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RESEARCH ARTICLE

The Role of Chemists in the Development of the Nigeria Sugar Industry– A Perspective

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Abstract

The Nigeria sugar industry, just like the sugar industries in various countries of the world, requires the services of various professionals for its operations. One such group of professionals are chemists, who work in various segments of the industry, such as factory operations, research and development (R & D), and in the educational sector. This study was aimed at discussing the duties of chemists in these key areas. It exposes chemists to their responsibilities towards the growth of the Nigeria sugar industry, which is instrumental in national development. Chemists are required in the quality control, quality assurance, production, water treatment, and wastewater treatment departments of sugar factories. The importance of R & D as it pertains to the industry was also highlighted. Some grey areas on the needs of the Nigeria sugar industry were stated, such as the replacement of the conventional sugar production process for a greener process. Others were independent analysis of the factories' products, and the utilization of bye-products to solve an array of national problems. It is expected that the full participation of indigenous chemists would act as a catalyst for the achievement of the goals of the Nigeria Sugar Master Plan which aims at revitalising the Sugar in Industry by year 2030.

Keywords: Chemistry; Nigeria; Research and Development; Sugar industry; Sugar factory

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Introduction

Chemists are individuals that utilize their knowledge of chemistry which is a central science and is considered by some as the connection between of all sciences (Meyer 2017). Chemistry's principles are used to solve both simple and complex problems for national development. An expert in chemistry is known as a chemist. There is, however, a misconception by some groups about the job of a chemist. Many believe that every chemist is expected to work within the research and development domain (Ribes 2019). While this may be true for a large fraction of chemists, chemists are also required and are found in other areas such as managerial positions, policy making, intellectual property protection, marketing, supply chain, technical services and development, and in the educational sector (Ribes 2019). Irrespective of where the chemist is found, the focus is usually to apply the principles of chemistry in delivering solutions that meet the customer's needs. The customer in this case could be an individual, an industry, or society at large (Finch et al. 2013; Tucker 2010).

The Nigeria sugar industry has been in existence for a very long time. Its primary objective is to ensure that Nigerians have access to affordable, high-quality sugar and sugar products that are produced in the country. With the support of the government, the industry has done a lot towards achieving its set objectives through the empowerment of Nigerians to take up various tasks in the industry and the enactment of various policies aimed at favouring local sugar production (Nmadu et al. 2013). One such policy is the ban on the importation of refined sugar into the country. The summary of the trend of consumption and production of sugar in the country over the span of three decades is shown in Figure 1. It can be observed that Nigeria's sugar consumption trend has increased at a geometric rate in the past decades. The nation saw a 19.6% increase in sugar consumption from the year 1990 to 2000, a 27.696% increase from the year 2000 to 2010, and a

55.372% increase from the year 2010 to 2020, which is also evident in the nation's per capita sugar consumption, which went from 6.6 kg to 7.1 kg, and from 7.1 kg to 7.7 kg for the years 2000–2010 and 2010–2020, respectively (Council 2022). Though the Nigeria sugar industry has existed for several decades, it is yet to meet the nation's sugar requirements from the major raw materials which is sugarcane, as the rest is obtained through the refining of imported raw sugar in the country (Council 2012). In fact, it currently supplies about two percent of the country's sugar needs, which has thrown the country onto the bandwagon of sugar import dependence as hundreds of billions of naira are spent annually to import raw sugar into the country from countries like Brazil (Council 2012). Again, local sugar production has experienced a decline in recent years. A total of 6.428%, 4.663%, 3.043%, and 2.753% of the nation's total sugar consumption were recorded to have been produced in the years 1990, 2000, 2010, and 2019, respectively, as shown in Fig. 1 (Council 2022). This has contributed to the food insecurity plaguing the nation, led to the loss of job opportunities for able-bodied Nigerians, and drained the nation's foreign exchange earnings (Olukunle 2016).

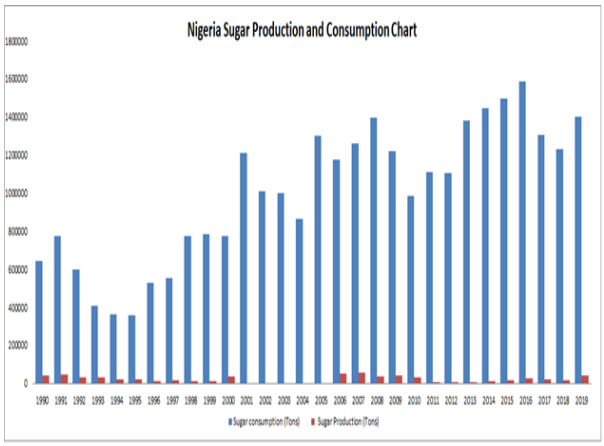

Figure 1. Nigeria sugar production and consumption chart from 1990-2019 (Council, 2022).

The industry brings together several professionals, such as administrators, engineers, chemists, microbiologists, environmental scientists among others, to manage the affairs of the industry. The inclusion and active participation of chemists in the industry with the same set purposes to improve the nation's sugar production capacity and to develop various sugar-allied industries, would lead to a chain of national developments. These would be in areas of job creation for unemployed Nigerians and the generation of electricity, in addition to sugar sufficiency for its citizens. This study was necessitated to show the importance of chemists in the development of the Nigeria sugar industry and the need for their participation in the affairs of the industry. The study gives an overview of the past and current state of the industry and the duties of chemists in the sugar production process. It also highlights other areas through which chemists can catalyse the development of the industry, such as research and development and in the educational sectors. It is expected that this study would be an eye-opener to expose chemists to the various gaps that need to be filled for the development of the sugar industry in Nigeria and elsewhere.

The Nigeria Sugar Industry: The Past to the Present

The Nigeria Sugar Industry has been in existence as far back as the Nigerian Independence era. The first sugar company in the country, the Nigeria Sugar Company (NISUCO), Bacita, was incorporated in 1961 with an installed capacity of 40,000 metric tons of sugar per annum (Akpan et al. 2013; Wada et al. 2001). Though the company started production three years later, the need to produce more sugar for the growing population catalysed the 1973 sugar production collaboration between the country and Benin Republic.

In 1973, the government, together with the Benin Republic government, jointly set up the Savè sugar factory, which was managed by Sociètè Sucrière de Savè, and production commenced ten years later, in March 1983. The second indigenous sugar company, the Savannah Sugar Company Limited (SSCL), located at Numan, in Adamawa state, was built with an installed capacity of 50,000 metric tons of sugar per annum (Wada et al. 2001). This company started production in 1980/1981. However, by the late 1990s, the federal government decided to privatize the two indigenous sugar companies for better management.

Since the beginning of the 21st century, there have been several attempts by the Nigerian government as well as private investors to establish sugar companies in the country. Some of such attempts were successful and are still in production till date, some were successful at first but shut down due to both external and internal factors, while others never really took off.

The need to attain self-sufficiency in sugar production prompted the Federal government in 1993 to establish the National Sugar Development Council (NSDC), a federal agency that would serve as a regulatory body for the sugar companies and a catalyst for the development of the Nigeria Sugar Industry (Akpan et al. 2013). The establishment of NSDC was informed by the realization of the ineffective and uncoordinated planning and supervision of the sugar sub-sector due to the absence of a body/agency that could coordinate and monitor sugar development in Nigeria. Such a regulatory body would enable the sugar industry contributes to the nation's industrial and economic development. Since its establishment, NSDC has recorded some successes and made history in the sugar story of the country, including the remittance of five billion naira from sugar levy to the nation's account (Akpan 2013).

In no distant time, the NSDC was tasked by the Federal Government of Nigeria to develop a blueprint for achieving self-sufficiency in sugar production within the quickest time frame possible (Usman et al. 2015). This gave birth to the Nigeria Sugar Master Plan (NSMP), which was approved in 2012. The NSMP provides a framework for setting goals, defining key actions, and generating and allocating resources to fund programmes in the industry (Council 2012; Paha et al. 2021). In addition, the Nigeria Sugar Institute (NSI) was commissioned in the year 2020 to provide the required manpower for the Nigeria Sugar Industry as well as conduct cutting-edge research that would catalyse the development of the Nigeria Sugar Industry. Though the NSMP has been around for a while and has set lofty targets for sugar production, the achievement and implementation of some of the stated targets, especially the increase in sugar production have been unsuccessful.

Currently, there are three major key players in the Nigeria sugar industry. They are the BUA group, the Dangote group, and Flour Mills of Nigeria (FMN) (NSDC, 2022; Wada & Gbabo 2019). BUA Group has two ultra-modern and automated mega sugar refineries, with a total combined capacity of about 1.5 million metric tonnes of sugar, aimed at creating about 5000 jobs for direct staff and 10,000 jobs for ancillary staff (BUA 2022). The first refinery, the BUA sugar refinery, is located at Tin Can Port Industrial Estate, Lagos state, while the second refinery, the Eastern sugar refinery, is located at 26, Azikiwe Road, Port-Harcourt, Rivers state.

In addition, the BUA group acquired the Lafiagi Sugar Company Limited (LASUCO) in Kwara state, said to have a milling capacity of 7000 metric tonnes of cane per day (tcd), and is expected to produce 140,000 metric tons of refined sugar per annum. The BUA group also established the Bassa sugar company in Kogi state (BUA 2022). The Dangote group acquired the Savannah Sugar Company (SSCL), an integrated sugar factory, from the federal government (Yuguda et al. 2020; Zemba & Obi 2018). The company also owns a sugar refinery, the Dangote Sugar Refinery (DSR), which has an installed capacity of 1.44 million metric tons of refined sugar per annum and is located in Apapa, Lagos State (Aliyu 2019; Dangote 2022; Nwalor & Adeniran 2013). Sunti Golden Sugar Estate (SGSE), a subsidiary of FMN, is located in the Mokwa local government area of Niger state (Wada & Gbabo, 2019). The plant, which produces only raw sugar from sugarcane, has a crushing capacity of 4500 tcd.

The FMN also owns a refinery, the Golden Sugar Company, located in Apapa, Lagos state. Golden Sugar Company has an installed capacity of 750,000 metric tons of refined sugar per annum. The FMN is also committed to expanding its operations in Nasarawa state (FMN, 2022).

In addition to these sugar companies, there are some other smaller sugar companies that are yet to start operations. Some of them include: Oyo Sugar Processors Limited, Iseyin, Oyo state; Goronyo Sugar Company, Goronyo, Sokoto state; Dangote Nasarawa Sugar Project, Tunga, Nasarawa state; and Great Northern Agribusines Limited, Gagarawa, Jigawa state (NSDC 2022). It is rather unfortunate that even with the rich history of the sugar industry in Nigeria, the industry can still be said to be in its infancy stage as it relies heavily on raw sugar importation to feed its growing population. However, it is believed that the conscious and conceited efforts of indigenous Nigerian chemists have the capability to change the narrative of this promising industry for the better.

Chemists in Sugar Factory Operations

The knowledge of different aspects of chemistry is required in different sections of the factory, which makes the services of chemists an essential ingredient for its smooth-running. Examples of such departments are shown in Fig. 2. This section gives an overview of the responsibilities of chemists in the sugar production operation.

Figure 2. Departments in the sugar factory that require the services of chemists.

Production

The term "production chemist," sometimes referred to as "shift chemist" or "chemist superintendent," refers to chemists in-charge of specific unit operations of the sugar production process, usually from the post-milling operations. The knowledge of separation techniques is very important as such techniques are applied in the process. Examples of such techniques include filtration, evaporation, crystallization, and centrifugation. In addition, knowledge of carbohydrate chemistry is required.

A common chemical reaction that occurs during the production process is the acid inversion of sucrose into its monomeric units of glucose and fructose, especially at elevated temperature. Another reaction that occurs usually early in the process is the polymerization of glucose units into dextran by microbes. This typically occurs in juices before heating during processing. It is therefore important that the production chemist utilizes his/her knowledge of microbial growth, pH, temperature, and time to minimize the occurrence of these reactions. The chemical reaction between milk of lime ($Ca(OH)_2$) and phosphoric acid (H_3PO_4) to produce tri-calcium phosphate is very important for processes that use the defecation process, as the presence of tri-calcium phosphate can lead to a greater size of colloid formation which enhances the rapid mud settling in the clarifier, faster mud filtration, and better sugar colour. In the double-sulphitation process, the knowledge of the production of SO_2 gas through the oxidation of a sulphur-containing compound, at the high temperature and pressure is required as well as the control of acidic conditions that this creates.

Major unit operations that exist post-milling in the sugar production process include: clarification, filtration, crystallization, centrifugation, and drying. The production chemists are responsible for ensuring that the raw juice is transformed into crystal sugar of high quality with the minimum amount of expensive sucrose losses. During the process, the production chemist must ensure that minimal fresh water is added to the process as well as that sugar loss is minimized throughout the process. It is important to state that knowledge of gravimetry is important in water as well as mass management in the process.

Quality control (QC)

Quality control is an essential part of the sugar production process, as sugar producers must ensure that the product complies with international as well as the customers' specifications. The QC personnel should be knowledgeable in both analytical and carbohydrate chemistry.

Sampling/Sample collection

The collection of samples during production falls on the shoulders of the QC personnel. To avoid putting the integrity of the sample at risk, the QC personnel should ensure that all equipment such as containers and spatula for the collection of samples are clean and sterilized. The personnel should also ensure that the right personal protective equipment (PPE) is worn while collecting the sample. There are two major reasons for this. The first reason is to ensure that the integrity of the sample is not compromised. The second reason is that PPEs help to protect the QC personnel. Examples of such PPEs include lab coats, hair nets, helmets, face masks, eye goggles, and hand-gloves.

In-process analysis

The QC personnel are responsible for the analysis of the cane from the moment it is offloaded at the cane yard, to when it is taken to the milling section, to extract the raw juice, to its clarification to produce the clear juice, and so on. Various parameters such as pH, Brix, and pol are analysed by the QC personnel on sugarcane, juice, mud, syrup, bagasse, molasses, and sugar. Some analyses are also performed to determine the efficiency of the sugar production process.

Preparatory index analysis is performed on the prepared cane before it enters the mill to determine the efficiency of the preparatory devices; mill extraction is performed on the juice to determine the efficiency of the mill. The moisture as well as the pol content of the bagasse can also be used to determine the efficiency of the mill and boilers. The Brix of the syrup can also be used to determine the efficiency of the evaporator.

The personnel must ensure that any material obtained whose results do not conform to specification should be reported to the process chemist. It is the duty of the QC personnel to ensure that the sugar and by-products conform to standard specifications. For example, refined sugar with an ICUMSA colour above 60 IU or purity below 99%, which is not up to standard specifications, should not be certified by the QC personnel and bagged. The QC personnel are also responsible for the analysis of untreated and treated water and wastewater.

Analytical Equipment Calibration

The QC personnel are responsible for the regular calibration of analytical equipment. Equipment such as weighing balances, polarimeters, refractometers, and pH meters need to be calibrated with their respective standards to avoid instrumental error during measurement.

Inventory keeping

The QC personnel are also responsible for ensuring that the inventory of all reagents and materials is kept up to date. This could help the management make informed decisions on the purchase of these materials when they are running out of stock. The personnel are also responsible for advising the management on alternative cheap and quality raw materials and equipment. For example, both OctapolTM and lead subacetate can be used for the clarification of juice for laboratory analysis, but the knowledge of the properties of such materials could enable the chemist

to make an informed decision on less expensive and effective alternative materials.

Documentation

Documentation is a key responsibility of the QC department. They are responsible for keeping the Daily Manufacturing Report (DMR) up to date during production. This report is a sheet containing different columns for the analytical results obtained in the laboratory at different time intervals. Visual graphing of this data is now occurring around the world and often displayed on large screens in the laboratories to ease interpretation of daily results. They are also responsible for the preparation and validation of their in-house methods of analysis, which are usually obtained from the ICUMSA Methods of Sugar Analysis or other analytical references with or without a few changes. Other documentation prepared and validated by the QC personnel include Standard Operating Procedures (SOPs) for the analysis of raw materials and reagents, and for the storage and usage of different chemicals and equipment.

Storage of materials

The chemist, as the QC personnel, is also responsible for monitoring the storage room where the sugar is stored. The chemist must ensure the room is clean and safe from rodents while also keeping tabs on the temperature and humidity of the room. In addition to the monitoring of the sugar storage room, the personnel are also responsible for ensuring the raw materials and chemicals used for production and chemical analysis are kept in a room at optimum conditions as stated by the manufacturer. The stored bagasse and molasses are not left out of their responsibility, as they must ensure the bagasse in the bagasse yard is properly covered to minimize contact with rain and wind. The temperature of the molasses tank should also be controlled.

Quality Assurance (QA)

Quality assurance can be defined as the activities performed to ensure quality in the process by which products are developed. This proactive process include many methods, all with the purpose of preventing defects in the process, final product the sugar, and by-products. Chemists engage in quality assurance by improving product development and testing the sugar production process so that defects do not arise when the sugar is being produced. During the sugar production process, the QA personnel are expected to foresee possible issues that could lead to prolonged down-time and to call the attention of the necessary personnel so as to avert such problems. The points where such issues such as sugar dust explosion may arise are referred to as "QA check points (Iwuozor et al. 2023e; Mohammed et al. 2023)." Examples of QA check points include packaging material receipt; raw material such as Vitamin A receipt; the point of bagging; the point of sugar re-melting with sweet water; the clarifier; cane storage at the cane yard; and cane preparation before milling.

The QA personnel are also in charge of handling consumers' complaints. All complaints regarding the packaged sugar, molasses, bagasse, or filter cake are handled by the QA personnel. It is their duty thereafter to investigate such complaints and ensure that genuine complaints are solved.

Water treatment

Fresh water is an important ingredient for the sugar production process. Fresh water is also used to mix chemicals such as milk of lime and to wash used equipment after production. The water from the water treatment plant is used to run the boiler, and the resulting steam is used to operate the juice heaters and evaporators. It is the duty of the chemist to ensure the water is treated, as poorly treated water could cause problems during the production process.

For example, water with a high total dissolved solids (TDS) could lead to solid deposition on the walls of heating equipment. To avoid such issues, knowledge of water treatment techniques, specifically adsorption and disinfection, is required. For example, the principle of adsorption is utilized in the sand bed filters, iron bed columns, activated carbon filters, among others depending on the quality of the water source (Iwuozor et al. 2023b; Iwuozor et al. 2023c). The personnel are also expected to undergo periodic backwashing and flushing operations.

Wastewater treatment

The influent into the wastewater treatment plant may include wastes from the mill from cleaning and washing juice leakages, spillages of mill bearing water and from process chemical boiling and tube cleaning of evaporator and pans, excess condensate water, pump leakages, daily and periodic cleanings, and laboratory wastes. The wastewater treatment plant ensures that the influent is treated, which is usually through the activated sludge process and is not harmful to the environment before it is sent off into the environment.

The chemist is also responsible not just for the wastewater treatment process but also for ensuring the quality of the treated water, such as TDS, Biological oxygen demand (BOD), pH, and Chemical oxygen demand (COD), conforms to acceptable standards. The chemist is also responsible for the production of the dried sludge from the wastewater, with the aid of a polyelectrolyte that serves as a coagulant for the sludge particles.

Chemists in Research and Development (R&D)

It is widely known that the sugar industry can achieve no meaningful development without a solid research and development base. In section eleven of the NSMP, the policy aims to leverage research and technology innovation (RTI) to catalyse the development of the Nigeria Sugar Industry (Council 2012). The chemist's role in research and development (R&D) is divided into two major parts; the discovery of new materials, processes, and information and the upgrading of already existing materials, processes, and information. It involves innovative and technology-based diversification of sugarcane processing to yield new industrial products. However, there is misinformation regarding R & D in the industry. Many seem to think that the proof of R & D is in research publications. While this may seem true in some cases, it is not always the reality as not all research findings in the industry are published on the internet. In lieu of this, the real proof of R&D in the industry is the improvement in technological advancement as well as an increase in sugar production at a lower cost. Although the role of chemists in the sugar production process is well defined because of the active participation of chemists in the process, it is disheartening that chemists in Nigeria have played very little role in the R & D as pertaining to the industry. A major reason for this could be the lack of sufficient awareness of the industry's potential among the local community of chemists. This notwithstanding, a lot can still be done for the industry. Every business owner wishes to minimize cost and maximize profit without causing a decline in the quality of the product. The same is also applicable to the sugar industry which should utilise the services of chemists in achieving high quality sugar.

Chemists in the Educational Sector

Apart from the factory and laboratory, the impact of the chemist is also required in the classroom. Training the younger generation, in line with the current national need, would make them ready and prepared to drive this national goal to ensure that Nigeria doesn't just attain self-sufficiency but also becomes a sugar exporter in the near future. It is important that chemists in the teaching profession are properly trained in both theory-based and industry-based sugar processing. Visiting the sugar factories in the country could help improve their knowledge, which would also ensure that the right set of information is passed down to the next generation. A misconception that has been observed in this field is that some teachers or lecturers on teachings of the sugar production process dwell more on the double sulphitation method used for the production of plantation white sugar. Unfortunately, this method of sugar production is not being practiced in Nigeria. Even countries like India, where such methods are practiced, have started to put a stop to them because of some problems such as the high concentration of sulphur in sugar which are deemed carcinogenic. Nigeria uses the defecation method of decolourization, where the juice is converted into raw or brown sugar, which is then converted into refined sugar. It is therefore important that current industrial practices are taught in the class.

The way forward

For Nigeria to attain self-sufficiency in sugar production as well as become its major exporter and other materials obtained from its by-products, all hands must be on deck. Chemists are integral in the Nigeria sugar industry, and this report discusses their importance in the development of the industry. The report gives an overview of the past and current state of the industry and the duties of chemists in the sugar production process. It also highlights other areas through which chemists can catalyse the development of the industry, such as research and development and in the educational sector. Chemists work in a variety of sectors, including factory operations, research and development (R & D), and education. They are required in sugar factories' quality control, quality assurance, production, water treatment, and wastewater treatment departments. It is expected that this report would be an eye-opener to expose chemists to the various gaps that need to be filled for the development of the sugar industry. Chemists are encouraged to get cheaper, higher quality alternatives that are utilized in the sugar production process. Research is always on-going on sugar production in advanced countries through the green chemistry approach. In this approach, the addition of chemicals such as flocculants is minimized. One of the ways this has been achieved is by replacing the conventional decolourization and clarification technologies with membrane technology. However, some shortcomings, such as membrane selection, preparation, and integration, fouling control, low membrane cleaning efficiency, membrane preservation or shelf-life, and low separation selectivity on sucrose and other materials still exist with this (Zhang et al. 2021). Other studies that can also be engaged in include minimization of sucrose loss; substitution of chemicals with biological-based materials; water recycling and conservation during the production process. Though the quality of sugar products and bye-products in the market is being monitored by relevant agencies such as the National Agency for Food and Drug Administration and Control (NAFDAC), Standard Organization of Nigeria (SON), and NSDC, the independent analysis of sugar, sugar products and bye-products in the market could also assist in keeping the sugar factories on their toes, while ensuring strict adherence to standard specifications. In addition, such

studies could also assist in the fight against adulterated sugar in the market (Iwuozor et al. 2022a).

Another very important aspect of R & D in the Nigeria sugar industry involves strengthening the backward integration programme as enshrined in the NSMP. This involves the expansion of the industry's supply networks. The R & D involved in the utilization of the major raw material which is sugarcane or the by-products which are bagasse, molasses, and filter cake for the production of new materials should be encouraged. This would not just lead to the creation of allied industries, but would also be a means to put food on the tables of unemployed Nigerians, and lead to greater demand for the raw material by its increased cultivation. The creation of such allied industries and a growing demand for the by-products of the sugar industry could also lead to a fall in the price of sugar in the market, as experienced in countries like India. In lieu of this, sugarcane juice can be processed into sugarcane juice powder. The large untapped potential of the industry's by-products could also help solve an array of national.

Molasses can be utilized for the production of bioethanol in distilleries, lactic acid, rum, and for the production of foods like ginger bread, pies, or cookies (Iwuozor et al. 2022b; Iwuozor et al., 2022c; Iwuozor et al. 2022d). The press mud or filter cake can be utilized for the production of fertilizers. On the other hand, bagasse can be a catalyst for solving Nigeria's electricity problem as is done in countries like India. In India the sugar industry generates electricity with the aid of bagasse, which is sold and transferred to the national electricity grid and aids paper production problem where the abundance of bagasse, is used for the production of cheap, quality bagasse paper, particle board, biochar, composites, activated carbon, dish wares, and packaging materials (Emenike et al. 2023; Iwuozor et al. 2023a; Iwuozor et al. 2023d).

Conclusion

The readiness of chemists to collaborate with other technical professionals will greatly improve their main role in sugar production. This will facilitate new findings about sugar production both of local and international relevance. It is important that the non-environmentally friendly practices of the industry are changed with less harmful practices. Cheaper and more efficient techniques that target the analysis and treatment of the industry's effluent and gaseous emissions should be encouraged. In addition, sugar production efforts will not be completed until the residue from sugar is properly managed without having a negative impact on the environment. Collaboration with environmental scientists will lead to optimal treatment of such issues. The subjects of energy integration, the trade-offs between sugar fortification, cost, acceptability, and marketing are still in their infancy. Chemists' collaboration will be needed with process and mechanical engineers to underscore the energy need as the efforts on sugar production go from bench to batches. As the number and types of sugar fortification routes, types, and methods increase, the marketing strategies must be improved for their market and taste acceptability.

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