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South Africa's food system: An industry perspective on past, present and future applications of science and technology

The South African food system is facing severe challenges as increasing hunger, rising food costs, lack of dietary diversity, child stunting, foodborne illnesses, food waste and an obesity epidemic coupled with malnutrition are observed. In this study, we aimed to establish the application of science and technology advances in the food and beverage industry in South Africa in response to food consumption pattern changes since 1994 and how they could be used to address food security challenges. We found that food consumption shifts have been towards sugar-sweetened beverages, processed and packaged food, animal-source foods and added caloric sweeteners, and away from vegetables. These dietary shifts are concerning as they relate to public health. Most commitments to improve the nutritional status of South Africans have been limited to corporate social investment strategies and should be extended into core business strategies. Furthermore, although the South African food and beverage industry has kept pace with developments in food manufacturing practices, there has been little experimentation with non-commercial novel technologies. The expert survey revealed that indigenous African crops and food waste recovery are the two most promising emerging food sources that could be available to South Africans in the shortest time frame. South Africa has many enabling drivers to become a global leader in food technology advances. However, many barriers need to be overcome for industry, academia and government to collaborate to advance novel food science and technologies to reach commercialisation.

Significance:

- Drivers and consequences of food consumption changes in South Africa were modelled and broad food consumption trends between 1994 and 2009/2012 were identified.
- For the first time, the Access to Nutrition Index methodology was applied to South African owned food companies to identify strategies to enhance nutrition practices. Companies need to do more to deliver affordable and accessible products.
- Drivers and barriers in adopting advanced food science and technology were modelled. A collective ecosystem approach with industry, academia and government mobilisation around critical areas like hunger, malnutrition and poverty could be a way to tackle the failing food system.

Background

There are clear signs that the South African food system is facing severe challenges, as increasing hunger, rising food costs, lack of dietary diversity, child stunting, foodborne illnesses, food waste and an obesity epidemic coupled with malnutrition are observed.

Various factors affect food consumption, including accessibility, availability and choice. Food intake choices are influenced by several factors, such as geography, location, season, history, education, demographics, disposable income, government and other support services, urbanisation, globalisation, marketing, religion, culture, social networks, convenience, time and consumer attitudes.¹⁻⁴ Consequences are associated with changes in food consumption patterns, including health and environmental impacts.¹ It would be expected that changes in food consumption patterns would impact the food and beverage industry through product innovation demand, increased production capacity and efficiency improvements, applications of new science and technology, increased regulation on foodstuffs, and advancements in the value chain from raw materials, processing and distribution.

Various food- and nutrition-related studies conducted at provincial or community levels over the past few decades reported that South Africans have adopted more Western-oriented diets.^{5,6} South Africans consume a diet low in dietary variety, with informal urban areas worst affected.^{7,8} Based on a study by Steyn et al.⁹, in which they analysed dietary surveys, the South African adult population frequently consumed maize, sugar, tea, brown and white bread, non-dairy creamer, brick margarine, chicken meat, full-cream milk, and green leaves. Almost half (48%) of adult South Africans reported eating out of the home. Regarding frequency, most said they ate outside the home monthly (28.7%) or weekly (28.3%).⁷ There has never been a national dietary survey of adults in South Africa, and there has been only one national study on food consumption related to children, which was on children aged 1–9 years old in 1999.^{9,10} Furthermore, in a study by Steyn et al.¹¹ to determine if mandatory fortification implemented in 2003 had improved micronutrient dietary intake, they concluded that there is a lack of dietary intake studies and again highlighted the need for a national survey of children's dietary intake. Therefore, data on food consumption nationally is outdated and does not include all age groups, nor is there comprehensive data to analyse trends in the consumption of packaged foods and beverages.

The drivers of food consumption changes since 1994 in South Africa can be described through the environmental scanning technique of political, economic, social, technological, legal and environmental (PESTLE) factors. These factors ultimately lead to consequences for public health and the food system, as shown in Figure 1.

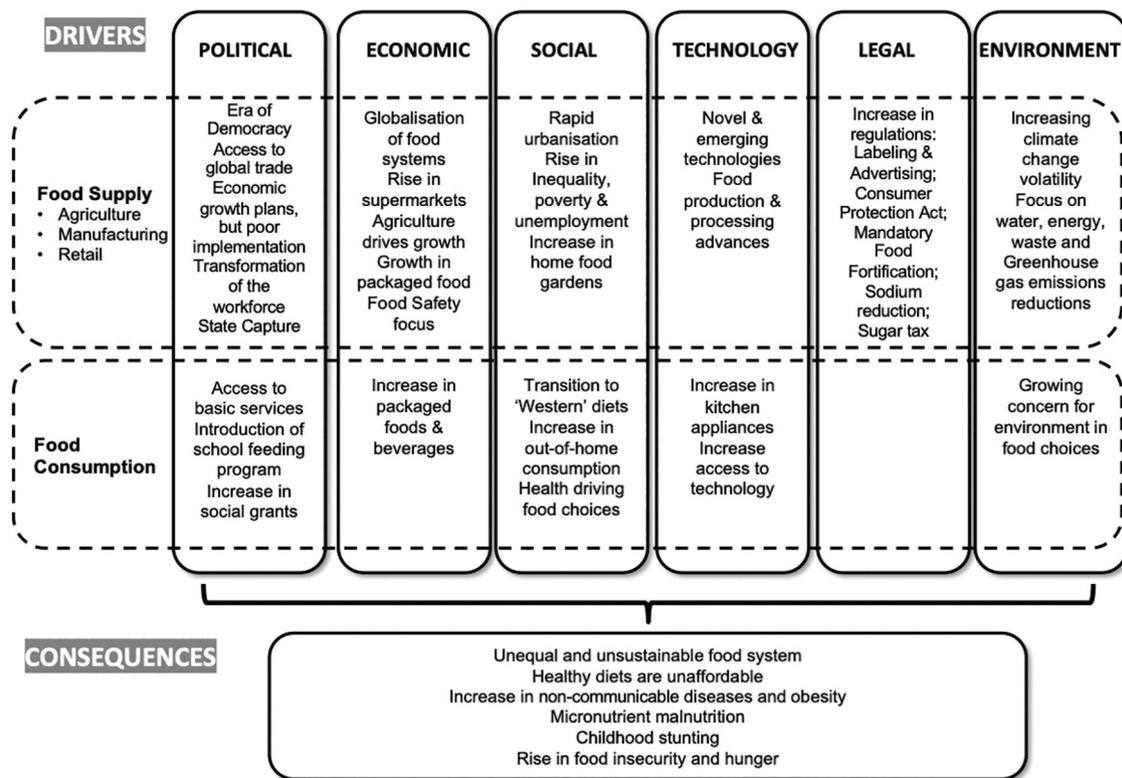


Figure 1: Drivers and consequences of food consumption changes in the South African food and beverage industry since 1994.

The most significant political change for South Africa in the last 30 years was the end of apartheid, culminating in the first democratic election on 27 April 1994. The post-apartheid government put various economic and transformation plans in place, which resulted in increased income per capita and the rise of the black middle class with significant spending power.¹² After economic and trade restrictions were lifted, social shifts occurred, such as increasing urbanisation, as the black population moved permanently from rural to urban areas looking for a better life.¹³ Unfortunately, the last decade saw a slowdown in economic growth due to policy uncertainty and energy constraints.¹⁴ Despite progressive legislative measures, women remain under-represented in the workplace.¹⁵ More than half the population still lives in poverty, and South Africa remains one of the most unequal countries in the world.¹⁶ Unemployment in 2019 was 29%¹⁴, with youth unemployment at 55% in 2019¹⁷.

Data from the South African National Health and Nutrition Examination Survey (SANHANES-1) conducted in 2012 revealed that 39% of women and 25% of men were obese and that obesity had increased since 2003.⁷ Diabetes affected 12.6% of adult women and 9.7% of adult men.⁷ Unfortunately, South Africa has made limited progress in reducing stunting in children under five years old, with 27% being stunted.¹⁸ Even though the SANHANES-1 survey indicated that anaemia and iron status have improved, poor micronutrient status remains common among young children.¹⁹ South Africa suffers from a double burden of disease with both overnutrition and undernutrition. South Africa is far from achieving the United Nations Sustainable Development Goal of Zero Hunger, with one in five South Africans (24%) in 2020 affected by moderate to severe food insecurity, while almost 15% experienced severe food insecurity.²⁰ Poorer households can spend more than 40% of their total expenditure on food, compared with the national average of 13%.¹⁹ Unfortunately, most South Africans cannot afford to maintain a healthy diet.²¹ Fortunately, the governments' various social assistance grants have been shown to reduce poverty and improve nutrition outcomes.¹⁴

Trade liberalisation post-apartheid saw international food and beverage companies entering South Africa, which led to increased competition for local players and the forming of partnerships.²² This resulted in rising global brand exposure and marketing to South Africans.^{4,23} Furthermore, supermarkets have grown significantly, especially in township areas,

accounting for about 60% of retail sales.^{24,25} The South African food and beverage manufacturing industry is dominated by a limited number of large national and multinational companies that control production capacity and sales across multiple food categories.²² The ten largest packaged food companies in South Africa accounted for 43.5% of total packaged food sales in 2020 (ZAR102 billion or ~1.8% of GDP in 2020).²⁶ This dominance is a result of the technical barriers to entry imposed by the apartheid government.

Access to essential services like water, sanitation and electricity has advanced in post-apartheid South Africa, with 90% of households in 2020 having access to electricity, compared with 58% in 1996.¹⁶ This improved access created increased demand for durable goods such as refrigerators, ovens and microwaves, offering broader food choices due to the expanded food preparation and storage options. Socio-economic trends in South Africa, such as urbanisation and population growth, are projected to double the demand for commodities and increase the need for high-value foods like dairy and meat by 200%.²³ As consumers become less trusting of the 'faceless' food and beverage industry and more aware of the effects of food production on the environment, they are increasingly considering product quality attributes such as food safety, nutrition, organic production, fair trade, free range, animal friendly and locally grown when making food choices.^{27,28}

Regarding legal drivers, the South African Department of Health has implemented regulations on the food and beverage industry in an effort to improve public health. These regulations require fortifying staple foods, limiting salt in some foods, and taxing sugary drinks.

Global food production is the single most significant driver of environmental degradation and transgressor of planetary boundaries impacting climate change and ecosystem resilience.²⁹ Current food systems are responsible for approximately one-quarter of anthropogenic greenhouse gas (GHG) emissions.³⁰ Food systems are a leading cause of deforestation, biodiversity loss, freshwater use and water pollution, yet are also ineffective in feeding people adequately.³⁰ South Africa's food system contributes 15–20% of GHG emissions.³¹ A total of 80% of South African land is suitable for livestock farming; overgrazing on erosion-prone soils has led to widespread land degradation, dramatically

reducing soil carbon storage.²³ Food production and processing are energy intensive, especially in a country dependent on coal-fired energy sources, substantially increasing the system's carbon footprint.²³ South Africa is a water-scarce country, with water fast becoming a crisis.³² A staggering 10 million tonnes of food (about one-third) go to waste in South Africa.³³⁻³⁵ The bulk of this loss (49%) arises from the processing and packaging stage and 18% from the consumption stage.³⁵ This is of great concern due to the substantial portion of discarded food still being edible, the loss in potential value if food waste is disposed of, together with the related wasted resources and emissions in producing the food in the first place.^{34,36}

The RethinkX report suggests that the world is on the edge of revolutionary disruption in food and agricultural production.³⁷ This results in uncoupling from land and sea resources to novel protein sources derived from bacteria, yeasts and fungi.³⁷⁻³⁹ Science and technology are constantly developing to tackle the challenges of globalisation, sustainability, and the requirement for a stable and secure food supply.⁴⁰⁻⁴² Regulatory authorities are also putting pressure on the food processing industry to minimise its impact on the environment.⁴⁰⁻⁴² Moreover, consumers demand safer, higher quality, and minimally processed food. According to a survey conducted in the UK food and beverage industry, the use of advanced technology has been linked to enhancements in product quality, cost savings, and the development of new products, despite the increasing need to improve sustainability and resource efficiency.⁴³ The study identified emerging technology trends, including improving efficiency, productivity and sustainability, and reducing salt and fat contents.⁴³ There has been no comprehensive research for South Africa related to applying advanced science and technology developments or emerging technology trends. However, it would be expected that the South African Food and Beverage Industry (SAFBI) has adopted advances in science and technology to keep pace with the evolving South African consumer, regulatory and competitive landscape.

We aimed to investigate how SAFBI has utilised scientific and technological advancements to tackle changes in food consumption patterns since 1994 and how these advancements can address food security challenges faced by South Africans.

Materials and methods

This study is a compilation of four studies and hence four materials and methods are described below.

Establish food consumption shifts since 1994

To examine changes in the consumption of packaged foods in South Africa since the end of apartheid, the FAOSTAT Food Balance Sheets and Euromonitor Passport databases were used to gather comprehensive and comparable national data on food items consumed. Both exported data sets were converted into per capita consumption figures to account for population growth. Intervals of five-year periods, from 1994 to 2009 for FAOSTAT Food Balance Sheets data, and from 1999 to 2012 for EUROMONITOR PFBC data, were compared. Time overlaps were examined in 1999, 2004 and 2009.

Determine science and technology advances by SAFBI

We explored how advances in science and technology and investments made by the food and beverage industry can meet changing food consumption patterns and maintain competitiveness. South African food and beverage industry trade magazines covering reported applications and investments in advanced science and technology developments were used to source these data. A database was created by collecting articles from the *South African Food Review* from 1986 to 2012 and the *South African Food and Beverage Reporter* from 1995 to 2012. The data were analysed to identify trends in the application of science and technology advances.

Determine nutrition practices by SAFBI

As the SAFBI reaches every household and South Africa has significant health concerns, we used a modified version of the Access to Nutrition Index (ATNI) methodology to assess how nutrition practices are integrated into the core of business practices. The ATNI is a global initiative that

evaluates the largest food and beverage manufacturers' policies, practices and disclosure related to nutrition and the degree to which these are embedded in core business functions. The methodology is based on existing international standards, guidelines and frameworks, such as those developed by the World Health Organization (WHO), Codex and other leading nutrition-focused organisations.⁴⁴ ATNI's assessment of companies' nutrition practices relies mainly on their statements and published materials. Due to the specific South African focus of this study, the methodology was adapted to local circumstances. For example, questions relating specifically to EU or US criteria and geographic and developed versus developing country criteria were excluded. Data were gathered from company websites and annual integrated reports for 2013 and 2016. The nutrition performance of the top three South African food and beverage manufacturers over three years (between 2013 and 2016) was then evaluated to understand if improvements were made in this area.

Establish and map underutilised and emerging food sources to address food security

A literature review was conducted to identify underutilised or emerging new food sources that could provide a solution to providing safe, affordable and nutritious food for vulnerable South Africans (results not presented in this paper). A survey was then designed around criteria related to affordability, nutrition, safety, consumer acceptance and regulatory environment. A quantitative expert survey was conducted with South African food professionals from industry, academia and government ($n = 40$) to evaluate the identified underutilised or emerging new food sources against the set of criteria to determine the most promising and the time frame in which these could be expected to be available to South Africans. Ethics clearance for the quantitative expert survey was received from Stellenbosch University on 15 July 2021 with project number 22423. Based on the findings from these combined studies, barriers and drivers were identified for key role players to utilise and harness science and technology to improve food security for all South Africans.

Results and discussion

Establish food consumption shifts since 1994

Food consumption patterns in South Africa have undergone significant changes over the past few decades, and are expected to continue evolving. Over the last few decades, various community- and provincial-level studies indicate that food consumption shifts in South Africa have been towards a more Western-orientated diet, with nutritional consequences contributing to increased obesity and other non-communicable diseases. The results suggest that people consume more kilojoules per day, with a preference for sugar-sweetened drinks, processed and packaged foods (including vegetable oils), animal-based products, and added sweeteners. The most significant changes in food consumption (>25% increase) were observed for soft drinks; sauces, dressings and condiments; sweet and savoury snacks; meat; and fats and oils (Figure 2). Unfortunately, this shift is leading to a decreased consumption of vegetables (Figure 2). The main factors driving this trend are convenience, nutrition, health, and indulgence. These changes in eating habits are concerning due to the resultant change in nutritional content and potential impact on public health.

Determine science and technology advances by SAFBI

Food and beverage multinationals traditionally spend far less on R&D (only accounting for 3% of total R&D spent globally in 2016) than other sectors like health care, automotive and technology.⁴⁵ We examined how advances in science and technology and investments made by the food and beverage industry are being utilised to adapt to changes in food consumption patterns and maintain competitiveness. SAFBI seems to adapt well to advancements in food manufacturing, such as automation, quality control, material handling, and centralised distribution centres with warehouse management systems. However, there is a lack of experimentation with non-commercial innovative technologies. Cilliers and Carinus⁴⁶ point out the innovation paradox where established businesses, in an attempt to ensure predictability and maintain high turnover and profits, soon spiral into low-innovation,

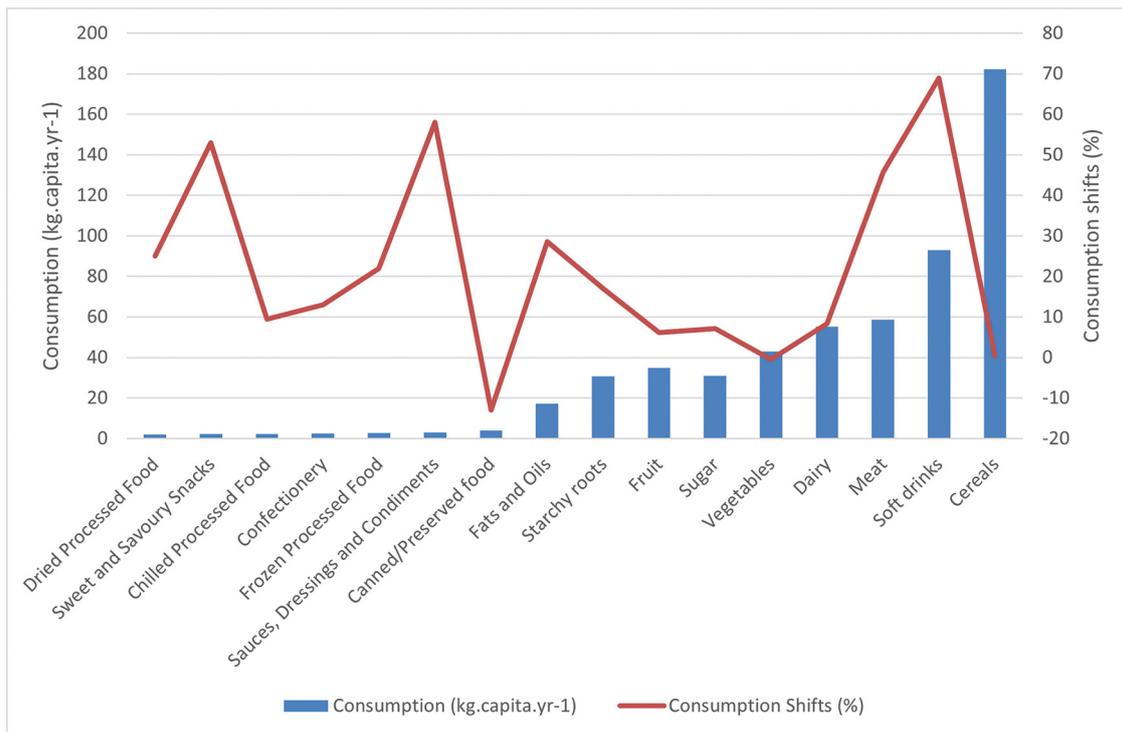


Figure 2: Per capita consumption and shifts in consumption of specific food categories in South Africa from 1994/1999 to 2009/2012 (FAOSTAT Food Balance Sheets & EUROMONITOR Packaged Food & Beverage Consumption).

low-risk, low-reward cycles. Start-ups can innovate quickly and adapt to consumer needs but lack the financial resources and credibility to deliver goods at scale. Some global food and beverage companies have created venture capital divisions to invest in food tech start-ups that are seen as an extension of their R&D departments and far less risky than significant merger and acquisition deals.⁴⁵ This is an example for South African food and beverage manufacturers to follow. It is promising to see Tiger Brands utilising its recently launched venture capital fund to invest in the plant-based protein start-up Herbivore Earthfoods.⁴⁷

Determine nutrition practices by SAFBI

The consequences of food consumption shifts in South Africa from a public health perspective unfortunately include increased obesity and other non-communicable diseases.^{5,48,49}

Utilising the modified ATNI methodology, we found that most commitments to improve the nutritional status of South Africans were limited to corporate social investment strategies and programmes and should be extended into core business strategies to fully leverage the market and corporate reputation opportunity that this offers. Nutrition could be more explicitly incorporated into business strategy with senior leadership responsibility. Transparency and reporting on research and development (R&D) programmes related to product formulation could be improved. The market opportunity to reach underserved consumers with optimal affordable and nutritious products has not been realised.

Establish and map underutilised and emerging food sources to address food security

Venture investors are increasing investments in food tech start-ups, especially those creating new types of food and production methods.⁵⁰ Global investment into food tech reached a record USD12.8 billion in 2021, significantly up from USD2.2 billion in 2017, where half of this investment went to companies creating alternatives to traditionally produced meat, seafood and dairy products.⁵⁰ It is expected that food tech investment is likely to grow further. South Africa already has start-ups innovating in cell-based meat (Newform Foods and Mogale Meats) and precision fermentation (De Novo Dairy).⁵¹ In exploring underutilised or emerging new food sources that could provide safe, affordable, nutritious foods

relevant to South Africans, we found that indigenous African crops and food waste recovery are two of the most promising emerging food sources available to South Africans in the next 3–5 years that meet the need for affordable, nutritious, safe and culturally appropriate food (Figure 3). Fermentation (precision and biomass) and insects for human consumption were identified to become available to South Africans in less than 5–10 years (Figure 3). The two underutilised or emerging food sources thought to have the most extended time frame of more than 5–10 years to commercialisation were algae and cell-based meat and seafood (Figure 3). The extended time frame for commercialisation for cell-based meat and seafood was related to the investment required, availability of stakeholders and specialised scientific support and research, and ability to reach scale with local production and processes. The major hurdle for algae indicated by respondents is acceptance by the South African consumer.

Respondents in this study indicated that, for any underutilised or emerging food source or technology to reach the South African retail shelves, there needs to be investment from industry, governments and academia into research, technical capability building and scale-up infrastructure for commercialisation. According to a report conducted by Mouton et al.⁵² and published in 2019, South Africa invests too little in R&D. Gross Domestic Expenditure on R&D (GERD)/Gross Domestic Product (GDP) has remained unchanged at around 0.8% for the last 15 years compared to an elusive national target of 1%, resulting in South Africa being ranked 44th on GERD/GDP in 2015.⁵² The number of patent applications (a proxy for research and innovation) registered by South African residents is low and has stagnated over the last 35 years.⁵³ Fortunately, there has been growth in academic pipelines for master's and doctoral graduates, increased publications, and significant participation of black people and women in the R&D workforce.^{16,52} Food sciences and technology feature second in publishing scientific research papers under agricultural sciences.⁵² It is promising that research projects like InnoFoodAfrica working on trying to increase dietary diversity by developing affordable, nutrient-dense and healthy food products from local African crops, are already underway.⁵⁴ According to KaMshayisa (Researcher and Lecturer, Cape Peninsula University of Technology; written communication; 11 April 2022), there is also research across multiple academic institutions on insects, from techno-functional properties, allergenicity and microbial aspects to new product development for human food. Bessa (Co-Founder and Chief Science Officer, De Novo Foodlabs;

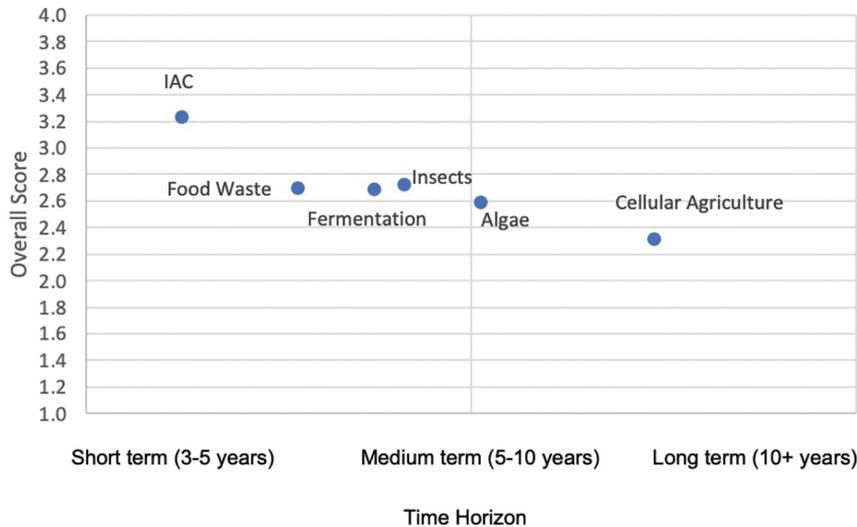


Figure 3: Time horizon and overall score analysis for commercialising underutilised and emerging food sources in South Africa (IAC = indigenous African crops).

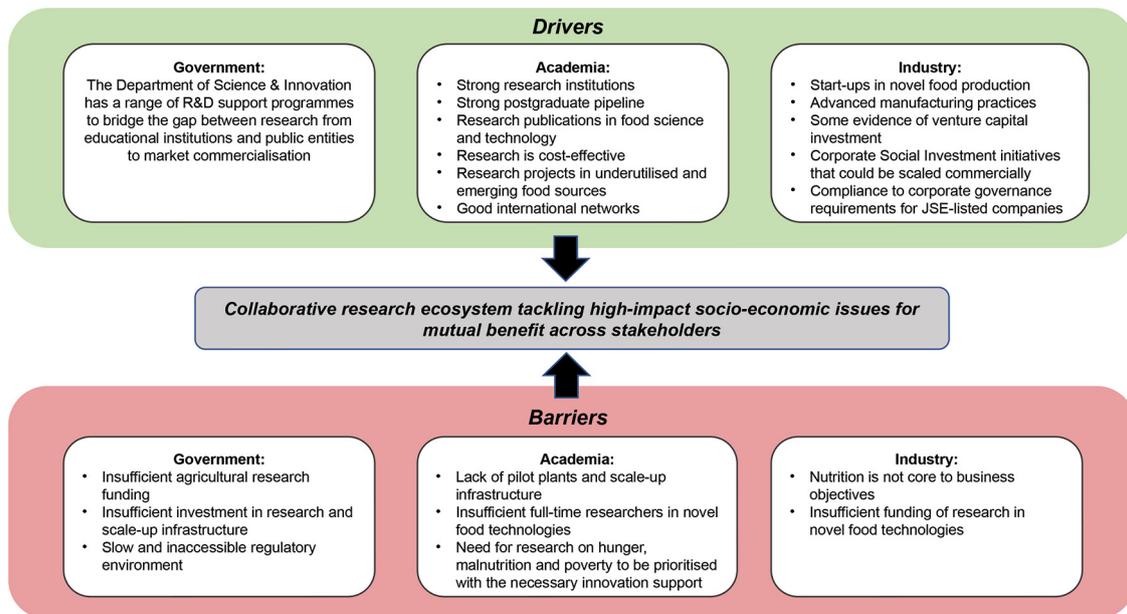


Figure 4: Summary of drivers and barriers to advancing new food science and technologies to commercialisation, across critical stakeholders.

written communication; 25 April 2022) states that research in South Africa is relatively cost-effective, and significant research can be conducted at a fraction of the cost to overseas universities. Bessa (Co-Founder and Chief Science Officer, De Novo Foodlabs written communication; 25 April 2022) also pointed out that South Africa lacks pilot plants' scale-up capabilities or co-manufacturing scale-up facilities to bring new technologies to market. This means that trials often need to be conducted overseas, which is complicated, costly and slow.

South Africa's National Development Plan recognises that science, technology, and innovation (STI) are crucial for boosting economic growth, creating jobs, and promoting socio-economic reform.⁵⁵ The Department of Science & Innovation offers various funding opportunities, including the Support Programme for Industrial Innovation and the Industrial Innovation Partnership Programme.⁵⁵ The Technology Innovation Agency also provides grants, loans, and equity support for technology development and commercialisation.⁵⁵ The Technology for Human Resources in Industry Programme facilitates research and development collaborations among private companies, universities, and science councils.¹⁶ The

government needs to ensure this funding and support for research skills and infrastructure, as well as acceleratory tax incentives for R&D, are accessible and provide an enabling environment for various stakeholders to collaborate and innovate to unlock new food science technologies. For example, in 2022, the government of the Netherlands announced funding of an initial USD60 million to expand and develop its domestic cultivated meat and seafood ecosystem.⁵⁶ The funding will be used mainly to invest in education and innovation in this emerging industry.⁵⁶ Our study also identified that for emerging or new food technologies to become available to South Africans, a progressive and agile regulatory environment needs to be in place, which is not the case today. Singapore's Food Agency, for example, approved the sale of cultivated meat in 2020, enabling start-ups like Eat Just to test and scale this technology in that country.⁵⁷

According to a 2019 White Paper on STI in South Africa, the National System of Innovation is hindered by several factors. These factors include insufficient and non-collaborative methods for setting an STI agenda, lack of policy coherence and coordination, weak partnerships between key stakeholders (minimal involvement from businesses and

civil society), inadequate monitoring and evaluation, insufficient high-level science, engineering, and technology skills for the economy, a small research system, an unfavourable environment for innovation, and significant underfunding.⁵⁵ In this study, we identified additional barriers to these, described in Figure 4, which must be overcome so that key stakeholders across the innovation system can collaborate to advance novel food science, technologies, and research to reach commercialisation.

Similar to how Israel has become known for its innovative technology, entrepreneurial spirit, supportive government policies and investment capital⁵⁶, South Africa has many enabling drivers to become a global leader in food technology advances (Figure 4). Israel now has over 100 companies operating in the alternative protein sector, with investment funding totalling USD114 million in 2020, of which government funding alone was USD18 million.⁵⁸

Conclusion

We have determined that food consumption shifts since 1994 have been towards increases in sugar-sweetened beverages, animal-source foods, and added caloric sweeteners, with a shift away from vegetables. These shifts in food consumption are concerning given their nutritional composition and potential effect on public health. Food security remains a significant and growing challenge for South Africa. Our findings indicate that there are under-utilised and emerging food sources that could go some way in addressing these and other socio-economic challenges like unemployment and inequality.

South Africa has strong research institutions supporting a healthy pipeline of postgraduate students, with research being conducted and published on many underutilised and emerging food technologies and sources. It is cost-effective to conduct research in South Africa, and with local and international funding, food science and technology research could build further necessary skills, capabilities and expertise. South Africa has a robust agricultural sector and an advanced and growing food and beverage manufacturing industry, with recent food tech start-ups conducting research and developing novel technologies in cell-based and precision fermentation. However, a lack of pilot plants and scale-up facilities for start-ups and innovators hinders these ideas from scaling up quickly and reaching the market. This often means costly and time-consuming trials offshore. The government could play a significant role in connecting the critical players across the research ecosystem and food value chain, including small-scale farmers, around essential research agendas such as hunger and malnutrition. They could co-invest in the relevant infrastructure for shared facilities where multiple innovators could collaborate to reach scale-up and provide accessible tax incentives for R&D investment to spur the food and beverage industry to overcome their risk aversion to innovating in novel food science technologies. The food and beverage industry could also invest in food tech start-ups to accelerate their commercialisation efforts and reach scale quicker. Our findings suggest that joint research collaborations in indigenous African crops and food waste recovery would be an excellent place to start as they are the most promising, near-term emerging sources of food to be utilised to achieve affordable, nutritious, safe and culturally appropriate food.

South Africa must become more resilient to climate change impacts on food security through collective engagement with critical stakeholders to harness the benefits of novel and emerging food science technologies. Many examples exist of countries doing this for enormous economic and food security benefits. If all stakeholders recognised their responsibility to address the failing food system and transform how food is produced, future diets of South Africans could be far more diverse and nutritious. This could further positively impact food security, employment generation and the overall economy.

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Data availability

The data supporting the results of this study are available upon request to the corresponding author.

Declaration of AI use

No AI tools or large language models were used in the development of this work.

Authors' contributions

L-C.R-R.: Conceptualisation, methodology, data collection, data analysis, validation, data curation, writing – initial draft, project leadership, project management. G.O.S.: Conceptualisation, methodology, writing – revisions, student supervision. Both authors read and approved the final manuscript.

Competing interests

L-C.R-R. worked in the South African food and beverage industry while conducting this research as part of her PhD thesis.

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