THIRTY YEARS OF PROGRESS IN THE SOUTH AFRICAN SUGAR INDUSTRY THROUGH BENCHMARKING AND TECHNICAL INNOVATION

By

S.B. DAVIS

Sugar Milling Research Institute, c/o University of KwaZulu-Natal, Durban, South Africa
sdavis@smri.org

KEYWORDS: Review, Performance, Innovation.

Abstract

THE SOUTH African cane sugar industry prides itself as being one of the world leaders in technical efficiency. The various factories in the industry openly share weekly, monthly and annual technical performance figures through the central milling research organisation, the Sugar Milling Research Institute (SMRI). The sharing of information allows for effective benchmarking, leading to continuous performance improvements, as illustrated using a number of performance parameters from selected years from 1974 (the year of the previous ISSCT Congress in Durban) to 2006. A particular value of note is that the average sucrose extraction for the South African industry exceeded 98% for the first time ever in the 2005–2006 season. In addition, performance improvements have been achieved through continuous technical innovation, the replacement of milling tandems with diffusers being one of the prime examples. At the same time, the number of factories has reduced from 20 in 1974 to 14 in 2006, accompanied by increasing factory capacity, with the average cane crush rate rising from 169 tonnes per hour in 1974 to 302 tonnes per hour in 2005. This rationalisation of the industry has led to greater economies of scale, and with the long crushing season (an average of 251 days in 2005), the South African industry continues to be cost-effective in the face of strong international competition.

Introduction

The South African sugar industry has a long history of sharing technical performance figures between factories, with the first review being presented by HH Dodds in 1925. In that year, there were 25 factories in South Africa with a total annual production of 239 851 tonnes of sugar.

At present, numerous factory figures are reported weekly and monthly to the SMRI, and 43 parameters are issued to the industry weekly and 93 monthly for each mill and for the industry.

This allows the South African factories to compare relative performances for benchmarking purposes, and the review of performances is a highlight of the annual South African Sugar Technologists' Association Congress.

The South African industry has been a pioneer in the development of gas chromatography for the accurate measurement of sucrose in factory streams, and the industry converted to sucrose-based reporting in 1981, replacing the less accurate pol-based values previously used.

In addition, a number of derived parameters are calculated which allow comparisons that are essentially independent of cane quality, which varies between factories and between years. Examples of these are Factory Performance Index (van Hengel, 1974), Corrected Reduced Extraction (Rein, 1975), Corrected Reduced Boiling House Recovery (Lionnet and Koster, 1986) and Crystal Recovery Efficiency (Peacock and Schorn, 2002). This paper focuses on the changes and improvements in the South African sugar milling industry since the last ISSCT Congress that

was held in South Africa, in 1974. The South African cane sugar industry remains one of the most technically efficient in the world, as a result of continuous research and development, and some of the technical innovations that have helped the industry to remain efficient will be described.

History of the industry from 1974 to 2007

The size of the industry has grown from an annual production of around 15 million tonnes of cane in 1974 to a peak of just under 24 million tonnes in 2000. The annual production is shown in Figure 1, along with the tonnes of sugar manufactured each year. There are some noticeable dips in the production, in 1980, 1983 and from 1992 to 1995, all being the results of severe droughts.

More recently, the 2003 and 2004 seasons were affected by drought, and the industry is only now recovering from this, with good rains having fallen in 2006.

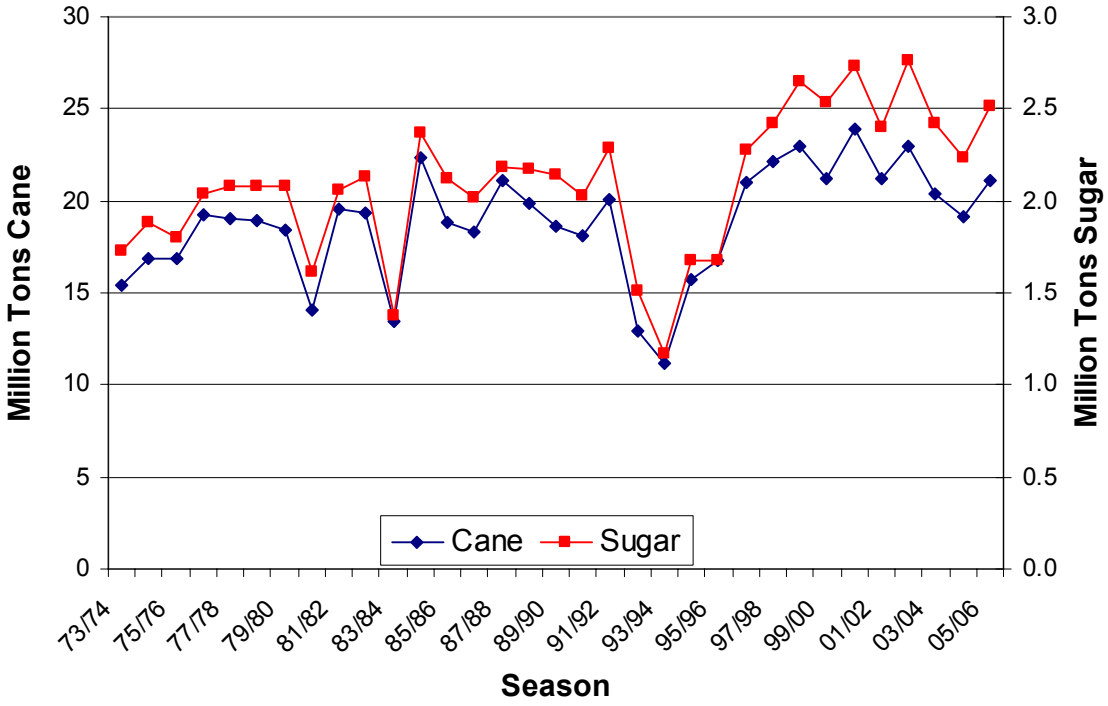

Fig. 1—Cane and sugar production in South Africa since 1973.

Despite this growth of the industry, the number of factories has declined, from 20 in 1974 to 14 at present. During this period, two new large mills have been built, one at Felixton in northern KwaZulu-Natal (1984), and one at Komatipoort in Mpumalanga province (1994), while the mills that have closed have been old and generally of small capacity.

Consequently, and along with expansions at many other mills, the average crush rate in the industry has steadily increased, as shown in Figure 2. Once again, the effect of the severe drought can be seen in the lower crush rate for the period 1991 to 1995.

During this time, the cane quality has steadily improved, as a result of the efforts of the South African Sugarcane Research Institute (SASRI), previously the South African Sugar Association Experiment Station (SASEX).

The Estimated Recoverable Crystal (ERC) parameter, introduced by van Hengel at the 1974 ISSCT Congress (van Hengel, 1974), takes into account pol, fibre and non-pol in cane, and is an appropriate measure of the improvement in cane quality (Table 1), as a result of improved varieties and better agricultural practices.

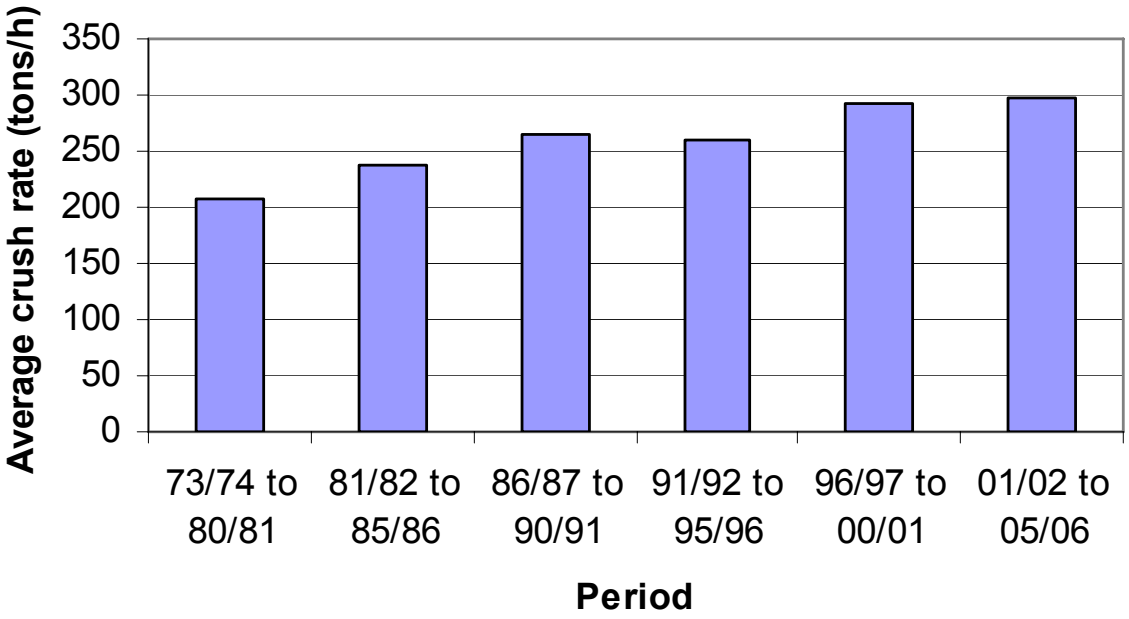

Fig. 2—Average cane crush rate for South Africa since 1973.

Table 1—Pol in cane and estimated recoverable crystal in cane in South Africa since 1975.

Period*	Pol % cane	ERC % cane
1976–1980	12.78	10.97
1981–1985	12.46	10.68
1986–1990	12.52	10.87
1991–1995	12.59	10.82
1996–2000	12.96	11.27
2001–2005	13.45	11.71

*Values are only quoted from 1976 onwards since ERC was not used prior to this.

Technical improvements

Diffusers replace milling tandems

The major technical innovation in the South African industry, and one in which South Africa still leads the world, is the use of diffusers for extraction of sucrose from cane. The use of diffusers has long been practised in South Africa, and several designs have been tried and tested over the years, including the Saturne and DDS designs, the unique FS design used at Pongola for a number of years, and currently the de Smet, BMA and Tongaat-Hulett designs.

Diffusers have gradually been replacing milling tandems in South Africa, as shown in Figure 3, because of their lower capital and operating costs and higher extractions.

As a result of this, sucrose extraction from cane has continued to increase (Figure 4), with the 2005–2006 season being the first ever where the average extraction for the entire industry exceeded 98%, and some diffuser factories regularly record weekly average extractions of over 98.6%.

This has also been achieved by a steady improvement in bagasse moistures, from an average of 52.67% for 1973 to 1980, to an average of 50.15% for 2001 to 2005, with the figure being below 50% for the past two years.

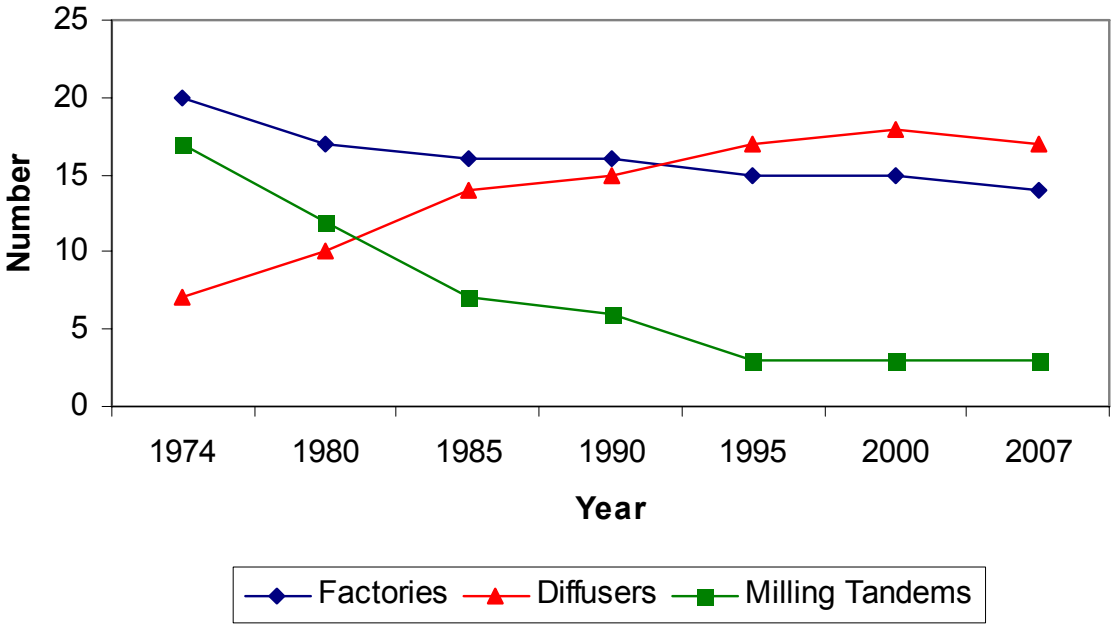

Fig. 3—Numbers of factories, milling tandems and diffusers in South Africa.

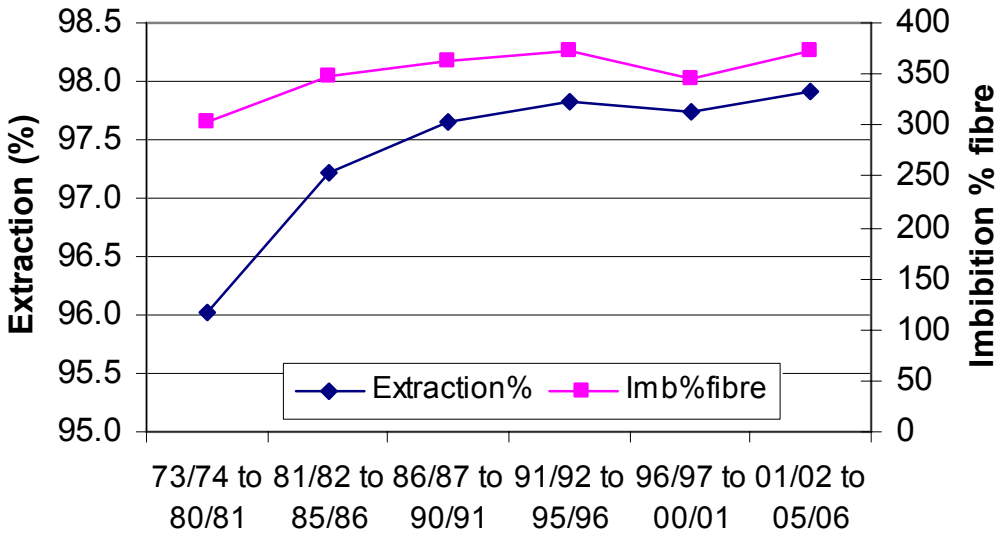

Fig. 4—Extraction and imbibition in South Africa since 1973. (The extraction value for 1973–1980 is pol-based, the others are sucrose-based.)

Part of the advantage of a diffuser over a milling tandem is that higher imbibition rates can be applied to achieve these good extractions, although at the cost of greater steam requirements for evaporation.

As a consequence, imbibition rates have increased (Figure 4) from an average of 286% on fibre in 1974 to 380% on fibre in 2005, while some factories run up to 500% on fibre during certain periods. As a result, pol % bagasse values have decreased to be consistently less than 1% and pol lost in bagasse as a percentage of pol in cane has fallen from 4.51% in 1974 to 1.97% in 2005.

Mud recycle to diffusers

A more recent innovation has been the recycling of clarifier mud to the extraction lines. This concept is not new, but has proved to be mostly trouble-free when applied to diffusers (Jensen and Govender, 2000), allowing factories to do away with Oliver filters altogether, and thereby reduce the sucrose losses and high operating costs associated with these filters, including costs for disposal of filter cake.

In addition, this has improved the supply of boiler fuel by terminating the use of bagacillo for mud conditioning, permitting higher imbibition rates to be used, and has reduced evaporation requirements by no longer applying filter wash water.

The practice is now well accepted in South Africa, with six factories recycling mud throughout the season, while two others do so when they are able, but revert to mud filtration in difficult times, such as during rains when mud levels increase. As a result, the sucrose losses to filter cake have been reduced, as shown in Table 2, but it should be noted that, at all factories recycling mud full time, the sucrose losses to filter cake are now zero. Hence, for the industry as a whole, sucrose losses to filter cake have reduced, but are unchanged at mills still filtering mud.

Table 2—Sucrose losses to filter cake (% sucrose in cane) in South Africa since 1973.

Period	Sucrose in filter cake % sucrose in cane#	Filter cake % cane#
1973–1980	0.46*	4.51
1981–1985	0.34	3.87
1986–1990	0.28	3.27
1991–1995	0.24	3.56
1996–2000	0.23	2.04
2001–2005	0.17	1.33

These values are the ratio of filter cake to all cane in the industry, including factories practising mud recycling
* Pol-based

Improved clarifier designs

Good clarification remains at the heart of good sugar quality, and the South African industry has seen a gradual change from Bach and Graver clarifiers, to Rapidorr and Dorr 444 designs and more recently to trayless short residence time designs such as the SRI.

The recent expansion at the Komati mill has seen the installation of the latest SRI design clarifier, while the SMRI uses tracer testing and computational fluid dynamics modelling (CFD) to trouble shoot and improve the operation of existing clarifiers (for example, Peacock *et al.*., 2000; Chetty and Davis, 2001; Chetty *et al.*, 2002), while also researching and developing new and improved clarifier designs (Loubser and Davis, 2007).

Continuous vacuum pans

The use of continuous pans for crystallisation of A-, B- and C-massecuites has been widely adopted in South Africa, with much development work taking place here, particularly by Tongaat-Hulett Sugar.

This topic was reviewed in detail in a previous ISSCT Congress (Rein and Msimanga, 1999), so will not be covered in detail here. It is sufficient to note that the higher capacity per unit volume and steady operation of continuous pans make them particularly attractive when considering factory expansions, and when improving steam economy in a factory.

However, despite this and the detailed benchmarking of such boiling house parameters as massecuite exhaustions, purity drops and molasses target purity differences, the industry has not managed to improve on its already good boiling house recovery in the past 33 years.

This is also reflected in the sucrose losses to molasses and undetermined losses, which have remained steady (Figure 5). The reasons for the unchanged molasses losses are not clear, but factors such as the long crushing season, high massecuite viscosities, high extractions and the young age of cane at harvest (due to eldana borer infestation in carryover cane in coastal areas) have been suggested to have an influence.

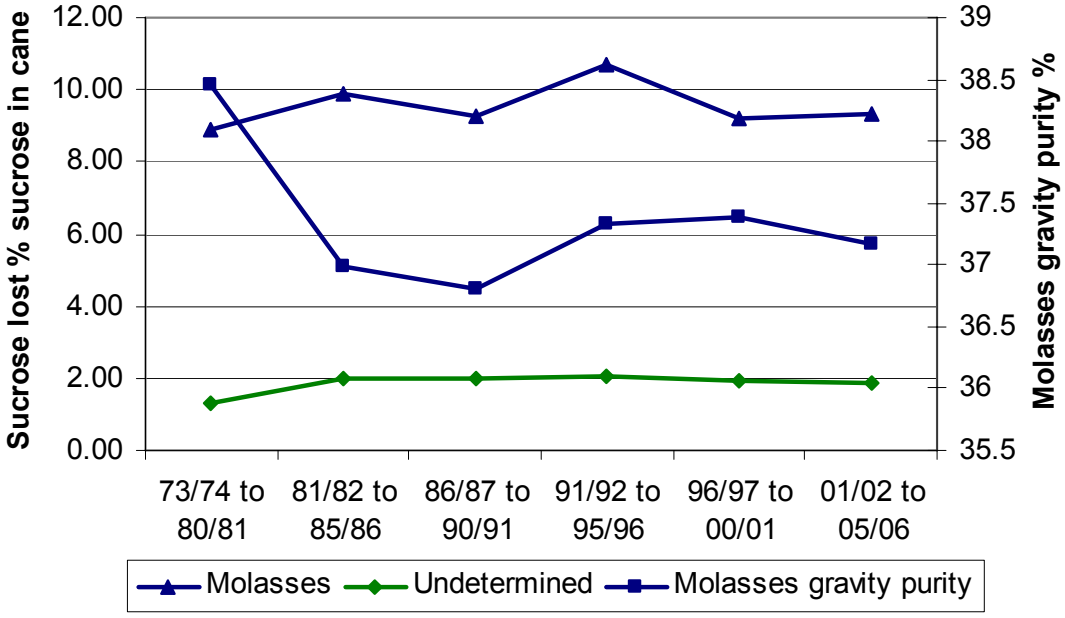

Fig. 5—Sucrose losses to molasses, undetermined losses % sucrose in cane and molasses purity in South Africa since 1973. (The values for 1973–1980 are pol-based, the others are sucrose-based.)

Instrumentation

The old adage goes 'you can't control what you can't measure', and the South African industry has always been at the forefront of measurement and control, with the development of new instruments being a prime part of the SMRI's research output (Gooch *et al.*, 1999).

On-line meters for measurement of colour and turbidity developed by SMRI staff (Stone, 1995, 1999) are in use at several factories to monitor clear juice quality, and to monitor the quality of liquors in refineries.

An important development was that of the radio frequency (RF) probe for pan control, replacing the conductivity method (Radford and Cox, 1986). The reliability and cost-effectiveness of this device and its use for brix measurement in massecuites was a contributing factor to the large-scale adoption of continuous pans in the South African industry, as such pans are dependent on reliable measurement of the state of the massecuite in each cell for good control.

More recently, a Displacement Rate Index (DRI) machine developed by the SMRI (Loubser and Gooch, 2004) has been adopted by many mills in the industry as a more meaningful replacement for the old preparation index method of assessing cane preparation. Another project made use of a commercial gas analyser to measure ethanol released from shredded cane as a means of detecting deteriorated consignments of cane (Loubser and Gooch, 2005).

Maintenance and reliability

Despite the South African industry's focus on maximising performance figures and recoveries, it also recognises that steady operations are essential for this, and that high throughputs make for a more cost-effective factory. Hence, there has been much emphasis placed on improved

reliability of the machinery through proper maintenance. Tools such as condition monitoring and vibration analysis have been used, along with modern planning software to optimise the effectiveness and costs of machinery maintenance.

As a result of this, the time efficiency of the industry has improved considerably in the past few years.

Figure 6 shows the Overall Time Efficiency of the industry, a measure of the percentage of available time during which crushing took place. Also shown are the percentage of scheduled stops and the percentage of other stops, *i.e.* those due to breakdowns and factory operational problems.

The improvement is clearly evident, and the industry aims for a target of less than 5% of available time being lost to other stops, a target that has been achieved on average for the past five years.

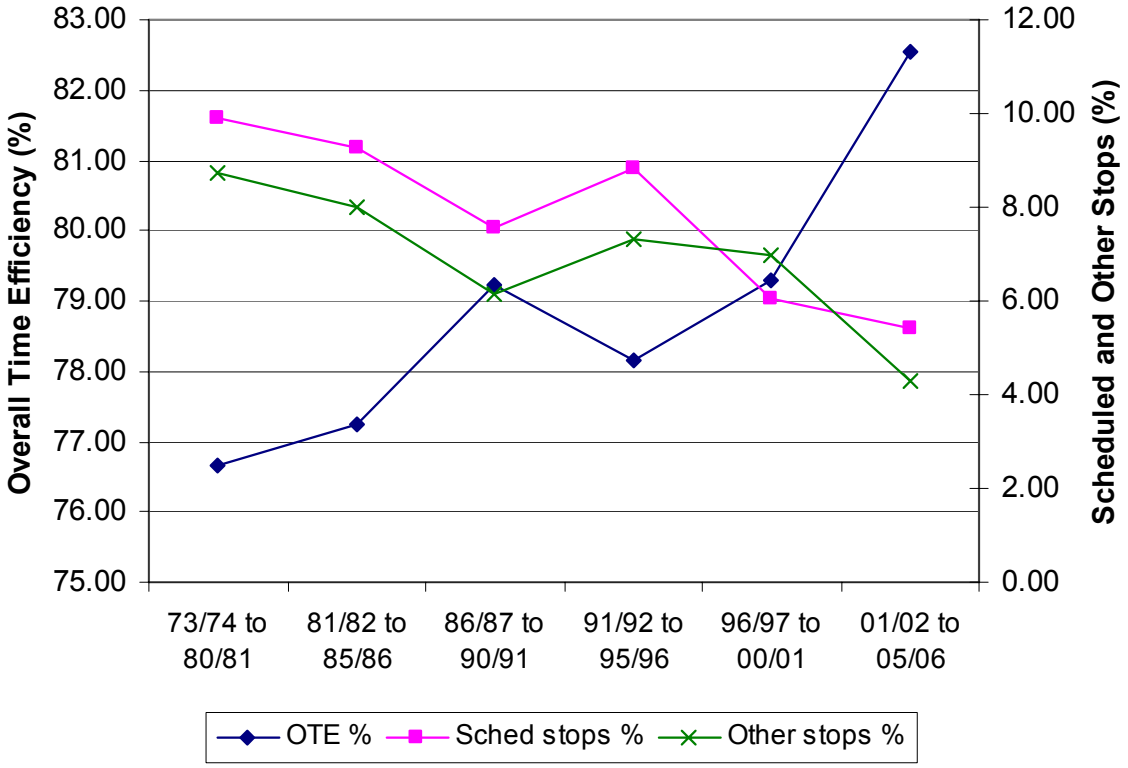

Fig. 6—Time account parameters in South Africa since 1973.

The bottom line

The South African cane sugar industry has long recognised that, because of its geographical location at the southern end of the cane-growing regions of the world, and the associated sub-optimum growing conditions, it could only remain competitive by striving for high technical performance through benchmarking and innovation.

The long crushing season, which is usually in excess of 220 days, and was up to 251 days in 2002, places heavy demands on the factory operations, particularly when crushing early and late in the season when cane quality is not always what is desired.

In addition to this, there has been heavy pressure placed on it by international competition and, in recent years, a low world sugar price.

It is thus remarkable that even under these conditions, the single parameter that all sugar industry workers, whether technologists or not, can easily understand, the cane-to-sugar ratio, has continued to improve (Figure 7).

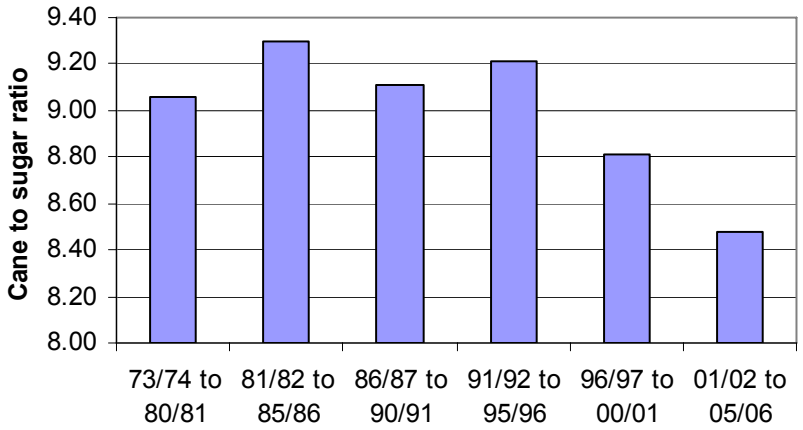

Fig. 7—Cane-to-sugar ratio in South Africa since 1973.

Conclusions

This paper has briefly discussed some of the notable changes and improvements in the technical efficiency of the South African cane sugar industry in the years since the last ISSCT Congress in Durban. It is evident that, in the face of numerous challenges, both climatic and economic, the South African industry has remained highly competitive and has continued to improve and innovate. This is testament to the dedication and hard work of the South African sugar technologists, and the willingness to co-operate and share information to the benefit of the industry.

Acknowledgements

Apart from the obvious acknowledgements to the technologists who have brought about the improvements and innovations in the industry, grateful thanks are due to Solly Achary and Elwyn Muller of the SMRI for their assistance in the preparation of the data on which this paper was based.

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TRENTE ANS DE PROGRES DANS L'INDUSTRIE SUD AFRICAINE GRACE AUX COMPARAISONS ET INNOVATIONS TECHNIQUES

Par

S.B. DAVIS
Sugar Milling Research Institute, c/o University of KwaZulu-Natal, Durban, South Africa
sdavis@smri.org

MOTS CLEFS: Revue, Performance, Innovation.

Résume

L'INDUSTRIE Sud Africaine est a l'avant garde du progrès et sa performance est parmi les meilleures du monde. Le Sugar Milling Research Institute, l'organisation centrale de recherche sucrière, distribue des performances techniques hebdomadaires, mensuelles et annuelles. Ce partage d'informations et les comparaisons qui s'ensuivent améliorent la performance; on décrit ces améliorations de 1974 (le congres ISSCT a Durban) a 2006. On note particulièrement l'extraction du saccharose au niveau de l'industrie qui a dépasse 98% pour la première fois en 2005–2006. Les innovations techniques ont aussi amélioré la performance; un exemple typique est le remplacement des moulins par la diffusion. Le nombre de sucreries a diminue de 20 en 1974 a 14 en 2006, et le tonnage horaire a passe de 169 tonnes en 1974 a 302 en 2005. Cette rationalisation et les longues campagnes en Afrique du Sud (251 jours en 2005) sont des atouts économiques. L'industrie Sud Africaine reste très efficiente en face de la compétition internationale.

TREINTA AÑOS DE PROGRESO DE LA INDUSTRIA AZUCARERA SURAFRICANA CON EL BENCHMARKING Y LA INNOVACIÓN TECNOLÓGICA

Por

S.B. DAVIS
Sugar Milling Research Institute, c/o University of KwaZulu-Natal, Durban, South Africa
sdavis@smri.org

PALABRAS CLAVE: Revisión, Desempeño, Innovación.

Resumen

LA INDUSTRIA azucarera surafricana se enorgullece de ser una de las líderes mundiales en eficiencia tecnológica. Las diferentes fábricas en la industria comparten abiertamente datos de comportamiento técnico semanal, mensual y anual a través del Sugar Milling Research Institute (SMRI). La información compartida permite un benchmarking efectivo, y lleva a mejoramientos continuos de comportamiento como lo comprueban las cifras desde 1974 (año del anterior Congreso de la ISSCT en Durban) hasta el 2006. Un caso particular es el de la extracción directa promedio que superó el 98% por primera vez en la zafra 2005–2006. Adicionalmente se han logrado mejoramientos de comportamiento con la innovación tecnológica continua, donde el reemplazo de los trenes de molinos por difusores es el caso más sobresaliente. Al mismo tiempo, el número de fábricas se redujo de 20 en 1974 a 14 en el 2006 mientras que la tasa de molienda promedio creció de 169 en 1974 a 302 toneladas por hora en el 2005. Esta racionalización de la industria ha conducido a mayores economías de escala y con mayores duraciones de zafra (promedio 251 días en 2005) la industria surafricana continúa siendo rentable frente a una fuerte competencia internacional.