THE 50TH ANNIVERSARY OF THE SUGAR MILLING RESEARCH INSTITUTE

BS PURCHASE

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Abstract

The Sugar Milling Research Institute (SMRI) was founded in 1949 as a joint venture involving Natal Sugar Millers, the Council for Scientific and Industrial Research (CSIR) and the University of Natal.

In the early years the SMRI's main priority was the improvement of South African sugar technology by providing training and advisory services, including a factory performance benchmarking service. Research and development was subsequently given higher priority, accompanied by the development of an extensive analytical service. Changes in the funding, staffing, control, services and focus of the Institute are outlined, and examples of achievements are presented.

Current trends and technical developments are summarised and recent changes to facilitate flexibility of response to individual factory requirements are explained. Conjecture as to future technologies and the role of the Institute is given.

Introduction

In the 50th year of operation of the Sugar Milling Research Institute (SMRI), this paper serves to record some of the history of the Institute, outline its existing operations, and indulge in some conjecture about the future.

History

The SMRI is among the older research institutes dealing with sugar processing. Dates of establishment of some other institutes are shown in Table 1.

Table 1. Dates of establishment of some sugarcane research institutes.

Year	Name and country of research institute
1891	Audubon Sugar School (moved from New Orleans to Baton Rouge in 1925), USA.
1900	Bureau of Sugar Experiment Stations (BSES), Australia
1912	Sugarcane Breeding Institute (SBI), Coimbatore, India
1925?	Proefstation Oost Java (POJ), Java
1925	South African Sugar Association Experiment Station (SASEX)
1936	National Sugar Institute (NSI), Kanpur, India
1940	Sugar Processing Research Institute Inc. (SPRI), USA
1942	Jamaican Sugar Industry Research Institute
1946	Taiwan Sugar Research Institute
1949	**Sugar Milling Research Institute (SMRI), South Africa**
1949	Sugar Research Institute (SRI), Australia
1949	Barbados Sugar Research Unit
1953	Mauritian Sugar Industry Research Institute (MSIRI)
1964	National Sugar Cane Research Institute of Cuba
1969	Copersucar (CTC) (moved to present site in 1979), Brazil
1975	Vasantdada Sugar Institute (VSI), Maharashtra, India

Articles and memoranda of association

The Institute was formally incorporated under the Companies Act on 4 August 1949, following three years of negotiations between the Natal Sugar Millers' Association, the Council for Scientific and Industrial Research (CSIR) and the University of Natal. Signatories to the Articles of Association were Messrs GM Hulett, RS Armstrong, GV Crookes and UWM Campbell from the Natal Sugar Millers; BFJ Schonland and KA Lewis from the CSIR and WJ O'Brien from the University of Natal.

The Articles of Association make provision for control through a Board of Control consisting of five nominees from the Sugar Millers and one each from the CSIR and University.

Membership

Initially only factories in South Africa were members; referred to as Associate Members. By 1960, an Affiliate Member scheme had been initiated which enabled eight non-South African factories to join under a scheme which involved a reduced fee but no representation on the various committees. Affiliate members have been located in the following countries: Ethiopia, Malawi, Mozambique, Somaliland, Swaziland, Tanganyika, Uganda, Zimbabwe.

Table 2. Trends in membership numbers and types.

Year	1950	1955	1960	1965	1970	1975	1980	1985	1990	1995	1999
Associates	16	15	16	17	19	18	17	17	17	18[1]	19[2]
Affiliates	0	0	8	5	10	10	7[3]	7	7	8[4]	5[2]

[1]New Komati mill
[2]Mount Edgecombe and Glendale closed and three Swazi mills moved from affiliate to associate
[3]Five Mozambique mills withdrawn and two Swaziland mills joined
[4]Nakambala (Zambia) joined.

Some of these members withdrew when South Africa left the Commonwealth but factories in Swaziland, Zimbabwe and Malawi have been long term members. The trends in membership numbers and types are shown in Table 2.

In 1999, the three Swaziland factories were welcomed as full Associate Members in recognition of the fact that Swaziland is a member of the South African Customs Union and is located within the geographic spread of the South African industry.

Funding

Initially funding was provided equally by the Sugar Millers and the CSIR, with the University of Natal providing accounting and administration services. The Sugar Millers steadily increased their portion of the funding to approximately 75%. In 1989 the CSIR ceased further contributions, and soon afterwards the University began to charge for its services. As from that date, 'user pays' services such as consulting, analyses and training had to provide alternative sources of funding. The levies on sugar produced by Affiliate Members (i.e. non-South African members) were also increased steadily from 10 to 50% of the Associate Member rates. Trends in funding are shown in Figure 1.

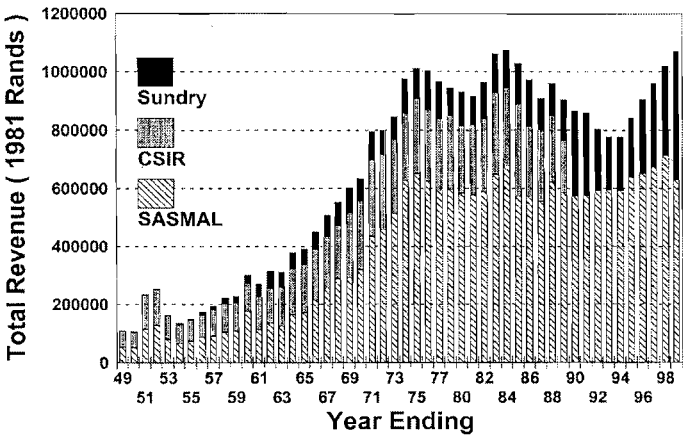

Figure 1. Trends and sources of funds (adjusted for inflation to 1981 Rands).

Staffing

The total number of permanent staff employed increased steadily for the first 30 years and then stabilised at about 45. Since 1980, approximately one-third of the staff have been university graduates while another third have held technical diplomas (Figure 2). A total of 339 people have been employed – the shortest tenure being two days and the longest being 35 years.

Conditions of service were initially linked to the CSIR but have been controlled by the sugar industry alone since the mid-1980s, with an independent pension scheme being established in 1994.

Employees have been drawn from at least 13 different nationalities, giving something of a United Nations flavour

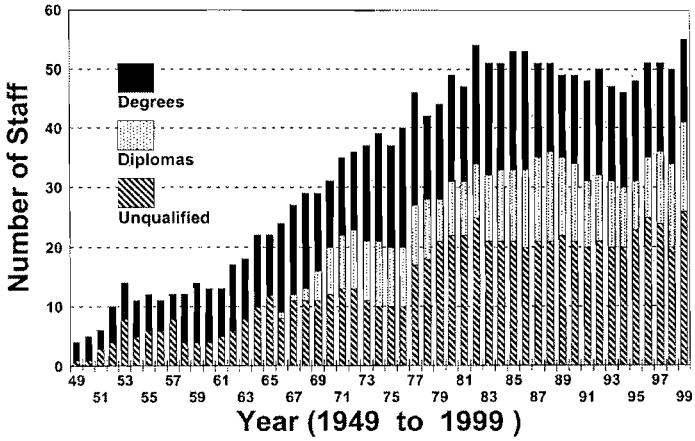

Figure 2. Trends in numbers and qualifications of staff.

and hybrid vigour. Five marriages have blossomed between staff members.

Control and management

Ultimate control has always rested with the Board of Control which has determined that Associate Members consist of all South African member factories and that representatives of these factories elect an Advisory Research Committee to consider the Annual Research Programme. The Research Programme is drawn up in close consultation with factory staff.

Day-to-day management is the responsibility of the Director and Heads of Divisions. The size and numbers of Divisions change periodically according to research focus. Current divisions are:

- Analytical Services
- Administration (including training)
- Cane Handling (formerly biotechnology)
- Chemical Research
- Engineering
- Processing.

Services offered

Extension and training

Early activity was concentrated on technology transfer and soon led to the establishment of formal training courses. In 1964 a Training Division was established to run a three-year National Diploma course in Sugar Technology, which was later supplemented with a two-year certificate course. The diploma courses ran for 20 years and produced 92 graduates, many of whom rose to senior positions in the industry. By 1984 the demand for this type of training had declined, and the courses were replaced by an annual intense three-week course in sugar technology aimed at science and engineering graduates who were new to the industry. In 1993 this was expanded to a Ten-week Course in Sugar Engineering which is run every 18 months and gives a good grounding in sugar technology for engineers-in-training. Numbers attending this

course have expanded from 11 in 1993 to 34 in 1999, with a total of 103 having attended the five courses.

An annual one-week course in sugar technology has been offered since 1980 and has been attended by a total of 569 delegates. An innovation in 1989 was a two-day Sugar Technology Overview offered on site for agriculture, administrative and maintenance personnel. Thirty-five such courses have been presented to a total of 702 delegates.

Since 1990 the Training Officer has worked closely with the Industrial Training Centre in the provision of courses in Sugar Manufacture and Laboratory Practice at the Training Centre.

Collation and co-ordination

Since 1951 the Institute has undertaken the collating of factory performance parameters from all member mills and redistributing them for benchmarking purposes. This is done on a weekly and monthly basis, culminating in an Annual Review at the South African Sugar Technologists' Association (SASTA) Congress. To ensure validity of the data the Institute assists all factory laboratories by providing weekly check samples and an auditing service. Furthermore, samples of mixed juice and molasses from each mill are analysed at the Institute each week, using chromatography to analyse specifically for sucrose so that sucrose-based factory balances can be produced. This accurate benchmarking service is regarded by many as the most significant service offered to the industry.

The Institute has periodically co-ordinated industrial responses to issues such as safety legislation, co-operation with the International Commission for Uniform Methods of Sugar Analyses (ICUMSA) and the production of publications such as the Laboratory Manual for South African Sugar Factories. It has also arranged colloquia to share ideas on topical issues (Table 3) and has represented the industry in international societies such as the ICUMSA and the International Society of Sugar Cane Technologists (ISSCT).

Analytical services

An extensive analytical service is offered to support inter-factory comparisons, sugar marketing, research, special investigations and quality control at factories. The demand for these services has increased appreciably in recent years, prompting a decision to achieve internationally recognised accreditation of the services, effective from 1998.

Research

Research has been a fundamental function and has taken various forms, from simple co-ordination of ideas to participation in large projects involving the CSIR and a number of universities.

In broad terms, areas of research have covered analytical methods, cane quality, sugar extraction and recovery, sugar quality, by-products and environmental protection. A detailed list of successful projects completed in the first 40 years is given by Purchase (1989a), some of the highlights being:

- the introduction of lime defecation and the use of flocculants (1954)
- early trials of diffusion leading to advocation of diffusion which is now used extensively in South Africa (1955)
- co-ordination of a 'Mutual Milling Project' leading to appreciable increases in extraction (1960 –)
- development of a procedure for measuring starch and an understanding of the effect of starch on filtration (1962-64)
- early trials of resin decolourisation of refinery liquors (1973)
- development of processes for hydrolysis of bagasse and fermentation of hydrolysates (1980-90)
- optimisation of filter station operation (1981)
- measurement and modelling of thermal degradation of sugars in evaporators (1984-87)
- introduction of a suitable routine method for assessing cane staleness (1985)
- consolidation of knowledge on the causes of mill roll failure (1987)
- development of a model relating liming of diffusers to acetic acid production and subsequent corrosion of vapour lines (1987)
- assessment of new instruments and factory equipment.

During the past 10 years progress has been made in the following areas:

- Development of improved instruments for measuring preparation index, juice clarity, mud concentration and sugar contamination of refinery condensates

Table 3. Subjects of colloquia of topical interest.

Year	Colloquium topic
1972	Milling
1975	Boiling, crystallisation and curing of C-massecuites
1976	Evaporation and allied subjects
1977	Steam generation
1978	Diffusion
1979	Clarification and filtration
1979	Factory maintenance and time efficiency
1980	Applications of gas chromatography to factory control
1981	Boiler feedwater
1981	Caneyards
1982	Raw sugar quality
1983	Instrumentation and control
1984	Effluent and domestic water treatment
1985	Refining
1986	Milling
1987	Energy management
1988	Cane quality
1989	Plate heat exchangers and falling film evaporators
1989	Cane preparation and diffusion
1990	Boiling schemes and colour
1991	ISSCT three-day workshop on factory performance monitoring
1991	Training of senior process personnel
1992	Processing of droughted cane
1992	Corrosion control
1994	Production of factory performance reports
1994	Clarification and alternative technologies
1995	Activated carbon
1997	Energy
1998	Good manufacturing practice
1999	Effluent treatment

- Evaporator performance, including scale control and assessments of various designs
- Control of sugar colour using various chemical agents, including ozone
- Improved understanding of colour transfer from liquor to crystal
- Improved understanding of bridging behaviour of bagasse
- Identification of theanderose as a marker of cane sugar (not beet sugar) and as a cause of crystal deformation
- Modelling of sucrose degradation in high brix solutions
- Chromatographic separation of molasses and refinery jets
- Near infra-red spectroscopy for analysis of cane and juice components
- High performance anion exchange chromatography with pulsed amperometric detection for routine analyses of specific sugars
- Improved understanding of effects of cane quality and cane varieties on processing.

Current trends and technical responses

Current trends which the SMRI recognises in its planning include:

- Diminishing trade barriers accompanied by increasing world sugar production, with consequent increasing international competition for markets.

  This is stimulating even greater emphasis on lowering costs of production, and on improving the quality of the end products. It also emphasises the advantage of any co-products which may improve the profitability of sugar production.
- Increased emphasis on environmental issues, including health and safety of workers and customers.

  This necessitates greater care with cane burning, effluent and smoke-stack control, use of lead in pol analyses, hygiene in factories, and end product composition with respect to chemicals such as sulphur dioxide.
- Further closure of small factories in South Africa, and consolidation of factory ownership into a lesser number of large companies which have become increasingly involved in sugar industries of surrounding countries.

  This has stimulated demand for SMRI training and consulting in these surrounding countries. It has also called for greater SMRI sensitivity to the fact that the large companies each have different needs and expectations.

Technical advances in response to such trends tend to be steadily incremental rather than dramatic, and they tend to take place simultaneously on numerous fronts. Such advances may escape due attention, thereby diminishing awareness of progress and of new opportunities. Some areas of current advancement worldwide are highlighted below.

Cane quality

Technical responses to the drive for cost reduction include emphasis on improving the quality of cane. Some countries, such as Jamaica, which previously paid for cane purely on a mass basis, have introduced quality parameters, while South Africa has been reviewing its quality based payment scheme with the intention of introducing additional quality parameters such as purity, fibre and ash in cane. The introduction of near infra-red spectroscopy (NIR) techniques with potential to analyse a variety of cane quality parameters very quickly makes it easier to introduce sophisticated quality payment schemes, and is therefore the subject of intense research at the SMRI (Schaffler and de Gaye, 1997).

One effect of the emphasis on cane quality is a growing realisation that cane processing starts in the field and not at the factory. Harvesting procedures and delivery scheduling can have more impact on sugar recovery than some of the carefully controlled processes in the factory. The challenge is to fully quantify the costs and benefits of improving cane quality. Specific technical challenges relate to improved control of cane burning to minimise delays between burning and cutting, development of transport scheduling systems which minimise delays, development of better harvesting and cleaning equipment to minimise extraneous matter, and optimisation of season length. Computer models which facilitate decisions on harvesting and factory processing on an integrated basis are under development, with the SMRI playing a significant role.

Pressure to diminish pollution from the burning of cane is impacting on the cane quality issue and is causing the harvesting of unburnt cane to receive increasing attention. The prospect of receiving additional trash on the unburnt cane has promoted investigations into cane cleaning plants, with experimental plants being commissioned in Colombia and Mauritius in the late 1990s. Development of mechanical harvesters specifically for unburnt cane is also receiving focus, particularly in Australia. Rock and sand removal plants have been installed recently at some South African factories, and the SMRI is involved in assessing their effectiveness.

Cane processing

Within the factory, the trend is towards continuous processing. Success has been achieved with continuous pans and crystallisers but high grade continuous centrifugals are still under development (Broadfoot *et al.*, 1999). A joint project between the SMRI and the Sugar Research Institute (SRI) in Australia has been established in this area.

Continuous processing has brought with it a demand for sophisticated monitoring and control equipment such as radio frequency probes and neural networks (Lan Sun-Luk and Chabriat, 1999). Instruments for on-line monitoring are being developed for parameters such as juice colour and turbidity, mud consistency, sugar colour and moisture, and traces of sugar in refinery condensates. Some of these instruments have already been developed by the SMRI (Gooch *et al.*, 1999; Stone, 1999).

Alternative forms of cane extraction are under development, with diffusion now being well established in South Africa and various simplified versions of milling (e.g. two-roll mills) being developed elsewhere (Bonin, and Govaert, 1999).

Juice clarification is the subject of renewed focus, with improvements arising from better designs of clarifiers, more effective use of flocculants and improvements to liming procedures. Advances in this area can reduce costs and improve sugar quality. Computational fluid dynamics is playing a significant role in improving the design of clarifiers and other items of equipment (Steindl, 1996). New technologies for supplementing juice clarification and purification include the use of membrane filtration and de-ashing resins. These require further development before being widely adopted.

Recycling of clarifier underflow to the extraction plant has recently been applied in some diffuser factories, where it represents an opportunity to reduce capital and operating costs by eliminating the filter station (Meadows *et al.*, 1998).

Falling film evaporators, particularly of the plate type, are being developed because they show promise as a means of reducing capital costs and rates of fouling. Such evaporators require chemical cleaning, which has prompted increased focus on cleaning chemicals and procedures. A joint project between the Technical University of Berlin and the SMRI has contributed substantial knowledge in these areas (Walthew *et al.*, 1997).

Heightened sensitivity to sulphur in sugar dictates that, where juice sulphitation is applied, it must be closely controlled to minimise residual sulphur dioxide. Customer concerns about product safety are creating competitive advantages for producers who manufacture under an accredited quality management system.

Co-products

Current interest in co-product development is focussed on co-generation of electricity. Countries where coal is not abundant have particular interest in this and have formed the Cane Energy Network for collaboration in developing the technology. Parallel developments of significance to co-generation include very high pressure boilers, energy efficient combined cycle gas-steam turbines involving gasification of bagasse, and systems to increase the fuel supply by delivering cane trash. Theoretically, if the envisaged high technology co-generation can be developed, then revenue from electricity could approach that from sugar, giving huge economic advantage to sugar industries which are able to benefit from electricity sales.

Recovery of sugars and potassium from molasses by chromatography is another area showing promise for further development.

Responses to changing demands

The balance between research and services

The SMRI has never been a pure research institute. Involvement with analytical services, collation of factory figures, consulting and training has had the beneficial effect of ensuring that the researchers are kept aware of the realities of the industry which they serve. Following the 1989 withdrawal of CSIR funding, the need to raise replacement funds through user-pays services has at times created an over-emphasis on paid services at the expense of genuine research. Records of staff time allocations (Figure 3) indicate that this was particularly true between 1989 and 1993, when the Institute was adapting to this need. In 1995 additional staff were employed specifically for a contract to routinely analyse mixed juice for the Cane Testing Service, hence the step-change in routine services. The number of papers presented by SMRI authors at the annual SASTA congresses (Table 4) gives some reassurance that research again received due attention after 1993, although the continuing increase in demands for non-research services in more recent years has refocused attention on the issue of balance between research and non-research services.

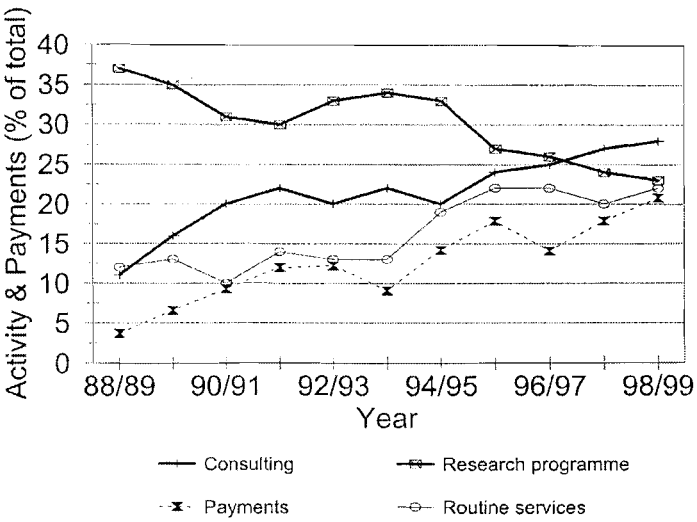

Figure 3. Trends in staff time allocations and user-pays income.

In response to the concerns that research could be prejudiced by the demand for services, additional staff were employed in 1998 and a transparent scheme of realistic charges for services was introduced in 1999 for a one-year trial period. Such a scheme is essential for ensuring that genuine research conducted for all members jointly is not threatened by an unbalanced demand for underpriced services used by only some members.

Table 4. Numbers of SASTA papers involving SMRI authors.

Year	1979-89	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Papers	8,5 average	8	5	5	10	10	7	14	8	13	9

New service categories and charges

The system developed recognises four categories of services, each with a different rate of charge:

Category 0: Research on projects that have the support of the industry as a whole as indicated by the fact that they are on the Annual Research Programme as approved by the Advisory Research Committee and ultimately by the Board of Control.

Charge rate: No charge (covered by levy).

Category 1: Investigations which are related to projects on the Research Programme but are requested by a particular member for investigation of that member's facilities, i.e. the SMRI does not request access to the facilities as part of a Research Programme project. For example, a member requesting measurement of heat transfer on a particular evaporator cannot claim that this is part of a Research Programme project on evaporators.

Charge rate: Salary-related costs of staff involved plus costs of analyses, transport, accommodation and special equipment or chemicals.

Category 2: Non-research services such as technical audits, consulting and analyses.

Charge rate: As for category '1' but including overhead running costs and costs of 'overhead' staff.

Category 3: Confidential work and work for non-members.

Charge rate: As for category '2' but including an 'interest' charge on the insured value of all SMRI assets apart from vehicles, and a 25% surcharge on the total.

Work done under categories 0-2 is not confidential although, where a member has paid for services, the resulting reports are circulated only to that member, with the understanding that other members may have access to the reports on specific request (pure analytical reports being excepted). This non-confidentiality means that full costs need not be recovered on the understanding that some benefits will arise to all members.

Conjecture about the future

Before indulging in some conjecture about future technical developments in the sugar industry it is helpful to look back at past technical developments and their incorporation into the South African industry. Table 5 shows relevant data and illustrates that, where a fundamentally new technology eventually finds an application in the sugar industry, this has generally taken 25-35 years. Modern information technology will probably reduce this time lag but, considering the number of fundamental advances in the past 15 years, there must be a whole crop of technologies waiting to be harvested by the sugar industry.

Information technology

On the 40th anniversary of the SMRI, attention was drawn to the IBM personal computer (PC) as a new development that was likely to impact strongly on the industry (Purchase, 1989b). The impact on research has already been vast but the major impact on the industry has still to come in areas of modelling, scheduling, automation, storage and retrieval of knowledge, communications and training.

Further exploitation of the powers of the PC must be a future focus area for the SMRI and the industry. Existing field and factory models need to be integrated into holistic decision making tools; financial models will help with decisions on research priorities; new research management software will assist with planning of projects and recording of results in a form which is readily accessible when the project is re-visited; modelling techniques such as computational fluid dynamics will help to optimise design and operation of equipment; improved communication techniques are already facilitating collaborative research and conferences; neural networks are beginning to show promise in automation; process simulation programmes need to be developed as operator training tools and computer based training has potential for distance learning.

Maintenance of factory efficiency

The SMRI's contributions to maintenance of efficiency must continue to receive focus in the future. Minor failures in this area can have an economic impact as big as, but opposite to, the introduction of a new technology. Accurate analytical services combined with an effective and comprehensive factory benchmarking service, technical auditing and consulting all help to minimise loss of revenue through inadvertent losses of sugar. Factory efficiency is particularly important because a major portion of the cost of sugar production (about 80%) has been incurred by the time juice is extracted from cane. Any losses thereafter impact heavily on profit – a loss of only about 0,15% of the sugar produced by South African members is equivalent in value to the entire SMRI budget.

Co-products

The future viability of sugar enterprises is becoming increasingly dependent on their ability to produce profits from co-products. Electricity is an attractive co-product because it has a large market and its generation from bagasse can be integrated easily with a sugar factory. Prices offered for this electricity are not presently attractive in South Africa, but this is likely to change as existing coal based generation capacity is used up (by the year 2005) and the government's policies on marketing of electricity change. Anticipated incentives for use of renewable fuels add to the interest in co-generation. The development of energy efficient co-generation based on combined gas-steam cycle generators, higher pressure boilers and trash recovery seems a fruitful area for future focus.

In the more distant future the development of commercial fuel cells running on sugar or bagasse hydrolysates and providing efficient energy conversion for motor vehicles and small scale electricity plants is a possibility.

Table 5. Dates of selected inventions and their first use in the SA sugar industry.

Date	Nature of invention	Date and use in sugar industry	Delay
1945	Microwave oven	*ca* 1984 - bagasse moisture analysis	39 years
1946 1950	Electronic computer First commercial computer	*ca* 1970	24
1952	Chromatography for analyses	*ca* 1975 (routine analyses - 1980)	23
1952	Gas turbine generator	*ca* 2005 (anticipated)	53
1953	Model of DNA	*ca* 1990 - gene mapping of cane	37
1955	Hovercraft patented	Pending??? - infield transport (no soil compaction and usable in wet weather)	?
1960	First surveillance satellite	*ca* 1998 - area under cane	38
1962	First communications satellite	Precision farming to come?	36+
1972	First earth resources satellite		
1964	First automated subway train	Comparatively, automation and data capture and training simulators are still in their infancy	25+
1965	First automated airliner landing		
1975	Computerised supermarkets		
1975?	Preparative chromatography on a large commercial scale	Research stage (used in beet industry)	24+
1967	DNA synthesised	Still early days with cane	30+
1970	First synthesis of a full gene		
1972	United Nations highlights global environmental changes and resource limitations	Major impacts still to come - renewable fuels from cane, burning restrictions, zero effluent	
1973	Computerised brain scanner	Cane consignment scanner???	27++
1976	Laser-produced ultra-strong fibres	Corrosion resistant replacement for chains??	23+
1985	IBM PC widely available	Rapidly developing applications	
1998	Sugar Fuel Cell (SuFuCell) patented	Rural electricity from sugars by an electro-chemical process???	
2004	Predicted first commercial fuel cell car (Opel/methanol)	Energy-efficient car running on Sugar Fuel Cell	

New processing schemes

Membrane filtration, ion exchange, electro-dialysis and ion exclusion chromatography are purification techniques with potential future application to cane juice. They introduce possibilities for omitting some of the current processes. Combined with consumer demand for more healthy (less purified) sugar they could facilitate the production of granulated amorphous sugar made from partially purified juice without the tedious multiple crystallisation and centrifugation stages. This would involve a paradigm shift by sugar technologists and marketers.

Research collaboration

A feature of modern scientific papers is that they inevitably involve multiple authors. This is a reflection of the multi-disciplinary approach required for progress. Increased collaboration with other research institutes, universities and industries is a trend likely to extend into the future, encouraged by the ease of e-mail communication, the need for rationalisation of resources and the potential for reducing lag time between concept and innovation.

Conclusions

Throughout its 50 years, the SMRI has steadily changed its services in response to the requirements of the industry it serves. Support and guidance from the industry has been critical to success, as has the general competence and dedication of staff. Definite challenges exist for the future.

Acknowledgements

The past and present SMRI staff, Boards of Control, Advisory Research Committees and sponsors of the Sugar Milling Research Institute are thanked for their contributions to the progress of the Institute over 50 years.

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