallest scale of production, scenarios 3 and 4 differ in 0.98% (20.10% and 21.09%, respectively). Hence, it might be interesting to achieve an investment effort to procure a factory that allows a wider portfolio, reducing the risk involved.

An increasing trend can be seen when the same scenarios of the different productions scales are compared. Nevertheless, the larger the scale is the smaller is the interval differences. As a result, an optimum size of plant could be reached for the characteristics described above.

Consequently, whey processing seems to be a good option to add value to this by-product in South Africa. Whey powder would be the best option, followed by a combination of WPC 80% and lactose. The third place would be occupied by the production of WPC 80%, leaving the no-processed whey in the last position. Based on the present results, scale of production plays an essential role in the profitability of a cheese manufactory with different whey processing options.

# Sumario

La industria láctea mundial ha adquirido la capacidad de expandir los usos y derivados de la leche, expidiendo al mercado mundial nuevos productos. A través de la separación de los diferentes componentes de la leche, se pueden obtener concentrados proteicos, de carbohidratos, minerales o grasos, normalmente en forma de polvo. Es así como se ha creado una nueva industria de ingredientes o componentes lácteos. La tecnología actual permite incluso la extracción de micro-componentes lácteos, como la lactoferrina. Aunque tanto sus propiedades para la salud como las reológicas hacen a estos productos muy interesantes para la industria alimentaria y de bebidas, también tienen aplicaciones en otras industrias como la farmacéutica, de pinturas, plásticos o papel. Sin embargo, existen muchos países, entre ellos Sudáfrica, en los que estas tecnologías aún no han sido implementadas, permaneciendo como importadores netos de dichos productos. Estos ingredientes son usados allí, a pesar de que el país aun no cuenta con la infraestructura necesaria para su producción. Las compañías transformadoras lácteas líder del país pertenecen a multinacionales que importan dichos ingredientes desde sus sucursales situadas en países con gran capacidad productiva lechera, como Nueva Zelanda.

El objetivo de este proyecto fin de Master es determinar si una fracción de dicha industria de ingredientes, específicamente aquella dedicada al procesado del suero, podría ser viable en Sudáfrica, a la vez que se estudia el impacto de las economías de escala.

Es por ello que se ha considerado la creación de una fábrica de queso tipo Gouda, con obtención de suero como subproducto. Las opciones de procesado o no de dicho suero se han recogido en un árbol de decisión, con el que se pretende escoger la opción que aporta un mayor beneficio. Cuatro escenarios se han diseñado siguiendo la evolución que esta industria ha experimentado en países en los que ya está establecida: 1) concentrado del suero resultante y venta a la industria de alimentación animal; 2) deshidratado y pulverizado del suero desnatado; 3) ultrafiltrado de suero desnatado para extraer WPC 80% (concentrado de proteínas séricas al 80% de concentración proteica) y venta del perneado (componentes residuales no retenidos por ultrafiltración) concentrado; 4) cristalizado del perneado para obtener lactosa. Cada uno de estos escenarios añade un nuevo paso o rama al árbol de decisión. Los escenarios 2, 3 y 4 requieren grandes inversiones, debido al equipamiento especializado involucrado en ellas. Cuatro escalas de producción han sido analizadas: 400, 800, 1,200 y 1,600 Toneladas de leche/día. Para el desarrollo de este estudio se han utilizado precios de productos lácteos, electricidad, agua y otros suministros

(material de empacado y aditivos) y salarios basados en el mercado y las condiciones laborales sudafricanas. Los costes del equipamiento han sido calculados a partir de precios europeos. Los costes de construcción de edificios han sido estimados a partir de los costes de instalación de maquinaria. El modelo, que se ha desarrollado utilizando hojas de cálculo, ha sido diseñado para estudiar la rentabilidad de la inversión necesaria para los diferentes escenarios.

De la cantidad inicial de leche en las distintas escalas el 10% se transforma en queso, 0.77% en nata, 1.12% en nata de suero, 2.78% en WPC 80% y 3.29% en lactosa. A pesar de ser tan bajos estos porcentajes, la rentabilidad aparece positiva, incluso elevada (el escenario de menor rentabilidad es un 18.22%), en todos los casos, quizá debido a los elevados precios usados en los cálculos o a la falta de información con respecto a costes incluidos en el modelo (ej. Coste de terrenos, transporte de leche o costes financieros).

Cuanto más fina es la extracción, más cara se convierte, debido a los altos costes de maquinaria requeridos y los costes derivados de ella. El segundo escenario resulta tener la mayor rentabilidad para cada una de las escalas de producción. La extracción de lactosa y proteínas (cuarto escenario) parece ser más ventajosa que sólo la extracción de las primeras (tercer escenario). Por último, la menos rentable de las opciones ha resultado ser la concentración y venta de suero a la industria de alimentación animal. El cuarto escenario supone un 29.11% más de inversión en maquinaria que el tercero, lo cual confirma los resultados obtenidos por otros autores.

Para la menor escala de producción, los escenarios 3 y 4 se diferencian en un 0.98% de rentabilidad (20.10% y 21.09%, respectivamente). Por ello, podría resultar interesante realizar un esfuerzo de inversión y desarrollar una fábrica que permitiera una mayor diversificación de productos, disminuyendo así su riesgo.

En caso de comparar los mismos escenarios en las distintas escalas, se puede observar una tendencia creciente en la rentabilidad. No obstante, cuanto mayor se hace la escala, menores se vuelven las diferencias entre los intervalos. Como consecuencia, se podría alcanzar un tamaño óptimo de fábrica para las características descritas.

En resumen, el procesado de suero parece ser una buena opción para añadir valor a este subproducto en Sudáfrica. La producción de suero en polvo ocuparía la opción más rentable, seguido por una combinación de WPC 80% y lactosa. En tercer lugar estaría la producción de WPC 80% dejando el suero no procesado en la última posición. Basándonos en los presentes resultados, las economías de escala juegan un papel esencial en la rentabilidad de una fábrica quesera con diferentes opciones de procesado de suero.

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# 1. Introduction

Whey is obtained after the precipitation/coagulation of milk casein or microfiltration of skim milk. It still contains 6% of nutrients from which 75% is lactose, 13% are whey proteins, 2% is fat and 10% minerals (Westergaard, 1994). It is considered one of the major disposal problems of the dairy industry when treated as a waste, due indeed to the oxygen required to the fermentation of its nutrients (expressed in BOD –Biochemical oxygen demand- and COD –Chemical oxygen demand-) (Mawson, 1994). Therefore, different uses have been given to it, namely, fertiliser or feed for cattle and pigs. However, scientific-technical development incorporates new interesting alternatives for whey, introducing some of its nutrients in the human food chain. A niche market of milk and whey Ingredients, components extracted from both milk and whey, exist already in the most developed dairy producing countries. Thank to these products, a new generation of goods, some with improved nutritional value others with better rheological characteristics, may be launched to the consumer markets.

Although South Africa accounts with a well developed dairy sector with a well established traditional dairy products market, it has not started its race into the ingredient production yet. Ingredients are currently used by the South African processing industry, despite they are mainly imported from larger milk producers like the Netherlands or U.S.A. Dairy companies leading the local processing sector belong to multinational companies that import their own commodities from their branches at large milk-producing-countries like New Zealand. Therefore, the local processing industry has not found the incentive to start innovating into this new market and depends entirely on external markets.

The objective of this MSc Thesis is to determine the viability of whey processing for a cheese manufacture plant in South Africa, focussing on the impact of scale of production and degree of whey fragmentation. By doing so, whey processing in South Africa could contribute to import substitution and reap value-adding benefits. Through a decision tree approach, the most profitable combination of whey derivates will be decided.

The ingredient market is still rather new and risky, involving large investments. Nevertheless, large added values accompany these Ingredients that are sold in the world market. That is why the development of the present Thesis has undergone some difficulties regarding companies' secrecy polices, resulting in gaps of information that had to be covered by assumptions and estimations.

# 2. State of art of the South African Dairy Industry. Facts and figures about the Ingredient Market

## 2.1. South African Dairy industry

South Africa was the country of the African continent with highest GDP (Gross Domestic Product) in 2006 (Wold-Bank, 2007) with US $255 millions. The agricultural sector contributes to 2.7% o the GDP, 41% of which corresponds to Dairy industry (EVD, 2008).

An average year in South Africa is divided into a rainy and dry season. Therefore, in many of the areas where dairy cattle is kept, mainly in the districts along the southern coast (Western Cape, Eastern Cape and KwaZulu-Natal), there is a need for temporary irrigation. In December 2006, more than 68% of South African milk was produced in these three regions. All holdings had pasture-based production systems with the exception of some intensive producing farms in the Western Cape. Due to this production system, the average daily production per cow in the country was around 15.2 litres (Coetzee and Maree, 2007b).

In the last ten years, the number of milk producers has declined by 47%, leading to 3,727 producers in January 2007 (Coetzee and Maree, 2007b). As the decreasing trend continues, the average daily production per herd goes up, reaching volumes of 1,288 litres per day per herd (Coetzee and Maree, 2007a).

South African annual cow milk production was 2,970,965 Tons in 2006 (FAOSTAT, 2007), approximately 8% for own consumption on farms and calves feeding , 3% for the informal market, and 89% for the formal market (Coetzee and Maree, 2007a). The Dairy secondary industry comprised 227 milk buyers and 468 producer-distributors in January 2007. Besides, more than 460 producers transform and sell their products directly to consumers or retail market. The latter is concentrated among three main companies, owners of hyper-/supermarket chains, who share more than 75% of the Dairy Distribution Market (MPO, 2005). This dominant position enables those to put pressure onto lower levels of the production-processing chain. Such pressure can be revealed in many ways, being milk prices one of the most common. A large percentage of the products manufactured by Processors reach consumers through these Retail companies. Processors, at the same time, transfer their low prices to milk producers. This situation does weak favour to the development of a robust Dairy producing sector.

Besides, the advantage-position these companies occupy allows them to obtain cheaper products from the world trade market. In order to compete with imported products, milk prices are again pulled down, which have repercussions on the last step of the Distribution chain, the producers (MPO, 2005).

## 2.2. Dairy consumption, exports and imports of ingredients

During 2006, 60% of the milk produced in South Africa was used for milk and fresh milk products. The remaining 40% was dedicated to the production of concentrated products: cheese, butter, milk powders and whey powders. Figure 1 depicts the product distribution in South Africa during 2006.

Conventional products like milk and cream, yoghurt and other fermented products, butter and cheese share already a mature position at the market, while functional products gain relevance among consumers (see Table 1). This can be shown in the potential growth of 1 to 3% expected for some of the companies operating within the South African Ingredient market for the coming years (Maas, 2007).

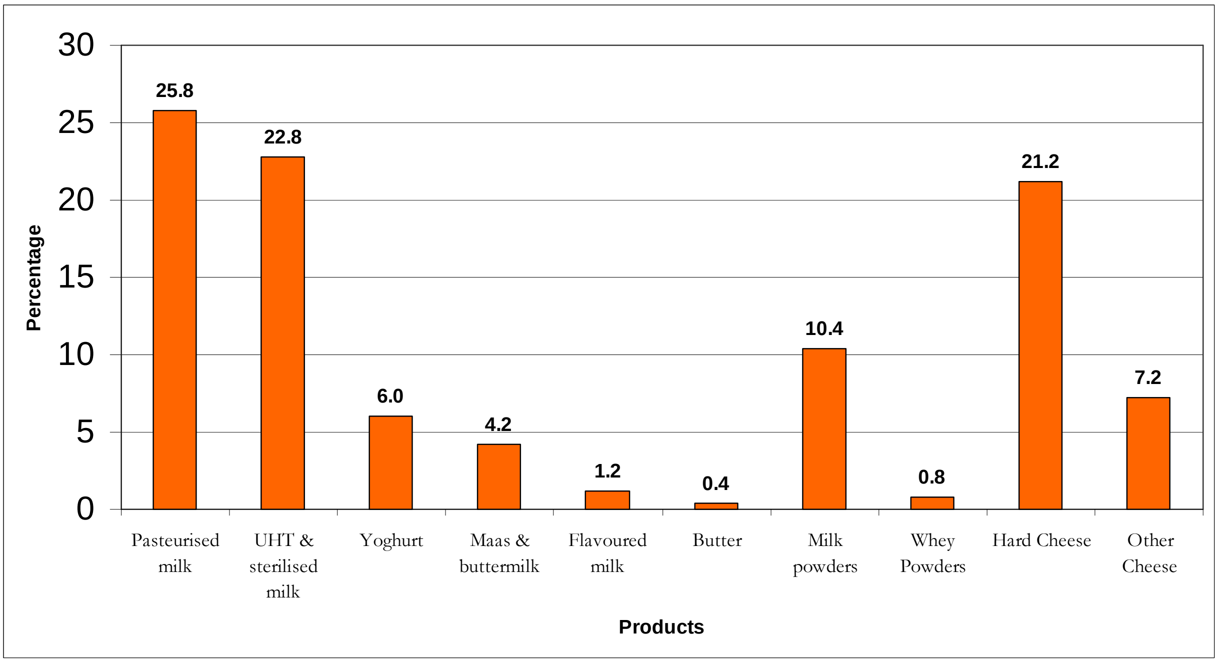


**Figure 1.** Distribution of South African dairy products during 2006 (in%) (Coetzee and Maree, 2007a)

**Table 1.** Milk production, consumption and trade of milk and dairy derivates in South Africa during 2006 (Joubert, P, 2007 and Trade map, 2007)

| Products | Production ($10^3$ Tons) | Consumption ($10^3$ Tons) | Import ($10^3$ Tons) | Export ($10^3$ Tons) |
|---|---|---|---|---|
| Liquid milk and cream | 807.2 | - | 4,9 | 9.9 |
| Milk and milk products[1] | | - | 4.5 | 0.9 |
| Yoghurt | 117.5 | - | 0.03 | 4.5 |
| Cheese | 89 | - | 4.5 | 1.5 |
| Cheddar | 27.7 | - | n.a. | n.a. |
| Gouda | 16.4 | - | n.a. | n.a. |
| Butter | 3.4 | - | 3.0 | 0.6 |
| Buttermilk (powder) | 2.5 | - | 1.5 | 0.5 |
| Butteroil (AMF) | 0 | - | 0.2 | 0.2 |
| Full fat milk powder | 14.6 | - | 3.0 | 2.5 |
| Skim milk powder | 12.3 | - | 5.8 | 1.5 |
| Whey powder | 10.1 | - | 12.5 | 2.4 |
| Demineralised whey | - | 7.0[3] | 7.4 | n.a. |
| Lactose | - | 7.0[3] | 7.5 | 0.1 |
| Casein & Caseinates | - | 2.9[3] | 2.9 | n.a. |
| WPC | - | 2.1[3] | 2.1 | n.a. |
| MPC | - | 0.01[3] | 0.01 | n.a. |
| Liquid whey | 1.2 | n.a. | n.a. | n.a. |

[1] Includes Preparations of cereals, floer, starch/milk for infant use.
[2] (Maas, 2007).
[3] Entirely imported
n.a. not available

In many occasions, the production of some of these conventional products requires the addition of ingredients derived from the milk component industry to improve both their nutritional or physical properties. The Dairy processing industry of South Africa is currently supplied from such ingredients mainly by import. 6,069 Tons whey (liquid and powder) were imported in 2006 from France, followed by Ireland with 963 Tons (Trade-Map, 2007). Whey proteins, on the contrary came from the U.S.A. (327 Tons) and New Zealand (40 Tons), while the later exported 2,136 Tons of Skim milk powder, leaving Australia in a second position with 1,147 Tons (Trade-Map, 2007). Table 1 shows more detailed figures about other ingredients as WPC or lactose.

The largest dairy companies in South Africa are multinationals who import Ingredients from their branches in traditional milk-producing-countries like New Zealand. That is maybe why an Ingredient industry has still not being developed in the country. Whey processing in South Africa could therefore contribute to import substitution and reap value-adding benefits.

# 3. Literature review

## 3.1. Milk composition and extraction possibilities

Milk is possibly the most complete foodstuff in nature from the nutritional point of view, meant to supply all the nutrients newborns require to survive their first living time. Therefore, it is a source of a wide variety of bioavailable components with a high nutritional value (Boland *et al.*, 2001). The average cow milk composition is shown in Appendix 1. However, these quantities can vary considerably depending on the cow's breed, feed or time of the year. Milk is mainly comprised of water (87.25%) and only the remaining 12.75% contains protein (3.27%), fat (4.00%), carbohydrates (4.60%), mainly lactose, and minerals (0.85%).

Large financial returns can flow through the isolation of some of these milk components, which are used as ingredients together with other commodities in order to give rise to a new generation of dairy products. Besides, new applications often appear in many other fields like plastic production, pharmacology or paper manufacture. To date, separation techniques have opened a new door to an alternative dairy processing (Huffman and Harper, 1999). Some milk components, like several milk fat components i.e. triglycerides and sphingolipids, are included under the umbrella of Nutraceuticals due to their ability to imprint health and disease preventive advantages (Steijns, 2001). Whey proteins are applied in the manufacture of products as water-binding, thickening properties, gelling, emulsifying and foaming agents (Foegeding and Luck, 2002). Further applications of the different fragments are shown in detail below. Therefore, an emerging Ingredient industry is gaining importance within the Dairy industry. A scheme of the different possibilities of ingredient extraction that can be obtained from raw milk fragmentation is described in Figure 2.

Once at the Dairy processing plant, raw milk normally passes through heat treatments (Thermisation, Pasteurisation, UHT) or membrane processes (microfiltration) in order to extend its shelf life by inactivating or removing possible micro-organisms it could content. Pasteurisation, for example, increases milk's shelf-life up to 8-10 days at 5-7ºC, while UHT does it up to months (Tetra-Pak, 2003). By drying and pulverizing full-cream liquid milk Whole milk Powder is obtained, increasing its shelf-life up to 2 years. Solid content of the dried product keep constant and seasonal variations in the supply may be avoided (Westergaard, 1994). Cream may be separated from skim milk through centrifugation and further transformed into butter with buttermilk as a sub-product of the churning process. Anhydrous milk fat (AMF), also called butteroil, can be further extracted from cream or butter by removing most of their moisture content. AMF can be refined by fractionation into high melting (40-41ºC), medium melting (32-34ºC) and low melting (24-28ºC) milk fat components (De Wit, 2002).

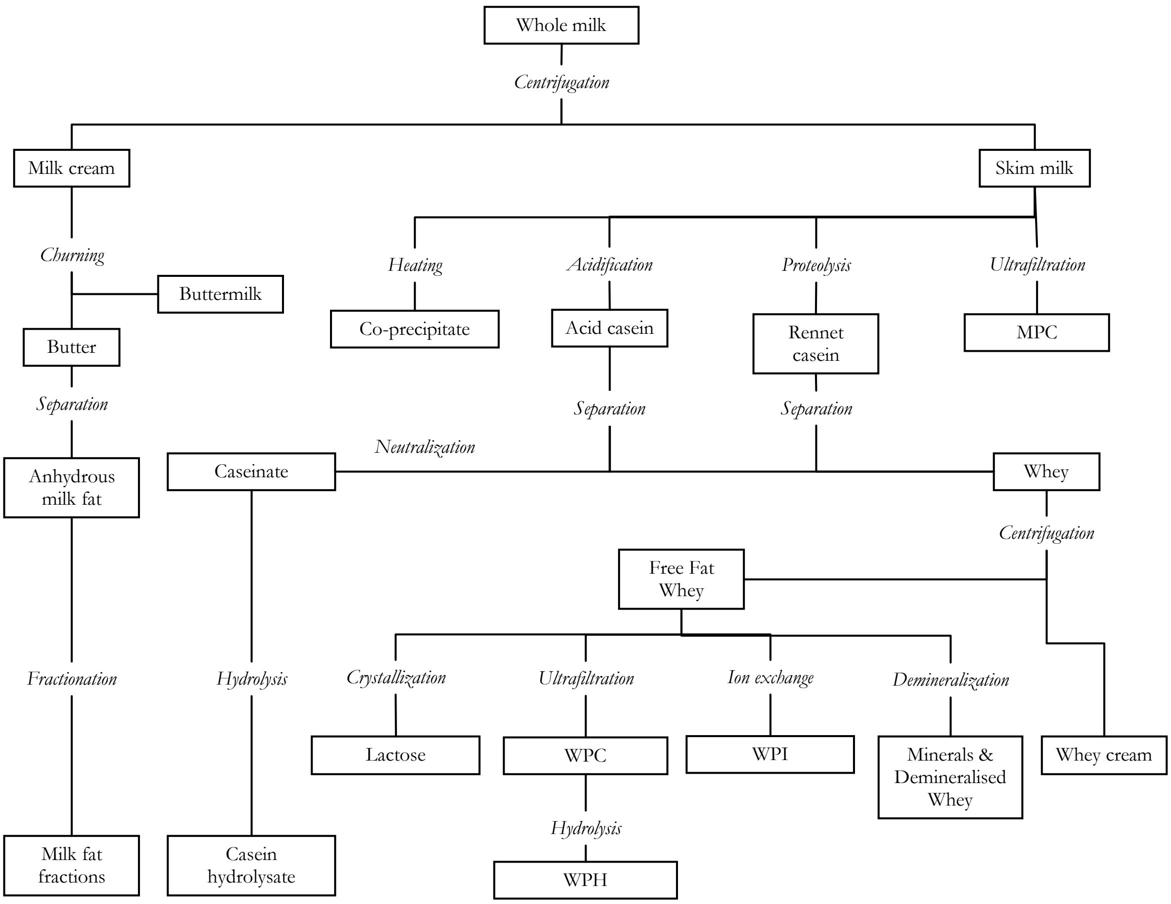


**Figure 2.** Scheme of possible products obtained from the fragmentation of whole milk (De Wit, 2002)
Note: MPC (milk protein concentrates), WPC (whey protein concentrates) WPH (whey protein hydrolysates), WPI (whey protein isolates)

Skim milk may be dried and powdered as well. Protein co-precipitated is recovered after heat treatment of skim milk at 90ºC, either with or without addition of $CaCl_2$ followed by a pH decrease to 4.6 (De Wit, 2002). The different components of skim milk can be extracted through separation technologies. Milk casein may be separated from the rest of the milk components by coagulation or precipitation with rennet or biological/mineral acid. The remaining components of milk after this procedure are diluted in water, forming whey. As a result, rennet casein (minimum pH 6.3, used for example for cheese manufacture) and acid casein (pH 4.6) are obtained, respectively (Westergaard, 1994). Other techniques are based on molecular size differences, allowing the splitting of milk proteins (milk protein concentrates (MPC) and milk protein isolates (MPI), likewise generating whey as a by-product) or whey proteins (whey protein concentrates (WPC) and their isolates (WPI)). WPI can be also taken apart from the rest of the whey based on ionic charge differences (Huffman and Harper, 1999).

Thus, whey is the waste by-product from casein coagulation and precipitation or the separation of proteins from milk through microfiltration techniques. For many years it has been dumped in the rivers or used as a fertilizer or an animal feedstuff due to its still rich nutritional content (6 %), from which 70-75% is lactose, 8-13% are whey proteins, 10-15% minerals and 2% is fat (Jelen, 2002, Westergaard, 1994). Nevertheless, the application of the techniques above mentioned by the Dairy industry allows a value-addition to this waste. Consequently, whey has been dried and powdered or whey proteins have been extracted by filtration techniques. Lactose could be separated through crystallisation procedures. Whey resulted from the manufacture of certain cheeses has high content in minerals (0.5 %), which confers a salty taste (De Wit, 2002). Techniques like Ion Exchange, Nanofiltration or Electrodialysis have enabled the demineralisation of whey, making it more suitable for further processing and utilisation.

To date, the Dairy industry has also aimed its efforts to extract individual molecules or milk compounds like Lactoferrin, β-lactoglobulin, α-lactalbumin, immunoglobulins and enzymes like lactoperoxidase (included in figure A under Whey Protein Isolates (WPI)). These so called Bioactive peptides included under the umbrella of Nutraceuticals have been proven to have a positive impact on body functions or may influence health (Kitts and Weiler, 2003). Their physiological functionality affects to the cardiovascular, nervous, gastro intestinal and immune system.

## 3.2. Application of milk components

The milk Ingredient industry does not generally aim at the retail market. As previously mentioned, milk fragments are included in the manufacture of other products to improve their nutritional value (physiologically functional food) or their physic-chemical qualities. Acid whey is often used in the fabrication of beverages due to its citrus fruit flavour (De Wit, 2002). Lactose contributes with colour and flavour in the confectionery industry, as well as milk fat improves the palatability of candies. The emulsifying properties of milk proteins make them suitable to enhance the miscibility of formula ingredients. Some other uses of these ingredients are shown in Appendix 2.

Lately, new applications have been investigated regarding the utilization of WPI and WPC 80% to form intact films and coatings in the surfaces of objects (Balagtas *et al.*, 2003). An economical model designed to determine the impact of these applications in whey prices, showed increases between 0.96% and 3.82%. As a result, further research in applications of milk and whey derivates should continue to motivate other sources of milk price increments.

## 3.4. Existing models supporting decision making and thesis objective

Some simulation models have been designed to support the decision making process regarding the possible utilisations of whey. That is the case of SuperPro Designer (ver. 4.9) used to compare the performance of different combinations of products, namely WPC (in different concentrations), lactose, ethanol, demineralised whey, Manouri cheese and WPI (Kotoupas *et al.*, 2007). Linear programming was used to estimate the impact of milk composition and κ-casein genotype in Cheddar cheese and whey production, determining the economic value of the different milk components to optimize a cheese plant profits (Johnson *et al.*, 2007). Economies of scale in whey processing are of great importance for the capital investment, determining the product market price required to break even (Peters, 2005). Increase in efficiency through specialisation within the company or in bargaining power could be other added advantages to an increase of production scale.

From the wide variety of milk components that may be extracted, this study has been focused only in those that can be derived from whey. Therefore, it intends to provide a model to support decision making when it comes to choose what to do with the whey obtained from the cheese manufactory and to determine financial-economic viability of a whey processing factory in South Africa. A decision tree approach has been adopted to choose the best option regarding whey processing at a Gouda cheese manufactory in South Africa and has estimated the impact of economies of scale.

# 4. Methodological framework

## 4.1. Method and scenarios

### 4.1.1. Products included in the model

This MSc Thesis has been focused in the study of the viability of different options of whey processing. Thus, possibilities of product diversification previous to whey production have not been considered and only the production of Gouda cheese has been included. This cheese variety already occupies an established position in the South African market. Whey resulted from its production has lower mineral content than that of other types of cheese i.e. Cheddar. Therefore, from a technical perspective, a more simplified whey management is required. These are the reasons why Gouda cheese has been chosen instead of other cheese variety.

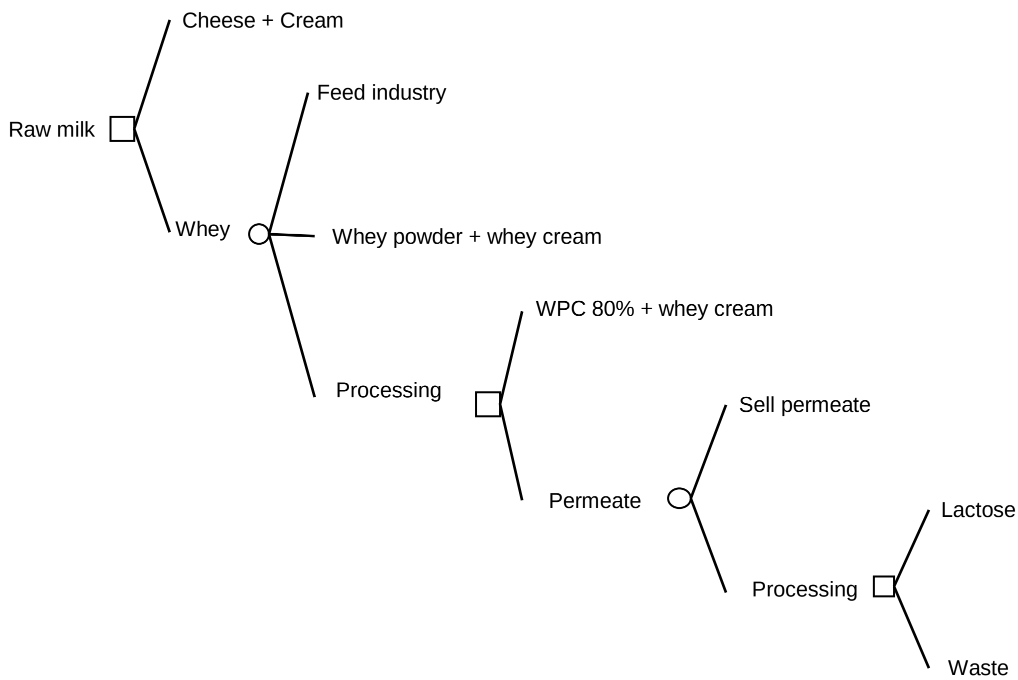


**Figure 3.** Decision tree summarizing the possibilities considered for whey processing

Note: The different branches of the tree are indicated with a square or a circle depending on its nature: products generated from processing are preceded by a square, while decisions to be made are designated by circles

Different options of whey handling have been considered (in consultation of experts (Altamirano, 2007, Borkus, 2007)), reflecting the development of the whey processing industry in countries like the Netherlands or the U.S.A.: 1) concentrate the resulted whey and sell it to the feed industry; 2) spray dry defatted whey to get whey powder; 3) ultrafiltrate defatted whey to extract WPC 80% (80% protein concentration) and sell the concentrated permeate (leftover components not retained by Ultrafiltration); 4) Crystallise the permeate to obtain lactose. Figure 3 shows these options formulated as a decision tree.

#### 4.1.2. Scenarios and scales of production

For the purpose of the study four scenarios have been designed with the following end products:

- Scenario 1: Gouda cheese, cream and concentrated whey for feed.
- Scenario 2: Gouda cheese, cream and whey powder.
- Scenario 3: Gouda cheese, cream, whey cream, WPC 80% and concentrated permeate.
- Scenario 4: Gouda cheese, cream, whey cream, WPC 80%, lactose and waste.

Each of the scenarios adds a step in the decision tree. Scenarios 2, 3 and 4 are investment-intensive due to the high-technology machinery they require. A financial-economic model has been developed to assess the performance of each of the scenarios and has been tested for four different scales of production: 400 Tons/d, 800 Tons/d, 1,200 Tons/d and 1,600 Tons/d milk. The starting point of 400 Tons milk/d was considered based on the realistic milk availability data at two neighbour districts of the Western Cape area, Swellendam and Heidelberg.

### 4.2. Data collection

#### 4.2.1. Production related data

Tables 2 and 3 show the parameters required to calculate the amount of goods produced (in Kg) from raw milk and their South African market prices, respectively. These prices are based on import prices. As a result, annual income can be estimated assuming a 100% sale of the goods produced.

**Table 2.** Parameters used for end products' calculations[1)]

| Product Parameters | Value | Units |
|---|---|---|
| Milk density | 1.030 | Kg/l |
| Fat content in raw milk | 3.8 | % |
| Fat content in standardized milk | 3.5 | % |
| Fat content in cream | 40 | % |
| Amount of cheese produced from milk | 10 | % |
| Water added for cheese production | 20 | % |
| Fines content in whey | 0.034 | % |
| Whey cream content in whey | 1 | % |
| Protein content in whey | 0.6 | % |
| Lactose content in whey | 4.6 | % |
| Water added for WPC 80 % production | 10 | % |
| Protein content in WPC 80% | 22 | % |
| Lactose content in WPC 80% | 1.6 | % |
| Efficiency of lactose extraction from permeate | 65 | % |

[1)] (Altamirano, 2007)

**Table 3.** Prices per product used for calculations[1)]

| Product | Price ZAR/Kg |
|---|---|
| Gouda cheese | 43.75 |
| Cream | 18.50 |
| Whey for feed | 0.10 |
| Whey powder | 10.00 |
| Whey cream | 18.50 |
| WPC 80% | 100.00 |
| Permeate from WPC | 0.10 |
| Lactose | 30.00 |
| Waste | 0.10 |

[1)] (Fourie, 2007)

### 4.2.2. Costs estimations

Table 4 shows different parameters used for calculations of fixed and variable costs. The former includes depreciation costs of machinery and buildings. In all cases, calculations are made based on plants operating 365 days per year. Processing equipment prices for the first scale of production are based in APV and Tetra Pak technology (Table 5). Upgrading factors founded on the economies of scale have been applied for the calculations of machinery cost for the larger scales of production (800, 1,200 and 1,600 Tons/d milk): 1.5, 2 and 2.5, respectively [1](Beeftink, 2007, Borkus, 2007). All machinery is imported from Europe, being the exchange rate used 10 ZAR/€ and applying an increase in the prices of 10% corresponding to shipping expenses and import taxes. Machinery prices have been derived from the above mentioned engineering companies' budgets, with accuracy (in machinery prices) of +/- 20%.

[1] Machinery price information was not available for the second, third and fourth scales of production. These factors are estimations suggested by Marvin Borkus and Luuk Beeftink.

**Table 4**. Parameters used for cost calculations

| | Parameters | | Value | Units |
|---|---|---|---|---|
| General | Operating days | | 365 | Days/year |
| | Operating hours | | 20 | Hours/day |
| | Days of milk reception | | 365 | Days/year |
| Fixed costs | Machinery [1] | | | |
| | | Shipping levy | 10 | % |
| | | Exchange rate | 10 | ZAR/€ |
| | | Lifespan | 5 | years |
| | | Residual value | 10 | % |
| | | Maintenance | 6 | % of machinery cost |
| | Buildings [2] | | | |
| | | Lifespan | 15 | years |
| | | Residual value | 10 | % |
| | | Maintenance | 1 | % |
| Variable costs | Water [4] | | 7.30 | ZAR/Kl |
| | Energy [3][4] | | 0.23 | ZAR/Kw |
| | Packaging [5] | | | |
| | | Price 20Kg bag | 8.00 | ZAR/bag |
| | | Cheese packaging | 1.25 | ZAR/Kg |
| | Price Raw milk [5] | | 2.50 | ZAR/l |

1) (Olivier, 2007)
2) (Beeftink, 2007, Borkus, 2007)
3) Fixed costs derived from the cost of hiring a Transformer should be added: 355.400 ZAR/year
4) (Swellendam-Municipality, 2007)
5) (Fourie, 2007)

**Table 5.** Equipment prices for product processing [1]

| **Processing equipment** | **Price** € | **Price** ZAR |
|---|---|---|
| Milk reception at the factory | 369,760 | 4,067,365 |
| Cream processing | 350,000 | 3,850,000 |
| Cheese making | 6,800,000 | 74,800,000 |
| Whey clearing & whey cream separation | 826,000 | 9,086,000 |
| WPC processing | 5,045,000 | 55,495,000 |
| Permeate & whey concentration | 1,250,000 | 13,750,000 |
| Lactose extraction | 5,990,000 | 65,890,000 |
| Whey powder processing | 3,826,000 | 42,086,000 |
| Various [2] | 1,645,000 | 18,095,000 |

1) APV and Tetra Pak (2007)
2) Included steam & compressed air generation and distribution, pipes, installation and starting, automation, refrigeration, civils, electrical distribution and cooling compressor.

The construction costs of the buildings containing product processing are estimated from the equipment cost, being this one 20% of the total building costs (Burger, 2007). The remaining construction costs, namely, civil, mechanical, instrumentation and electrical work and contingency, are 20%, 20%, 5%, 15% and 20%, respectively. Engineering wages involve a surplus of 15% and an extra 20% has been considered for other expenses.

Appendix 3 contains detailed information about the building construction costs and the total project investment.

The cost of labour has been calculated bearing in mind South African labour policies and standards regarding salaries. Two shifts per day are considered for all scales of production. As the upgrade in scale is done through an increase in equipment capacity, the labour costs for the larger scales of production were considered the same (Table 6). Appendix 4 shows detailed labour cost calculations.

**Table 6.** Annual labour cost and number of employees required for each scenario[1)]

| Scenarios | Number of employees | Labour cost ZAR/year |
|---|---|---|
| 1 | 92 | 10,958,000 |
| 2 | 123 | 14,554,000 |
| 3 | 123 | 15,404,000 |
| 4 | 193 | 18,500,000 |

[1)] (SSK, 2008)

Variable costs include cost of raw material, energy consumption, processing water consumption, packaging and additives required for cheese manufactory (sodium nitrate, salt, starters, colorant and calcium nitrate). All of them are based on South African prices. Table 7 shows additives requirements for Gouda cheese production and prices.

The replacement of capital equipment as well as fixed operation costs, such insurance and taxes are not taken into account for the calculation of the Net Profit. Seasonal variation on milk composition was also not considered.

**Table 7.** Additives requirements for Gouda cheese production and their prices [1)]

| Additives | Amounts required | Units | Prices | Units |
|---|---|---|---|---|
| Rennet | 0.005 | l/100 l milk | 131 | ZAR/l rennet |
| Starter | 0.8 | % | 0.06875 | ZAR/l milk |
| Salt | 2.9 | Kg salt/Kg cheese | 1.018 | ZAR/Kg salt |
| Calcium chloride | 0.024 | l/100 l milk | 3.95 | ZAR/l $CaCl_2$ |
| Sodium nitrate | 0.024 | Kg/100 l milk | 6 | ZAR/Kg $NaNO_3$ |
| Colorant | 0.005 | l/100 l milk | 36 | ZAR/Kg Colorant |

[1)] (Wiid, 2008)

## 4.3 Model design

A spreadsheet model has been designed to estimate the viability of each of the four scenarios. Full plant operation is assumed. Previously mentioned inputs are used to calculate potential revenues (R), variable (VC) and fixed costs (FC), gross margin (GM) and total investment. As a result, the net profit (NP) of each scenario in the corresponding scale of production has been assessed.

Total investment = $I_M$ x 100/20 x (1+0.15 +0.20) (1)

$R = N_i \times p_i$ (2)

$VC = C_{Ml} + C_{BM} + C_{MM} + C_E + C_W + C_L + C_S + C_P$ (3)

$GM = R - VC$ (4)

$FC = d_M + d_B$ (5)

$NP = GM - FC$ (6)

ROI = NP/ Total investment (7)

Where,

$I_M$ is the investment in machinery

$N_i$ is the amount in Kg of each product per year (Gouda cheese, cream, whey cream, whey powder, WPC 80% and lactose)

$p_i$ is the price of each product in ZAR.

$C_{Ml}$ is cost of milk

$C_{BM}$ is cost of building maintenance

$C_{MM}$ is cost of machinery maintenance

$C_E$ is cost of electricity consumption

$C_W$ is cost of water consumption

$C_L$ is cost of labour

$C_S$ is cost of supplies

$C_P$ is cost of packaging

$d_M$ is depreciation of machinery

$d_B$ is depreciation of buildings

From the multifarious profitability measures available, Return on Investment (ROI) has been used to compare the different cases due to the data nature. Nor interest rate has been included in the study, neither have been any time considerations. All the calculations have been done based on the revenues and costs of a typical year.

# 5. Results and discussion

## 5.1. End products related results

From the initial amount of milk of the different scales of production 10% turns cheese, 0.77% cream, 1.12% whey cream, 2.78% WPC 80% and 3.29% lactose. The rest is waste recycled as CIP (Cleaning-In-Place) sanitizing and rinse water. Table 8 shows the amounts (in Kg/d) generated of the final products.

**Table 8.** Daily amounts of final products produced per scale of production and scenario

| Scales of produciton (Tons/d) | Products | Kg/d produced | | | |
|---|---|---|---|---|---|
| | | Scenario 1 | Scenario 2 | Scenario 3 | Scenario 4 |
| 400 | Gouda cheese | 39,700 | 39,700 | 39,700 | 39,700 |
| | Cream | 3,090 | 3,090 | 3,090 | 3,090 |
| | Whey powder | - | 27,322 | - | - |
| | Whey cream | - | 4,492 | 4,492 | 4,492 |
| | WPC 80% | - | - | 3,126 | 3,126 |
| | Lactose | - | - | - | 9,629 |
| 800 | Gouda cheese | 79,400 | 79,400 | 79,400 | 79,400 |
| | Cream | 6,180 | 6,180 | 6,180 | 6,180 |
| | Whey powder | - | 54,644 | - | - |
| | Whey cream | - | 8,984 | 8,984 | 8,984 |
| | WPC 80% | - | - | 6,252 | 6,252 |
| | Lactose | - | - | - | 19,258 |
| 1,200 | Gouda cheese | 119,100 | 119,100 | 119,100 | 119,100 |
| | Cream | 9,270 | 9,270 | 9,270 | 9,270 |
| | Whey powder | - | 81,967 | - | - |
| | Whey cream | - | 13,476 | 13,476 | 13,476 |
| | WPC 80% | - | - | 9,378 | 9,378 |
| | Lactose | - | - | - | 28,886 |
| 1,600 | Gouda cheese | 158,800 | 158,800 | 158,800 | 158,800 |
| | Cream | 12,360 | 12,360 | 12,360 | 12,360 |
| | Whey powder | - | 109,289 | - | - |
| | Whey cream | - | 17,968 | 17,968 | 17,968 |
| | WPC 80% | - | - | 12,503 | 12,503 |
| | Lactose | - | - | - | 38,515 |

The daily production of Gouda cheese in the factory presented in this Thesis might be too large to find a place in the local market, most of all for the higher scales of production. Apart from that, the only production of this cheese variety may limit the market possibilities of this factory and diversification of the cheese chain should be born in mind. By increasing the product portfolio, this enterprise would diminish its risk. A marketing study should be carried out to dig into the possibilities of producing other varieties as soft, Italian or Cheddar cheese. The market of these products was in 2006 4.7, 13.6 and 27.7, respectively (Joubert, 2007). However, the production of different varieties of cheese would result in higher investment, because of the specific machinery required (Tetra-Pak, 2003), and different whey quality. Cheddar cheese, for example, generates whey with 7.1% Total solids (TS), with 0.91% protein and 0.47% fat content. In contrast, whey from Quarg cheese contains 6.3% TS, from which 0.76% is protein and 0.14% is fat (Gallardo-Escamilla *et al.*, 2005). Therefore, further studies considering product combination should be carried out, always bearing in mind the quality of the whey generated.

## 5.2. Profitability

Table 9 sums up the results obtained from the model for each of the scenarios and scales of production. Despite the low percentages obtained of each of the final products, ROIs appeared positive in all cases. Market component prices in South Africa were high in comparison with those registered by the USDA (United States Department of Agriculture). In the case of whey powder, the price used in the model is almost double of that of the USDA (USDA-NASS, January 2008). Sensitivity analysis could be used to determine the minimum prices required to assure the viability of a whey processing factory in South Africa. The inclusion in the model of other costs (i.e., land, transport or financial costs) could change the current picture and show the relevance of economies of scale. Indeed, investments in dairy processing plants carried out in milk-ingredient exporting countries, like the Netherlands, are only considered at a starting size similar to that of the third scenario (Altamirano, 2007, Beeftink, 2007, Borkus, 2007). Therefore, lower ROIs could be expected and further investigation is required.

The second scenario showed the highest ROI within each scale of production. The extraction of lactose seemed to be more advantageous than only protein extraction, since the ROI of the fourth scenario is higher than that of the third one. Finally, the least profitable was the cheese factory that concentrates whey and delivers it to the feed industry. The finer the extraction, the more expensive it becomes due to the high cost of machinery required and its related costs. Only in the case of the plant processing 400 Tons/d milk, there is an increase in the price of machinery of 24.73 % when comparing the first two scenarios (not drying vs. drying the whey). When scenarios 1 and 3 are compared, this increase is 56.37%. The fourth scenario involves 29.11% higher investment in machinery than the third one. This confirms the results of Kotoupas *et al.* (2007) who described a higher percentage of operating costs (47.30%) associated with the production of WPC than that associated with lactose extraction (34.80%). The investment in machinery for the up-scaling of the plant has been realised by raising the prices 1.5, 2 and 2.5 times, respectively, in relationship with the basic scale. That is why the percentages mentioned above are conservative in the rest of the scales.

For the smallest scale of production, scenarios 3 and 4 differ in 0.98% (20.10% and 21.09%, respectively). Hence, it might be interesting to achieve an investment effort in order to get a factory that allows a wider portfolio, reducing the risk involved. Despite enlarging the portfolio, the choice for the former would involve an investment 351.94 millions ZAR cheaper. The ROI difference between both scenarios increases in the upper scales (1.23% for 800 Tons/d, 1.35% for 1,200 Tons/d and 1.42% for 1,600 Tons/d). However, further research is needed to assess risk estimations.

Regarding the scale of production, an increasing trend can be seen when the same scenarios are compared. In the first scenario, 400, 800, 1,200 and 1,600 Tons/d milk have ROIs of 18.22%, 28.07%, 33.06% and 36.05%, respectively. Table 8 shows the rest of the ROIs for the mentioned scales. Nevertheless, the larger the scale, the smaller the interval differences, i.e., 9.86% differentiates first scenarios of the smallest scale from the immediate larger one, while only 4.99% does between 800 and 1,200 Tons/d. The upgrade to 1,600 Tons/d increases the percentage by 2.99%. As a result, an optimum size of plant could be reached for the characteristics described above, beyond which ROIs would be still positive, but the differences between scales would not be sufficiently large to justify the additional investment.

**Table 9.** Model results for the different scenarios at each scales of production

| Scenarios | Investment (Million ZAR) | Revenues (million ZAR/year) | Variable costs (million ZAR/year) | Gross Margin (million ZAR/year) | Fixed costs (million ZAR/year) | Net Profit (million ZAR/year) | ROI (%) |
|---|---|---|---|---|---|---|---|
| 1 | 773 | 656 | 455 | 201 | 60 | 140 | 18.22 |
| 2 | 964 | 784 | 464 | 320 | 75 | 245 | 25.42 |
| 3 | 1,209 | 800 | 463 | 337 | 94 | 243 | 20.10 |
| 4 | 1,561 | 920 | 469 | 450 | 121 | 329 | 21.09 |
| | | | | | | | |
| 1 | 1,159 | 1,313 | 897 | 416 | 90 | 325 | 28.07 |
| 2 | 1,446 | 1,569 | 911 | 658 | 112 | 545 | 37.71 |
| 3 | 1,813 | 1,601 | 907 | 693 | 141 | 552 | 30.45 |
| 4 | 2,341 | 1,840 | 915 | 924 | 182 | 741 | 31.68 |
| | | | | | | | |
| 1 | 1,546 | 1,970 | 1,339 | 631 | 120 | 511 | 33.06 |
| 2 | 1,929 | 2,354 | 1,357 | 997 | 150 | 847 | 43.91 |
| 3 | 2,418 | 2,401 | 1,350 | 1,050 | 188 | 862 | 35.67 |
| 4 | 3,122 | 2,760 | 1,361 | 1,398 | 243 | 1,155 | 37.01 |
| | | | | | | | |
| 1 | 1,933 | 2,627 | 1,780 | 847 | 150 | 696 | 36.05 |
| 2 | 2,411 | 3,139 | 1,803 | 1,336 | 187 | 1,148 | 47.64 |
| 3 | 3,023 | 3,202 | 1,793 | 1,408 | 235 | 1,172 | 38.80 |
| 4 | 3,902 | 3,680 | 1,806 | 1,873 | 303 | 1,569 | 40.22 |

There are other factors that may determine the convenience of extraction of components apart from the economy of scale, namely, the price of the raw material, the energetic costs and the internal demand. The price paid to South African farmers for their milk during the development of this study is 2.5 ZAR/Kg, equivalent to approximately € 0.25/Kg. As a comparison, this price was € 0.27/Kg on March 2007 in Europe (LTO-Nederlands, 2007). The development of a local ingredient extracting factory could be a strategy to increase the money farmers get for their milk, due to the high prices ingredients have in the world market. The second factor will be further treated in section 4.3.3. Further research is required to determine more precisely the internal demand for ingredients. Ingredient industry is still new and risky, which makes extremely hard to get reliable market information about it all over the world.

## 5.3. Present risks for the establishment of a dairy processing plant in South Africa

### 5.3.1. Milk quality

South African dairy industry deals with three grades of milk from the hygienic point of view: A, B and C, being A the top quality milk. The former is defined by a Bactoscan count inferior to 80,000 c.f.u. (colony forming unit). The second between 80,000 and 300,000 c.f.u. and the later larger than 300,000 c.f.u. On a general basis, it can be said that 75% of the total milk collected is grade A milk, 20% is grade B and 5% grade C (Rijs, 2007).

This study has been developed assuming top quality milk (grade A milk), which is recommended to get good quality cheese and whey derivates according to all sources consulted (Altamirano, 2007, Robertson, 1981). Milk of lower quality may influence cheese yield and alter milk composition. Table 10 shows changes in composition of mastitic milk in comparison to top quality milk. In general decreased percentages can be observed for lactose, Casein, $Ca^{2+}$ and total fat fraction. However, within this fraction the proportion of Free Fatty acids increases with respect to the proportion in top quality milk. The inflammation of the Udder results in an increase of capillary permeation, allowing more serum proteins in to the milk, resulting in higher whey protein contents.

**Table 10.** Comparison of milk composition between normal and mastitic milk [1)]

| Milk component | Normal milk (%) | Mastitic milk (%) |
|---|---|---|
| Fat | 3.45 | 3.2 |
| Free fatty acids | 0.64 | 1.17 |
| Total protein | 3.61 | 3.56 |
| Casein | 27.9 | 22.5 |
| Whey protein | 0.87 | 1.98 |
| Lactose | 4.85 | 4.4 |
| $Na^{+}$ | 0.057 | 0.104 |
| $Ca^{2+}$ | 0.136 | 0.049 |

[1)] (Robertson, 1981)

Besides, other influences of poor milk quality on cheese-making are a reduction on rennet coagulation and non-fat-solids content, delayed acidification by starter bacteria and undesirable changes in taste of cheese.

An increase in the scale of production could imply a problem from the top-quality-milk supply point of view. South Africa is a rather extend country. The quality of its roads differs from untarred roads to highways, being the formers the most characteristic from rural areas in which the main agricultural activity is located. As milk transport is done in isolated (not refrigerated) trucks, transport collecting distances would become longer, which might have an impact in milk quality.

### 5.3.2. Labour

The extraction of ingredients is carried out in a factory style-production which requires very specific machinery with a high level of automation. Therefore, competent labour with technical education trained in quality issues (HACCP, Hazard Analysis and Critical control Points) is needed to control and operate a plant with such characteristics.

Wages considered for the calculations of labour costs are over valued in this study. Skilled employees are a scarce good sometimes in South Africa, most of all in the rural areas, reason why a premium needs to me paid to get the right personnel (SSK, 2008).

After apartheid, South Africa has implemented some labour laws to increase employment equity (Department-of-Labour, 1998). Different ethnic groups need to be represented in the structure of a company and an Employment equity plan must be submitted annually to the Director General of Labour, where it is analysed. These policies might restrict the labour possibilities of the factory of study.

As a result, the availability of qualified labour and specialists could be troublesome in case the production scales step-up. Labour costs would be increased accordingly.

### 5.3.3. Electricity supply

Lately, South Africa has been suffering from frequent energy shutdowns, due to insufficient power supply. This power crisis, as appointed by South African Press, is endangering the countries economics prospects (Klein *et al.*, 27 Jan. 2008) . That is why the establishment of a factory with the energy demands mentioned above could imply some limitations, especially for the larger scales of production.

Due to this energetic scarcity, industries already established in South Africa are facing some difficulties and have been forced to install generators or stop their production. According to Eskom's (South African energy company leader) finance director, Mr Bongani Nqwaba, South African new power projects will become operational in 2013, reason why industrial projects should be held back (Naidu *et al.*, 20 Jan. 2008).

# 6. Conclusions & recommendations

Based on the results of the present study the following conclusions may be drawn:

1. A decision tree approach seems to be a useful tool to support decision making considering different possibilities of whey processing.
2. Based in the current study, whey processing seems to be a good alternative to add profit to whey from cheese factories in South Africa. Even the smallest scale of production considered accounted positive ROIs in the four scenarios studied.
3. Considering the scenarios separately, the option to produce whey powder seemed to be the best, followed by a combination of WPC 80% and lactose. As third best option remained the extraction of WPC 80%, selling a permeate rich in lactose to other transforming industries.
4. The present results show the influence of the scale of production on the profitability of a cheese manufactory with different whey processing options.
5. Based on the model, one can assume that an optimal plant size or production scales can be reached. However, future research is required to determine this optimal size.

Other recommendations for future research include the following:

1. Closer interface of science and industry should provide additional insight into the feasibility of the plants considered in the present study.
2. Further research should be carried out considering other options for milk processing like the extraction of WPI, Casein, milk fat components or a combination of them.
3. Other strategies that should trigger further study could be the possibility of processing whey from cheese factories as raw material, specialising the production in whey derivates.
4. Further studies focusing on optimal factory size determination should also help in the decision making process.

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# 8. Appendixes

## Appendix 1. Standard cow milk composition (Walstra et al., 2006)

| Component group | Component | Amount g/Kg | |
|---|---|---|---|
| **Water** | | | **872.5** |
| **Carbohydrates** | | | **46.07** |
| | Lactose | 46 | |
| | Glucose | 0.07 | |
| **Proteins** | | | **32.8** |
| | $\alpha_{s1}$-casein | 10.7 | |
| | $\alpha_{s2}$-casein | 2.8 | |
| | β-casein | 8.6 | |
| | ϰ-casein | 3.1 | |
| | γ-casein | 0.8 | |
| | α-lactoalbmumin | 1.2 | |
| | β-lactoglobulin | 3.2 | |
| | Blood serum albumin | 0.4 | |
| | Immunoglobulins | 0.8 | |
| | Lactoferrin | 0.1 | |
| | Miscelaneous (including Proteose-Peptone) | 0.7 | |
| | Fat Globule Membrane Proteins | 0.4 | |
| **Fat** | | | **40** |
| | Triglycerides | 39.32 | |
| | Diglycerides | 12 | |
| | Monoglycerides | 1.2 | |
| | Free Fatty acids | 4 | |
| | Phospholipids | 32 | |
| | Cerebrosides | 4 | |
| | Sterols | 12.8 | |
| | Caroteroids | 0.08 | |
| | Gangliosides | 0.4 | |
| **Vitamins** | | | **0.016** |
| | Vitamin A | 0.001 | |
| | Vitamin $B_1$ | 0.0004 | |
| | Vitamin $B_2$ | 0.0017 | |
| | Vitamin C | 0.0125 | |
| | Vitamin D | 0.000002 | |
| **Minerals** | | | **8.6** |
| | Calcium, bound | 1.15 | |
| | Calcium, ionic form | 0.09 | |
| | Magnesium | 0.07 | |
| | Potassium | 1.50 | |
| | Sodium | 0.45 | |
| | Chloride | 1.10 | |
| | Phosphate | 2.10 | |
| | Sulphate | 0.10 | |
| | Bicarbonate | 0.10 | |
| | Lactic acid | 0.20 | |
| | Miscellaneous (including trace elements and organic acids) | 1.90 | |
| **Others** | | | **0.114** |
| **Total** | | | **1,000** |

## Appendix 2. Milk ingredients origin and uses

| Ingredient | Origin | Uses |
|---|---|---|
| Whole milk powder | Whole milk | Recombination of milk and milk products, Bakery (Increase water-binding capacity), Substitute for egg, Confectionery industry, Chocolate production, ready-cooked meals, Dessert industry (Ice-cream, Custard, Mousses, Puddings & Sauces), animal feed, Beverage industry, Blending & Repacking Market, Fermented milk industry, Infant & Weaning industry. |
| Skim milk powder | Skim milk | Feed, Bakery, Beverage industry, Blending & Repacking Market, Confectionery industry, Dessert industry (Ice-cream, Custard, Mousses, Puddings & Sauces), Fermented milk industry, Health & Wellness industry (medial, body-building & life-style), Infant & Weaning industry, Savoury Soups, Sauces & Gravy industry, Sports & Nutritional drink industry (Sport & Energy drinks). |
| Whey powder | Whey | Feed, Paint industry, Bakery, Beverage industry, Blending & Repacking Market, Confectionery industry, Dessert industry (Ice-cream, Custard, Mousses, Puddings & Sauces), Fermented milk industry, Health & Wellness industry (medial, body-building & life-style), Mayonnaise & Salad cream industry, Savoury Soups, Sauces & Gravy industry, Spreads industry (Butter & Margarine). |
| MPC | Skim milk | Blending & Repacking Market, Fermented milk industry. |
| MPI | Skim milk | Health & Wellness industry (medial, body-building & life-style). |
| Acid casein & Caseinates | Skim milk | Additive in paper manufacture, Paint industry, cosmetic industry, food industry as emulsifier in meat, cream and milk substitutes, Feed, Beverages industry, Blending & Repacking Market, Confectionery industry, Fermented milk industry, Health & Wellness industry (medial, body-building & life-style), Savoury Soups, Sauces & Gravy industry, Sports & Nutritional drink industry (Sport & Energy drinks). |
| Rennet casein | Skim milk | Cheese production, production of artificial plastics, production of synthetic fibres, Bakery, Savoury Soups, Sauces & Gravy industry. |
| WPC 35% | Whey | Fermented milk industry, Health & Wellness industry (medial, body-building & life-style), Infant & Weaning industry, Mayonnaise & Salad cream industry, Savoury Soups, Sauces & Gravy industry, Sports & Nutritional drink industry (Sport & Energy drinks). |
| WPC 80% | Whey | Fermented milk industry, Health & Wellness industry (medial, body-building & life-style), Infant & Weaning industry, Mayonnaise & Salad cream industry, Savoury Soups, Sauces & Gravy industry, Sports & Nutritional drink industry (Sport & Energy drinks). |
| Lactose | Whey | Edible: Confectionery industry, Health & Wellness industry (medial, body-building & life-style), Infant & Weaning industry. Pharmaceutical, industry |
| Demineralised whey | Whey | Infant & Weaning industry. |
| WPI | Whey | Health & Wellness industry (medial, body-building & life-style). |
| Cream & Creamers | Cream | Bakery, Beverage industry, Dessert industry (Ice-cream, Custard, Mousses, Puddings & Sauces), Savoury Soups, Sauces & Gravy industry. |
| Butter | Cream | Beverage industry, Blending & Repacking Market, Confectionery industry, Dessert industry (Ice-cream, Custard, Mousses, Puddings & Sauces), Fermented milk industry, Savoury Soups, Sauces & Gravy industry. |
| Buttermilk | Cream | Bakery, Blending & Repacking Market, Confectionery industry, Dessert industry (Ice-cream, Custard, Mousses, Puddings & Sauces), Health & Wellness industry (medial, body-building & life-style). |

Note: MPC (milk protein concentrate), MPI (milk protein isolates), WPC (whey protein concentrates), WPI (whey protein isolates)

**Appendix 3. Data for building cots calculations (in Million ZAR)**

| | 400 Tons/d | | | | 800 Tons/d | | | |
|---|---|---|---|---|---|---|---|---|
| | **Scenario 1** | **Scenario 2** | **Scenario 3** | **Scenario 4** | **Scenario 1** | **Scenario 2** | **Scenario 3** | **Scenario 4** |
| Equipment (including installation) | 115 | 143 | 179 | 231 | 172 | 214 | 269 | 347 |
| Civil work | 115 | 143 | 179 | 231 | 172 | 214 | 269 | 347 |
| Mechanical work | 115 | 143 | 179 | 231 | 172 | 214 | 269 | 347 |
| Instrumentation work | 29 | 36 | 45 | 58 | 43 | 54 | 67 | 87 |
| Electrical work | 86 | 107 | 134 | 173 | 129 | 161 | 202 | 260 |
| Contingency | 115 | 143 | 179 | 231 | 172 | 214 | 269 | 347 |
| CAPITAL | 573 | 714 | 896 | 1,156 | 859 | 1,072 | 1,344 | 1,735 |
| Engineering (15% beyong capital) | 86 | 107 | 134 | 173 | 129 | 161 | 202 | 260 |
| Others (20% beyong capital) | 115 | 143 | 179 | 231 | 172 | 214 | 269 | 347 |
| BUILDINGS TOTAL COST | 659 | 822 | 1,030 | 1,330 | 988 | 1,232 | 1,545 | 1,995 |
| **TOTAL INVESTMENT [1]** | **773** | **965** | **1,209** | **1,561** | **1,160** | **1,447** | **1,814** | **2,342** |

[1] Total investment is calculated from the sum of Buildings and Equipment costs

| | 1,200 Tons/d | | | | 1,600 Tons/d | | | |
|---|---|---|---|---|---|---|---|---|
| | **Scenario 1** | **Scenario 2** | **Scenario 3** | **Scenario 4** | **Scenario 1** | **Scenario 2** | **Scenario 3** | **Scenario 4** |
| Equipment (including installation) | 229 | 286 | 358 | 463 | 286 | 357 | 448 | 578 |
| Civil work | 229 | 286 | 358 | 463 | 286 | 357 | 448 | 578 |
| Mechanical work | 229 | 286 | 358 | 463 | 286 | 357 | 448 | 578 |
| Instrumentation work | 57 | 71 | 90 | 116 | 72 | 89 | 112 | 145 |
| Electrical work | 172 | 214 | 269 | 347 | 215 | 268 | 336 | 434 |
| Contingency | 229 | 286 | 358 | 463 | 286 | 357 | 448 | 578 |
| CAPITAL | 1,146 | 1,429 | 1,791 | 2,313 | 1,432 | 1,786 | 2,239 | 2,891 |
| Engineering (15% beyong capital) | 172 | 214 | 269 | 347 | 215 | 268 | 336 | 434 |
| Others (20% beyong capital) | 229 | 286 | 358 | 463 | 286 | 357 | 448 | 578 |
| BUILDINGS TOTAL | 1,317 | 1,643 | 2,060 | 2,660 | 1,647 | 2,054 | 2,575 | 3,325 |
| **TOTAL INVESTMENT** [1] | **1,547** | **1,929** | **2,418** | **3,122** | **1,933** | **2,411** | **3,023** | **3,903** |

[1] Total investment is calculated from the sum of Buildings and Equipment costs

## Appendix 4. Data for labour calculations

| | Plant Operations Manager | Number | Unit Cost ZAR/year | Annual Cost ZAR/year |
|---|---|---|---|---|
| Cheese manufacture | Factory Manager | 1 | 800,000 | 800,000 |
| | Section managers (Cheese, Financial manager, Marketing manager) | 3 | 500,000 | 1,500,000 |
| | Administrative personnel (secretary) | 2 | 120,000 | 240,000 |
| | Shift Supervisors | 6 | 250,000 | 1,500,000 |
| | Process Operators | 4 | 150,000 | 600,000 |
| | Process Assistant Operators | 4 | 95,000 | 380,000 |
| | Process – semiskilled | 36 | 35,000 | 1,296,000 |
| | Cleaners and Helpers | 10 | 35,000 | 360,000 |
| | Fork Lift Drivers | 4 | 48,000 | 192,000 |
| | Cheese Maker and Quality Analysis (QA). | 4 | 350,000 | 1,400,000 |
| | Lab Assistants | 6 | 120,000 | 720,000 |
| | Maintenance Foreman | 2 | 300,000 | 600,000 |
| | Fitter | 4 | 200,000 | 800,000 |
| | Maintenance Assistants | 6 | 95,000 | 570,000 |
| | **TOTAL** | **92** | | **10,958,000** |
| WPC 80% | Sector manager | 1 | 450,000 | 450,000 |
| | Secretary | 1 | 120,000 | 120,000 |
| | Process Operators | 4 | 150,000 | 600,000 |
| | Process Assistant Operators | 4 | 95,000 | 380,000 |
| | Process – semiskilled | 4 | 35,000 | 140,000 |
| | Cleaners and Helpers | 10 | 35,000 | 350,000 |
| | Fork Lift Drivers | 2 | 48,000 | 96,000 |
| | QA | 2 | 350,000 | 700,000 |
| | Lab Assistants | 6 | 120,000 | 720,000 |
| | Maintenance Foreman | 1 | 300,000 | 300,000 |
| | Fitter | 2 | 200,000 | 400,000 |
| | Maintenance Assistants | 2 | 95,000 | 190,000 |
| | **TOTAL** | **39** | | **4,446,000** |
| Lactose | Process Operators | 2 | 150,000 | 300,000 |
| | Process Assistant Operators | 4 | 95,000 | 380,000 |
| | Process – semiskilled | 6 | 35,000 | 210,000 |
| | Cleaners and Helpers | 8 | 35,000 | 280,000 |
| | Fork Lift Drivers | 2 | 48,000 | 96,000 |
| | Cheese Maker and QA | 2 | 350,000 | 700,000 |
| | Lab Assistants | 2 | 120,000 | 240,000 |
| | Maintenance Foreman | 1 | 300,000 | 300,000 |
| | Fitter | 2 | 200,000 | 400,000 |
| | Maintenance Assistants | 2 | 95,000 | 190,000 |
| | **TOTAL** | **31** | | **3,096,000** |
| Whey powder | Process Operators | 2 | 150,000 | 300,000 |
| | Process Assistant Operators | 4 | 95,000 | 380,000 |
| | Process – semiskilled | 6 | 35,000 | 210,000 |
| | Cleaners and Helpers | 6 | 35,000 | 210,000 |
| | Fork Lift Drivers | 2 | 48,000 | 96,000 |
| | Cheese Maker and QA | 2 | 350,000 | 700,000 |
| | Lab Assistants | 2 | 120,000 | 240,000 |
| | Maintenance Foreman | 1 | 300,000 | 300,000 |
| | Fitter | 2 | 200,000 | 400,000 |
| | Maintenance Assistants | 2 | 95,000 | 190,000 |
| | Section manager | 1 | 450,000 | 450,000 |
| | Administration personnel (secretary) | 1 | 120,000 | 120,000 |
| | **TOTAL** | **31** | | **3,596,000** |

**Appendix 5. Data for energy, water and packaging cost calculations for the four scenarios and scales of production**

| | 400 Tons/d | | | 800 Tons/d | | | 1,200 Tons/d | | | 1,600 Tons/d | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Energy consumption** | **Kw/h** | **Kw/year** | **ZAR/year** | **Kw/h** | **total Kw** | **ZAR/year** | **Kw/h** | **total Kw** | **ZAR/year** | **Kw/h** | **total Kw** | **ZAR/year** |
| Scenario 1 | 2,700 | 19,710,000 | 4,888,700 | 4,050 | 35,478,000 | 9,226,140 | 5,400 | 47,304,000 | 11,946,120 | 6,750 | 59,130,000 | 14,666,100 |
| Scenario 2 | 3,150 | 22,995,000 | 5,644,250 | 4,725 | 41,391,000 | 10,586,130 | 6,300 | 55,188,000 | 13,759,440 | 7,875 | 68,985,000 | 16,932,750 |
| Scenario 3 | 3,600 | 26,280,000 | 6,399,800 | 5,400 | 47,304,000 | 11,946,120 | 7,200 | 63,072,000 | 15,572,760 | 9,000 | 78,840,000 | 19,199,400 |
| Scenario 4 | 4,050 | 29,565,000 | 7,155,350 | 6,075 | 53,217,000 | 13,306,110 | 8,100 | 70,956,000 | 17,386,080 | 10,125 | 88,695,000 | 21,466,050 |
| **Water consumption** | **Kl/d** | **Kl/year** | **ZAR/year** | **litre/d** | **litre/year** | **ZAR/year** | **litre/d** | **litre/year** | **ZAR/year** | **litre/d** | **litre/year** | **ZAR/year** |
| Scenario 1 | 80 | 29,200 | 213,160 | 160,000 | 58,400,000 | 426,320 | 240,000 | 87,600,000 | 639,480 | 320,000 | 116,800,000 | 852,640 |
| Scenario 2 | 80 | 29,200 | 213,160 | 160,000 | 58,400,000 | 426,320 | 240,000 | 87,600,000 | 639,480 | 320,000 | 116,800,000 | 852,640 |
| Scenario 3 | 124 | 45,427 | 331,614 | 248,913 | 90,853,257 | 663,229 | 373,370 | 136,279,886 | 994,843 | 497,826 | 181,706,515 | 1,326,458 |
| Scenario 4 | 124 | 45,427 | 331,614 | 248,913 | 90,853,257 | 663,229 | 373,370 | 136,279,886 | 994,843 | 497,826 | 181,706,515 | 1,326,458 |
| **Packaging** | **Powder Tons/year** | **Cheese Tons/year** | **ZAR/year[3]** | **Powder Tons/year** | **Cheese Tons/year** | **ZAR/year[3]** | **Powder Tons/year** | **Cheese Tons/year** | **ZAR/year[3]** | **Powder Tons/year** | **Cheese Tons/year** | **ZAR/year[3]** |
| Scenario 1 | 0 | 14,491 | 18,113,125 | 0 | 28,981 | 36,226,250 | 0 | 43,472 | 54,339,375 | 0 | 57,962 | 72,452,500 |
| Scenario 2 | 9,973 | 14,491 | 22,102,171 | 19,945 | 28,981 | 44,204,342 | 29,918 | 43,472 | 66,306,514 | 39,890 | 57,962 | 88,408,685 |
| Scenario 3 | 1,141 | 14,491 | 18,569,499 | 2,282 | 28,981 | 37,138,998 | 3,423 | 43,472 | 55,708,497 | 4,564 | 57,962 | 74,277,996 |
| Scenario 4 | 4,655 | 14,491 | 19,975,300 | 9,311 | 28,981 | 39,950,600 | 13,966 | 43,472 | 59,925,900 | 18,622 | 57,962 | 79,901,200 |

[1] Energy consumption necessary to cover machinery work, steam production and cooling.

[2] Water consumption required for product washing. Water for steam production, cleaning or other purposes is not included.

[3] Packaging costs are derived from the costs of the bags in which powders are packed (capacity of 20 Kg powder/bag) and the cost of packaging material per Ton of cheese

**Appendix 6. Variable costs data containing raw material expenditure and additives for cheese production (sodium nitrate, rennet, brine salt, colourant, starters and calcium chloride) at the different scales of production**

| Tons milk/d | Raw milk | | Sodium nitrate | |
|---|---|---|---|---|
| | Requirements | Costs | Requirements | Costs |
| | Tons/year | ZAR/year | Kg/year | ZAR/year |
| 400 | 146,000 | 365,000,000 | 34,777 | 208,663 |
| 800 | 292,000 | 730,000,000 | 69,554 | 417,326 |
| 1,200 | 438,000 | 1.095,000,000 | 104,332 | 625,990 |
| 1,600 | 584,000 | 1.460,000,000 | 139,109 | 834,653 |

| Tons milk/d | Rennet | | Salt | |
|---|---|---|---|---|
| | Requirements | Costs | Requirements | Costs |
| | l/year | ZAR/year | Kg/year | ZAR/year |
| 400 | 7,245 | 949,128 | 42,022,450 | 42,778,854 |
| 800 | 14,491 | 1,898,256 | 84,044,900 | 85,557,708 |
| 1,200 | 21,736 | 2,847,383 | 126,067,350 | 128,336,562 |
| 1,600 | 28,981 | 3,796,511 | 168,089,800 | 171,115,416 |

| Tons milk/d | Colourant | | Starters | |
|---|---|---|---|---|
| | Requirements | Requirements | Requirements | Costs |
| | Kg/year | l/year | l/year | ZAR/year |
| 400 | 7,245 | 1,159,240 | 1,159,240 | 9,962,219 |
| 800 | 14,491 | 2,318,480 | 2,318,480 | 19,924,438 |
| 1,200 | 21,736 | 3,477,720 | 3,477,720 | 29,886,656 |
| 1,600 | 28,981 | 4,636,960 | 4,636,960 | 39,848,875 |

| Tons milk/d | Calcium chloride | |
|---|---|---|
| | Requirements | Costs |
| | l/year | ZAR/year |
| 400 | 34,777 | 137,370 |
| 800 | 69,554 | 274,740 |
| 1,200 | 104,332 | 412,110 |
| 1,600 | 139,109 | 549,480 |