FOOD ENGINEERING IN SOUTHERN AFRICA - A DOUBLE AGENDA

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ABSTRACT

Available statistics for the Southern African Development Community (SADC) show that a high proportion of the region's people are undernourished. Agricultural production forms a large part of the economies of most of the states. Food processing is a relatively small sector of the economies. There is a low spend on research and development. Formal food engineering teaching and research are almost non-existent. On the other hand some very sophisticated processing plants are operational in the region, particularly in the brewing sector.

One of the initiatives that are taking place is the production of a database of small/medium scale processing methods and energy balances for a wide variety of food products.

Case studies reveal that engineering and equipment supply are often inappropriate to the requirements.

Needs for the region, in terms of food processing, must include the use of appropriate technology coupled to agricultural infrastructure. Appropriate technology is not limited by scale.

INTRODUCTION

The fourteen countries of the Southern African Development Community (SADC) include some of the poorest in the world. The region has a history of colonialism, misguided post colonial handouts, undemocratic regimes and civil strife. The scourge of HIV/AIDS is more serious in this part of Africa than elsewhere in the world. Infrastructure is lacking particularly, but not only, in the rural areas. Due to the small size of the national economies the effects of currency trading and economic variability in the West has made for an economic roller coaster ride in the region.

Against this background, statistics are often outdated, misleading, and confusing. Food engineering research, as we understand it, is not a priority. Nevertheless, the application of sound engineering is required to

limit post harvest losses in order to improve food security in the region

and

improve the quality of processed goods as an earner of foreign exchange on the global market.

This is the double agenda of scientists and engineers in Southern Africa.

The problems facing the food industry in third world countries have been under discussion for a long time. Papers delivered at ICEF2 in 1979 form a part of this debate[1,2,3].

Almost a quarter of a century later, the findings of the first conference of the Food Science and Nutrition Network for Africa (FOSNNA) held in 2002 echoed many of the sentiments of earlier writers. The conference listed, amongst others, the following shortfalls[4]:

- *Inconsistent government policies and limited investment in Agriculture that did not give priority to food and agriculture in resource allocation leading to food insecurity and nutritional problems*.
- *Food processing was in its infancy in most countries of Africa. There has been little investment in food research and development.*
- *Poor appreciation of food quality and food marketing strategies.*
- *Poor infrastructure (roads, power, cold-chain facilities) in the rural areas, where most of the food was produced, handled and stored.*
- *In some countries, there was still conflict and instability that affected food production*.
- *Shortage of manpower, facilities and training*.
- *High post harvest losses leading to low food availability*.
- *Poor networking within institutions themselves, between nations, regional and international institutions ....*

That is, in my opinion a fair summary of the situation. Sadly, in 25 years, we have not found solutions appropriate to the problems of Southern African food production.

SOUTHERN AFRICA - DEMOGRAPHICS, INCOMES, POVERTY AND RESEARCH

Countries

Fourteen countries make up the Southern African development community. These are:

> Angola, Botswana, Democratic Republic of the Congo (DRC), Lesotho, Malawi, Mauritius, Mozambique, Namibia, South Africa, Seychelles, Swaziland, Tanzania, Zambia, and Zimbabwe.

Of these, only the Seychelles is considered amongst the Nations of *high human development* and seven are considered to have *low human development*[5].

Population and Food Supply

Table 1 lists the population (estimated for 2001), the estimated per capita income in US$ and the percentage of the population who are undernourished or in need. The degree of need is reflected in various ways and from different sources.

These figures show quite clearly that there are tremendous needs. Given the effects of the crisis in Zimbabwe, the increase in the AIDS orphan population, and the present drought, they are probably very optimistic.

TABLE 1 AFRICAN POPULATION, GDP PER CAPITA AND POVERTY

	Population (Millions) projected 2001 [5]	GDP per capita (US$) 2000 [5]	Under-nourished (% of Population) Ave for 1998-2000 [5]	% of Population below the poverty datum line [6]	Calories per Capita food supply (2001)[7]
Angola	12.8	701	50	n/a	1953
Botswana	1.7	3066	25	47	2292
DRC	49.8	99	73	n/a	1535
Lesotho	1.8	386	26	49.2	2320
Malawi	11.6	166	33	54	2168
Mauritius	1.2	3750	5	10.6	2995
Mozambique	18.2	200	55	70	1980
Namibia	1.9	1730	9	n/a	2745
Seychelles	0.1	6912	n/a	n/a	2461
South Africa	44.4	2620	n/a	50	2921
Swaziland	1.1	1175	12	n/a	2593
Tanzania.	35.6	271	47	51	1997
Zambia	10.6	354	50	86	1885
Zimbabwe	12.8	706	38	60	2133
For Comparison					
France	59.6	22129	n/a	n/a	3629

GDP and Agriculture

The total estimated product of the SADC countries for 2001 was 171 billion US$[5]. This was 13% of the GDP of France for the same period.

Of the total for the region, 66% was contributed by South Africa and only 34% by the remaining 13 countries. Indeed, the GDP of South Africa makes up almost 25% of the product of the whole of Africa. The province of Gauteng, the smallest in terms of land area of the nine provinces of South Africa and housing some 8 million people contributes 10% of the product of the continent of Africa. Africa currently houses approximately 780 million people.

Table 2 gives the relative size of agriculture in the economies of the SADC Countries. By comparison, the percent of agriculture in the GDP for developed countries is in the region of 2 to 2.5%. On this table the GDP in given as Billion US$ Purchasing Power Parity (PPP).

TABLE 2 THE CONTRIBUTION OF AGRICULTURE TO THE GDP OF SADC COUNTRIES[6]

	GDP (US$ billion PPP)	Agriculture % of GDP
Angola	10.1	7
Botswana	10.4	4
DRC	31.0	58
Lesotho	5.1	18
Malawi	9.4	37
Mauritius	12.3	10
Mozambique	19.1	44
Namibia	7.6	12
Seychelles	0.6	3.1
South Africa	369.0	5
Swaziland	4.4	10
Tanzania	25.1	49
Zambia	8.5	18
Zimbabwe	28.2	28

Generally in developed nations the value of food processing is approximately equal to the value of agricultural production. However, for Southern African countries the value of food processing as a percent of the value of agriculture varies from around 5% (Angola) to 55% (South Africa)[8].

Research and Development

An indication of the extent of research and development within the SADC countries is given on Table 3. Not surprisingly, the figures are very low in comparison with those of France. No data is available for the other countries in SADC.

TABLE 3 RESEARCH AND DEVELOPMENT IN SADC COUNTRIES[5].

	Research and development (R&D) expenditures (as % of GNP)	Scientists and engineers in R&D (per million people)
Mauritius	0.3	360
South Africa	0.6	992
For comparison		
France	2.2	2718

FOOD ENGINEERING RESEARCH AND DEVELOPMENT

Universities

To my knowledge, there is no school or university department of food engineering or food process engineering within the SADC Region. On the border of SADC, the University of Nairobi will be offering an option in food engineering from this year. The Engineering Council of South Africa (ECSA) does not presently consider food engineering as a separate entity (in line with civil, mechanical, agricultural, etc).

Of the six schools of chemical engineering in South Africa, accommodating between them about 1300 students, there appears to be no food related research being carried out. However, one university department (Natal) seems to be interested in embarking on food related work.

Of the schools of chemical engineering in the other SADC countries, the only one that appears to be active in food engineering is the Department of Chemical Engineering of the Eduardo Mondlane University in Mozambique.

The research at this department includes the following[9]:

1. *Enhancement of the Use of Quality Criteria for Crop Improvement of Beans and Cowpeas in the Eastern and Southern African Region*
2. *Weaning Food Project*
3. *Biochemical Aspects of Cassava Processing*
4. *Environmentally Friendly Packaging Solutions for Enhanced Storage and Quality of Southern Africa's Fruit and Nut Exports*
5. *Combidry*

There are presently two departments of agricultural or biosystems engineering at South African Universities. There are less than 100 students in these departments. Apart from some work into essential oils, there is no research being done on food processing at these departments. At one of the universities, the department was known as the "Department of Agricultural and Food Engineering" until quite recently but this name has now been dropped.

Some research into solar drying has been conducted in the department of Agricultural Engineering at the University of Zambia.

Parastatal and Commercial Developments

Some work in the production of small scale equipment designed for rural industries has been done by both parastatal and commercial organisations. Typical of this type of machine are those produced by the South African Agricultural Research Council's Institute for Agricultural Engineering (ARC-IAE) (Figs 1 and 2). These include roasters and mills for small scale peanut butter production and honey separators. The Rural Industries Promotion Company (RIPCO) in Botswana has designed and built a dehulling machine which is marketed throughout Africa.

Some of the pieces of small scale equipment that have been developed are manually driven. Some have electric drives.

Fig 1 Small scale peanut roaster *(ARC)*

There have been a number of attempts to develop and franchise small scale bakeries and dairy processing plants designed around the size of a standard 6m shipping container. Success with this type of project has been varied. There is a school of thought amongst workers in the field of rural development in Africa, that many of the small scale processing developments are not sustainable.

On a larger scale, commercial developments in Southern Africa have included, for instance, the setting up of a process for soya milk production in a large modern facility, and also development of novel mixing technology. South Africa also boasts some of the largest and most modern breweries in the world.

As far as I am aware, the only ones of the so called *novel processes* to be employed locally are industrial microwave heating and irradiation.

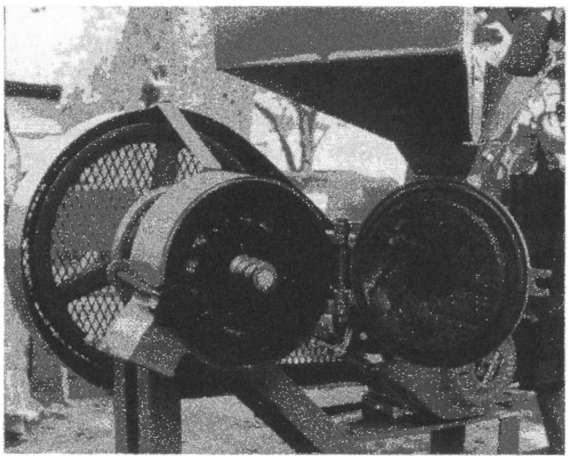


Fig 2. Small scale peanut mill *(ARC)*

PROCESS ENGINEERING CONSULTING IN SOUTHERN AFRICA (A PERSONAL VIEW)

The bulk of my own consulting work is concerned with two aspects of food processing. These are:

the design of plant to modern sanitary standards and auditing of existing installation in terms the same standards (particularly within the liquid food industries)

and

the production of a data base of mass and energy balances.

Sanitary standards

Sanitary standards for food processing plants in South Africa are largely included in two documents:

Regulations under the Health Act R918

and

South African Standard Code of Practice Food Hygiene Management SABS049

These two documents provide considerable guidelines with regard to walls, floors, ceilings, etc. but provide very little input or direction with regard to plant and machinery. South Africa does not have a legislated or regulated equivalent to the European directives and standards, which, in my opinion, form the best basis for the hygienic design and for the audit of food processing factories.

Broadly, I consider, under the umbrella of *European standards,* the following documents:

a European Community Machinery Directive: Safety Directive 91/368/EEC (1991) which came into effect in 1995 and which requires that machinery for use in food manufacture (*agri-foodstuffs machinery*) must comply with a number of hygienic requirements.

b The EC standard EN 1672 -2: 1997. *Food Processing Machinery - Safety and Hygiene Requirements - Basic concepts - Part 2: Hygiene requirements.*

c Publications of the European Hygienic Machinery Design Group (EHEDG) published either in their full format or in shortened form in the journal *Trends in Food Science and Technology.*

The reason that I prefer to work with this documentation, as opposed to any others is that:

a It deals specifically with equipment and covers a wider range of equipment types
b It forms a generalised legal requirement
c It provides guidelines for verification

d It stresses the need for the provision of cleaning instructions for all equipment.

In some sectors of the Southern African food industry there is poor knowledge of and scant regard for hygienic design. This needs to be corrected primarily through education and secondarily through regulation. There is a danger that over stringent or inappropriate application of design standards might be counter-productive in developing communities where food is scarce.

I was recently called in to inspect a pipe work installation for a sensitive beverage product. Non-hygienic ball valves had been installed where butterfly valves would be the norm. The EHEDG recommendations state quite clearly *that the area between the ball housing and seal housing must be cleanable..... Traditional ball valves are not designed for CIP*[10] The error cost several million SA Rand in contaminated product.

Food Processing Data Base and Energy Balances

One of the initiatives towards disseminating information on food processing is one that has been introduced by ESKOM, the South African energy supplier. Agrelek, the agricultural marketing arm of ESKOM is creating an electronic database of production methods for food products. The concept is to provide the small/medium scale would-be-processor with basic descriptions of the process stages as well as listings of applicable government regulations, suppliers and specialist consultants. The information should allow him to assess the requirements of the project and make use of the equipment suppliers or consultants should he wish to proceed.

At present the format of the database is being revised. There are a total of 668 product reports either completed or in progress. Although most of the information is only available in house, some outlines are available on http://foodproc.bluebox.co.za.

A part of the documentation on the database is a mass and energy balance for each of the products. These balances are designed to provide the following information -

a The theoretical product yield

b The approximate total energy requirement in $kJ\ kg^{-1}$

c An assessment of which steps in the process are energy intensive and should thus be checked or re-checked during process design

These balances are produced but not published on a spread-sheet (MS-Excel). Where necessary, for instance, when different formulations or processing methods are applicable more than one sheet is produced per product.

The spread-sheet is roughly divided to the following areas:

a <u>Assumptions</u> which include the scale of the operation, the yield, the specific heats and other product data and the time allowed each day for production and for start up/cleaning.

Where specific heat data is not readily available this is calculated on a separate sheet based on product composition.

b The Mass Balance calculation on the basis of 1 kg of product and also 1 hour or one day of operation.

c The Energy calculations

In general, the energy usage is divided between electrical energy and energy derived from burning of fossil fuels.

A division is also made between energy for process and service. Service equipment includes boiler motors, cooling water systems and air compressors. Water treatment plant and effluent treatment are not included in the calculations. HVAC, lighting, and cleaning are included separately. Generally, cleaning is calculated from a ratio between the start up/cleaning time and the production time. An allowance is made for additional hot water requirements.

All energy is reported on the spreadsheet as kJ per kg of product. This is then converted for each step in the process to percent of the total energy input.

Wherever possible heat and cooling are calculated using standard calculations.

Heat loads for processing rooms are taken from published data.

Energy for pumps can be assumed using typical flow and pressure drop calculations.

Evaporators and dryers are calculated using separate energy balance sheets.

Refrigeration energy requirements are based on theoretical COP values together with a factor designed to include the fans, pumps and other equipment used.

Where detailed information is not available as for any other items of equipment such as mixers, bowl cutters, centrifuges, filling machines and cooling towers an estimate is made as follows

$$e = 3600\ p / (m_h s)$$

where e is the required energy input in kJ kg^{-1}
p is the installed power (kW) (equipment supplier's information)
m_h is the mass flow of final product (kg/hour)
s is a service factor for the machine

d A flow diagram to which the figures for each stage of the process are transferred.

e Installed power added on a separate listing.

The data on the spreadsheet is transferred to a descriptive document (MS Word) and a Diagram (MS PowerPoint). The numerical information on these documents is linked to the spreadsheet. The design is to allow easy alteration of data (from the assumptions onwards) without publication of the original spreadsheet.

Three of the diagrams are given here as Figures 3,4,5. Figures 3 and 4 illustrate that entirely different results are obtained for the same product produced at different scales of operation.

Approximately 150 product sheets have been completed. Of these 50 have been converted into a new format expressing energy in terms of percent of total requirement. It is hoped to be able to publish some of this information in the not too distant future.

APPROPRIATE TECHNOLOGY AND THE DOUBLE AGENDA

In order to illustrate what I believe is appropriate technology for Africa, I would like to indicate some examples of inappropriate technology taken from my own files.

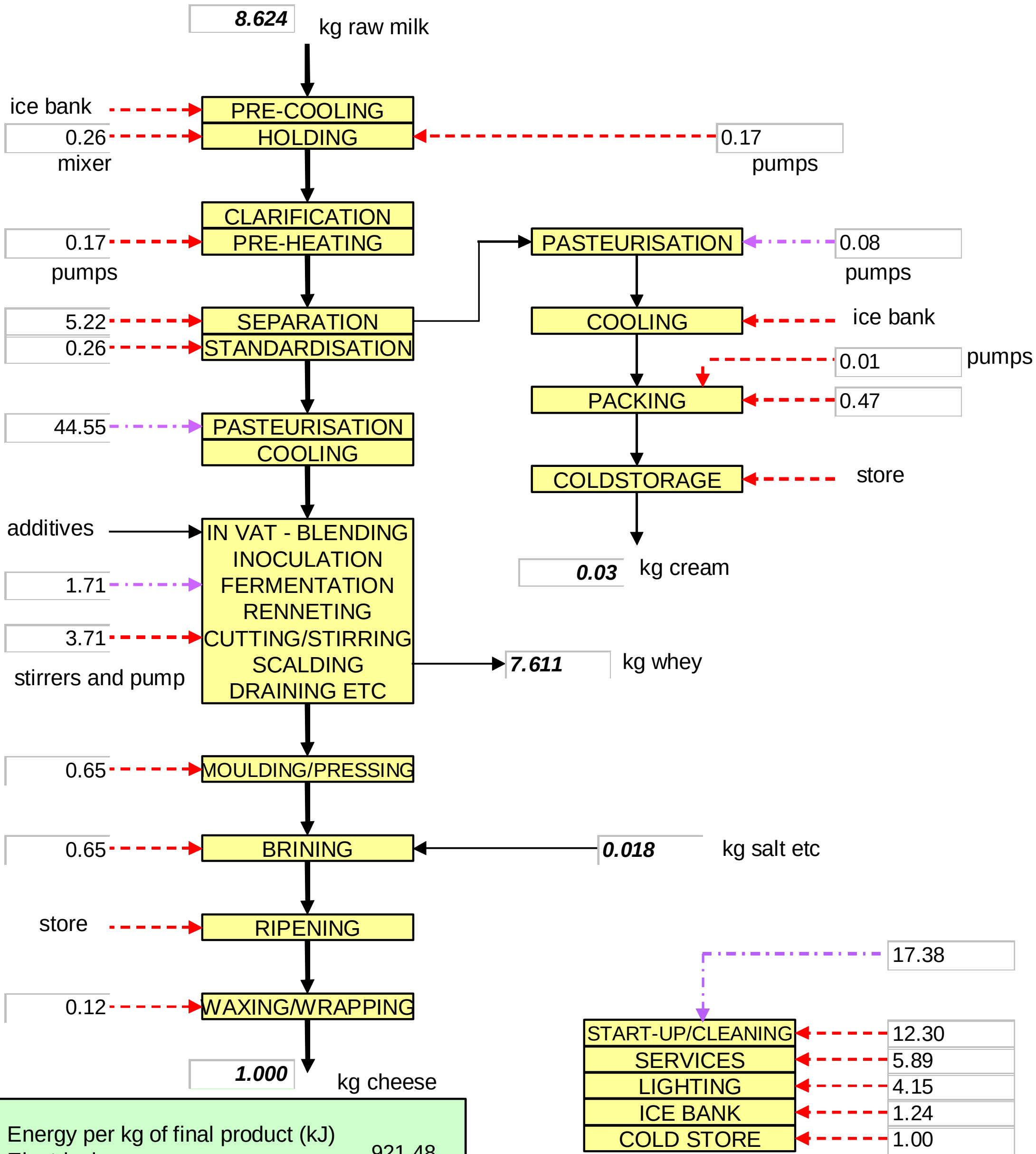
Case 1. A Fruit Plant in a SADC country.

The plant in question would cost, I believe, upwards of ten million US$ if installed today. It was installed by a European contractor as part of an aid package supplied by his government. The contractor bought most of the machinery from equipment suppliers in his own country, removed the nameplates and attached his own name tag. This was, presumably, to assure him of spares orders. The factory consisted of a citrus extraction and concentration plant, a mango and tomato extraction facility, a concentration and canning plant for tomato paste, a pineapple canning line, a beverage bottling line and a small meat plant. Services plant was included in the contract.

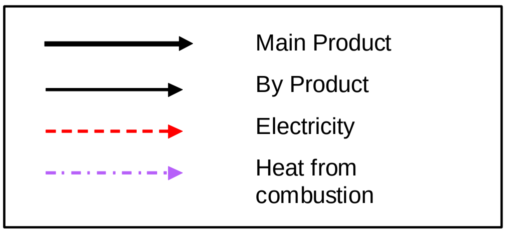
The plant was inappropriate because:

- the nearest good pineapple growing area was 1000 km distant.
- the boilers were fired on diesel which needed to be transported by rail several thousand kilometres. Coal fired boilers using coal from a few hundred kilometre distant would have saved the operation over 80% of the fuel bill. To aggravate the situation, single effect tomato evaporators had been installed.
- the citrus evaporator was incapable, as designed, of producing a quality concentrate.
- agricultural capacity and infrastructure were inadequate to keep the plant supplied with tomatoes, which was the main line.
- much of the equipment, particularly service equipment could have been sourced in the SADC region leading to cheaper and easier maintenance.

Sadly, at the time that I was at the plant analysing some of the problems, tomato paste of European origin was selling at the shop down the road cheaper than the local plant



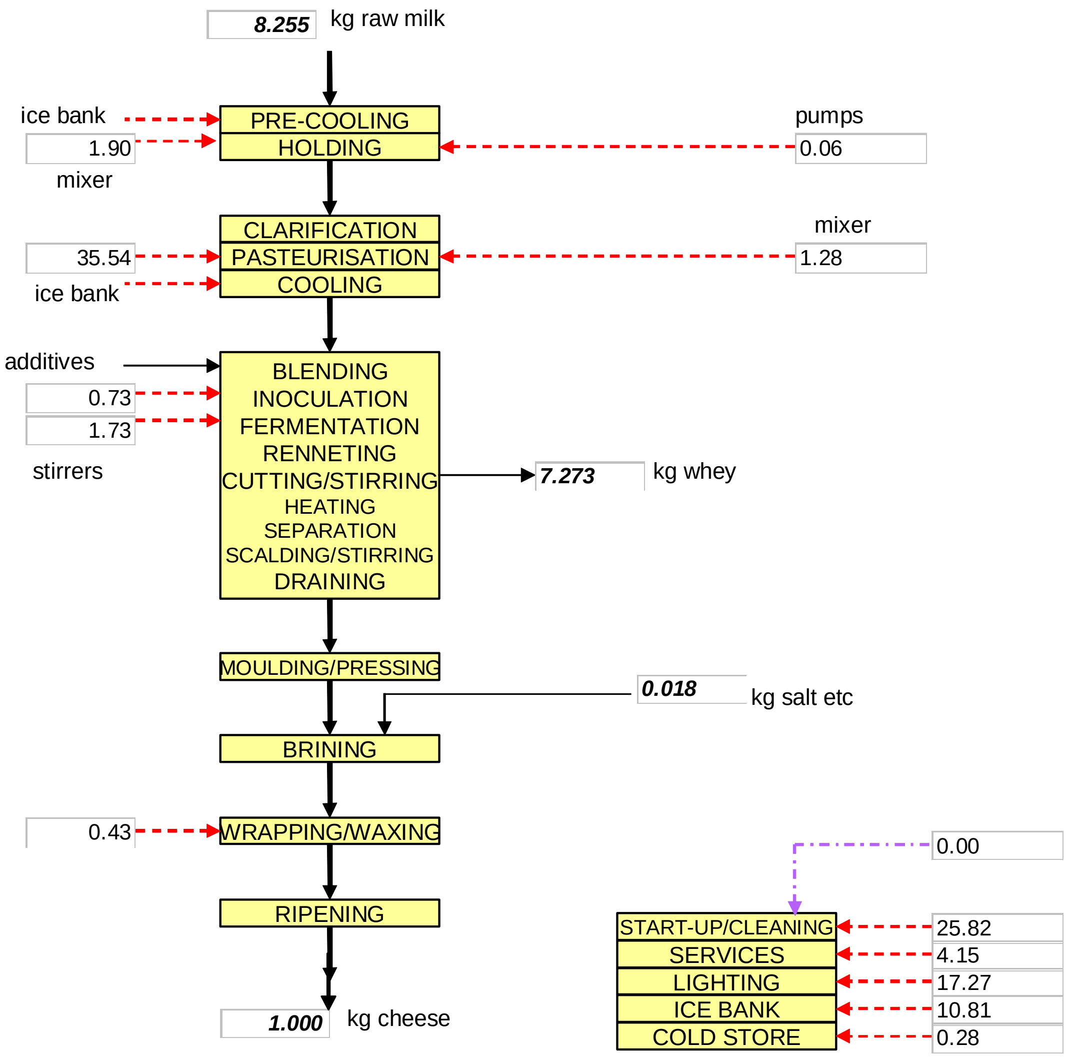
Energy per kg of final product (kJ)	
Electrical	921.48
Other	1618.21
Total	2539.69
Energy per kg of feed (kJ)	
Electrical	106.85
Other	187.64
Total	294.48
Installed Power (kW)	57.75



ENERGY DIAGRAM
PRODUCT: Gouda Cheese (1)
QUALIFIER: Medium Dairy (10000 l milk/day)
ASSUMPTIONS:
1. Milk is received cool (7 deg)
2. Cream is batch pasteurised and packed
3. Negligible Product losses
4. Composition: Dry matter 58%, Fat in total solids 54%, Salt 1.8%
5. Yield 1 kg cheese from 8.6 kg milk

ENERGY INPUTS IN % OF TOTAL REQUIREMENTS

Figure 3 Energy diagram for Gouda Cheese



Energy per kg of final product (kJ)	
Electrical	6681.09
Other	0.00
Total	6681.09
Energy per kg of feed (kJ)	
Electrical	809.33
Other	0.00
Total	809.33
Installed Power (kW)	104.89

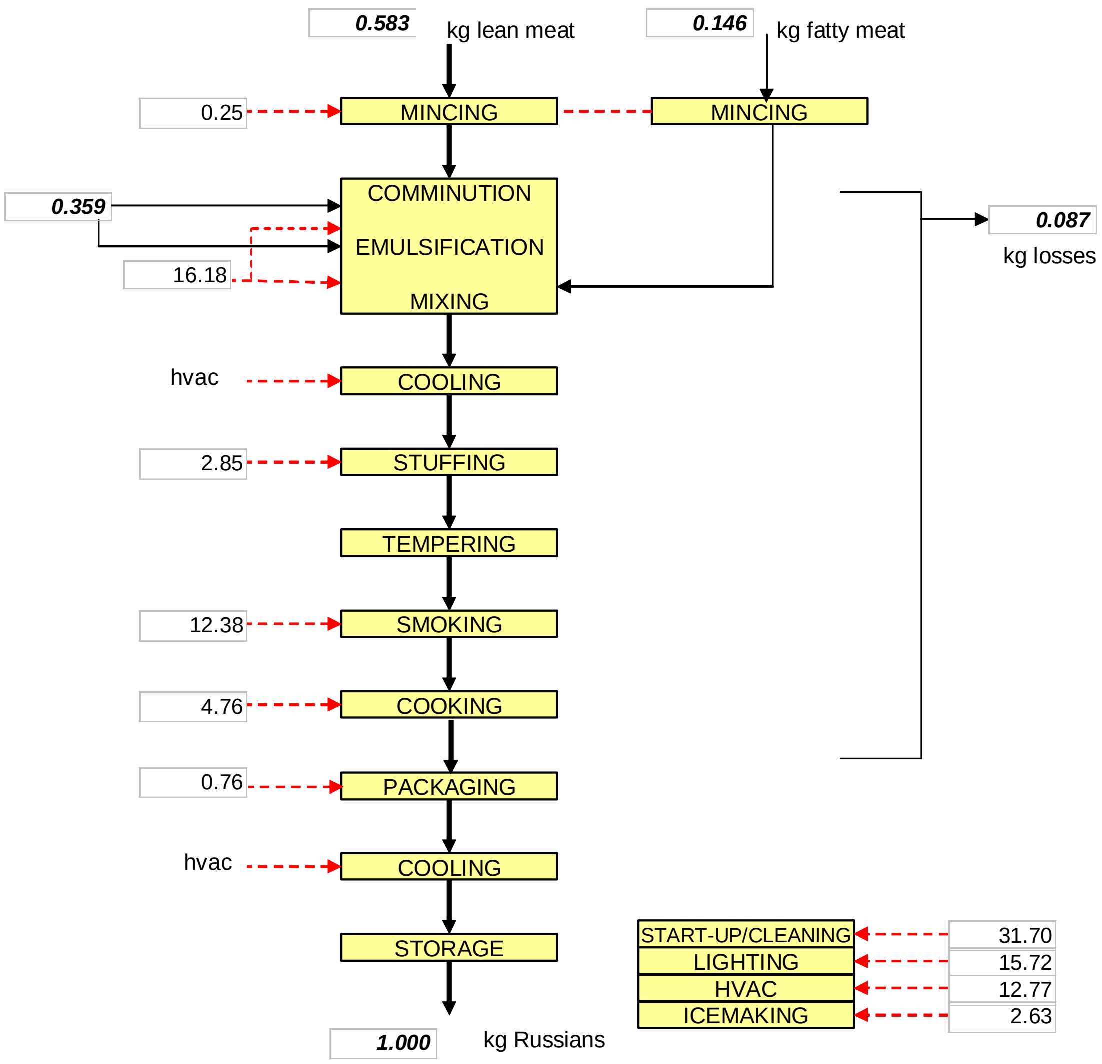
Main Product
By Product
Electricity
Heat from combustion

PRODUCT: Gouda Cheese (2)
QUALIFIER: Small Dairy (500 l batch)
ASSUMPTIONS:

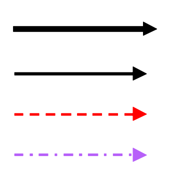
1. Milk is received from the parlour
2. Cream is not separated
3. Negligible Product losses
4. Composition: Dry matter 56% ;
   Fat in total solids 53.9 %, Salt 1.8%
5. Yield 1 kg cheese from 8.26 kg milk

ENERGY INPUTS IN % OF TOTAL REQUIREMENTS

Figure 4. Energy diagram for Gouda cheese – small scale



Energy per kg of final product (kJ)	
Electrical	1511.84
Other	0.00
Total	1511.84
Energy per kg of feed (kJ)	
Electrical	2594.94
Other	0.00
Total	2594.94
Installed Power (kW)	35.78



ENERGY DIAGRAM

PRODUCT: Russians (cooked sausages)
QUALIFIER: Small Factory (300 kg product per day)
ASSUMPTIONS:

1. 8% losses (mainly in smoking and cooking)
2. Sausage contains 67% meat, 33% water and other ingredients
3. Process cooling uses ice/ iced water as ingredients
4. Storage of raw meat included in HVAC (Heating ,Ventilation and Air Conditioning)

ENERGY INPUTS IN % OF TOTAL REQUIREMENTS

Figure 5 Energy Diagram for Russians (Cooked Sausages) could produce it. The European paste was believed to be subsidised.

Case 2. A South African Processing Facility

A plant was built by a local contractor in South Africa for a locally based but multinational company. The plant was intended to produce considerable volumes of a bottled product for local use and for export.

I was called in to analyse some problems when the operation had been running for less than 15 months.

We found it was necessary to replace:

- most of the process vessels - they were fabricated from the wrong grade of material and were not sanitary
- the pipe work and valves, because the material was not correctly chosen, had corroded
- the positive pumps which had been incorrectly specified
- the mixing equipment which was unsanitary, ineffective, and dangerous to personnel.

Further, the boiler, steam piping, cooling towers and air compressors were found to be inadequate for the design capacity and also had to be replaced. The electrical control gear was unsafe and the SCADA was too sophisticated for the process requirements.

Case 3. Mixing

Errors of this type are not limited to local contractors. A client of mine, whose process is heavily dependent on good batch blending, employed a large and well respected multinational equipment manufacturer and contractor for the design and installation of a new plant. The contractor chose to use pumps and static mixers for the batch blending operation. The result was 2 tank turn overs (tto) of mixing per hour where 17 tto is the requirement for mixing of the product in question. Blending in 20 minutes was required.

CONCLUSION - THE DOUBLE AGENDA

The SADC region desperately needs investment. I believe that food processing as a boost to agricultural production is an ideal vehicle for job creation. However, in order to do this, each project would require that:

- the infra-structure and logistics be addressed
- the agricultural component be addressed.
- training be included
- sanitary plant design be good and appropriate local equipment should be used particularly for the service areas. This is important in order to keep supply lines for spare parts short.
- private sector participation be included.

- local partnerships, probably in South Africa be investigated.
- environmental impact be properly assessed
- sustainability be assessed. This depends on all of the above being addressed.

If the second item of the agenda, the creation of an export based industry, is to met, then “appropriate” technology will not be synonymous with “small scale” technology. Cooperative arrangements at farm level may be necessary in order to boost volumes.

It is unlikely that many jobs will be created within a modern food processing plant. By addressing the agricultural logistics simultaneously, however, job creation on a meaningful scale should be possible.

Some of the constraints, opportunities, and results are indicated on Figure 6.

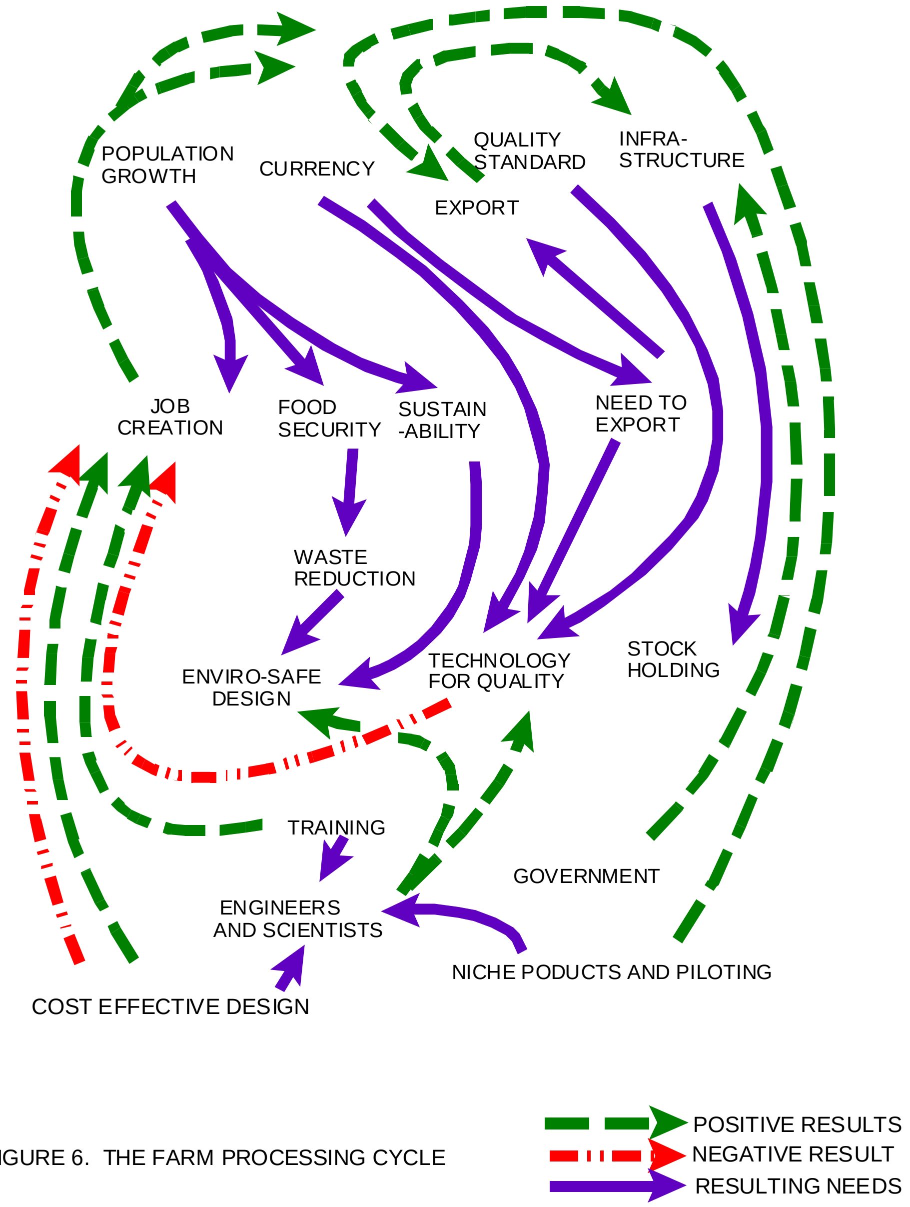


FIGURE 6. THE FARM PROCESSING CYCLE

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