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Assessment of Village Level Sugar Processing Technology in Tanzania

A. S. Chungu
C. Z. M. Kimambo
T. A. L. Bali

RESEARCH ON POVERTY ALLEVIATION

Research Report No. 01.4

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Abstract

The Institute of Production Innovation (IPI) and the Faculty of Engineering (FoE), both of the University of Dar es Salaam (UDSM) innovated a plant for processing crystalline sugar from sugarcane, at village level in the mid 1980s. Fourteen such plants, as of 1999, have already been manufactured by IPI, twelve were installed and among them some are operational in different parts of Tanzania. The plant installed in a typical Tanzanian village and operated efficiently, would fulfil the sugar demand of all villages within its neighbourhood and be able to use sugarcane grown within a 10km radius economically. Also the adopted process, scale and the developed unit operations make the equipment to be unique in Tanzania, as no other similar equipment at its capacity has been developed in Tanzania or imported to the country. The process operations for this equipment involve juice extraction by sugarcane crusher, concentrating the sugarcane juice by boiling it at atmospheric pressure, crystallising the obtained syrup and then separating the sugar crystals from the molasses by centrifuges. The sugar is finally sun dried. There have been operational and logistical problems for the existing plants, such as lack of agricultural extension service, poor management, inadequate infrastructural support, and low sugar productivity.

This research assessed the technical, social, economic and environmental impact of the installed sugar processing equipment in the surrounding villages and the country at large. It also studied the extent of the problem with respect to transferring the manufacture of the equipment to industry, for wider dissemination of the technology. Whenever appropriate, researchers provided on site advise to the key players in the technology. The research involved travelling to nine selected sites. Mara Estate, Dudumera Sukari Company, Hanang' and Magugu Estates inBabati district; Usa River in Arumeru district; Mwembe in Same district; Zombo and Yovi Estates in Kilosa district and Mungu Nisaidie Farm in Songea district, for an in depth study of the problems. This research lasted for two years, between June 1997 and June 1999 and was divided into two phases: Phase I started in June 1997 and was concluded in April 1998 with an Intermediate Report and Phase II started in July 1998 and ended in June 1999. A round of site visits was conducted for each of the two phases. This report covers both Phase I and II of the research project.

A review of literature shows that, for the open pan system, the operational parameters during the concentration process (pH, temperature and time) are the controlling factors for the rate of sugar recovery. Other scholars claim that the low sugar recovery in open pan system is caused by lack of an optimal design choice. These are two different theses and therefore called for further study to justify the correct hypotheses as well as to pave the way to the solution of the problems in the small-scale sugar industry. It has been found that poor management of the production processes has caused the low sugar recovery rates that were exhibited in some sugar processing sites. Indeed, the low level of endowment of orgaware and humanware has caused the poor

performance of the technology in the selected sites. Those sugar sites with high levels in orgaware and humanware have been able to sustain services to sugar consumers, sugarcane outgrowers as well as to their employees. The failure in achieving the expected linkages between the plant owners and sugarcane outgrowers is for the time being caused by the plants owners' inward looking behaviour and failure of the plant owners to manage relationships with the sugarcane outgrowers.

Dissemination of the research results has been through international conference, local seminars and workshops, which were organised at IPI and also by REPOA, local media articles, on site advice, and the ultimate publication of the findings of this research project.

Abbreviations

CEFE	Competency based Economies through Formation of Entrepreneurs
CFW	Common Facility Workshop
CRDB	Co-operative and Rural Development Bank
FoE	Faculty of Engineering
H	Humanware
I	Infoware
IPI	Institute of Production Innovation
IToT	International Training of Trainers
KRI	Kibaha Sugarcane Research Institute
KSCL	Kilombero Sugar Company Limited
KSL	Kagera Sugar Limited
MSE	Mtibwa Sugar Estates
NBC	National Bank of Commerce
NECO	National Engineering Company
O	Orgaware
OPS	Open Pan Sulphitation
PO	Plant Owner
R&D	Research and Development
REPOA	Research on Poverty Alleviation
ROI	Return on Investment
S/N	Serial Number
SIDO	Small Industries Development Organisation
SO	Sugarcane Outgrower
SUDECO	Sugar Development Corporation
T	Technoware
TATC	Tanzania Automobile Technology Centre
TBS	Tanzania Bureau of Standards
tcd	tonnes of canes per day
TCI	Technology Climate Index

TFI	Technology Fitness Index
TPC	Tanganyika Planting Company Limited
VAT	Value Added Tax
VC	Village Council
VETA	Vocational Education and Training Authority
VPS	Vacuum Pan Sulphitation

Definitions of Technical Terms

Bagasse	the remaining stalk after crushing sugarcane
Brix	a percentage of soluble solids in sugarcane juice, measured by refractometer
Humanware	people embodied form of technology (human abilities)
Infoware	document embodied form of technology (facts and records)
Inversion	decomposition of sugar into simple sugars i.e. fructose and dextrose
Jaggery	amber, coloured and soft solid mass obtained by concentrating sugarcane juice
Massecuite	the concentrated syrup in which sugar has been crystallised
Molasses	dark brown viscous liquid obtained after separating sugar crystals from massecuite
Orgaware	institution embodied form of technology (organizational arrangements)
pH	a measure of acidity or alkalinity (acid <7, neutral = 7, alkaline>7)
Recovery rate	weight of dry crystalline sugar expressed as a percentage of weight of sugarcane used in producing it
Sucrose	*apuredisaccharide,* C12H22O11, also saccharos
Syrup:	concentrated juice from eyaporators before crystallisation
Technology climate	environment in which technology based activities are taking place
Technoware:	object embodied form of technology (physical facilities)

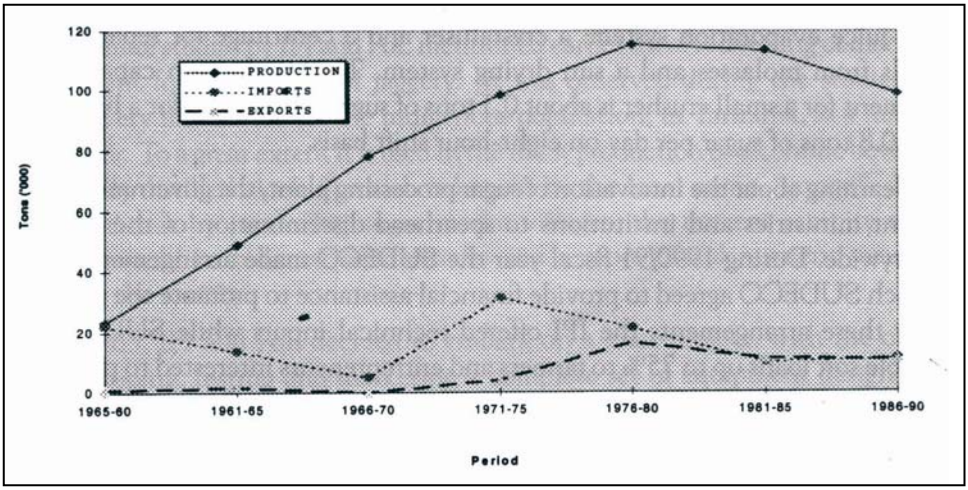
1.0 Introduction

1.1 Historical Background of the Sugar Industry in Tanzania

Since independence, Tanzania has been faced with chronic shortages of sugar for industrial and domestic use. As of 1997, the large sugar mills, namely, Mtibwa Sugar Estates Limited (MSE), Kilombero Sugar Company Limited (KSCL), Kagera Sugar Limited (KSL) and Tanganyika Planting Company Limited (TPC) had a combined installed capacity of 230,000 tons of sugar per annum. However, due to technical problems they produced only 110,000 tons as of 1998.

In 1985 the Sugar Development Corporation (SUDECO) conducted a detailed survey of the demand for sugar in Tanzania based on per capita demand of 14 kg. From a population of 22 million and a growth rate of 3.3%, the study projected that by the year 1990, sugar demand would rise to 360,000 tons. As explained above the average production of large mills was only 110,000 tons leaving an annual deficit of 250,000 tons. Figure 1 shows a 30-year trend of local production, imports and exports. The capacity utilisation of large mills in 1995/96 was recorded by SUDECO to be 61.7% (107,386 tons). This was far away from the required demand even of 1995, which was 409,600 tons.

Figure 1: Local Sugar Production, Imports and Exports



Source: The Netherlands Development Corporation, 1992

In Tanzania, as of 1997, the task of distributing sugar produced by large mills was mainly entrusted with the SUDECO, which purchased sugar and distributed it to regions according to allocation quotas fixed on the basis of population. Under that arrangement, sometimes sugar destined for some regions did not reach their targets due to various factors such as unreliable transport, poor roads, inadequate storage capacity and losses arising from spillage and pilferage. This resulted into a chronic scarcity of sugar in villages and small towns that are remotely located from main distribution points. Though currently, local importers also distribute sugar, there still exists sugar scarcity in the villages and towns that are remotely located from main towns.

Over the years several solutions have been sought to offset the sugar deficits. They include direct importation of sugar, installation of Open Pan Sulphitation sugar plants from India crushing 100-300 tons of cane per day (ted); and expansion and installation of large Vacuum Pan Sulphitation mills (1000-3000 ted). These solutions had limitations in practicability and extent of implementation. For instance, sugar importation was deemed too expensive thus serving only as a short-term measure.

In view of this situation, the Institute of Production Innovation (IPI) in collaboration with the Faculty of Engineering (FoE), both of the University of Dar es Salaam sought to get a practical solution to the problem. In 1984, IPI embarked on a Research and Development (R&.D) programme aimed at developing and testing a complete set of equipment for processing sugar at village level. The first prototype was successfully tested in July 1989 in Turiani village Morogoro Region. The main idea behind the innovation was to simplify complex industrial sugar equipment to get basic unit operations, and then devise a suitable process appropriate at the village or semi-urban areas. As shown on the Process and Instrumentation (P&.I) diagram in Appendix I, the complete set of equipment comprises of five units: a sugarcane crusher, settling tanks; juice evaporation system; a crystalliser and a centrifuge for separating sugar crystals from molasses and a sun drying system. The production capacity of the equipment for a small crusher is about 0.3 tons of sugar per day and for a big crusher is about 0.8 tons of sugar per day on eight-hour shift basis.

After learning about the innovation of sugar processing plant, the government directed relevant ministries and institutions to spearhead dissemination of the technology countrywide. During 1990/91 fiscal year the SUDECO made arrangements with IPI in which SUDECO agreed to provide financial assistance to promote the technology. Under these arrangements the IPI offered technical inputs while SUDECO made available soft loans up to 75% to farmers and entrepreneurs interested to purchase the equipment. So far out of the fourteen sets of the equipment which have been made, eight of them are supported by SUDECO, one by SIDO, one by SUDECO but managed by IPI, one by Peramiho Roman Catholic Mission and three by entrepreneurs from their own sources. Plants that were established with financial support from SUDECO are Mara Estate in Babati district, Usa River in Arumeru district, Mwembe in Same district, Kibaha Sugarcane Research Institute (KRI) in Kibaha district, Muhoro in Rufiji district, Lumuma in Mpwapwa district, Liuli in Mbinga district, and Kiabakari in Musoma district. In 1991, the IPI conducted a survey of potential sites for installation of the sugar processing equipment [1] in which a total of 134 sites were identified. Many of these sites are yet to be supplied with the sugar processing equipment.

1.2 Rationale and Objective for Development of IPI Sugar Processing Technology

The technology to produce crystalline sugar from sugarcane is known to have existed for many years. In Tanzania most of the sugar consumed has been produced in large-scale factories utilising the Vacuum Pan (VP) Systems. Prior to the introduction of small-scale sugar processing plants, the other uses of sugarcane in industrial scale were in relation to production of refined sugar substitutes such as brown sugar and jaggery. As the traditional sugar production factories (large-scale plants) failed to keep up with population growth, other means had to be looked for, to fill in the sugar supply gap. Apart from the short-term and expensive option of importing refined sugar, imported small scale sugar processing plants based on open pan sulphitation (OPS) technique were deployed, but with very poor and limited success[1].

In the early 1970s, jaggery became popular in Tanzania as white refined sugar became scarce and expensive. In separate studies conducted by IPI [2] and Faculty of Engineering [3], it was observed that some of the plants that had flourishing jaggery production units dating back to the 19th century were decimated. Efforts to revamp the jaggery production proved to be difficult due to the poor condition and lack of locally available equipment. In general, many of the fairly large farms possessed crushing and processing plants of medium to large size. There was very little by the way of smaller plants available to villagers for processing of smaller amounts of sugar into jaggery.

The two separate studies by IPI and FoE mentioned earlier involved testing of machines and equipment for production of jaggery. It was observed during the studies that jaggery had very limited use for the indigenous population, in Tanzania, as a nutrient and sweetener. To a great extent it is used in die illicit production of alcoholic beverages such as locally distilled alcohol, which is known by the local name, "gongo". It was also thought that by producing sugar in the villages, the current scarcity of the commodity would be reduced substantially and a more useful nutrient would be presented to the society.

Hence in 1985, IPI and FoE decided to embark on a joint project, with the overall aim of developing, testing and marketing a complete set of equipment designed for village level production of crystalline sugar from sugarcane. The study was divided into two phases. Phase I dealt with the establishment and assessment of a viable processes and prototype machinery to produce crystalline sugar. Phase II focused on the introduction and dissemination of the village level sugar production units in Tanzania.

The specific objectives of the study [4] were as follows:

1. To experiment and ultimately establish a viable process for small-scale sugar production.
2. To prove the suitability and reliability of locally developed prototype machinery in performing the duties they were designed for.
3. To conduct field-testing and to obtain in-service data and information necessary to devise technical improvements in subsequent prototypes and processes.
4. To incorporate modification redesign and produce improved version of complete prototype/zero series production sets of equipment for village level production of crystal sugar.
5. To identify, assess and select viable village sites for the installation and subsequent commissioning of sugar production prototype. Final field tests and training of the village operatives were included at this stage.
6. To identify potential manufacturers of commercial equipment and dissemination of village level sugar production units in Tanzania.

Phase I of this project [4] addressed the activities undertaken in fulfilment of the first two objectives. A set of locally designed and manufactured prototype equipment for production of crystalline sugar at village level was successfully developed and tested at various sites namely Turiani and Zombo in Morogoro region, in Tanzania. The prototype equipment comprises of a sugarcane crusher, boiling pan systems, crystallising unit, and a centrifuge. The system involves an open pan processing technique. Testing results focused on the design, manufacture and performance of the equipment and processes. Subsequent improvement of the equipment was also addressed based on the test results.

Phase II of the project focused on specific objectives 4, 5 and 6. The current research project, which is financed by REPOA, is an additional input to supplement the efforts of IPI who have been the key player in the project. Furthermore, the objectives of the REPOA research project fitted in very well within the broad objectives of Phase II of the IPI project.

1.3 Research Problem

In the rural and semi-urban areas, where there are no large capacity sugar producing plants, sugarcane is mainly used for chewing or making local brew. At the same time, people living in these areas are in need of crystalline sugar as a sweetener, but the sugar is not easily accessible or affordable. This was one of the motivating factors for IPI to develop a technology, which can produce crystalline sugar at the village level. The technology also creates employment opportunities within the village. IPI has already installed twelve sugar-processing plants in different villages in five regions of Tanzania. Before this research project was conducted, the performance of the sugar processing plants had not been scientifically and/or systematically assessed. This research thus studied the performance and impact of the technology on its surroundings and investigated the contribution and impact of technology in alleviating poverty.

1.4 Research Objectives

The overall objective of the research was to assess the technical performance and socio-economic impact of the IPI sugar processing technology in selected regions in Tanzania. The study therefore focused on the dynamics around the sugar processing technology related to the operational attributes of the owner, employees, surrounding sugarcane farmers and communities, and other support services. The specific activities of the research work were as follows:

(i) To study the extent of the problems the sugar processing plants are facing and whenever appropriate to provide on-site advise i.e. action-oriented research.

(ii) To determine factors which affect the utilisation of the sugar processing technology in the selected villages in the country.

(iii) To evaluate the suitability of the sugar processing technology in the respective villages in terms of techno-socio-economic aspects as well as environmental

(iv) To identify constraints which limit dissemination of the sugar processing technology.

(v) To chart-out strategies for dissemination of the sugar processing technology in the country.

(vi) To assess the impact of the sugar processing technology on environment.

(vii) To establish, the average sugar consumption in the selected villages, which surround the village-level sugar processing plants.

1.5 Hypotheses

The following were the hypotheses for this study:

i. Introduction of the sugar processing plants has stimulated expansion of sugarcane cultivation by surrounding subsistence farmers.

ii. The low sugar recovery rate of the IPI plants is largely contributed by the operational factors in the production process.

iii. Smooth operation of the sugar plants (technically fewer failures, economically profitable and socially beneficial) induces manufacturing of the equipment and adoption of the technology by the entrepreneurs nation wide.

iv. Ownership, management and operation of the IPI sugar processing technology at village level has redressed traditional gender bias in the field of technology since both men and women have equal access.

v. The existence of the processing plants at village level has alleviated poverty and increased income among the villagers - plant owners, individual sugarcane outgrowers and plant workers.

vi. The relative fitness of the humanware, orgaware and climate of the users of the technology determine the appropriateness of the sugar processing technology in the rural set-up.

The schematic causal relationship of the hypotheses with respect to the technology is indicated in Figure 2.

1.6 Research Methodology and Techniques

The research work was conducted by participatory method using focused groups, key informants, individual interviews, as well as observation by researchers. Data collection covered technical, social, economical and environmental impact made by the installed equipment. Participants in the research included owners of the sugar processing plants, sugarcane farmers (including outgrowers), employees in the sugar plant (operators), and the surrounding communities. Action oriented research was adopted so as to feed solutions to the problems relevant to the participating research partners. Sites for carrying out the study were identified as those in Arusha (5), Kilimanjaro (1), Ruvuma (1) and Morogoro (2) regions, making a sample size of nine out of the thirteen sites that have already been supplied with the IPI plants. These fall into two main categories, namely those ones supplied with sugarcane from outgrowers and those utilising sugarcane from their own farms. It was expected that the socio-economic characteristics of the two categories would be different.

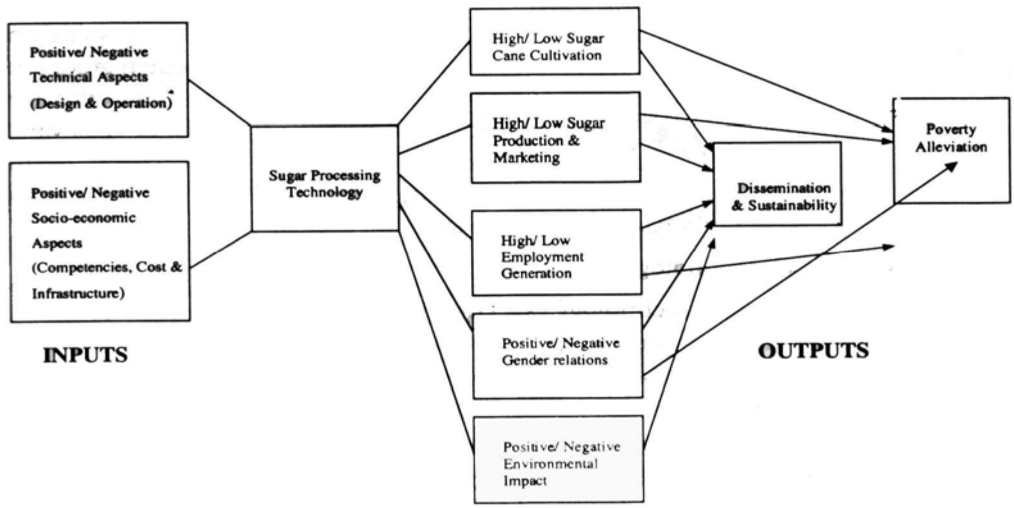
The basic information required for the study was collected as per sample questionnaire (Appendix IV for Plant Owners). Separate questionnaires were also prepared for surrounding village governments, sugarcane outgrowers, sugar consumers, and supporting mechanical workshops. Secondary data was collected from other organisations involved with the technology such as IPI, SUDECO, SIDO, relevant regional and district government offices etc. The data collection was done mostly during crushing season, which usually takes 110-150 days (4-5 months) a year, starting from the month of June or July. A two-year research was required for comprehensive data collection and analysis and also to investigate the dynamics of the sugar industry in Tanzania and the village level sugar processing plants in particular.

Data collected was analysed qualitatively as well as quantitatively by computer coding using Microsoft Excel programmes. Descriptive statistics, mainly the frequency distribution was used to analyse the level of impact made by the installed equipment. Conferences, seminars and workshops were utilised to discuss and evaluate the existing problems facing the sugar industry. Participants in those included key players in the sugar industry and technology in general. These include international experts and officials from government ministries (Industries and Trade, Agriculture, Planning

Commission, Research Institutions and Finance), and the private sector (potential entrepreneurs and traders).

The framework for technological appropriateness in rural development in Tanzania

Figure 2: Conceptual Framework for Research Hypotheses



developed by Chungu [7] was used to analyse the suitability of sugar technology in the mpective sites. The Technology Fitness Method [7, 8] and Analytical Hierarchy lethod [7, 9] were adopted in analysing the appropriateness of the technology in **each** sugar site. The Business Model [10] was also used to determine the business viability of each site.

The socio-economic impact assessment usually focuses on problems, conflicts and canstraints on livelihoods and natural resources. In many of the social impact studies, there is a tendency to either ignore or over look historical contexts or cultural factors especially those unintended consequences of projects like the sugar processing «hnology. This study has tried to avoid such pitfalls by involving the interested parties (plant owners, the individual outgrowers and the sugar consumers) in focus group discussions and key informant interviews. Historical and cultural aspects within i»e socio-economic context have been studied.

2.0 Literature Review

It has been pointed out that the utilisation of technology to enhance socio-economic activities in societies has'been a disappointment in most cases. A major cause of failure has been the lack of a coherent conceptual framework for technology development and promotion [7]. The problem of "fitting" technology with needs of society and thereafter providing for effective utilisation is the centre of issues of technology appropriateness in many developing countries. The term appropriate technology has been discussed extensively and clarified [8], [11] and [12]'. In Tanzania, the issues of technology acceptability by the user of the technology have been documented [7] with respect to oil processing technology. The choice of technology with regard to the milling industry in Tanzania was also studied [13]. A study on small scale edible oil processing technology owned and managed by women groups in the Iringa region of Tanzania [7], found the main factors affecting the effective utilisation of technology in a particular setting to be the attributes of orgaware, humanware, and technology climate. This was the case when the level of development of the technoware had reached optimal functioning level. A definition of the term "technology" for a common base understanding is thus crucial.

2.1 Definition of Technological Terms

Many literature categorise technology as a combination of hardware (i.e. machines, equipment, todls, materials, etc.,) and software (i.e. know-how,-skills, experience, information, management, etc.,). However, it was later found useful [14, 15] to view technology in a disaggregated form as comprising four interrelated components, which take the following attributes:

- *Object'embodiedform or "technoware"* - tools, capital goods, intermediary goods, products, physical equipment, machinery, physical processes, etc.;
- *People-embodied form or "humanware"* - understanding, capacity for systematic application of knowledge, know how, human capability, human labour, specialised ideas, skills, problem solving capacity, etc.;
- *Document-embodied form or "infoware"* - knowledge about physical relationships, scientific and/or other forms of organised knowledge, principles of physical and social phenomena, technical information, specifications, standards, computer software, etc.;
- *Institution-embodied form or "orgaware"* - organisational work assignment, day-to-day operations of production, social arrangements, means for using and controlling factors of production, organisation of raw materials, processes, tools, products and devices for use by people.

It was argued that technology does not operate in a vacuum, but within an "operational" environment, which is called the technology climate. Technology climate of a country was defined as the national setting in which technology-based activities are carried out. The climate includes factors such as physical infrastructure; support facilities such as repair services, maintenance and other technological extension service; setting-up of the R&.D institutions; and" political systems at various administrative levels for regulatory, property rights, etc. The two terms, climate and environment will be used interchangeably in this study. This broader definition of technology will be adopted for this study so that technology is not treated as a "black box"

2.2 Processing of Sugar and Project Viability

It is claimed that the IPI crystalline sugar processing equipment is simple, easy to operate and investors can easily afford it because it is relatively cheap. Test results conducted have identified its performance capacity and labour requirement. One set of the equipment using a small crusher has a capacity of handling 15 tonnes of sugarcane on a three-shift basis (24 hours) or 5 tonnes of sugarcane in one shift (8 hours). One unit can produce 33 tonnes of sugar and 20 tonnes of molasses in 110 days (one crushing season) on one-shift basis. The equipment with a big crusher can handle about 16 tonnes of sugarcane in one shift, providing 88 tonnes of sugar per 110 days (one crushing season). The description of the IPI equipment and processes is appended (Appendix II).

Several areas suitable for sugarcane cultivation exist in Tanzania. IPI conducted a survey in 1991[1] of potential sites in which a total of 134 sites in Iringa, Morogoro, Tanga, Arusha, Kilimanjaro, Ruvuma, Rukwa, Mwanza, Mtwara and Coast regions were identified. Many of these sites (apart from the 14 whose equipment have already been made) are yet to be supplied with the sugar processing equipment. It was projected [5] that about 2000 small sugar plants will meet 50% of national sugar demands in the year 2000, a factor not new considering that over 8000 small sugar-processing plants had been installed in India alone by the end of the 1970's [6]. These plants are installed in small sugarcane pockets where large capacity mills are not viable.

The Co-operative and Rural Development Bank (CRDB) [16] undertook an independent study to assess the economic viability of the IPI sugar processing technology as well as getting data for persuading more entrepreneurs to buy the sugar processing equipment. At the time (1990), the technology was found to have a benefit-cost ratio of 1.3 and internal rate of return of 53.9% when the cost of capital was at 31%. To date, fourteen plants have been manufactured for different villages and no socio-economic analysis at field conditions (at entrepreneur's sites) had been done. The adoption of the IPI sugar technology is relatively low (14 out 134 potential sites [1] in eight years). The equipment is still being manufactured by IPI itself, which by now, should have been transferred to a local manufacturing industry for wider dissemination. The factors that hinder the rate of diffusion of the sugar technology in the country are not yet known and documented. It is not yet established whether the factors found in a study of the oil processing technology [7] which are reported to be technology specific, are applicable to the sugar processing technology. Furthermore, the study did not cover factors affecting manufacturers of a commercialised R&D result.

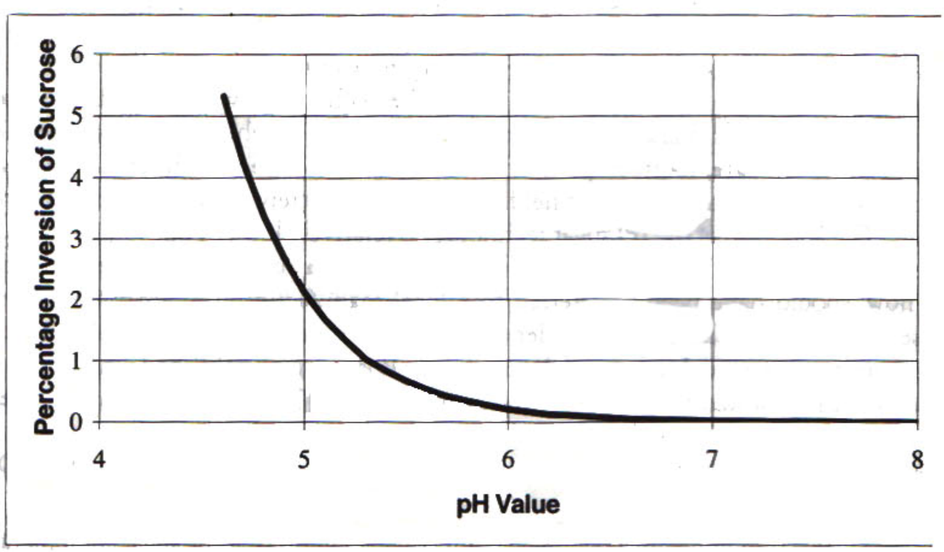
Elisante (1994) arguing from a technical point of view, claims that the sugar equipment developed by IPI is not an optimum design because it has low sugar recovery (4% to

5%) since it uses an Open Pan System (OPS)[2]. A recommended recovery rate by IPI for the plants [17, 18] is 5% to 6%. Based on this data, the low sugar recovery seems not to be a design fault but an operational problem. However, mini sugar plants imported from India with capacity between 100 to 300 ted also using OPS but with sulphitation process gives a sugar recovery of 6% to 7%, while the big mills (more than 1000 ted) employing vacuum pan technology ranges from 8% to 10% [17, 18].

The choice of OPS was by design and as both OPS and vacuum Pan System (VPS)[3] techniques were known to IPI at the time of design. It was then argued [19] that the low recovery of sugar makes the IPI sugar equipment less attractive economically and consequently discouraging would be entrepreneurs from buying the equipment as they are denied an increased income because of less value added to the product (sugarcane), easy access to crystalline sugar and employment generation. This has affected the adoption of the sugar processing technology and deserve to be studied further together with other economic viability factors i.e. input-output relationships and demand for the product (price).

The problem of low sugar productivity has two theses. One thesis is that the equipment has a design fault and factors to this effect have to be established by the designers at the IPI. The other is that the design is optimal but the production operations are not followed as recommended by the IPI. The latter thesis is supported by Dever Research

Figure 3: Percentage of Sucrose Inverted per Hour at 100 °CR at Different pH Values



Source: Chen (1985)

Institute [20], which argues that low sugar recovery is an inherent bottleneck in OPS caused by sucrose losses that occur due to boiling sugarcane juice for long duration at elevated temperatures. Sucrose (saccharose, cane sugar, and beet sugar) is a carbohydrate of the formula $C_{12}H_{22}O_n$. It is a disaccharide consisting of two monosaccharidic components (glucose and fructose) that are condensed at their glycosidic groups.

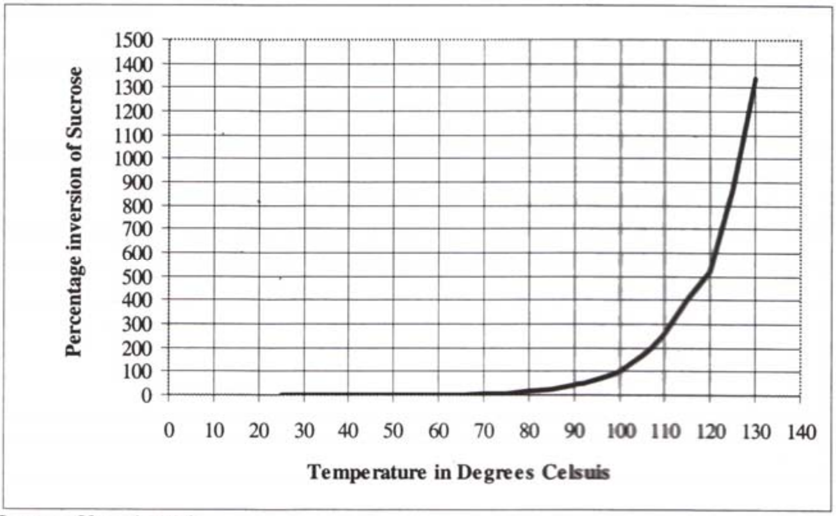
Commercial refined sugar contains about 99.99% of sucrose [21]. It is obtained by producing juice from sugarcane or sugar beet roots, purification of this juice by chemical and physical means, evaporation of the water, and separation of the sugar crystals. The sugarcane juice when clarified has 18-20 brix and this has to be raised to 85-90 brix for sugar crystals to be formed. A very large amount of water is therefore removed in the evaporation process. During the evaporation process the sugar undergoes decomposition by inversion. Inversion is a process in which sugar (sucrose) is hydrolysed into its simple components sugars glucose and dextrose [22]. The reaction for the inversion process is as shown in the equation that follows:

C12H22O11	+	H2O	®	C6H12O6	+	C6H1206
Sucrose		water		glucose		dextrose

There are three factors, which directly affect and increase the rate of inversion of the sugar during juice boiling [23]: the acidity of the juice (pH), temperature used for boiling and duration of boiling. Sugarcane juice is naturally acidic with pH of 5.2-5.6. The inversion loss is accelerated if the juice is boiled in acidic condition as indicated in Figure 3 [23, 24]. However, during clarification of the juice, lime is added. Lime addition raises the pH of the juice to 6.5-7.0 i.e. neutralised. The neutral juices do not accelerate inversion rate during boiling. In open pan sugar technology developed by IPI, the clarified juice sent for boiling are near or about neutral and there is almost no extra loss due to this factor i.e. the pH. As for the temperature, the inversion effect is very minor at low temperatures about 60-70°C, whereas inversion increases rapidly when the temperature is above 100°C. Figure 4 shows the relationship between inversion rate and temperature. The figure has been prepared, taking the rate of inversion at 100°C as 100 [23, 24]. Sugarcane juice starts boiling at 100.5°C. As the water evaporates and juice is concentrated the temperature of boiling rises and at 85-90 brix, the boiling temperature rises to about 110-112 °C.

Since inversion rate increases with increasing temperature, *a* substantial amount of sugar is lost due to the inversion. This loss is saved in large-scale technology by boiling the juice in vacuum. The boiling temperature of water drops from 100 °C to a lower temperature depending on the magnitude of vacuum applied. Typical value shows that sufficient vacuum is applied so that the boiling takes place at 60-70 °C and keeps the inversion loss to a minimum. This is not the case in open pan boiling

Figure 4: Relationship Between Inversion Rate and Temperature



Source: Chen (1985)

where the juice is boiled at atmospheric pressure and therefore inversion cannot be reduced. That is to say that inversion loss is inherent in open pan boiling. Since this is the technology, which is used in all IPI sites, managing the three factors (pH, temperature, and duration of boiling) that directly affect and increase the rate of inversion of the sugar during juice boiling would be inevitable.

3.0 Analysis of Research Finding and Hypotheses Verification

3.1 Hypothesis. No. 1: Sugarcane Outgrowers

[Introduction of the sugar processing plants has stimulated expansion of sugarcane cultivation by surrounding subsistence farmers]

The IPI village level crystalline sugar processing equipment was developed with intention that it would be applicable to a typical Tanzanian village but was not expected to be owned and run by subsistence farmers in the villages due to high investment costs of acquiring the plants. The possible option for subsistence farmers would be for them to organise themselves as a co-operative group, or committed individuals and seek loans to acquire the technology. Past experiences in Tanzania, have proved that most co-operative projects do not succeed. But it was assumed that the plants would benefit the surrounding subsistence farmers (outgrowers) by providing them with market for their sugarcane. This is in addition to providing a more affordable source of sugar and molasses in the village and employment generation.

The assumption that the plants would stimulate expansion of sugarcane cultivation by surrounding subsistence farmers was difficult to prove in certain locations because most of the entrepreneurs who acquired the sugar processing plants have their own sugarcane farms, which are sufficient to meet the requirements of the processing plants. The sugarcane production capacity by plant owners is as summarised in Table la. Table Ib summarises the sugarcane production capacity by surrounding villages. Out of the nine sites covered in this study, only three used sugarcane which was supplied by outgrowers. The three plants that have not yet started processing sugar, namely Hanang, Magugu and Usa River, all have sugarcane farms which are big enough to meet all the requirements of the sugar processing plant. However, there is some potential for outgrower to supply the Usa River plant if it became operational. This is because sugarcane growing at the farm has stopped and the farm is presently being used for other crops. There is doubt that the plant owner would be willing or capable of organising cultivation of sufficient sugarcane to cope with the capacity of the plant.

With exception of the sugar processing plants in the Kiru valley in Babati district and Yovi Estates who entirely depend on the supply of the sugarcane from own farms, the remaining sites had some dependency on the supply of sugarcane from outgrowers. The Mwembe site in Same district is the one which solely depend on outgrowers (Table la&b). Others such as Zombo in Kilosa district and Mungu Nisaidie Farm in Songea to some extent depend on outgrowers. Therefore, only three sites namely Mwembe, Zombo and Mungu Nisaidie Farm..have demonstrated interactions with communities with regards *to* cane supply. An investigation of sugarcane production and supply would be interesting but requires longer period of research - 3 or more years. In addition, even the Ministry of Agriculture and Food Security does not have any data regarding the production and use of sugarcane from small and medium scale farmers in Tanzania.

Table **la: Annual Sugarcane Production by Plant Owners**

S/N Site	District	Acreage		Production (tons) - Estimated	
		Total	Cultivated	Yield per Acre	Total
1 Mara	Babati	1,763.0	150.0	35.0	5,250.0
2 Dudumera	Babati	1,00.0.0	300.0	35.0	10,500.0
3 Hanang	Babati				
4 Magugu 5	Babati	-	'		
Usa River	Arumeru				
6 Mwembe	Same	3.0	1.0	23.3	23.3
7 Zombo	Kilosa	20.0	15.0	12.0	180.0
8 Yovi	Kilosa	2,780.0	600.0	16.0	9,600.0
9 Mungu Nisaidie	Songea	200.0	100.0	22.5	2,250.0

Table Ib: Sugarcane Production by Surrounding Villages

S/N	Site	District	Village	Outgrowers			Sugarcane Production	
				Inter-viewed	Total	Acreage	Yield [tons/acre]	Total Yield [tons]
1	Mara	Babati	Kiru Dick	4	15	0	-	-
2	Dudumera	Babati	Kiru Ndogo	4	10	0	-	-
			Kiru Six	4	20	12.5	35.0	437.5
3	Hanang	Babati	-	-	-	-	"	-
4	Magugu	Babati	-	-	-	-	-	-
5	Usa River	Arumeru	-	-	-	-	-	-
6	Mwembe	Same	Bangalala	11	200	125.0	14.0	1,750.0
			Mteke	4	300	600.0	25.0	15,000.0
			Mtunguja	6	165	165.0	27.5	4,537.5
			Mwembe	10	450	200.0	15.0	3,000.0
			Ruvu Mferejini	4	60	150.0	35.0	5,250.0
7	Zombo	Kilosa	Nyali	4	10	2.5	12.0	30.0
			Zombo Lumbo	4	10	1.5	18.0	27.0
8	Yovi	Kilosa	Kisanga	2	10	7.5	16.0	120.0
			Msolwa	2	20	0.5	23.0	11.5
9	Mungu	Songea	Liganga	14	50	3.75	10.0	37.5
	Nisaidie		Litisha	4	10	15.0	25.0	375.0
			Lugagara	4	10	10.0	25.0	250.0
			Nakahuga	3	8	4.0	30.0	120.0

The sites that depend on the supply of sugarcane from outgrowers have not performed satisfactory in business terms. The poor performance of the technology has also affected the relationship with outgrowers whose livelihood depended on supplying canes to the sugar plants. The advantage for the outgrowers compared to other competitors (chewing and local brewing), was receiving total cash immediately after selling the canes. Therefore with the improvement in the orgaware, humanware and infoware components of the plant owners enabled the outgrowers to benefit from their produce.

All the villages that feed the plant at Mwembe namely Bangalala, Mwembe,Mtunguja, Mteke and Ruvu Mferejini were visited also during both phases of the research. The visit made in 1997 stimulated villagers to increase sugarcane growing. However, the plant owner could not buy the sugarcane due to lack of reliable transport facility resulting in sugarcane being sold in retail and some being spoilt in the farms. There was an increased yield of sugarcane as a result of the El Nino rains, which the local brew (dengelua) market could not cope with. Moreover, people who buy sugarcane for production of "dengelua" do not pay the farmers promptly. There is still a big potential for growing of sugarcane as a cash crop in the area, 'especially in the low lands, where the other cash crops such a coffee do not grow. Although no concrete data was provided, the farmers claim that the processing plant has stimulated the production of sugarcane in the area which is in plenty with villagers pushing the plant owners to buy their sugarcane and start production of sugar.

During the first visit to the Mungu Nisaidie Farm, the processing plant was using sugarcane from some outgrowers in surrounding villages. However, relationship between the villagers and the plant owner was not good, mainly because of personality problems. During the second visit it was observed that the sugar processing plant did not have many links with surrounding villagers as far as supply of sugarcane is concerned. There were only two sugarcane outgrowers for the plant, one in Nakahuga village (1 acre) and the other in Lipokela village (1/2 acre).

The processing plant at Zombo was buying sugarcane from surrounding villagers because the farm owned by the plant owner could not meet the requirement of the plant. However, the full potential for buying sugarcane from outgrowers was not realised because the plant was not operating effectively. By the time of the second visit to the site, the sugar processing plant had been moved from its original location to a hew location at Miyombo Estate due to family dispute over inheritance of family properties. The processing plant machinery was moved in March 1998. The plant owner has rented 50 acres of sugarcane farm, of which 15 acres were already planted and the rest were awaiting rains before being planted and' another sugarcane farm of 200 acres next to the farm, which the plant owner has also rented. The two farms had a jaggery plant installed hut no longer operational. With such large farms surrounding the plant the potential for outgrowers benefiting from the processing plant is marginalised.

The potential for realising stimulation of sugarcane growing by subsistence farmers surrounding the IPI processing plants has been minimal because farmers who had big enough sugarcane farms to meet the capacity of the plants acquired the sugar processing plants. The few cases where there was potential for outgrowers to supply sugarcane to the processing plants and to expand the farms have not been fully utilised.

After Phase I of the research, some of the problems that caused poor performance of the sugar processing plant at Mungu Nisaidie Farm and Mwembe were solved. The problems were non-optimal use of the sugar cane crusher and unavailability of a transport facility respectively. Despite solution of the problems, the Mungu Nisadie Farm owner has expanded his own farm and stopped using outgrowers' sugarcane. Mwembe plant is still using outgrowers' sugarcane but there are still complaints and dissatisfaction among the outgrowers regarding their relation with the processing plant. The Mwembe site thus supports the hypothesis that the introduction of the sugar processing plants has stimulated expansion of sugarcane cultivation by surrounding subsistence farmers. The failure in achieving the expected linkages between the plant owners and sugarcane outgrowers is caused by two factors. One, the plant owners' inward looking behaviour, which makes them wanting to be independent of sugarcane outgrower, by expanding their own farms to meet the requirement of the processing plants and two, applicable to Mwembe, Zombo and Mungu Nisaidie, is the failure of the plant owners to manage/handle the sugarcane outgrowers because of their low levels of orgaware and humanware.

3.2 Hypothesis No. 2: Sugar Recovery Rate

[The low sugar recovery rate of the IPI plants is largely contributed by the operational factors in the production process]

The sugar recovery for the IPI sugar production plants is 5 - 6% compared to the 7 -7.5% obtained for the OPS systems and 8.2 - 9.4% for the Tanzanian VP plants. This research has revealed that many factors contribute to poor sugar recovery in the IPI plants. They include the following:

(a) Poor quality and type of sugarcane was observed at Zombo and Mungu Nisaidie sites.

(b) Improper handling of sugarcane at Zombo and Mungu Nisaidie sites, particularly after harvest and before crushing (in some cases canes were left for days before collection from the farm and actual crushing).

(c) Poor crushing efficiency due to too old and/or faulty crushers (some of the crushers being used are not made by IPI and are too old, such as the one at Zombo site).

(d) Uncontrolled neutralisation/clarification process. There is a possibility that acidic juice was being used (no site visited had acidity test being applied to ensure that neutral state has been reached).

(e) Big inversion losses in the boiling process due to the use of untrained and inexperienced personnel; and lack of the relevant measuring instrument (brixmeter). This occurred at Zombo, Mungu Nisaidie, Mwembe and Dudumera sites

(f) Poor crystallisation process. This is caused by improper operation of the process. In some cases the process was not continuous and the duration of the crystallisation process in all the sites was far less (16 hours) than the one of 1 to 3 days, which was recommended by IPI.

(g) The crystal sizes achieved were in most cases very small which means a lot of small crystals are being thrown away in the molasses, a loss which could be minimised by using a finer mesh screen and increasing crystallisation period. This occurred at all sites that were operational.

(h) Harvesting sugarcane at the wrong time (rainy season or before or after the sugarcane is mature), which implies a low sugar concentration. In some of the sites visited, the processing takes place throughout for 7 to 10 months. It is therefore expected that the sugar recovery would be low during the rainy season. This was observed at Mungu Nisaidie and Mara Estate sites.

All these factors reflect poor management of the production processes. It should be noted here that during trial sugar production using the IPI equipment [4], a recovery rate of up to 5 - 6% was achieved. The sugar recovery rate as exhibited by Mara Estates is 3.8%, Dudumera is 4.6, Mwembe is 3.0%, Mungu Nisaidie is 5%, Zombo is 3.3%, and Yovi is 3.9%. The argument that the low recovery rates are due to the use of OPS would only be true when referring to the recovery rates of 8 - 9.4% of VPS, which the technology was not designed for. If the low sugar recovery was caused by technical factors it would have not been possible for Mungu Nisaidie and Dudumera plants to reach the recommended sugar recovery rates. This research has therefore supported the hypothesis that the low sugar recovery of IPI sugar-processing plants is largely contributed by operational factors in the production process including inadequate training and failure to retain those trained operators on the part of the plant owners.

3.3 Hypothesis No. 3: Technology Transfer and Dissemination

[Smooth *operation of the sugar plants (technically fewer failures, economically being profitable and socially beneficial) induces manufacturing of the equipment and adoption of the* technology *by the entrepreneurs nation wide]*

3.3.1 Technology Maturity

During the surveys, many technical problems related to design and manufacturing of the IPI technology were observed. The problems involve almost all the pieces of equipment, including the crusher, settling tanks, juice pump, evaporators, crystalliser, centrifuge and the washing pump. The summaries of main technical problems, which result in frequent failure of the equipment, are shown in Appendix V.

Inadequacies in the existing pieces of equipment, such as lack of in-built safety protections including belt and gear guards were common features of the IPI equipment. Some accidents particularly at the Mara site had happened because of lack of guards on the equipment. Poor layout of the plants was found to be another problem in their operation. In some of the sites, boiling massecuite is carried in buckets for long distances to the crystalliser. It was reported that a serious burning accident occurred at the Zombo site as a result of this situation.

With the exception of Yovi Estate site, all the sites surveyed, drying of the washed sugar is achieved by open sun drying. There is a big demand for mechanical driers similar to the one developed at Yovi Estates. Poor drying due to lack of sunshine and poor hygienic conditions of the open sun drying process has resulted in poor quality of the sugar produced. The drier at Yovi Estate was fabricated at the'site and is of vibrating bed type but the performance is not satisfactory because it does not dry sugar properly, even after repeating the drying process thrice. Following the recommendations of Phase I of the research [32], IPI decided to embark on a project to develop a sugar drier similar to the one, which was installed at Yovi Estate. Design and manufacture of the drier was completed at IPI during the time of the research project and is currently undergoing field-testing at Mara Estate.

There has been frequent failure of equipment in some of the sites, as a result of poor manufacturing quality. Manufacturing of some parts of the sugarcane crusher, especially those which involved casting (gears and rollers) was subcontracted to external workshops namely Tanzania Automobile Technology Centre (TATC). In some cases, the products manufactured at TATC workshop did not meet the specifications required for the equipment. When that happened, IPI normally tried to correct the problems by machining in the IPI workshop, instead of rejecting the parts outright. As a result, the problem was transferred to the plant owners. A similar situation occurred for construction of the evaporators, which was normally done by local sub-contractors, because of poor supervision.

The spray gun for washing sugar, which was supplied by IPI, was not working in all sites except Zombo. The spray gun that was supplied by IPI is very weak and very expensive and is essentially a bicycle pump that has been modified. At Zombo site, the original IPI spray gun made from bicycle pump, was still functional and had no problem, which is attributed to the good maintenance and service offered by plant owner every time he uses the gun. However, the processing plant at Zombo has not been operating long enough as it is the case with the other plant. Two sites, namely Mwembe and Dudumera decided to develop improved spray guns of their own and later an IPI engineer was sent to Mwembe site to work with the plant owner in

improving the gun further. The spray guns are being made out of worn out motor vehicle shock absorbers. Prototypes of the gun have been made at IPI workshop, and were distributed to the other sites. Assessment of their performance could not be covered in this research project because the distribution was made towards the end of
the project, prompting another study later.

Thus in summary it shows that the IPI sugar equipment had manageable technical problems that could not stop the operations of the plant. However this information does not affirm technical perfection of the IPI technology.

3.3.2 Economic Performance of the Technology

(i) **Business *Performance***

Financial and economic data for all the sites that were operational was collected and analysed using a Business Model [10]. The model was used to determine the business viability of each site. The model runs on Microsoft Excel computer software. Summary of research finding on relevant parameters such as investment, equity, sales, costs, profits, cash balance and return on investment for all the sites analysed are presented in Table 2.

The results in Table 2 are based on data that was available from the plant owners and villagers at the time of the visits. The Business Model results presented the projected financial performance of the plants, for a period of five years since 1997. However, as shown in Appendix V, the equipment in all the sites was installed and started operating at different times ranging from 1991 to 1995. The data used in this analysis did not cover all the period during which the plants have been operational. Only average data over a small period of time, in most cases for the previous crushing season was used. The figures presented in Table 2, reflect the actual situation of 1997/98 and not for long-term operation of the sites. It can be noted that the sites with positive return on investment (ROI) include two privately financed (Yovi estate and Mara estate) and one that received loan from SIDO (Dudumera). Although it is difficult to conclude that success in business is linked to the mode of financing, the literature survey suggests that the level of endowment of humanware, orgaware and climate friendliness seem to induce business success.

There are few sites i.e. Mara Estate in Babati district, which have had a trouble free operation and exhibit the best business performance. Dudumera has on average a good performance, but not as good as Mara Estate because the capacity of the plant has not been effectively utilised. Yovi Estate has been operating continuously and in full capacity but it exhibits a lower business performance because of too high operational costs. This results from high cost of running big electricity generators and paying highly qualified experts from Zanzibar. The plant owner also wants to run his plant like a large-scale sugar factory, by using highly qualified and paid experts and converting the plant into an electrically powered plant, using his own generators. All this results

Into high operational costs, which were not expected for the village level sugar processing technology.

The negative values in ROI for Mwembe, Zombo and Mungu Nisaidie farm, indicates that there was a subsidy paid by another party who expected returns from it without the plant owner's consciousness. Some plants however like Mungu Nisaidie received a lot of grant from the Peramiho Roman Catholic Mission to cover costs, which were caused by poor performance of the plant. It was encouraging to see that after the first visit to the plants, improvements were made and by the time of the second visit, Mungu Nisaidie and Mwembe plants had started showing signs of improved performance.

Table 2: Summary of Business Performance at Different Sugar Plants for 1997/98

S/N	Site	Total Investment (TSh.)	Equity (%)	Sales (TSh.)	Costs (TSh.)	Profits (TSh.)	Cash Balance (TSh.)	ROI* (%)
1	Mara	19,572,875	100	104,940,000	88,024,420	16,915,580	26,429,975	86
2	Dudumera	10,858,947	54	16,302,000	14,480,060	1,821,940	820,990	17
3	Hanang	-		-	-	-	-	-
4	Magugu	-		-	-	-	-	-
5	Usa River	-		-	-	-	-	-
6	Mwembe	9,186,067	19	4,536,000	5,897,040	-1,361,040	73,907	-16
7	Zombo	4,301,125	17	6,160,000	7,190,420	-1,030,420	-509,918	-32
8	Yovi	14,833,521	100	61,620,000	57,354,170	4,265,830	11,042,871	29
9	Mungu Nisaidie	12,845,740	2	21,960,000	25,830,800	-3,870,800	-2,110,688	-30

*** ROI - Return on Investment**

(ii) Effect of Type of Energy Used

The IPI crystalline sugar processing equipment is available in two versions depending on the type of energy available at the site. One version is for sites that have no electricity power supply, in which case diesel engines are commonly employed. The other version is designed for sites that are connected to electric power supply. This version utilises electric motors as prime movers. Most of the existing sugar-processing sites are situated in locations where there is no grid electricity supply. Of the entire nine sites covered in this study, only one site that is Mwembe in Same district is powered by electricity.

Table 3: Prices of IPI Sugar Processing Plants as of 1999

S/N	EQUIPMENT	PRICE/COST	
		DIESEL	ELECTRIC
1.	Crusher	5,440,500.00	5,361,200.00
2.	Settling tank	910,800.00	910,800.00
3.	Evaporator pans	3,311,000.00	3,311,000.00
4.	Crystalliser	2,005,000.00	1,935,000.00
5.	Centrifuge	1,615,000.00	1,458,000.00
6.	Transmission shaft	2.064.200.00	0.00
7.	Prime movers	9,000,000.00*	2,787,000.00**
8.	Installation and commissioning	1,500,000.00	1,500,000.00
	Total	**25,847,000.00**	**17,288,000.00**

* Two engines 16 and 26 Hp

** 25kW (crusher), 4kW (crystalliser), 7.5 kW (centrifuge)

The type of power available for the sugar processing plant has a bearing on the capital investment required for the project and also operating costs that arise from energy component. Diesel powered plants have a higher investment cost, due to the high cost of diesel engines compared to electric motors. Table 3 summarises the capital costs of acquiring the equipment for diesel and electric type of plants.

Table 4: Energy Cost of IPI Sugar Processing Plants

S/N	Site	Type of Power	Work days /week	Diesel Fuel			Electricity	
				Litres /day	Price (TSh/litre)	Cost (TSh/ month)	(kVA/kWhr) /month)	Cost (TSh/ month
1	Mara (Mr. Patel)	Diesel engine	7	55	380	585,200	N/A	N/A
2	Dudumera (Mr. Chaghan)	Diesel engine	4	40	380	243,200	N/A	N/A
3	Hanang (Mr. Hatia)	Diesel engine	-	-	-	-	-	-
4	Magugu (Mr. Odedra)	Diesel engine	-	-	-	-	-	-
5	Usa River (Mr. Kanji)	Diesel engine	-	-	-	-	-	-
6	Mwembe (Mr. Mrutu)	Grid electricity	3	N/A	N/A	N/A	825	45,000
7	Zombo (Mr. Huwel)	Diesel engine	3	25	400	120,000	N/A	N/A
8	Yovi (Mr. Salum)	Diesel engine	6	100	290	695,520	N/A	N/A
9	Mungu Nisaidie (Mr. Kinyero)	Diesel engine	6	26	440	274,560	N/A	N/A

The energy component with respect to operating costs is also higher for diesel powered plants than for electric powered plants. Table 4 summarises the energy costs for the sugar processing plants covered in this study. It can be seen that, on average, the cost of electricity is one eighth that of diesel. In addition, there is transport cost and time involved in procuring the diesel fuel, as most of these plants are located far from the diesel supply points. The extra cost of procuring the diesel is not included in the data presented in Table 4.

Another disadvantage of diesel engine powered plants compared to electric powered plants is their higher maintenance and service requirement and costs. Environmentally, electric powered plants are better than diesel power plants, because of the latter's high pollution. Thus the economic performance of electric powered plants is better than diesel engine powered plants although for the case of Mwembe site other factors affecting the business performance of the plants outweigh the advantage of energy costs. Indeed, a policy intervention is required to popularise electric powered sugar processing plants in Tanzania. It was observed that at Mungu Nisaidie Farm in Songea, biogas is used as an alternative fuel for diesel engines which has enabled the plant to reduce diesel consumption from the 26 litres to 18 litres per day.

(iii) Source of Financing

Based on the figures obtained from this research, it is evident that the business performance of the IPI village level sugar processing plants justifies investment for entrepreneurs who are interested to own the plants. It should be noted at this point, that most of the processing plants, which are installed, were acquired using soft loans from IPI/SUDECO (1), Peramiho Roman Catholic Mission (1), SIDO (1) and straight from SUDECO (8). Entrepreneurs through their own financial resources acquired the remaining three plants.

IPI's involvement as a financier of sugar processing plants came after successful field-testing of the first IPI prototype in Turiani and Kilosa during the late 1980's and early 1990's. The prototype was given to the present owner of the Zombo processing plant as a loan financed by SUDECO but administered by IPI. The intention of IPI/ SUDECO was to recover the purchasing cost of the plant. A small penalty is to be paid by the plant owner for failure to meet the loan repayment schedule. There is no other sugar processing plant, which has been financed by IPI, neither does it have any resources to provide credit to entrepreneurs intending to get involved with sugar processing business.

Loan repayment by SUDECO financed plants has not been easy. Both Usa River and Mwembe plants have had a long history of operational problems and have not been able to save any money for loan repayment. The prospects of SUDECO continuing to finance dissemination of the IPI sugar processing technology are slim. All the large-scale sugar processing plants, which were owned by the government through SUDECO have been privatised. The future of SUDECO is still not certain, but even if it will continue to exist, it will not have as much financial resources at its disposal for investing in dissemination of 1PI equipment.

SIDO provided financial support for establishing only one of the fourteen plants that have been made by IPI and is installed at Dudumera plantations in Babati district. The amount of the principal loan given to the company was TSh. 5,000,000.00. According to the repayment schedule, which was agreed between SIDO and the company, the loan is to be repaid in twelve (12) instalments over a period of three years (from 1st June 1996 to 1st March 1999). The total amount that would be paid in the end is TSh. 6,155,978.00. By Mid September 1998, the company had repaid a total of TSh. 4,000,000.00 to SIDO, in four instalments of TSh. 1,000,000.00 each but not on the required dates thus increasing accrued interest. The outstanding loan was approximately TSh. 3,000,000.00 indicating that the company was lagging behind in loan repayment. However, there are positive indications that the company will be able to repay the loan. The financial position of SIDO has deteriorated in recent years, and rarely offer credit facility to entrepreneurs wanting to establish small industries, including sugar-processing plants.

The Peramiho Roman Catholic Mission provided financial support for establishment of the plant at Mungu Nisaidie Farm. The plant faced many problems, including frequent failure of equipment, particularly the sugarcane crusher resulting into spending a lot of money in maintenance and loss of revenue when the plant is idle. The Mission continued to provide financial support to the farm to cover the losses. Discussion with priests at the Mission indicated that they were happy with the IPI technology and are willing to support more sugar processing plants provided the problems that were facing the plant are solved. The Peramiho Roman Catholic Mission and probably other religious organisations and non-governmental organisations remain potential collaborators of IPI in dissemination of the crystalline sugar processing equipment, including entrepreneurs who can afford to acquire the IPI equipment through their own sources. However, for a vast majority of potential sugar processing plants entrepreneurs, commercial banks such as the former National Bank of Commerce [NBC (1997)], CRDB (199b) Ltd, Akiba Commercial Bank etc. are the only possible source of financing. When the IPI technology was proven, back in 1990 [16], an independent Model Feasibility Study for a Village Level Site Producing Sugar from Sugarcane was conducted by the then Co-operative and Rural Development Bank. The result was very positive and the bank was willing to provide loans to entrepreneurs interested in acquiring the plants. However, the difficult conditions and high interest rates of banks discourage many potential owners of the plants. Moreover, the Cooperative and Rural Development Bank has since 1996 been privatised and is more commercial oriented than a development bank. Further research is recommended for all categories of potential financiers to establish whether they can finance the dissemination of the IPI sugar technology and other related technologies.

3.3.3 Employment Generation

Table 5 shows employment status in each site by gender. The employment ranges from 13 to 36 people which is classified by the Tanzanian industrial census of 1989 as falling under small-scale industries thus making the IPI sugar processing technology a small-scale industry.

An employment of 22 people has provided the highest labour productivity of 38.5 kg of sugar per person-day. Mara Estates in Babati district exhibit this figure (Table 5). Yovi Estates in Kilosa district is the highest employing 36 people and producing 30.5 kg of sugar per person-day. Dudumera Sukari Farm in Babati districts with 13 employees produces 28.5 kg of sugar per person-day. Based on the employment status (Table 5), the average number of employees for each site is around 20 people showing the optimum employment generation for the IPI sugar processing technology to be 20 employees producing 38.5 kg of sugar per person-day.

Table 5: Employment Generation in Each Sugar Processing Plant by Gender

S/N	Site/Owner	Location	Employment			Labour Productivity (kg sugar/person-day)
			Female	Male	Total	
1	Mara (Mr. Patel)	Babati, Arusha	10	12	22	38.5
2	Dudumera (Mr. Chaghan)	Babati, Arusha	2	11	13	28.5
3	Hanang (Mr. Hatia)	Babati, Arusha	-	-	-	
4	Magugu (Mr. Odedra)	Babati, Arusha	-	-	-	-
5	Usa River (Mr. Kanji)	Arumeru, Arusha	-	-	-	-
6	Mwembe (Mr. Mrutu)	Same, Kilimanjaro	5	8	13	11.5
7	Zombo (Mr. Huwel)	Kilosa, Morogoro	0	15	15	13.3
8	Yovi (Mr. Salum)	Kilosa, Morogoro	20	16	36	30.5
9	Mungu Songea, Nisaidie (Mr. Kinyero)	Ruvuma	4	12	16	12.5

The IPI recommends an average of 55kg of sugar per person-day. This is derived from a 16 tons cane capacity per day producing 800 kg of sugar using 10 people, while the other technology of 5 tons cane capacity per day also employing 10 people, produces 300 kg sugar per day. However, the three sites namely, Mara Estates, Yovi Estates and Dudumera Sukari Farm, from the business point of view, have exhibited a positive net profit, cash flow and return on investment (Table 2). Due to optimum use of manpower and other managerial artilleries, the Mara Estates has demonstrated higher profits almost four folds of the Yovi Estates and ten folds compared to Dudumera Sukari Farm. For the remaining sites, their performance in business terms has not been satisfactory. Therefore, the optimum employment capacity for the IPI sugar technology is 20 people aimed at producing about 770 kg of sugar per person-day.

The discussions so far thus show that the hypothesis that the technology is socially beneficial holds true to a large extent because it has generated employment at the sugar plant, surrounding workshops and farms.

3.3.4 Quality and Price of Sugar

Sugar is a product that is in high demand among consumers in all the surrounding villages because its sweetness adds palatability of food. The prices of the sugar produced by the IPI technology are also lower than the imported sugar or produced from the local large scale sugar industries such as KSCL, MSE, TPC and KSL (Table 6).

Table 6 Sugar and Molasses Prices at Different Sugar Plant Sites, 1998

Item	Site/Owner	Location	Molasses Price	Sugar Price [TSh.]		
				IPX Plant	Market	Villagers' Pref.
1	Mara (Mr. Patel)	Babati, Arusha	110	440	600	450
2	Dudumera (Mr. Chaghan)	Babati, Arusha	50	360	600	450
3	Hanang (Mr. Hatia)	Babati, Arusha	-	-	-	-
4	Magugu (Mr. Odedra)	Babati, Arusha	-	-	-	-
5	Usa River (Mr. Kanji)	Arumeru, Arusha	'	-	-	-
6	Mwembe (Mr. Mrutu)	Same, Ki'njaro	150	360	530	430
7	Zombo (Mr. Huwel)	Kilosa, Morogoro	140	300	450	365
8	Yovi (Mr. Salum)	Kilosa, Morogoro	100	340	475	450
9	Mungu Nisaidie (Mr. Kinyero)	Songea, Ruvuma	300	310	525	380

Note: *Pref. Preference*

This allows many people at the lower cadre of the society with low purchasing power to buy the sugar produced by the IPI technology. The quality of sugar produced by the IP1 technology in the sites of Mara Estates, Yovi Estates and Dudumera Sukari Limited were found to be of acceptable quality comparable to the brown sugar prevailing in the market. Some families that cannot afford to buy the sugar were found to use molasses to sweeten porridge and tea. This phenomenon was reported in Ruvuma, Kilosa (Zombo), and villages surrounding the Mara Estates. Molasses in Ruvuma was not only used by the poor but even the well-off class like the missionaries who further processed the molasses for producing candies and cookies for their own consumption which in turn gave employment to other people in the society.

The brown sugar produced by the IPI technology does not have only the palatability characteristics, but also contains valuable nutritional elements to the human body, as the process does not use chemicals. It was reported [27] that sugar provides a substantial proportion of energy requirements for people between the age of 6 and 36 months.

This means that a process that produces chemical free sugar would be most suitable for children and also be in line with the current worldwide motto, calling for deployment of environmentally friendly technologies. The IPI sugar technology has since been striving to meet those conditions. The technology was designed with environmental conservation considerations. Mungu Nisaidie Farm has established a new (export) market to Denmark, apart from the Peramiho Roman Catholic Mission, for their sugar. Due to the demand for these two markets for organic sugar (sugar produced without the addition of any chemical), lime is no longer used in the production process at the plant.

At Yovi Estate, production of crystalline sugar had stopped since the past two crushing seasons because of lack of market for sugar produced. Only jaggery was being produced at the processing plant. A sample of sugar produced at the plant was sent to the Chief Government Chemist for analysis and was found to have too high sulphate ash content and not properly dried. Accounting for the stoppage of producing crystalline sugar. Although an expert had been brought to the plant from large-scale sugar processing factory in Zanzibar the problem of market for sugar was still evident, as sugar produced two years back was still piled up in the company godown in Morogoro town and was being sold at the same price as sugar produced in large sugar factories. It was not possible to lower the price because of the high production costs of the plant and cost of transporting the sugar to Morogoro. The high production costs were a result of high cost of energy to run the generators at the plant and payment for the highly qualified experts employed by the company. The situation was the same for jaggery and molasses and large amounts were lying in the company's store.

The price of sugar in Songea town was TSh. 450.00 but in the villages it was TSh. 500.00. Before the introduction of Value Added Tax (VAT), which became effective in July 1998 cheap sugar from Malawi had flooded the market in Songea. The price of sugar at that time went down to TSh. 300.00-per kg. After the introduction of VAT, the situation came back to normality. The examples from Yovi and Songea show that sugar quality and price varies between the rural market, where the sugar is produced and urban markets. Urban people have a higher purchasing power and tend to be more selective with regard to quality. The example of Songea also shows how macro economic policies can have an impact on the viability of the sugar processing technology though introduction of the VAT system.

The first part of the hypothesis i.e. that the quality and prices of the sugar produced by IPI plants is competitive to other forms of sugar found in the area hold true for all areas surveyed whereas the second part of the hypothesis depends on whether plants followed the process as recommended by IPI and also if some improvements were implemented on the technology including provision of a sugar drier, improvement of the sugar washing and provision of all the plants with the necessary measuring instruments. At the time of the study, the quality of sugar produced by IPI plants was not as good as other types of sugar available in the market.

3.3.5 Impact on Environment

In the context of the sugar processing technology, the impact on environment would encompass all parameters including sourcing the raw materials and labour; undertaking the processing of sugar; and ultimately selling of the sugar and molasses. Two types of environmental impact were identified namely, physical environment and social environment.

(i) Physical Environment

The physical environment in sugar processing involves activities in the cane farming management and processing of cane into sugar. Sugarcane farming requires land clearing. In most of sugar processing sites, the sugarcane farming area has long been established except for Mr Kinyero (Mungu Nisaidie farm) in Ruvuma region who had to clear the land to establish own farm of sugarcane. In this case, trees and grasses had to be cut-off to pave way to the sugarcane plantation. About 100 acres were cleared for cane plantation.

Water has been reported, as an important ingredient in sugarcane farming and thus have effect on environment in the sugar processing areas. In the uphill of Same districts where Mr Mrutu (Mwembe Site Owner) fetches his sugarcane supply for the sugar plant, farmers have invaded even natural sources of water (water springs) for cultivation of sugarcane and other food crops. One such source of water being cultivated by a nearby farmer is just in front of the village office in Mhezi ward, Mwembe-Mbaga division in Same district.

Even the village council is not conscious of the hazards created by the farmers on the environment. Very few villagers realise the implications to their daily life but have no powers to stop the process of cultivation. On the other hand in Kiru valley in Babati district, there has been severe fights between villagers and farm owners namely, Mara Estates, Dudumera Farm and Hanang Estates (Hatia) concerning supply of water. For example in Kiru valley sugarcane farms are irrigated with water from uphill where villagers also need the water for their animals and gardening. In such cases, conflict of interest emerges and fights have erupt several times creating social stress.

Also the villages surrounding the Mungu Nisaidie sugarcane farm of Mr Kinyero put the farm into fire as a manifestation of their resentment for his undertaking of farming in that area despite the lease of 99 years. Further Mr Kinyero has been very instrumental in the provision of ground-well water to about three villages and even provided free sugarcane seedlings to villagers with expectation that in turn they would sell to him the sugarcane. This so-called contract farming was not well managed and many of the contractors defaulted.

During processing of the sugar, energy is required to heat the evaporation pans. It was found that all sites that were visited use bagasse for firing evaporation pans when crushing season start (June or July i.e. after rain season). It was also noted that all sites that were operating as from late November to January were using firewood except Yovi Estates in Morogoro, which still used bagasse. The Yovi Estates has constructed a shade to store bagasse, which can be used even in rainy seasons thus conserving the environment from destroying natural trees.

(ii) Social Environment

The processes undertaken during the processing of sugar determine the social environment. In sugar processing, the main by-products produced are molasses and bagasse. Of the two by-products, molasses has found so many uses including supplementary feed for animals, production of alcohol, sweetening of porridge for poor household, biogas digester catalyst during cloudy days, production of guru and production of alcohol (mainly illegal alcohol - gongo) which is responsible for polluting the social eco-system.

Table 7 indicates the amounts of molasses produced and consumed by the communities per day. The Kiru valley in Babati is very much affected by this phenomenon and labour sourcing is reported to be very difficult. The Kiru valley has been producing jaggery for some years selling mainly in Dodoma, Tabora, and-Shinyanga. The same market also absorbs the produce from Kilosa district as reported by Zombo and Yovi Estates. Some little amounts were sold to the local surrounding villages for production of alcohol. The sugar processing plants therefore have maintained the status quo for molasses/jaggery being sold to the local communities and consumed locally with exception of the Yovi Estates who transport it to the Morogoro Municipality for use as animal feed and production of local alcohol. Similarly the sugar produced by the sugar processing plants is locally consumed within the district except Yovi Estates which managed to sell about *15* tons of sugar in early 1997 in Tabora region. In this respect, the sugar processing plants can be claimed to have assisted in reducing pollution of the social environment in Dodoma, Tabora and Shinyanga by converting the suppliers of jaggery to provide a different product (i.e. sugar).

Table 7: Production Data for Sugar, Molasses and Baggasse

S/N	Site/Owner	Location	Sugar-cane (tons/day)	Sugar Produced (kg/day)		Molasses Produced (kg/day)			Bagasse (tons/day
				Reported	Recovery	Reported	Predicted	Sold	Predicted
1	Mara (Mr Patel)	Babati, Arusha	22	840	3.8%	580	880	580	13
2	Dudumera (Mr Chaghan)	Babati, Arusha	8	370 .	4.6%	300	320	300	4
3	Hanang Mr. Hatia	Babati, Arusha	-	-	-	-	*	-	-
4	Magugu Mr. Odedra	Babati, Arusha	-	-	-	-	-	-	-
5	USA River Mr. Kanji	Arumeru, Arusha	-	-	-	-	-	-	-
6	Mwembe (Mr Mrutu)	Same, Kil'njaro	5	150	3.0%	180	200	180	2.5
7	Mungu	Songea,	4*	200	5.0%	200	160	165	2
	Nisaidie Farm (Mr Kinyero)	Ruvuma	15**	600	4.0%	800	600	565	7.5
8	Zombo (Mr. Huwel)	Kilosa, Morogoro	6	200	3.3%	100	240	100	3
9	Yovi Estate (Mr. Salum)	Kilosa, Morogoro	22.5	1,100	4.9%	1,000	900	900	11.25

- Using IPI crusher and operating from June to December six days a week Using own
- crusher bought from Kisumu.

3.3.6 Transfer of the Manufacturing Technology

Transfer of technology i.e. equipment and machinery to commercial manufacturers refers to both production of new sets of equipment machinery and providing managerial support for maintenance and repair services to installed sites. Table 8 gives a summary of manufacturing, repair and maintenance abilities of some of the workshop facilities that were visited with respect to the sugar plant sites.

Jandu Plumbers Company Limited is situated in Arusha Municipality. The company has one of the biggest and oldest metal working workshops in Arusha and can perform all operations required for production of IPI crystalline sugar processing equipment. The company is of particular interest to IPI especially in relation to transferring the crystalline sugar processing equipment, because it has a long tradition of producing sugarcane crushers. They are the leading and probably the only manufacturers of sugarcane crushers in the country. The crushers manufactured by Jandu Plumbers have a capacity of 2 to 4 tons of sugarcane per hour. Many of the existing jaggery producers in the country, particularly those located in Arusha region use sugarcane crusher, manufactured by Jandu Plumbers. It was reported that the Company has sold a total of thirty (30) crushers and with such a background they are considered to be the natural transferees of the IPI technology. With the IPI technology and hence having a bigger market potential not only serving jaggery producers, but also crystalline sugar producers.

The company was only interested in the additional pieces of equipment to be used with their own crusher that they believe is very successful and efforts are being made to ensure that Jandu Plumbers accept the possibility of transferring the crystalline sugar processing equipment to the company for commercial production and relevant information has been communicated to the company to enable them reach a rational decision in the acquisition of the village level crystalline sugar processing technology.

Table 8: Technology Transfer and Dissemination in Tanzania

S/N	Site/Location	Repair and Maintenance Ability	Manufact-ring Ability	Possible Manufacturer of the Technology	Remarks
1	Mara (Babati, Arusha)	High for diesel engine, welding and fitting activities. Own a mini workshop.	None	Jandu Plumbers in Arusha has the capacity and capability and has been assisting the plants in Arusha region for the provision of the spare parts.	A negotiation between the IPI and Jandu Plumbers started in early November 1997 as a result of this research however the process has not born fruits due to large investment and limited market of the technology.
2	Dudumera (Babati, Arusha)	High in welding and fitting and have a mini workshop	None	SIDO common facility ' workshop has limited capacity, lacks the casting facilities	
3	Hanang' (Babati, Arusha)	Moderate fitting activities	None		
4	Magugu (Babati, Arusha)	Moderate fitting activities	None		
5	Usa River (Arumeru Arusha)	None	None		
6	Mwembe (Same, Kilimanjaro)	High in welding, fitting and innovativeness	None	None	Can be served with Arusha manufacturer
7	Zombo (Kilosa, Morogoro)	Moderate welding and fitting activities	None	Carpet workshop lacks foundry for casting and business motive	Like many parastatals, it cannot undertake manufacturing due to lack of business motive
8	Yovi (Kilosa, Morogoro)	High welding, fitting and sugar processing abilities	None	None	
9	Mungu Nisaidie (Songea, Ruvuma)	Low ability in fitting activities	None	Peramiho Missionary workshop lacks the foundry for casting and the business motive drive.	Peramiho Missionary is a development organisation. It lacks foundry and since it is not business organ, it cannot manage the manufacturing of the technology and sell.

The information included specification and capacity of IPI plants, necessary infrastructure and requirement for sugar processing sites, manufacturing and installation data and costs, recommended prices for the different components of the plants, transfer fees to be paid to IPI and some economic data on the sugar industry in Tanzania.

The latter includes data on sugar requirement in Tanzania, selected data on sugarcane production in Tanzania, installed capacity, production capacity, capacity utilisation, production costs and prices of sugar for large-scale factories such as KSCL, MSE, TPC and KSL.

However, Jandu Plumbers turned down the offer to manufacture the sugar processing equipment. The most probable explanation is transfer fees and royalty costs. Also not being sure of the size of the market for the equipment and whether investment will be recovered. This situation is also true of other technologies developed by IPI and other related institutions. On the side of IPI also it is difficult to just give away the designs of its products because they are means of getting financing for its Research and Development (R&D) work especially given the fact that linkage with the London based Patent Office are not yet established and the patent law in Tanzania is not yet operational. As a result of this situation some commercial manufacturers without formal agreement with IPI have copied some of IPI technologies. Jandu Plumbers Company had for example received in 1992 all the drawings for the IPI crystalline sugar processing equipment which means that they could manufacture the equipment if they wish to do so. The only hindrance factor could be the economies of scale and not the legal system.

SIDO has a number of workshops, known as Common Facility Workshop (CFW) established mainly in regional SIDO industrial estates, in order to provide services, including maintenance to the industries operating in the Estates. Recently, the performance of the small-scale industries has been poor and as a result, most of the industrial estates are closed down. However, the CFW's in many regions are still operational. The CFW also are potential transferees of the IPI sugar processing plants. Visits were made to SIDO workshops in Arusha and Songea town. Both workshops are still operational. They provide services to the general public on a commercial basis including spare parts manufacture and commercial production of some pieces of machinery such as grain mills; grain hullers; metal grills; wood saws; various wood working machines including combination wood planners, circular sawing machines, water pumps and edible oil pressers. During the visit to SIDO Arusha, in Phase I of the research, discussion was held on the possibility of transferring the manufacture of IPI crystalline sugar processing equipment. SIDO showed interest but they have not so far responded to the offer made to them. The visit to the company during Phase II of the research revealed that the performance of the workshop is going down and probably they will not be in a position to undertake the transfer of production of the sugar processing equipment.

The Songea workshop is not as well equipped and organised as the Arusha workshop. The sugar processing plant at Mungu Nisaidie Farm has attempted to use the services of the workshop but with disappointing results. A crusher gear was taken to the workshop for repair but the repair could not be performed properly. Finally the gear was taken to Mang'ula Mechanical workshop in Morogoro region for repair. The opinion of the researchers is that the SIDO workshop in Songea could only be used for minor repair works for the sugar processing plants.

The National Engineering Company (NECO), based in Dar es Salaam City has a metal working workshop, and is capable of handling large jobs. IPI has had previous experiences with NECO. In the early 1980's IPI attempted to transfer the production of one of its developed prototype, manually operated oil seed press. The experience turned out to be disappointing, as NECO could not produce according to IPI specifications. Despite this experience, IPI still wishes to transfer the sugar processing equipment to NECO. A memorandum of understanding had been signed between NECO and IPI with regard to the transfer of manufacture of sugar processing equipment. At the time of signing the memorandum, NECO was still a parastatal organisation. The privatisation process began before conclusion was reached on this matter; therefore the decision to acquire the technology was subject to acceptance by the new owner of the company. The interest of the new owner has recently focused on provision of spare parts to big industries of sugar, ginneries, textiles etc.

Rajani Industries also in Dar es Salaam City too has a metal workshop capable of undertaking the manufacture of IPI crystalline sugar processing equipment. Initially in 1994 the company showed interest in acquiring the IPI technology, but it has been slow to make a decision because of social-cultural reasons based on religion and change of economic policies in 1995 on sugar as a basic commodity to be imported duty free. No transfer has taken place to date.

Tanzania Automobile Technology Centre (TATC) situated in Kibaha district, Coast Region has one of the biggest and well-equipped mechanical workshops in the country. Manufacturing of parts of the IPI crystalline sugar processing plant was sub-contracted to TATC including casting of gears and rollers for the sugarcane crusher. The Centre has a big potential to undertake transfer of manufacturing of the plants. The research team found out that there is no attempt, which has been made by IPI to transfer the production of the equipment to TATC, despite the fact that IPI always subcontracted the casting works to TATC. On the other hand TATC lacks entrepreneur spirit and business managerial capabilities and thus cannot be a transferee. TATC was conceived to be an R&D institution. The quality of parts that have been made at TATC has not always been good, but there is big room for improvement, if IPI and TATC worked together. In some cases, parts made did not conform to specification, thus causing problems in assembly and subsequent operation of the machinery. This shows the lack of business orientation to customer satisfaction.

Mang'ula Mechanical Workshop, in Morogoro region, is one of heavy mechanical workshops in Tanzania and has a big potential for undertaking the manufacture of the sugar processing equipment. Presently it offers services to some of the sugar processing plant. For example, crusher gear was casted at the workshop to replace one that was broken at Mungu Nisaidie Farm in Songea. IPI had communication with the company previously, on the possibility of transferring manufacture of its' equipment but the company did not take up the IPI offer.

There are other workshops of no significance in terms of manufacturing the IPI sugar processing equipment, but which provide services to the processing plants. They include the Tanzania Carpet Company's workshop in Kilosa district and Peramiho Roman Catholic Mission Workshop in Songea district. The plant at Zombo is very close to the TCC and has benefited from services offered by the company. But it has since been sold and the factory was closed down. Peramiho Roman Catholic Mission maintains very close relation with Mungu Nisaidie Farm. Apart from providing financial support to the farm, the mission provides market for the sugar produced at the farm. The Mission has a moderate mechanical workshop and a training school for artisans. The workshop is capable of undertaking minor repair works for the sugar processing equipment at Mungu Nisaidie Farm and it has been offering such services.

The issue of formal transfer of manufacture the IPI sugar equipment is the most difficult problem that has been facing the institute, throughout its existence. Initially, it was thought that the major reasons for failure in achieving the transfer were the poor economic situation, which the country was facing, and the infancy stage of the metal working industry [26] and given the improvements it was expected that the transfer would be easier. According to IPI's experience, market for developed products has never been a problem. Despite efforts to transfer the manufacturing of the equipment to commercial workshops and the good business performance of the equipment demonstrated so far, no positive response has been received ten years after the technology was developed and tested. The poor response is probably due to reluctance on the side of potential transferees to pay the transfer fees required by IPI and uncertainty about the potential market for the equipment.

Although the technology was proven ten years ago, operation of the sites that are installed started very recently. The delay in dissemination of the equipment made IPI unable to obtain the necessary feedback required for improvement of the technology. This issue of transfer of manufacturing needs further study. Therefore the issue of transfer of the sugar processing technology to commercial manufacturers is not as straightforward as this hypothesis suggests. There are more factors linked to manufacturers than technical, economic and social performance of the technology in the respective sugar processing sites. The three factors mentioned above play a major role in determining whether or not a technology is transferable to commercial manufacturers.

3,4 Hypothesis No. 4: Gender, Ownership Pattern and Political Milieu

[Ownership, management and operation of the IPI *sugar processing technology at village level has redressed traditional gender bias in the field of technology since both men and women have equal access]*

3.4.1 Gender Relations

Information gathered from both the key informants' interviews and focus group discussions suggests that the ownership patterns among the processing plant owners and the individual sugarcane outgrowers follow patriarchal lines. The head of the household (husband and father) owned the family property namely the land, production tools including vehicles and processing plants and domestic animals. The information might have been generalised from the point of view of the local people. But the management pattern on the part of the plant owners of the Asian origin seems to follow the male dominance trend in so far as technological management is concerned. This has been taken as the indication that ownership and management of the technology is male dominated.

In all the six operating sugar processing plant sites, men dominate sugarcane cutting, loading, unloading and crushing to centrifuging. Women labour tended to be hired in areas of boiling massecuite, collecting baggasse and drying sugar except for the Mwembe site where a large proportion of the plant labour force has been reported to be women. Since the plant was not in operation due to scarcity of sugarcane, this information could not be verified through observational techniques. The labour force in all the sites surveyed is made up of only adults. There was nobody who would fall under the category of children (below 18 years of age).

All 84 individual outgrowers who were interviewed have reported that both men and women participate in the cultivation of sugarcane. It was revealed further that women are primarily responsible for food crop production and weeding the sugarcane fields while men tilled the cane fields, harvested and marketed the sugarcane. This was explained within the cultural contexts where men seem typically responsible for disposing off family produces whenever necessary. In larger sugar estates, the labour force is predominantly made of migrant male labourers. This may not be surprising when we look at the history of labour migrations where it was common for a young man to migrate in search of economic opportunities. Men controlled the means and instruments of production except for hand hoes and small domestic animals (chicken, ducks and rabbits).

With regard to the operations of the sugar processing plant, the technology has been able to deploy both genders in its performance. Hypothesis has not been fully supported by the information gathered from all the surveyed plant sites and surrounding areas, as far as ownership is concerned.

3.4.2 Socio - Economic - Political Aspects

Socio-economic impact study is a process of determining both physical and Social consequence of the village level sugar processing technology. The aim was to identify economic returns, problems and prospects of each sugar processing plant. Specific issues addressed in the study include control of resources and gender relations. Table

9 shows the profiles of the villages that surround the sugar processing plants. Mwembe in Same district exhibits the highest number of outgrowers and sugarcane yield followed by Mungu Nisaidie Farm in Songea district.

All the sugar processing plants are family businesses controlled in the same manner as the other family properties such as cultivable land, livestock and vehicles. Incidents of conflict over the control of irrigation water sources in the sugarcane cultivation have been reported in Arusha, Kilimanjaro and Ruvuma regions sites mainly because local people are facing irrigatable land shortage while the government has leased vast area of such land to private and mostly alien farmers who are not only hoarding the land but also irrigation water sources. The frustrations of this deprivation of local people is shown through the enmity between the leaseholders and villagers as seen in frequent destruction of sugarcane fields by either setting them on fire or deliberately grazing on the farms.

At Mara Estate, the owner was contemplating selling the whole -business (farm and processing plant) and investing in another business. Another farmer in the area had sold his farm and invested his money elsewhere. The reason for this sudden exodus from the sugarcane farming business was land disputes with surrounding villagers. This land problem was to be presented to the United Republic President as a political issue.

The performance of the sugar processing plants is affected by policies and taxes imposed at both local and central government levels. At Dudumera estate, new taxes have been introduced recently, and are said to reduce the attractiveness of the crystalline processing business. The new taxes include: central government land lease fee has been increased from TSh. 2.00 to TSh. 600.00 per acre, local government land levy has been increased from TSh. 50.00 to TSh. 500.00 per acre, new local government tax of TSh. 10.00 per kilo of sugar or jaggery produced, has changed to Value Added Tax (VAT) of 20% plus introduction of Vocational Education and Training Authority (VETA) levy of 2% of salaries of employees.

Indeed to some extent the performance of the sugar technology has been affected by the socio-economic political milieu in the respective area which partially support the hypothesis The adoption of the technology implies that it is economically viable but the conflict ridden social and political relations among the local people and plant owners and the government agencies inhibit local sustainability of the adoption of technology. However, it is worth noting that in real terms the taxes are too many and may significantly contribute to rising of operational costs of the sugar plants. This study has revealed that the price of sugarcane was not affected by increase of the taxes (Table 2).

3.5 Hypothesis No. 5: Poverty Alleviation

[The existence of the processing plants at village level has alleviated poverty and increased income among *the villagers* - plant *owners, individual sugarcane outgrowers and plant workers]*

In the efforts to support the sugar sector in late 1980s, poverty alleviation was not explicitly mentioned as a major objective in the IPI sugar technology development programme. The main objective was to introduce the technology in the rural areas where sugarcane is abundant on one hand while on the other sugar was a scarce commodity. It was conceived that entrepreneurs who would own the technology would be centres of technological development in terms of employment generation and provision of sugar within and the surrounding villages. The ownership of the technology was not directly oriented towards the poor, but this does not imply that the poorest segments of the population surrounding the sugar plants have not benefited from the technological intervention. Likewise, it does not exclude the poorest segment from owning the technology particularly for those endowed with entrepreneurial innovative ideas.

Table 9: Village Profiles for IPI Crystalline Sugar Processing Sites

S/N	Site	District	Name of Village	Village Population	No. of House-holds	Weekly Sugar Consumption		Per Capita Sugar Con-sumption (kg/year)	Labour Market (Tsh./ day)
						House (kg)	Village (tons)		
1	Mara	Babati	Kiru Dick	2,500	400	1.00	0.4	8.32	750.00
2	Dudumera	Babati	Kiru Ndogo	2,350	420	1.50	0.6	13.52	750.00
			Kiru Six	886	204	2.30	0.5	29.12	700.00
3	Hanang	Babati	-	-	-	-	-	-	
4	Magugu	Babati	-	-	-	-	-	-	-
5	Usa River	Arumeru	-	-	-	-	-	-	-
6	Mwembe	Same	Bangalala	5,378	600	3.00	1.8	17.16	1,000.00
			Mteke	1,516	377	2.00	0.8	27.56	700.00
			Mtunguja	2,350	587	3.00	1.8	40.04	500.00
			Mwembe	4,063	857	2.00	1.7	21.84	500.00
			Ruvu Mferejini	4,673	425	2.10	0.9	9.88	1,000.00
7	Zombo	Kilosa	Nyali	1,642	462	1.30	0.6	19.24	1,200.00
			Zombo Lumbo	2,100	420	1.00	0.4	9.88	750.00
8	Yovi	Kilosa	Kisanga	3,000	800	0.75	0.6	10.40	1 ,000.00
			Msolwa	3,500	681	0.20	0.2	3.12	1,100.00
9	Mungu Nisaidie	Songea	Liganga	1,970	HS	1.00	0.4	10.40	1,000.00
			Litisha	1,980	420	0.30	0.1	2.60	750.00
			Lugagara	1,905	750	2.00	1.5	40.56	1,200.00
			Nakahuga	2,018	423	1.50	0.6	15.60	1,000.00

Source: Survey Data (1998)

This study was also expected to give contribution to understanding of the causes and effects of poverty in the societies surrounding the sugar processing plants. In all interviews with plant owners, village councils and individual sugarcane outgrowers, the subject of poverty was discussed in details. The objective of the researchers was to find out how the villagers perceive poverty, the causes of poverty and the percentage of the village population that is considered to be poor.

The areas covered in the study are divided into three geographical areas covering the south, central and northern Tanzania. As such it could be regarded as a good representative sample of the country. Although these locations differ in the type of economic activities, levels of development of the societies and weather conditions, they are all categorised as rural areas and they commonly grow sugarcane. The main economic activity in all the locations is agriculture with the exception of Ruvu Mferejini village in Same district and Kisanga village in Kilosa district where animal husbandry is the main economic activity for the large portion of the population.

Assessmen

Even within the same village there were significant variations among the villagers as to the definition of poverty and the percentages of the population that are poor. The definitions of poverty as given by the villagers are derived from Table 10(a) as follows:

(i) The level of endowment of basic needs such as food, shelter, bedding, clothing, sanitation, education, health services, education. This definition was very subjective and varied from place to place.

(ii) Level of self-sufficiency, including level of endowment of means and tools of production. A person who could not manage his/her own life and had to be helped by others or seek employment from others is regarded to be rJbor.

(iii) Social status e.g. marital status. A man who could not get married was regarded as being poor in Same and Kilosa districts.

(iv) Monetary income. A take home income of less than TSh. 1,000.00 per day was regarded to be below the poverty line in Kilosa district.

(v) Acreage of land cultivated. In Same district one acre is regarded as a minimum and below that one is considered to be poor.

(vi) Harvest per year. Seven bags of maize per year were regarded as adequate in Songea district.

(vii) Number of cows. In Ruvu Mferejini village, Same district, anything below ten cows was regarded as poor.

(viii) Means of acquiring income. Poverty was also defined according to means by which income is earned. If a person earns his or her income through unlawful means, he/she is regarded as being poor. For example in Same district, thieves are regarded to be poor.

The above definitions could be grouped into two categories based on their causes, as explained below. Although many factors were attributed to the causes of poverty and varied from place to place, there was a consensus among all the villages that the root cause of poverty was attributed to personal behaviour of the individuals concerned including carelessness, laziness, drunkenness, and extravagance. These are factors that are within the control of the individual concerned. There are other factors such as physical disability, illness, aging, and poor weather conditions, which apply to some members of the community and are not within their control. Apart from factors that are specific to some individual.

Table 10(a) Definition of Poverty by Villagers

PLACE/ DISTRICT	DEFINITION	POOR (%)	CAUSES
Kim Valley, Babati	Not capable of feeding self and family throughout the year without seeking employment	10	Carelessness, not well looked after farms
	Can not cultivate their land and feed themselves therefore work in others farms	25	Laziness, carelessness, poor harvest due to poor rains
	Can not cultivate their land and feed themselves therefore work in others farms	25	Laziness, carelessness, poor harvest due to poor rains
Kilosa	Lack of means of income, house, wife, basic food. Minimum take home income ef TSh. 1,000.00	<10	
	No shelter, no clothing + bedding, no soap, no money, can not cultivate, no hoe, poor diet	10	
	No house, no mattress, no food	1	Laziness
	Disabled; Nothing - no bicycle, no farm, no house		Disabled
	No poverty but laziness		Laziness
	Poor resources and living environment, less than one acre cultivated, old without children support	33	Extravagance, laziness and carelessness
Songea	Poor farming, housing, clothing, food, bedding	33	Carelessness, laziness, drunkenness
	Not having money	Majority	Primitive agriculture
	Not able to get basic needs, can not manage own life, dependent on others, no farming inputs		Laziness
	Housing, harvest, economic projects, living environment, food, annual income (up to 7 bags of maize)	50	Lack of fanning inputs due to high prices and lack of credit, demoralised
	Can not meet basic needs	50	Not hardworking
	No clothing, housing, food, money	1	Carelessness
Same	No food, live from hand to mouth, no good place to sleep, no wife. Thieves	2	Physical disability, drunkenness, shortage of land, primitive agriculture due to lack of education
	No income, no house or assets	50	Laziness, national economic hardships, poor harvest due to drought and poor seeds
	Poor nutrition	10	Laziness, shortage of land, infertility of land
	No cash, poor clothing, poor food, can not educate children	10	Laziness, drunkenness, shortage of land, poor harvest due to poor weather
	No resources to sustain themselves, have to be supported by others	0	Laziness, illness, aged, physically disabled, drought
	No reliable supply of food, can not educated children, no shelter, no clothing	33	Drought
	Dependent on others	Very few	Laziness, drought
	No animals (less than 10 cows), amount of land cultivated - less than 1 acre, can not afford basic needs e.g. education, food, shelter etc.	30	Carelessness (weather not a problem because of irrigation)

Key: PO Plant Owner, VC Village Council, SO Sugarcane Outgrower members of the societies, there are factors, which cut across most of the community members and apply in all the four districts. These could be mitigated, given appropriate policy intervention measures. The factors are as follows:

(i) Poor harvests due to poor weather conditions such as drought and floods. The only exception is Ruvu Mferejini village in Same district, where drought is not a problem because of irrigation farming being applied.

(ii) Lack of farming inputs such as farm implements, seed, fertilisers and pesticides due to high prices and lack of credit.

(iii) Shortage of land particularly in Same district,

(iv) Primitive agriculture due to lack of education,

(v) Land infertility,

(vi) Poor quality seeds.

According to the respective villagers' own assessment, the percentage of their population that is considered to be poor is 25% in Kiru Valley, Babati district; 30% in Same district, 33% in Kilosa district and 50% in Songea district.

In terms of the poor, three categories of potential beneficiaries can be distinguished as being the sugar consumer, plant employees, and sugarcane outgrowers. As pointed out above, the ownership of the sugar technology did not necessarily exclude the poor, particularly those with entrepreneurial characteristics. Therefore some data on the wealth of all (nine) plant owners is presented in Table 10(b), with the view to assess their wealth status before and after acquisition of the technology. Similar data is presented for selected individual sugarcane outgrowers who have been selling their sugarcane to the processing plants.

With respect to sugar consumers, the argument here is more of being able to get sugar at a more affordable price rather than that of increased income or saving. In most villages the consumption of sugar by households was found to be very low and in many rural households, sugar was viewed as not being an absolutely essential dietary requirement. It was only purchased, when there was sufficient money to do so, and this was mostly during harvest periods for families depending on farming and during labour peak season for families depending on wage labour. The average household sugar consumption for a typical rural family was found to range from 0.2kg/week to 3kg/week for household size ranging from 2 to 8 people (1.35 kg per week per household of five people). The per capita sugar consumption figures for the villages surrounding the sugar processing plants were calculated based on the data on village population and weekly village sugar consumption. The latter were obtained from local shopkeepers. All these figures are presented in Table 9. The average per capita sugar consumption for all villages visited is 17.5 kg per annum. Some households in the areas use molasses as a sweetener because it is cheaper than crystalline sugar. Thus the IPI.

Table 10(b): Economic Returns as Reported by Plant Owners and Outgrowers

			ITEMS POSSESSED AND SOURCE OF FINANCE	
S/N	Site	Beneficiary	Sale of Sugarcane	Sale of Products from IPI Plant
1	Mara	Plant Owner	House, 3 cars, 9 tractors, 1 milling machine, Sugar processing plant, 14 tractor ploughs, more than 100 hoes, more than 70 cows, sheep, goats, radio and radio call, and furniture	Crop store, 1 saloon car (Toyota Mark 11), 2 bicycles, 1 bull cow (TSh. 150,000.00), Bank account, 2 diesel engines, 1 irrigation pump set (US$ 17,000.00), child school fees (TSh. 9 million/annum)
2	Dudumera	Plant Owner	3 cars, 10 tractors, 1 motor cycle, 1 milling machine	.
3	Hanang'		-	-
4	Magugu		-	-
5	Usa River		.	.
6	Mwembe	Plant Owner		No data but it is expected that some property was acquired
		Individual Sugarcane outgrowers	Hand hoes (6), kerosene lamps (4), mattresses (4), goats (3), chicken (3), chairs /sofa sets (3), Beds (3), torches (3) kitchen utensils (3), radios (3), bank accounts (2), iron sheet rooted houses (2), extra agricultural piece of land (2), tables (2), grass thatched house (1), sheep (1), watch (1) and a dairy cow (1)	
7	Zombo	Plant Owner	One motor cycle	Maize milling machine and cattle
		Individual Sugarcane Outgrowers	Bicycle (1) and radio (1)	
8	Yovi	Plant Owner	Four tractors, four tractor ploughs, three bicycles and iron sheet roofed house	Solar energy equipment for radio call, sugar drier, a set of communication (radio call) equipment, bank account, mattresses, beds, cattle, sheep, goats, chicken, hand hoes and watches.
9	Mungu Nisaidie	Plant Owner		Ten hand hoes, a kerosene lamp, a torch, kitchen utensils, total of 24 acres of land, 2 bank accounts, 20 machetes ("mapanga")
		Individual Sugarcane outgroweis	Hand hoes (2), tables (2), chairs (2), beds (2), chicken (1), iron sheet roofed house (1), mattresses (1), kitchen utensils (1), fence (1) and kitchen shelter (1)	

Note:

(i) The sugar plant owners sold sugarcane to jaggery plants before introduction of the IPI plants (ii) The numbers in parentheses are quantities technology has enabled disadvantaged segments of the village populations under study to get alternative sweetener cheaply.

Therefore the hypothesis that the technology has alleviated poverty to some of the entrepreneurs owning the sugar processing plants namely Mara Estates, Dudumera and Yovi Estates; and also has provided an increased income to farmers, employees in the farms and at the processing plant including the respective entrepreneurs owning the sugar processing plants such as Mungu Nisaidie and Zombo sites has been supported. In addition, the technology has provided affordable sweeteners at village level, which is sometimes given on credit to employees of either plants or farms by the processing plant owners, e.g. Zombo site.

3.6 Hypothesis No. 6: Appropriateness of the Technology

[The relative fitness of the humanware, orgaware and climate of the user of the technology determine the appropriateness of the sugar technology in the rural set'Up]

The field data collected for all the six sites that were operational has been analysed using a Technology Assessment Model, developed by Chungu [7]. The model incorporates all aspects related to the technical aspects, human resource, organisation, information and the surrounding environment. The technical part includes production capacity, quality of sugar, energy utilisation, supporting workshop facilities etc., which are generalised as technoware. The other components of the technology included the humanware (human abilities), infoware (documented information), orgaware (organisational framework) and technology climate (technology environment).

Table 11: Technology Fitness for IPI Crystalline Sugar Processing in Each Site

S/N	SITE	DISTRICT	TCI	T	H	I	O	TFI
1	Mara	Babati	0.59	0.69	0.57	0.56	0.71	0.64
2	Dudumera	Babati	0.59	0.64	0.41	0.56	0.62	0.57
3	Hanang	Babati	-	-	-	-	-	-
4	Magugu	Babati	-	-	-	-	-	-
5	Usa River	Arumeru	-	-	-	-	-	-
6	Mwembe	Same	0.51	0.63	0.42	0.44	0.51	0.45
7	Zombo	Kilosa	0.33	0.56	0.17	0.02	0.35	018
8	Yovi	Kilosa	0.66	0.68	0.64	0.58	0.70	0.67
9	Mungu Nisaidie	Songea	0.24	0.61	0.09	0.28	0.27	0.29

The results are presented in the form of indices representing the technology climate index (TCI), technoware (T), humanware (H), infoware (I), orgaware (O), and technology fitness index (TFI) as shown in Table 11. The acceptable fitness for each of the components is when the index has a value of more or equal to 0.5. The results of technological fitness for each of the sugar processing plants are presented in diagram form in the Cobweb diagram known as the THIOC diagram (Figures 5 and 6). Figure 5 presents the appropriateness of the sugar processing technology at each of the site studied. It can be seen in Table 11 that Yovi, Mara and Dudumera sites made use of the technology properly than the other plants because their technology fitness index (TFI) is greater than 0.5 of acceptance level. Imperatively, the infoware, humanware, orgaware and climate Indices of Yovi, Mara and Dudumera sites are above the acceptance level and thus influenced the appropriateness of the sugar technology in the study area. The Cobweb diagram in Figure 6 compares two sites that are within the same locality. Comparatively therefore (referring to Figure 6), for the technology found operating in the same socio-economic and political context of the district, the sugar processing technology is more appropriately used at Yovi site than at Zombo site. In other words, the Zombo site had more difficulties in using the I 'I sugar processing technology than the Yovi site. This might have been attributed to their social-economic background in relation to entrepreneurial characteristics.

Owners in the Kiru valley in Babati district have inherited the business from within the family, all of whom belong to rich families of Asian origin. On the other hand, the owners of Mwembe and Mungu Nisaidie sites in Same and Songea districts respectively were initially employees. Whereas, Mr. Mrutu, the owner of Mwembe site was a government employee, Mr. Kinyero, the owner of Mungu Nisaidie site was an employee of Peramiho Mission, but both of them somehow managed to acquire the technology. Their apparent similarity in background not withstanding, it was intriguing to note that Mr. Kinyero was from the family of a well off farmer in Songea despite his low level education. On the contrary, Mr. Mrutu who got a post-primary education that enabled him to be employed by the government was from a peasant family in Same. These people share in common, exhibition of entrepreneurial characteristics as shown in (Table 12).

Reseachers' assessment of entrepreneurial behaviour endowment of the owner of operating processing plant is given in Table 12. The assessment shows that those owners of Asian origin, Messieurs Patel (Mara), Chaghan (Dudumera), and Salum (Yovi) are more entrepreneurial compared to their African counterparts, Messieurs Mrutu (Mwembe), Huwel (Zombo), and Kinyero (Mungu Nisaidie) who received just a minimum acceptable level of 5 points. Given the historical contexts of the African plant owners, it is possible to develop their entrepreneurial skills in areas they seem to be weak. For instance, Mr. Kinyero though weak in planning and power competencies, is strong in achievement competencies.

Figure 5 demonstrates the levels of endowment in each site with regard to humanware, infoware, orgaware and technology climate. The technoware does not vary with site specificity. It can be concluded that the level of infoware, humanware and orgaware

Figure 5: IPI Crystalline Sugar Site - Cobweb Diagram

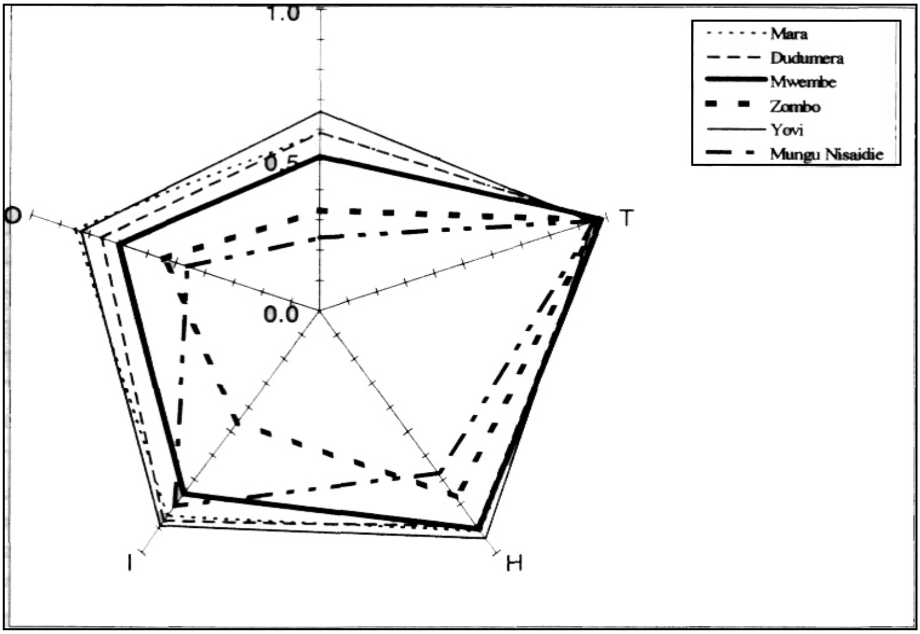


Figure 6: The THIOC Cobweb Diagram for Zombo and Yovi Sites both in the District, Kilosa, Morogoro'Region

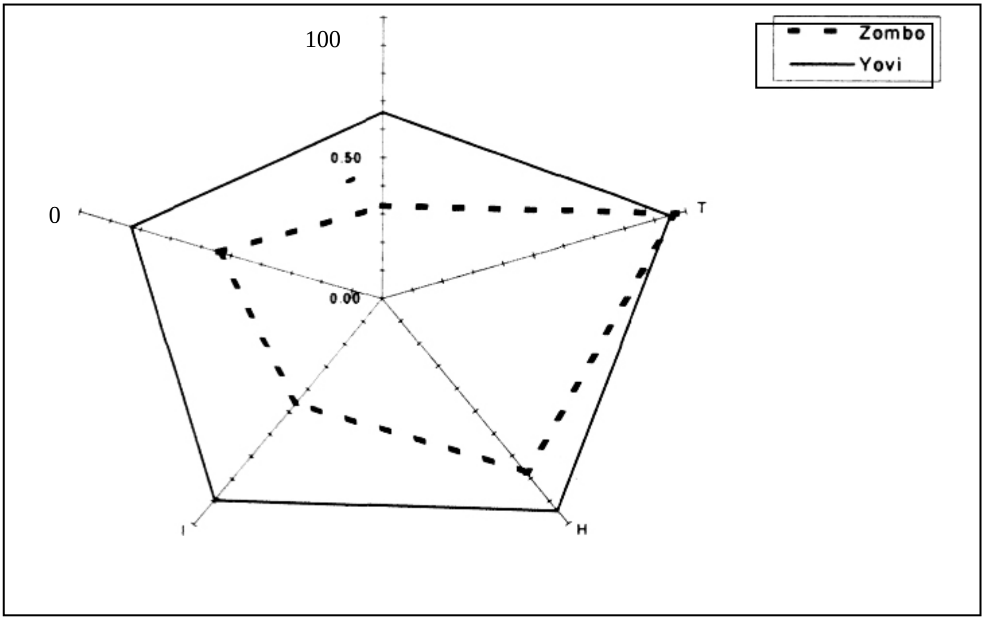


Table 12: Personal Entrepreneurial Characteristics for the Sugar Plant Owners

S/N	SITE/OWNER	PLANNING COMPETENCIES			ACHIEVEMENT COMPETENCIES					POWER COMPETENCIES		AVERAGE
		A	B	C	D	E	F	G	H	I	J	
1	Mara Estates	8	6	6	6	6	8	7	8	6	7	6.8
2	Dudumera	7	5	5	6	5	7	7	7	6	6	6.1
3	Hanang	4	3	2	4	1	2	3	3	3	3	2.8
4	Magugu	3	2	2	3	1	2	3	3	2	3	2.4
5	USA River	2	2	2	3	1	2	2	2	2	3	2.1
6	Mwembe	5	5	5	5	4	5	5	5	6	6	5.1
7	Zombo	5	5	4	6	5	5	5	5	7	6	5.3
8	Yovi Estates	9	7	7	8	8	8	-8	8	6	8	7.7
9	Mungu Nisaidie	5	5	4	7	6	8	6	8	5	5	5.9

Averages

S/N	SITE/OWNER	COMPETENCIES			TOTAL AVERAGE
		Planning	Achievement	Power	
1	Mara Estates	6.7	7.0	6.5	6.8
2	Dudumera	5.7	6.4	6.0	6.1
3	Hanang	3.0	2.6	3.0	2.8
4	Magugu	2.3	2.4	2.5	2.4
5	USA River	2.0	2.0	2.5	2.1
6	Mwembe	5.0	4.8	6.0	5.1
7	Zombo	4.7	5.2	6.5	5.3
8	Yovi Estates	7.7	8.0	7.0	7.7
9	Mungu Nisaidie	4.7	7.0	5.0	5.9

Key

0	None
2	Very Poor
4	Poor
5	Acceptable
6	Good
8	Very Good
10	Excellent

A	Goal setting	B	Information seeking
C	Systematic planning and monitoring	D	Opportunity seeking
E	Risk taking	F	Commitment to work contract
G	Demand for quality and efficiency	H	Persistence
I	Persuasion &. networking	J	Self confidence

endowment and conduciveness of the technology climate are the main factors that have governed the appropriateness of the sugar technology.

4.0 Policy Implications of the Findings

A number of issues that may require policy intervention at various key levels of the national economy have been identified as well as recommendations that are directed to relevant authorities.

4.1 Taxation

The performance of the sugar processing plants is affected by taxes imposed at both local and central government levels. Higher taxation levels reduce the attractiveness of the crystalline processing business. The study revealed that many of the IPI sugar plant owners suffer from accumulation of many taxes and levies that are not rationalised. The taxes include central government land lease, local government land levy, local government factory tax, VAT and VETA levy.

The case of Songea where cheap sugar imported from Malawi affected the market of sugar produced from IPI plant, shows how macro economic policies can have an impact on the viability of the sugar processing technology. The case also showed how the implementation of VAT, helped to control the situation. This is a recommendable fiscal intervention supporting the operation of indigenous technologies.

It is recommended that the different taxes that are being charged on the sugarcane farmers and processing plant owners be looked at with the view to rationalising them. It is also recommended that the level of taxation be reduced and possibly exemption be given for some of the taxes in order to promote wider dissemination of the technology.

4.2 Technology Transfer and Dissemination

The transfer of manufacturing of IPI developed equipment is one of the contentious issues that IPI has yet to find a way out. IPI has been addressing this issue for many year a (26). It has been found that the transfer of the sugar processing technology, just like the other IPI developed technologies, to commercial manufacturers is not as straightforward as thought. The process is affected by many factors that are beyond the capacity of IPI and that need to be addressed at policy level. They include technical, economic and social aspects of the technology that affect the potential transferees.

Formal transfer of manufacturing the IPI sugar equipment is the most difficult despite big efforts made to transfer the manufacturing of the equipment to commercial workshops and the good business performance of the equipment demonstrated. No positive response has been received ten years after the technology was developed and tested probably due to reluctance on the side of potential transferees to pay the transfer fees required by IPI and uncertainty about the potential market for the equipment in this era of economic liberalisation. The market uncertainty is caused by the relatively high investment cost of the technology vis-a-vis the competitive market from imported technologies or products. Another problem is the lack of appropriate financing mechanism for entrepreneurs who are willing to acquire the technology. It is recommended that the government be responsible to protect infant industries/ technologies through fiscal, financial and legal policies. As IPI and other related R&D institutions are government owned, they should consider waiving the initial transfer fee that is charged to transferees, so that the transfer of the equipment to commercial manufacturers could take place. Turnkey transfers should also be considered although the government should not shy away from its basic responsibility of financing R&D. The establishment of a financing mechanism that would ensure provision of the required investment capital for potential buyers of the technplogy is also recommended.

There is a need for IPI to seriously address technical improvements on the equipment that have been suggested in this study, so that the technology would become marketable. Monitoring of performance of equipment that are in the field in order to obtain the necessary feedback required for improvement of the technology is also necessary. The findings show that perhaps it was still early to start thinking about transferring the manufacturing of the equipment from IPI although no technology is trouble free. While IPI continues to perfect the sugar processing technology, possibilities of transferring the technology to a commercial manufacturer could still be explored. The delay in maturity of the technology for transfer was caused by among other things the delay in field testing and monitoring. From the literature surveyed, the size and capacity of the IPI technology is unique worldwide, thus efforts to develop it further and preserve it are recommended.

The findings show that the major causes of poor performance of the plants are weaknesses on the part of humanware, orgaware, infoware, and the technology climate at the respective sugar processing sites. These factors need to be looked at not only by IPI but also from the policy level. The study team is recommending the establishment of a programme of supporting rural entrepreneurs that would include provision of the necessary training.

4.3 Poverty Alleviation

This study has revealed that the IPI village level sugar processing plants play a very big role in alleviating poverty in the areas that they are installed. It has been shown, qualitatively, that the technology has increased the income of the respective processing plant owners, surrounding sugarcane farmers, employees of the farms and processing plants, and surrounding support services owners. The actual income earned per year by the plant owners and surrounding farmers and villagers, based on the data that is presented in Tables Ib, 2,9,10(a) and 10(b), may be a subject for further research. In addition, the technology has provided affordable sweeteners at village level.

Despite all the benefits provided by the technology, very little attention has been paid by the government to support the dissemination of this technology on a wider scale. It is now a decade after the technology was developed, there is only a total of fourteen plants that have been manufactured and sold in the whole country. It is recommended that the government play an active role in promoting the dissemination of the village level sugar processing technology as part of basic industry strategy in all the areas that have potentials. The potential interest groups such as NGO's, banks, manufacturing workshops and private companies should be motivated through fiscal and legal policies to participate in their relevant areas of support in the technology dissemination.

4.4 Extension Services

The research team was overwhelmed by the lack of knowledge, on the part of the government extension services, about sugarcane cultivation in all the study areas both at regional and district levels. There was also almost non-existent extension services provided to sugarcane farmers. The farmers were therefore left to struggle on their own. The explanation given was that sugarcane crop was left under the responsibility of SUDECO and the large-scale sugar processing factories. The Kibaha based sugarcane Research Institute was also visited and it is primarily supporting sugarcane producers in and around large-scale factories. However, it was also known that the above-mentioned organisations were only dealing with plantations owned by the large-scale factories and surrounding outgrowers which means the small-scale sugarcane growers were completely ignored.

This study has revealed that there is big production of sugarcane by the small-scale farmers and there are potentials for increased production. Also it has been shown that coupling small-scale sugar cultivation with IPI village level sugar processing plants plays a big role in improving the economic situation in the respective areas. It is therefore recommended that the government, particularly the Ministry of Agriculture and Food Security treat sugarcane produced by small-scale farmers as one of the cash crops in the areas where it is grown. It should also offer all the support needed similar to the other crops.

4.5 Energy Supply

The IPI sugar processing plant has been found to be most ideal when operated at the sites where grid electricity is connected with an investment saving of about 47% compared to the diesel-operated plant and operational costs of eight folds less than those of diesel-powered plants. However, most of the potential areas for installation of the plants are in locations that are without grid electricity. It was also shown that alternative fuels such as biogas could play a very big role in minimising the cost of energy for the plants. Such alternative sources of energy are also environmentally friendly.

As a policy intervention that will help to stimulate dissemination of the village level sugar processing technology, it is recommended that the government put more emphasis on its ongoing rural electrification programme with particular focus to areas that have potential for development of rural industries such as the village level processing plants. The efforts should not only base on expansion of the national grid, but utilise alternative and renewable sources of energy such as mini and micro-hydro power, biogas energy and other biomass energy sources, that are abundant in rural areas.

4.6 Land Ownership

The issues of ownership of land and access to irrigation water sources require urgent attention by both local and central governments in order to boost the morale and confidence of sugar processing plant owners. While the sugarcane growers pay vast amounts of money as land levy, they do not enjoy similar protection from surrounding villagers who are fighting for the same land owned by the farmers. Incidents of conflict over the control of land and irrigation water sources that were reported in Arusha, Kilimanjaro and Ruvuma regions have contributed to demoralising sugarcane fanners and processing plant owners. Also some sugarcane farmers have suffered big financial losses as a result of acts of sabotage by surrounding villagers. These acts seem to have passed without any action by both local and central governments.

It is recommended that the government take strong measures to ensure security of land owners. At the same time, the villagers surrounding large scale farmers should be assisted to acquire sufficient land to meet their requirement, without interfering with other production activities in the area, and in particular the sugar processing plants. The conflict of water for irrigation could be eliminated, if the villages surrounding the sugar processing plants and large-scale sugarcane farmers would have Village Water Committees that are effective.

4.7 Environmental Pollution

During processing of the sugar, energy is required to heat the evaporation pans. It was found that all sites that were visited use bagasse for firing evaporation pans when crushing season start (June or July i.e. after rainy season). It was also noted that all sites those were operating as from late November to January and so on were using firewood except Yovi Estates in Morogoro, which still used bagasse. The Yovi Estates has constructed a shade to store bagasse, which can be used even in rainy seasons thus conserving the environment from deforestation. This example needs to be emulated by all plant owners, and village governments surrounding the processing plants should institute strict environmental by-laws that would discourage the plant owners from utilising fuelwood resources in the villages.

The main by-products produced are molasses and bagasse and molasses has many uses including supplementary feed for animals, production of alcohol, sweetening of porridge for poor household, biogas digester catalyst during cloudy days, production of guru and subsequently producing alcohol usually illegal (gongo) which is responsible for polluting the social eco-system. In order to control the situation, measures should be taken to ensure that the people continue to benefit from the good uses of molasses mentioned above, while restricting the molasses falling in the hands of the illicit alcohol producers. Such measures could include encouraging and setting up a plant to produce alcohol for industrial use thus reducing the amount of molasses that is available for illicit alcohol production.

The observation made in the uphill land of Same where sugarcane was grown right at the source of water, is a typical example of lack of awareness of environmental conservation both on the individual farmers and the local governments. There is a strong need for the government to sensitise local governments on environmental issues, so that they could be agents for protection of environment in their respective villages. Local governments in respective sugar growing areas should take tough measures to protect the destruction of water sources as a result of competition for cultivation land for sugarcane.

5.0 Conclusions

In most literature surveyed, the emphasis has been based on upgrading the technoware part, which this research has found to be less of a problem compared to the other three components namely humanware, infoware and orgaware. It is therefore logical to start by thinking on how to eliminate the other causes of poor performance of the processing plants that are linked with the humanware, infoware and orgaware, before thinking of the VPS, which is technoware.

Some of corrective measures of the processing technology have been implemented by some of the plants operators. These include development of a better spray pump at Dudumera and Mwembe sites, development of an electric sugar drier at Yovi Estate and provision of in-built safety features in all equipment and processes at Songea, Yovi, Mara and Dudumera sites. Some of these improvements have also been incorporated in the IPI design based on their feedback, for future products.

It has been found that poor management of the production processes has caused the low sugar recovery exhibited in some sugar sites. Likewise, the level of endowment of the orgaware and humanware has caused the poor performance of the technology in the selected sugar sites. Those sugar sites with high levels in infoware, orgaware and humanware have been able to sustain services to sugar consumers as well as to their employees. All sugar-processing plants that were served by sugarcane outgrowers have low levels of infoware, orgaware and humanware, and thus exhibited poor performance indicating that technoware is not a prominent problem. The problem is in human aspects (humanware), documented facts (infoware) and institutional framework (orgaware). It has also been demonstrated that there is more to do with environment than the technoware itself. Thus intervention should focus on creating conducive environment for technology transfer and operations. The study revealed that the technology has made a very significant contribution in poverty alleviation to all the key players where it was used appropriately i.e. plant owners, sugarcane outgrowers, and the surrounding communities. It has also had an impact on other socio-economic aspects of the sugar industry dynamics in Tanzania.

The potential for assessing stimulation of sugarcane growing by subsistence farmers surrounding the IPI processing plants has been minimal because farmers who had big enough sugarcane farms to meet the capacity of the plants acquired most of the sugarcane from own farms. In the few cases where there was potential for outgrowers to supply sugarcane to the processing plants and to expand the farms, it has not been fully utilised because of poor relations between the plant owners and the outgrowers. Smooth operation of the sugar plants (technically, economically and socially) did not induce the manufacturing companies to acquire the sugar technology from IPI. However, the same factors played a biggest role in introducing the adoption of the technology by the entrepreneurs nation wide. There were other factors such as lack of financing and high taxation that are not within the control of the transferees, which hinder dissemination of the equipment.

6.0 Recommendations for Implementation

Several measures are proposed in order to facilitate smooth and successful dissemination, of IPI village level sugar processing technology. It is only after successful dissemination of the technology has been effected, that the full benefits of the technology in improving the economic conditions of rural people could be realised. The measures recommended for implementation are divided into two main categories. The first category consists of measures that require the attention of IPI, as the developer of the technology. The second category of measures is mainly for the attention of government and organisations that may be interested in promoting the IPI village level sugar processing technology. It should be recalled that at present there is no viable organisation in Tanzania that could undertake commercial manufacturing and dissemination of the IPI sugar processing technology. Therefore the authors are recommending IPI to continue manufacturing and disseminating the technology until such a time when a competent manufacturer and disseminators would emerge.

6.1 Measures that Require the Attention of IPI

The main recommendations to be addressed by IPI involve overcoming the technical and managerial problems associated with the IPI village level crystalline sugar processing equipment, so as to make it more marketable. These, include the following:

(i) Low Sugar Yield:

- Provide all plant owners with the required measuring instruments and train the staff accordingly.
- Properly train operators and sensitise plant owners to provide conducive working environment in order to enhance staff retention.
- Multi-stage centrifugation (planned to be implemented by Yovi Estates)
- Re-heat molasses with fresh juice and crystallisation.
- Use of VPS in not recommended at this stage of the development of the technology.

(ii) Develop a mechanical drier, preferably fired by bagasse (Yovi Estates has developed an electric powered sugar drier but it is poorly designed and does not function). As a result of the recommendation of this study IPI has already developed a sugar drier, which will undergo field-testing during the next crushing season.

(iii) Improve the design of the centrifuge with respect to vibrations, frequent belt wear and securing the cone. Mwembe site owner has implemented the latter improvement. IPI has started addressing these design problems.

(iv) Develop an improved spray pump following examples of Mwembe and Dudumera sites, and disseminate to the other sites. The assessment of their performance could become a subject of another study.

(v) Better supervise the manufacture of subcontracted pieces of sugar equipment to achieve good and smooth operations.

(vi) Perform better plant layout and installation works especially site layout to minimise material usage (transmission shaft) and manual carrying of materials especially hot syrup.

(vii) Provide in-built safety features in all equipment and processes (some of these i.e. guards have already been included in the recently delivered plant to • Musoma).

(viii) Wave the initial transfer fee that is charged to transferees, for the case of the village level sugar processing equipment, so as to initiate the transfer of the equipment to commercial manufacturers. However, selection of a committed transferee is vital.

(ix) Continue with monitoring performance of equipment that are in the field in order to obtain the necessary feedback required for further improvement of the technology and even design a better version than the current one.

6.2 Measures for Attention of Government and Associated Organisations

These are measures that need high-level policy machinery to be addressed. They are mainly brought to the attention of the government, both at the local and national levels. NGO's, religious organisations, banks, private organisations and individuals who are interested in supporting the village level sugar processing technology are also invited to take part in implementing the recommendations. The recommendations are summarised as follows:

(i) Harmonise taxes paid by plant owners with respect to sugar production.

(ii) Establish a financing mechanism that would ensure provision of the required investment capital for potential buyers of the technology.

(iii) Establish a programme of supporting rural entrepreneurs that would include provision of the necessary training.

(iv) The Ministry of Industries and Trade to play an active role in promoting the dissemination of the village level processing technology in all the areas that have potential by providing appropriate policies.

(v) Potential interest groups such as NGO's, banks, manufacturing workshops and private companies to assist government efforts in promoting the dissemination of the village level sugar processing technology.

(vi) The Ministry of Agriculture and Food Security to treat sugarcane produced by small-scale farmers as other cash crops, and provide all the support including extension services, as it is the case for other such crops.

(vii) The Ministry of Energy and Minerals to put more emphasis on ongoing rural electrification programme with focus being made to areas that have potential for the development of rural industries, such as the village level processing plants.

(viii) Where appropriate, use alternative and renewable sources of energy such as mini and micro-hydro power, biogas energy and other biomass energy sources, that are abundant in rural areas, rather than basing only on expansion of the national electricity grid.

(ix) The Ministries of Local Government and Regional Administration, and Land to ensure security of landowners involved in operating the village level sugar processing technology.

(x) Assist villagers surrounding large-scale farmers to acquire sufficient land to meet their requirement, without interfering with other production activities in the area, and in particular the sugar processing plants.

(xi) The Ministry of Local Government and Regional Administration to ensure that Village Water Committees are formed at Kim valley in Babati District.

Villages surrounding the sugar processing plants and large-scale sugarcane farmers should form effective Village Water Committees that would be able to sort out existing disputes over access to water sources.

(xii) The Ministry of Local Government and Regional Administration to sensitise villages in which the sugar processing plants are installed to institute strict environmental by-laws that would discourage the sugar processing plant owners from utilising fuelwood resources in their villages. The plant owners should be required to construct shades to store bagasse that can be used even in rainy seasons thus conserving the environment from being destroyed.

(xiii) Encourage the private sector to set up large-scale plant for production of distilled ethanol in areas that surround the village level sugar processing plants. The village level sugar processing plants have assisted in reducing pollution of the social environment by converting the suppliers of jaggery that is mainly used for production of illicit alcohol to provide a sugar. In order to reduce social pollution derived from molasses, a plant to produce alcohol for industrial use is recommended.

(xiv) Sensitise local governments on environmental issues, so that they become agents for environmental protection in their respective villages. Local governments in respective sugar growing areas should take tough measures to protect the destruction of water sources as a result of competition for sugarcane cultivation land.

6.3 Subjects of Further Research

The implementation of this research project has revealed areas that need further investigation. They include issues that have arisen in the cause of implementation of this research and those that were expected to be covered in this project but due to some reasons, including time and resources constraints, it was not possible to cover them fully. The researchers recommend further investigation to be done on the following subjects:

(i) In-depth study into the causes of poor sugar recovery rates in order to establish the contributing factor in the reduction of recovery rate. This could be achieved by isolating the factors, thereby achieving the maximum and minimum recovery rates for particular periods of time during the crushing season.

(ii) Assessment of impact that has been made by the new equipment that have been developed by IPI, based on the recommendations of this research project namely the improved spray gun, sugar drier and improved centrifuge.

(iii) Determination of the actual income earned per year by the plant owners and surrounding farmers and villagers.

(iv) Investigation on per capita sugar consumption in Tanzania.

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END NOTES

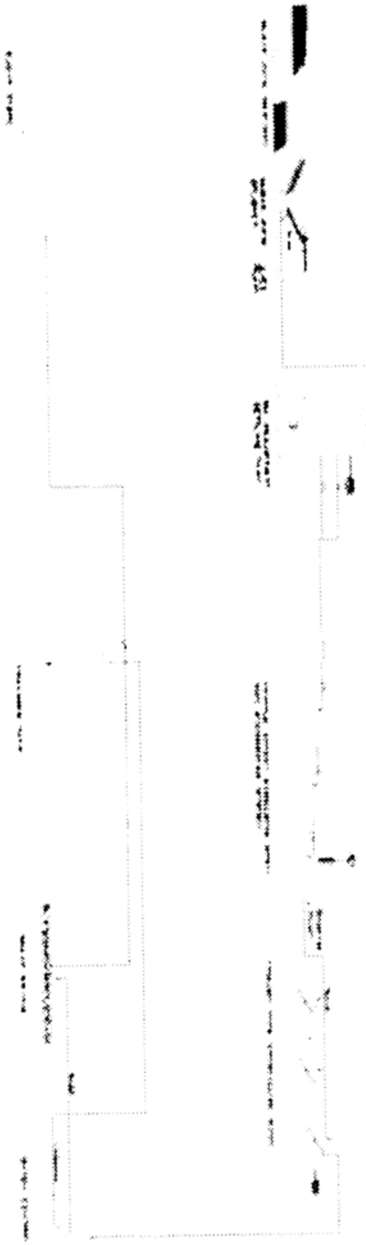
[1] Appropriate technology as pointed out by the authors is not an intrinsic quality of any technology, but derived from the surrounding in which the technology is to be utilised and also from the objectives of the user stakeholders. Appropriateness is, in addition, a value judgement of those involved in the decision-making.

[2] In OPS sugar juice is boiled and concentrated to syrup in shallow open pans that are exposed to the atmosphere and heated with naked fire or steam.

[3] In VPS evaporation is done in vessels that are under vacuum and heated indirectly through heat exchangers

[4] Indigenous two roller wooden crusher has been used in different parts of Tanzania (Songea and Same) for crushing sugarcane to produce jaggery and local brew (dengelua and puya). The IPI's is made out of cast iron.

Appendix I: Process and Instrumentation (P&I) Diagram



Appendix II: Description of IPI Process and Equipment

A 2 Introduction

The IPI-FoE crystalline sugar processing project involves the purchasing of a unit of sugar processing equipment, construction of a building for the equipment, transportation of the equipment from the place of manufacture to the final destination, installation of the equipment, and training of operators.

Sugarcane is processed in several ways. The products and technologies that have evolved have been dependent on social, technical and political factors. The Indian sub-continent has been the major innovator in this respect [24]. The main products presently made from sugar are jaggery, "khandsari", and crystal sugar.

Jaggery is a concentrated product of the whole cane juice by open pan evaporation. It is basically a non-refined sugar. It contains solidified forms of sucrose, dextrose and molasses. The yield of recovery is 10% of the sugarcane crushed. Khandsari is a creamy white/brown powdery sugar containing 94-98% sucrose and the rest molasses. Its recovery is 5-5.5%. The evaporation is achieved by open pan boiling and static crystallisation in earthen vessels. It is semi-refined brown sugar obtained by centrifuging massecuite. Crystal sugar is a refined product of cane processing. It is produced in two ways, namely using VP and OPS systems.

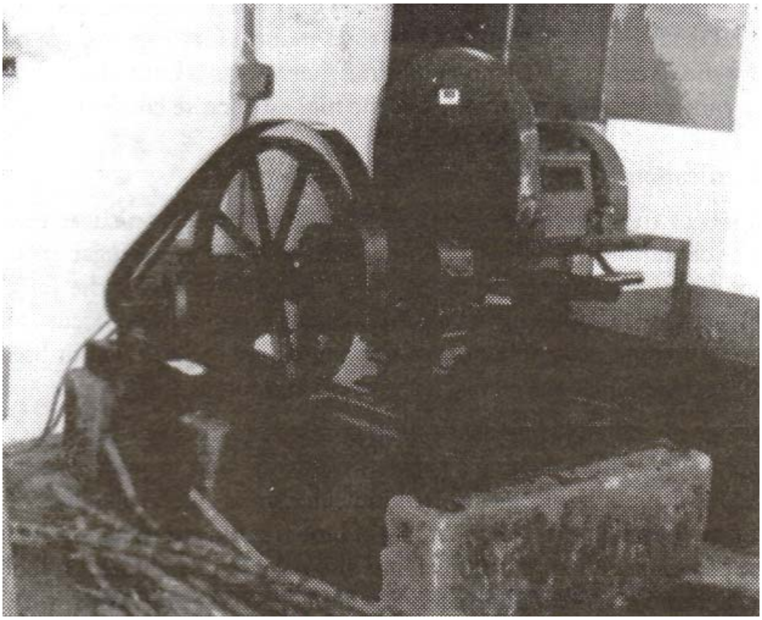
VP systems are used in modern large-scale sugar factories and produce crystals in a low temperature vacuum pan. Crushing capacity is usually over 1000 tonnes of cane per day. Recovery rate of sugar is in the order of 10% (Tanzanian factories have been producing at a recovery rate of 8.2 - 9.4%). OPS systems consist of a combination of both the features modern VP system and the khandsari system and are labour intensive. An open pan system and clarification achieve the evaporation by lime-sulphitation. The recovery rate is between 7 - 7.5% (sugar recovery from the IPI crystalline sugar plants is 5 - 6.6%). This refined sugar is slightly brownish crystal sugar. Mini sugar plants for up to 300 tonnes of cane per day have been developed in India and other parts of the world.

The IPI-FoE technology is based on OP system. It is the updating of the khandsari process and de-scaling of the OP system. The production process of crystal sugar involves six steps namely extraction of cane juice, clarification of the juice, evaporation and concentration to form sugar syrup, crystallisation of sugar, separation of sugar crystals from molasses (centrifuging) and drying of crystal sugar.

A 2.1 Extraction of Cane Juice

Extraction of juice from sugarcane is achieved by applying pressure to the cane. Passing it through of a sugarcane crusher squeezes the sugarcane[1]. Traditionally, for smaller units, three-roller horizontal power driven crushers or five-roller power driven crushers have been used. The modern OP systems use a six roller hydraulic crusher with cane preparation devices consisting o.f knives. By this method 66 - 68% juice can be extracted instead of 58 - 62% by the previous method. The IPI crusher is a three roller horizontal power driven. No cane preparation is necessary after harvesting. The crusher operates in two stages, namely the feeding and crushing stages.

Figure Al: Photograph of IPI Crusher



The optimum gap setting of the crushing stage must be done depending on the size of the sugarcane. The number of canes that can be fed into the machine is also dependent on-their sizes. The extracted juice is passed through an open sieve into a collecting tank. The IPI crusher was developed through a series of modifications, starting from a small crusher with a capacity of 625 kg of cane per hour to the present one which has a capacity of 1.5 tonnes of cane per hour. The design capacity of the latter crusher [1251] is to produce 1400 litres of juice, which is obtained after crushing 3000 kg of sugarcane in 2 hours (one batch).

In order to avoid losses due to drying and enzymatic inversion, sugarcane must be. transported and processed within 24 hours of harvest in the fields. A measurement of brix and weight are recorded prior to feeding canes into sugarcane crusher. A hand held refractometer is used to measure the sugar content and weight is measured using a weighing bridge. Bagasse is a by-product of the crushing process and it is stored in open sheds, after sun drying, for use as a fuel during subsequent boiling operations. The squeezed juice is dark brown in colour. It is allowed to accumulate at the crusher base, and then strained to remove dirt before being transferred to settling tanks. Transfer to settling tanks is effected by centrifugal pumps or by gravity depending on the terrain of the site.

Sugarcane is a perennial crop, which requires high temperatures, plenty of sunlight, at least 1525 mm of rainfall per annum unless grown with irrigation, high natural fertility otherwise it should be supplied with fertilizers, and good drainage. It has a useful life span of four to five years. The growing cycle to maturity varies with both ecology and type of sugarcane between 14 to 22 months for the plant/first crop and 12 months for the ratoon crop. In most countries, harvesting is limited to the 5-6 months when the cane reaches maturity and has the highest sucrose content.

A 2.2 Clarification of the Juice

Clarification of the sugarcane juice involves removing of non-sugar impurities by addition of chemicals, in order to minimise the retardation of sugar crystallisation. Moreover, sugarcane juice is naturally acidic (pH 4.0 - 5.5). If the juice is boiled whilst being acidic i.e. below pH value of 7.0, large inversion losses occur. The present IPI method is to use lime-sulphitation. The alternative method that utilises lime and sulphur dioxide requires special reaction vessels and furnace.

Lime is weighed and added gradually with constant stirring until the juice becomes neutral (pH. 6.8 - 7.0). A litmus paper is normally used to monitor juice pH. A yellow strip of Bromotymol Blue (B.T.B) indicator turns blue in alkaline solution and faint green at neutral point. About 2.5 kg of lime is sufficient to neutralise juice from one tonne of sugarcane. Application of lime also helps to precipitate insoluble calcium compounds, mostly calcium phosphate [$Ca_3(PO_4)_2$], that settles down with mud and other colloidal impurities. This has the effect of bleaching the sugar white.

A 2.3 Evaporation and Concentration of the Juice

Sugar juice is evaporated and concentrated in an open furnace (evaporator). The IPI evaporator consists of three open pans arranged in a cascading manner over a burnt brick furnace. This system is designed such that a successively higher concentration of juice is achieved at progressively higher temperatures. The furnace is essentially a long inclined tunnel that uses bagasse as a fuel. After clarification, the juice is transferred to the boiling pans via gravity fed distribution pipe network. The fire is lit in a fire chamber and it has to be controlled very carefully in order to get good results.

Fieure A2: Photograph of Evaporators

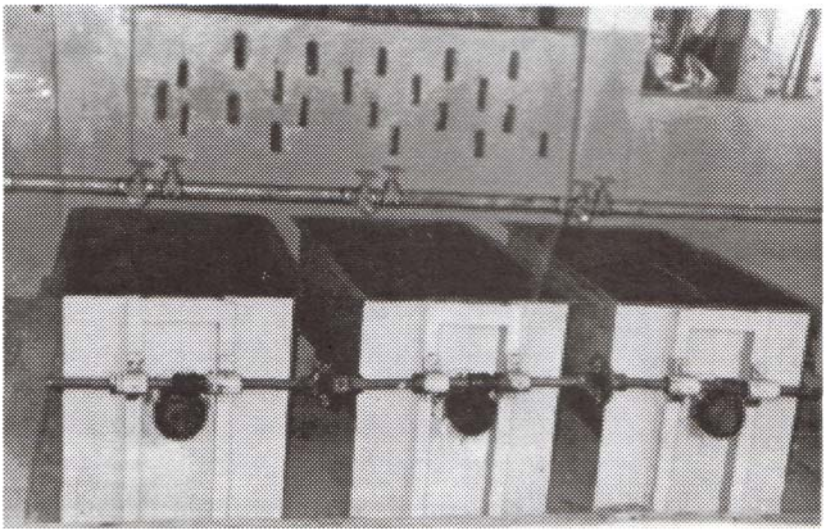
During the boiling process, dirt and scum, which contain coagulated materials like albumin, waxes, and gums, rise to the surface and are skimmed continuously using a perforated ladle and a strainer. Mucilaginous extracts of vegetable plants like okra (hibiscus escelentus) or castor oil (ricinus communis) may be added as surfactants to speed up coagulation of dirt and precipitates. To minimise losses, the skimmed material is filtered using a clean linen cloth and the filtrate is poured back into the boiling pan. The precipitate is a good animal feed additive.

Saturated syrup is transferred from the first pan to the crystalliser as the firing intensity is reduced to avoid caramelisation. When the first pan becomes empty, the juice in the second pan is allowed to flow into the first pan by gravity, through the operation of a gate valve. Similarly, the syrup in the third pan is transferred into the second pan, while the third pan is filled with fresh juice from the settling tanks. If all the juice is used up, the third, second and first pans respectively are filled with water in order to avoid oxidation of the pans. The time required getting the first syrup batch ready when starting with a cold furnace is about 2 hours. Subsequent batches take 30 45 minutes.

A 2.4 Crystallisation of Sugar

In this process, the tiny microscopic sugar nuclei get opportunity to grow into full table- sugar crystals. The process takes place in "U" shaped vessels with stirrers, called crystalliser. The stirrers rotate slowly in order to enhance the growth of bigger sugar crystals. The IPI crystallizer consists of a bank of three such vessels.

Figure A3 : Photograph of IPI Crystallizers



The hot syrup taped from the evaporator is transferred to the crystalliser manually or by gravity through a depending on the terrain at the site. The process requires a constant slow stirring motion for about 1-3 days depending on the quality of syrup and size of crystals required. Manual feeling and visual judgement are employed to determine if the required crystal size has been attained. The mixture produced is called massecuite, which is sugar crystals suspended in molasses, the mother liquid. After the full crystal size has been achieved, the massecuite produced is less viscous thus simplifying the process that follows i.e. centrifuging. Also the massecuite is brownish in colour.

The discharge of the massecuite from the crystalliser is done using buckets, which are carried manually to the centrifuge. The discharge should be done whilst the crystalliser is in motion to ensure constant massecuite uniformity.

A 2.5 Centrifuging

Centrifuging is basically a process of separating sugar crystals from molasses. The process is done in a machine called a centrifuge. The IPI centrifuge consists of a perforated metal basket lined with a fine sieve with 600 perforations per square inch. The basket is spinned rapidly at high-speed (1800 r.p.m.). Due to centrifugal force, most of the molasses is discharged through the screen leaving behind crystal sugar. Washing of the sugar crystals results in a product that is free from any traces of molasses. With the present IPI process, this is effected using a spray pump. The IPI spray pump is simple bicycle pump that has been modified by welding a perforated metal plate at the outlet.

Figure A4: Photograph of IPI Centrifuge

Spraying cold water to the sides of the rotating perforated basket of the crystalliser intermittently does washing of the sugar, until the required degree of cleanliness has been achieved. Washing also assists the centrifuging process by reducing the viscosity of the massecuite.

Prolonged running of the centrifuge gives drier sugar but very fine crystals escape through the screen. Molasses is a by - product of the centrifuging process. It contains 55 - 57% of the sugar crystals, which due to their small size escaped through the screen. To some extent, re-heating the molasses with fresh juice and letting it to undergo further crystallisation can recover the lost crystals of sugar. Molasses is a good animal feed additive and can be fermented to distil ethanol, which among many other uses is a raw material for processing of a great variety of industrial organic chemicals.

One unit of the present IPI centrifuge, which operates on a batch mode, can handle 17 kg of massecuite. One batch run takes 4 minutes, yielding about 5 kg of washed sugar, the rest being molasses. The above figures relate to optimum condition of massecuite.

Once the required degree of drying has been achieved, the centrifuging motion is stopped manually through a braking mechanism attached to the centrifuge. Discharging of the crystal sugar is effected by scooping the sugar through an opening at the bottom of the centrifuge basket after lifting a cone, which covers the opening when the centrifuge is in operation. The molasses is collected in buckets through a pipe and stored in tanks.

A 2.6 Drying of Sugar Crystals

The crystalline sugar obtained from the centrifuge is wet and needs to be dried in order to prevent formation of lumps and eventually deterioration of quality. Traditionally, sun drying has been used with the OPS plants. Presently, the IPI technology uses this technique, which may be unhygienic. Mechanical drier designs exist and have been used for this purpose elsewhere. They include rotary and vibrating base driers.

With the IPI technology, the wet crystalline sugar obtained from the centrifuge is spread on mats or clean floor or platforms, which are exposed to the sun. Turning of the sugar is required, although upon drying some of it breaks into very fine dust. Sun drying bleaches the colour of the sugar to some extent. It is advisable to retain some moisture in the sugar.

Figure A5: Schematic Drawing of Sugar Production Process Showing Typical Situation for the Sugar Drying Process Before the Sugar Drier was Developed

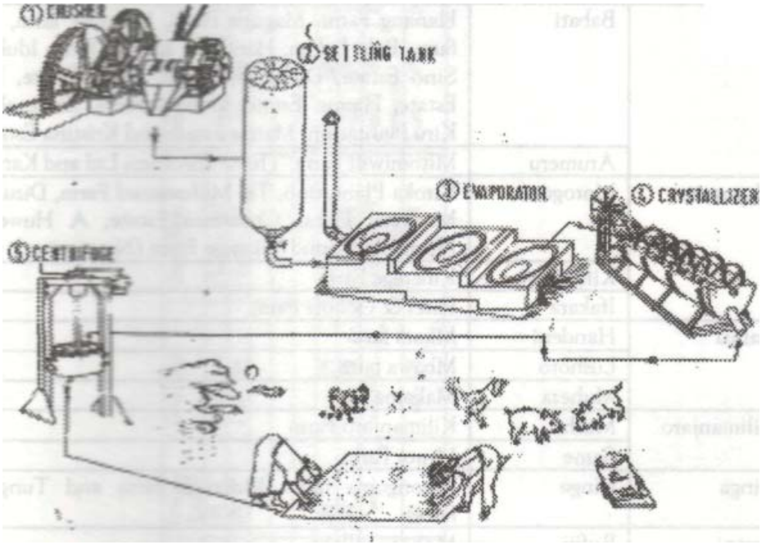
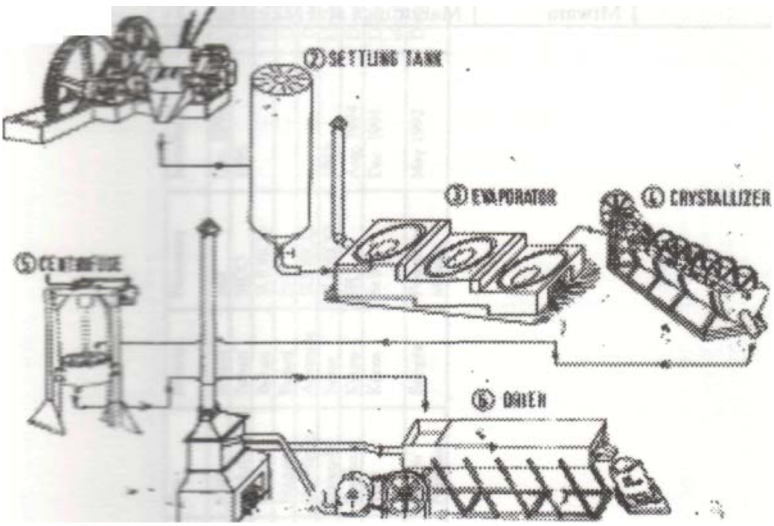


Figure A6: Schematk Drawing of Sugar Production Process Showing the Sugar Drier Developed bv IPI Following Recommendation of this Study



Areas under Sugarcane Cultivation in Tanzania

S/N	REGION	DISTRICT	SELECTED FARM
1.	Arusha	Babati	Hanang Farm, Magugu Farm, Masware farm, Miyombo farm, Balu Lakha, Handeco, Idulu 1 farm, Idulu II farm, Sino Estate, Dudumera Plant, Mara Estate, Rift Wall Estate, Hamin Estate, Odedra Farm, Endanahai Plant, Kiru Plantation, Marios Estate and Kristina Estate.
		Arumeru	Mitomiwili Farm, Tharan Brothers Ltd and Karangai
2.	Morogoro	Morogoro	Kiroka Plantation, Taj Mohammed Farm, Dizungu Farm, Msowero Plant, Christmas Estate, A Huwel's Farm, Mruma Farm and Vikonge Farm (Ngerengere)
		Kilombero	Kiberege Farm
		Ifakara	Patel & Gobole Farm
3.	Tanga	Handeni	Mkata farm
		Lushoto	Mbawa farm
		Muheza	Makame
4.	Kilimanjaro	Moshi	Kilimanjaro Farm
		Same	Mrutu Farm
5.	Iringa	Iringa	Kikongoma farm, Kidomali farm and Tungamalenga farm.
6.	Pwani	Rufiji	Mohoro village
7.	Kagera	Biharamulo	Biharamulo Co-operative Union
8.	Ruvuma	Songea	Mbawa Farm and Bonde la Lundo
9.	Mwanza	Kwimba	Ndugu farm
10.	Rukwa	Mpanda	Bonde la China, Bonde la Aruwira and Bonde la Ngwiba
		Sumbawanga	Bonde la Mwazye and Uzia
		Nkasi	Bonde la China, Nkola, Mfwizi and Mkwambe
11.	Mtwara	Newala	Bonde la Chiumo
		Mtwara	Mahurunga and Mkindani

Appendix IV: Equipment, Machinery and Installation Data

S/N	Site	District	Financier	Installation	Type	Crusher	Juice Pump	Settling Tanks	Evaporator	Crystalliser	Centrifuge	Drier
1	Mara	Babati	Self	Dec. 1994	Diesel	Not IPI	None	IPI	2 sets - IPI	2 banks - IPI	2 units - IPI	Sun drying
2	Dudumera	Babati	SIDO	1995	Diesel	Not IPI	None	IPI	1 set - IPI	1 bank - IPI	1 unit - IPI	Sun drying
3	Hanang'	Babati	SUDECO	-	Diesel	-	-	-	-	-	-	-
4	Magugu	Babati	Self	-	Diesel	-	-	-	-	-	-	-
5	Usa River	Arumeru	SUDECO	-	Diesel	-	-	-	-	-	-	-
6	Mwembe	Same	SUDECO	1993	Electric	IPI	IPI	IPI	1 set - IPI	1 bank - IPI	1 unit - IPI	Sun drying
7	Zombo	Kilosa	IPI	Aug. 1994	Diesel	Not IPI	IPI	IPI	1 set - IPI	1 bank - IPI	1 unit - IPI	Sun drying
8	Yovi	Kilosa	Self	Dec. 1991	Diesel/ electric	Not IPI	None	2 sets - IPI	Not IPI	2 banks - IPI & electric	2 units - IPI & electric	Electric drier
9	Mungu Nisaidie	Songea	Peramiho Mission	May 1992	Diesel	IPI/ Kisumu	IPI	IPI	1 set - IPI	1 bank - IPI	1 unit - IPI	Sun drying

Appendix V: State of Sugar Processing Technology at Each Site

No.	Site	Location	Present Status	Constraints/Weaknesses	Prospects/Strength	Recommendations
1	Mara (Mr. Patel)	Babati, Arusha	Fully operational and in perfect condition	• Problems of slow speed and vibration with centrifuge • Social problems related to the use of molasses in distilled alcohol (gongo)	• Abundant supply of own sugarcane • Competent personnel • Full capacity utilisation • Good quality product • Capability to market sugar and molasses • Good organisation, financial and technical management of the plant • Adequate infastructural support including equipment and support workshop to operate the plant • Technical improvements in various parts of the equipment (Ref. questionnaire)	• Successful project an good demonstration site
2	Dudumera (Mr. Chagan)	Babati, Arusha	Fully operational and in perfect condition	• Misalignment of centrifuge shaft due to unbalanced belt tension • Problem with centrifuge belts due to unequal pulley diameters • Additional set of crystallizers required • Sugar drier required • Plant capacity too small • Need assistance in installation of a bigger plant (100 tons of canes per day)	• Potential market for bigger sugar processing plant • Abundant supply of own sugarcane • Competent and qualified personnel • Full capacity utilisation • Capability to market sugar and molasses • Good organisation, financial and technical management of the plant • Adequate infastructural support including equipment and support workshop to operate the plant • Ability to suggest and carry out improvements on the equipment design	• Successful project an good demonstration site • To be supplied with second set of crystallizers • To be assisted in installation of the bigger plant from India

3	Hanang' (Mr. Hatia)	Babati, Arusha	Not started operation	• Claimed lack of labourers and sugarcane due to drought and therefore concluded lack of interest and commitment to the project	• Abundant supply of own sugarcane • Adequate infastructural support including equipment and support workshop to operate the plant • Capability to operate and manage the technology successfully	• Has not started operation • To be pressurised and if possible assisted to start production
4	Magugu (Mr. Odedra)	Babati, Arusha	Not started operation	• Claimed lack of labourers and sugarcane due to drought and therefore concluded lack of interest and commitment to the project	• Abundant supply of own sugarcane • Adequate infastructural support including equipment and support workshop to operate the plant • Capability to operate and manage the technology successfully	• The plant is not operating yet • To be motivated and if possible assisted to start production
5	Usa River (Mr. Kanji)	Arumeru, Arusha	Not started operation	• Lack of infastructural support including equipment to operate the plant successfully • Poor plant layout and installation work (massecuite to be carried in buckets to crystallisers) • Lack of sugarcane supply • Land dispute with surrounding villagers • Unfinished building • Broke down tractor, which drives crusher • Inability to repay loan • And therefore, lack of interest and commitment to the project	• Adequate land area and potential for growing own sugarcane	• The plant not operating yet • To reassess project viability and make suitable decision

8	Yovi (Mr. Salum)	Kiloza, Mo'goro	Fully operational and in perfect condition	• Financial management of the project • Require higher capacity plant	• Potential market for bigger sugar processing plant • Abundant supply of own sugarcane • Very competent and qualified personnel, including two former employees of Mahonda Factory in Zanzibar • Own developed electric sugar drier • Full capacity utilisation • Good quality product • Capability to market sugar and molasses • Good organisation and technical management of the plant • Availability of adequate diesel generator to runs all the equipment except the crusher • Adequate infastructural support including equipment and support workshop to operate the plant	• Successful project and good demonstration site

8	Yovi (Mr. Salum)	Kilosa, Mo'goro	Fully operational and in perfect condition	• Financial management of the project • Require higher capacity plant	• Potential market for bigger sugar processing plant • Abundant supply of own sugarcane • Very competent and qualified personnel, including two former employees of Mahonda Factory in Zanzibar • Own developed electric sugar drier • Full capacity utilisation • Good quality product • Capability to market sugar and molasses • Good organisation and technical management of the plant • Availability of adequate diesel generator to runs all the equipment except the crusher • Adequate infastructural support including equipment and support workshop to operate the plant	• Successful project and good demonstration site

9	Mungu Nisaidie (Mr. Kinyero)	Songea, Ruvuma	Operating but with lots of technical problems with equipment and operators	• Lack of technical skills and management • Lack of trained operators • Improper operation of equipment • Poor financial and management skills • Poor production planning • Poor relationship with surrounding villages • Immature crusher prototype (weak base frame) • Broken down centrifugal pump due to poor manufacturing • Poor plant layout and installation work (too long drive shaft with inadequate bearings and also massecuite carried in buckets to crystallisers) • Lack of adequate support workshop facility • Brixmeter required • Spray pump weak (frequent wear of rubber) • Problem with centrifuge (alignment of rollers/pulleys and belt wear) • Frequent wear of crystallizer gears	• Bush bearings for bottom centrifuge pulley changed to ball bearings • Discovery of how to use molasses to improve biogas production • Adequate supply of sugarcane and potential for increase growing by surrounding villagers • Sufficient market of sugar and molasses • Adequate infastructural support including equipment to operate the plant • Financial support from Peramiho Mission for other sugar processing projects • Sufficient market for sugar and molasses • Potential for increased sugarcane production by outgrowers • Innovative use of molasses to enhance biogas production	• To be supplied with latest version of crusher base frame by IPI • Faulty pump to be repaired by IPI • To be advised on best support workshops • Assistance on how to manage the technology, including the financial and also human aspect is required • To be trained on general resource management • Needs to employ a mechanic • Potential demonstration site for southern region

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