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Excellence in Agricultural Research and Development

Agring Bulletin

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Newsletter of the
ARC-Natural Resources and Engineering
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A word from the Editor …

Greetings to you our dear readers.

Welcome to the 14th edition of our external newsletter, Agring Bulletin. We take this opportunity to thank you all for reading our newsletter, which appears twice per annum. We strive to keep publishing articles with information that you will always find helpful in this era where clean energy resources and high efficiency in water use are topical.

Best regards
Dr Macdex Mutema

Dr Macdex Mutema
Editor (Snr. Research Engineer)

Modified Atmosphere Packaging (MAP) for fruit and vegetable preservation – by Ms Perm Mthethwa and Dr Sipho Sibanda

Packaging is one of the main driving forces in food marketing in developed countries. It plays an important role in the preservation and extension of the shelf life of both fruits and vegetables from the time of harvest up to consumption by consumers. Packaging helps to reduce the incidence of pest infestation, disease progression and microbial infestation. With the correct packaging and labelling, food can be safely stored, protected and adequately marketed. One of the best ways to package food is called Modified Atmosphere Packaging (MAP), which helps keep food fresh for a longer time compared to other packaging methods.

- **What is MAP and how does it work?**

Modified Atmosphere Packaging is a packaging technique used to extend the shelf life of fresh produce by changing the air composition around the produce through injecting gases such as nitrogen (N_2) and carbon dioxide (CO_2), as seen in Figure 1.

During this process, N_2 and CO_2 are injected into a package container, increasing their levels and reducing that of oxygen (O_2). Since oxygen plays a critical role in lipid oxidation reactions, reduced O_2 helps to slow down the product respiration rate, microbial activity and ripening, while increased CO_2 levels act as an antimicrobial agent to inhibit fungal and bacterial growth.

The goal is to keep food fresh by slowing down its natural decay process, so that it stays fresh and safe to eat for a longer time and maintains the product quality without preservatives. Maintaining a low temperature or dark storage conditions is crucial to inhibit microbial activities in MAP.

- **Benefits and drawbacks of MAP**

Modified Atmosphere Packaging offers several benefits, including extended shelf life, reduced retail waste, minimal or no need for chemical preservation, and overall good food appearance. However, MAP also has some drawbacks, such as high initial costs for the equipment, environmental concerns related to plastic use, the potential growth of food-borne pathogens due to temperature non-compliance by retailers and consumers, and the loss of MAP benefits once the packaging is opened or if it leaks.

- **Ideal gas composition**

A certain gas mixture must be met and strictly followed for food preservation. There are three main classifications of gas mixtures used in MAP, namely inert blanketing (N_2), semi-reactive blanketing (CO_2/N_2 or $O_2/CO_2/N_2$) and fully-reactive blanketing (CO_2 or CO_2/O_2). For MAP the ideal gas composition is 5-10% CO_2 and 1-5% O_2, differing significantly from atmospheric air which is approximately 78.1% N_2, 20.9% O_2 and 0.03% CO_2.

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The gas mixture and injection levels used in MAP vary depending on the specific product being preserved. It is crucial to maintain optimal oxygen levels, as excessive reduction can lead to anaerobic respiration, causing unwanted flavours and odours. For example, low O_2 levels can cause potatoes to develop black heart symptoms. The complication with the use of MAP is establishing a stable atmosphere within the packaging. Inert gases are preferred for use in MAP due to their non-reactive properties to food.

Besides the commonly used gases like nitrogen and carbon dioxide, others gases such as argon, carbon monoxide and sulphur dioxide are also used in MAP, although their benefits are limited and some pose toxicity risks. Additionally, argon is expensive due to its scarcity. Manufacturers must label MAP-packaged products and list the ingredients.

While MAP helps to preserve food, it can also cause chilling injury to some vegetables, but adjusting the gas composition can mitigate this. Nitrogen is a popular choice for MAP due to its inert, odourless and tasteless properties, which make it an ideal oxygen replacement to prevent spoilage. Carbon dioxide, another commonly used gas, also inhibits oxidation and growth of aerobic organisms, but excessive use can cause food to become sour. Unlike N_2, CO_2 can easily diffuse through plastic film, be absorbed by food products, and cause packaging collapse and deterioration.

- **Packaging materials used for MAP**

Packaging material is one of the most important considerations in MAP. The material must have low gas permeability to prevent leakage. Polymeric films are used to wrap food products in MAP to confine the modified gases. The key characteristics to consider when selecting packaging material for MAP foods include resistance to puncture, sealing reliability, antifogging properties, CO_2 and O_2 permeability, and water transmission rate. The common polymeric/plastic films used are polyvinyl chloride (PVC), polyethylene terephthalate (PET), polypropylene (PP), polyethylene (PE), biaxially oriented polystyrene (BOPS) and polystyrene (PS) shrink film, amongst others.

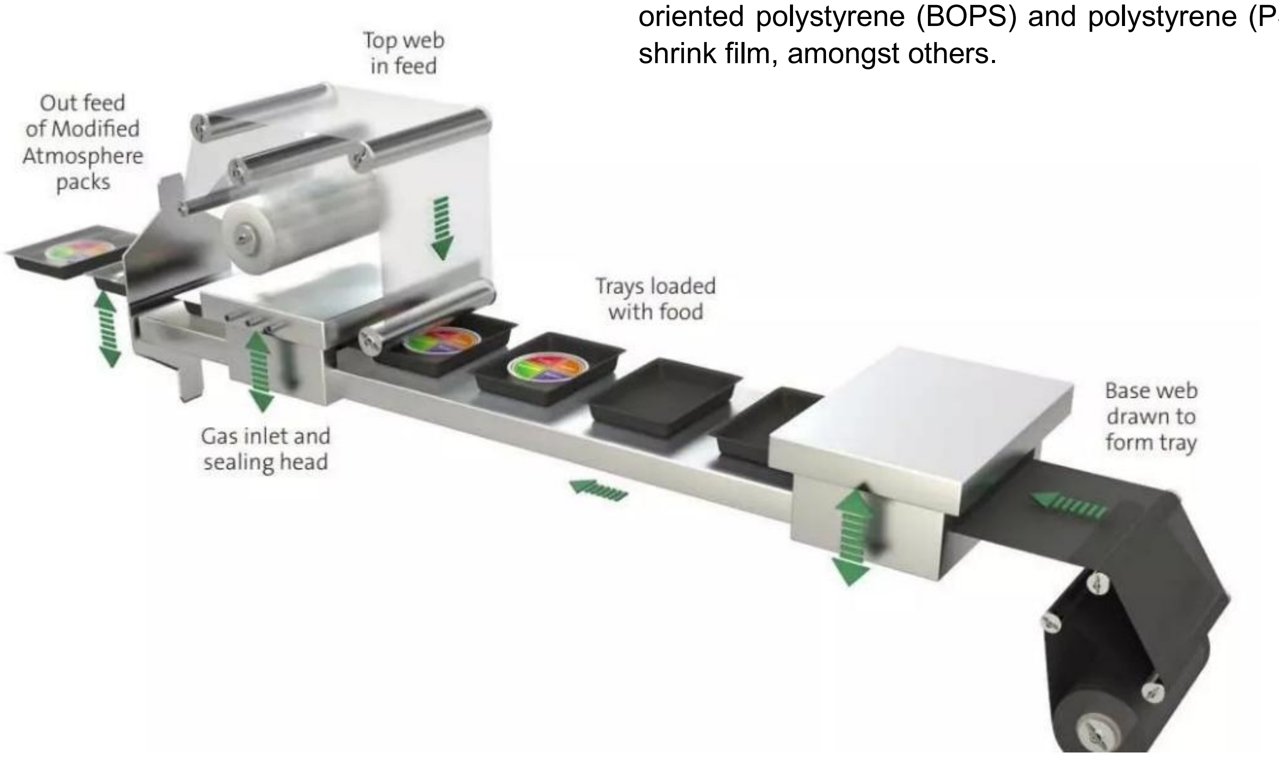

Figure 1: Modified Atmosphere Packaging process (source: Wenzhou Mwellpack Machinery)

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- **Initial and running costs of MAP**

Modified Atmosphere Packaging comes with high initial costs due to the expensive equipment and materials required. Additionally, operators need training, and the packaging film is costly due to its high-quality properties. Maintenance and gas costs also add to the overall expense. However, using MAP can help expand one's market reach, potentially leading to increased sales and profitability.

- **Vegetables considered for MAP and shelf-life extension**

MAP has been successfully applied to various vegetables, including broccoli, cauliflower, carrots, garlic and mushrooms, with other research also exploring its use for onions, sweetcorn and snow pea pods, using high water vapour permeable films as seen in Figure 2. The maximum shelf-life extension occurs at the lowest oxygen concentration before anaerobic respiration begins, but this also poses the greatest risk of spoilage.

The majority of products achieve a longer shelf life with MAP than with vacuum packaging. On average MAP can extend the shelf life of vegetables from days to weeks. For leafy vegetables, not much significant shelf-life extension can be achieved through MAP. Cabbage lifespan can be extended by 21 days at 4 ± 0.5℃ storage temperature and 90-95% relative humidity (RH); spinach shelf life can be extended by 7 days at 7℃ and 97% RH; and lettuce life expectancy extended by 8 days at 5℃.

The life expectancy of tomatoes can be extended by 21-35 days at 2-10℃, cucumber by 15 days at 4℃, cauliflower by 12-30 days at 1-5℃ and 90-96% RH, broccoli by 21-25 days at 1-10℃ and 90-95% RH, and mushrooms by 27 days at 4 ± 1℃.

As a guideline for atmosphere storage, fruit and vegetables with high moisture content may be stored at 0-5℃ and 90-99% RH, whereas fruit and vegetables with lower moisture content may be stored at a lower RH of 60-70% and a temperature of 4-9℃. ■

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Figure 2: Vegetables preserved through Modified Atmosphere Packaging (source: Internet)

Knowledge Exchange Days: Sharing information on the field performance of Agri-mats

– by Ms Sandisiwe Mahlamvu, Dr Macdex Mutema, Dr Calvin Sambo, Ms Manoshi Mothapo and Dr Khumbulani Dhavu

ARC-NRE Agricultural Engineering collaborated with the Limpopo Department of Agriculture and Rural Development (LDARD) to organise two Knowledge Exchange Days in Sekhukhune District under the theme "*Sorghum production under Agri-mats*" as part of the DoA-funded project on water saving options for climate-smart crop production in semi-arid areas. The first event was held at Ga-Radingwana village on 14 May 2025, while the second took place at Mphanama on the 15th. In total the two events were attended by 101 smallholder farmers and 17 officials (LDARD and ARC).

The aim of the Knowledge Exchange Days was to provide an opportunity for both communities to learn about the Agri-mats and how they have performed under farmers' management. The farmers were enthusiastic about the mulching technique and are looking to the future with great hope! ■

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Dr Macdex Mutema addressing the farmers

Small-scale farmers who are participating in the project

Mphanama and Ga-Radingwana village farmers listening to the presentations

Farmers visiting the sorghum plots where the Agri-mats are installed

Climate Change Mitigation and Adaptation: Upscaling Biogas Production in an Integrated Food and Energy System

– by Ms Manoshi Mothapo, Ms Primrose Magama, Ms Zikhona Buyeye, Ms Perm Mthethwa and Mr Siboniso Nkambule

Introduction

South Africa continues to face the dual challenges of food insecurity and the impacts of climate change, particularly in rural communities that rely on agriculture for their livelihoods.

Rising temperatures, prolonged droughts and erratic rainfall patterns are placing immense pressure on water availability, energy access and food production systems. To address these challenges, an ***integrated food and energy system (IFES)*** has emerged as a holistic approach to building climate resilience, improving food security and promoting sustainable resource use.

The IFES is designed to implement practical, community-based solutions that combine biogas energy generation, rainwater harvesting and sustainable agriculture through drip-irrigated vegetable gardens under shade netting.

A project funded by the Department of Agriculture has been rolled out at sites in six provinces of South Africa over the past 4 years: Masibekela and Sibange villages in Mpumalanga; KwaMbange in the Eastern Cape; Gunjaneni village in Mtubatuba, KwaZulu-Natal; Masia village in Limpopo; Rooifontein Trust in Thaba Nchu, Free State; and Mokasa 1, Mokasa 2 and Lokgabeng villages in Taung, North West.

The figure below illustrates the interaction between the three core IFES components: ***biogas digester***, ***rainwater harvesting system*** and ***drip-irrigated vegetable garden***. The closed-loop model exemplifies a sustainable nexus between food, energy and water security. Each site received training on the use, maintenance and benefits of the integrated system. Community members were also supported with agricultural inputs, technical advice and monitoring visits to ensure successful adoption.

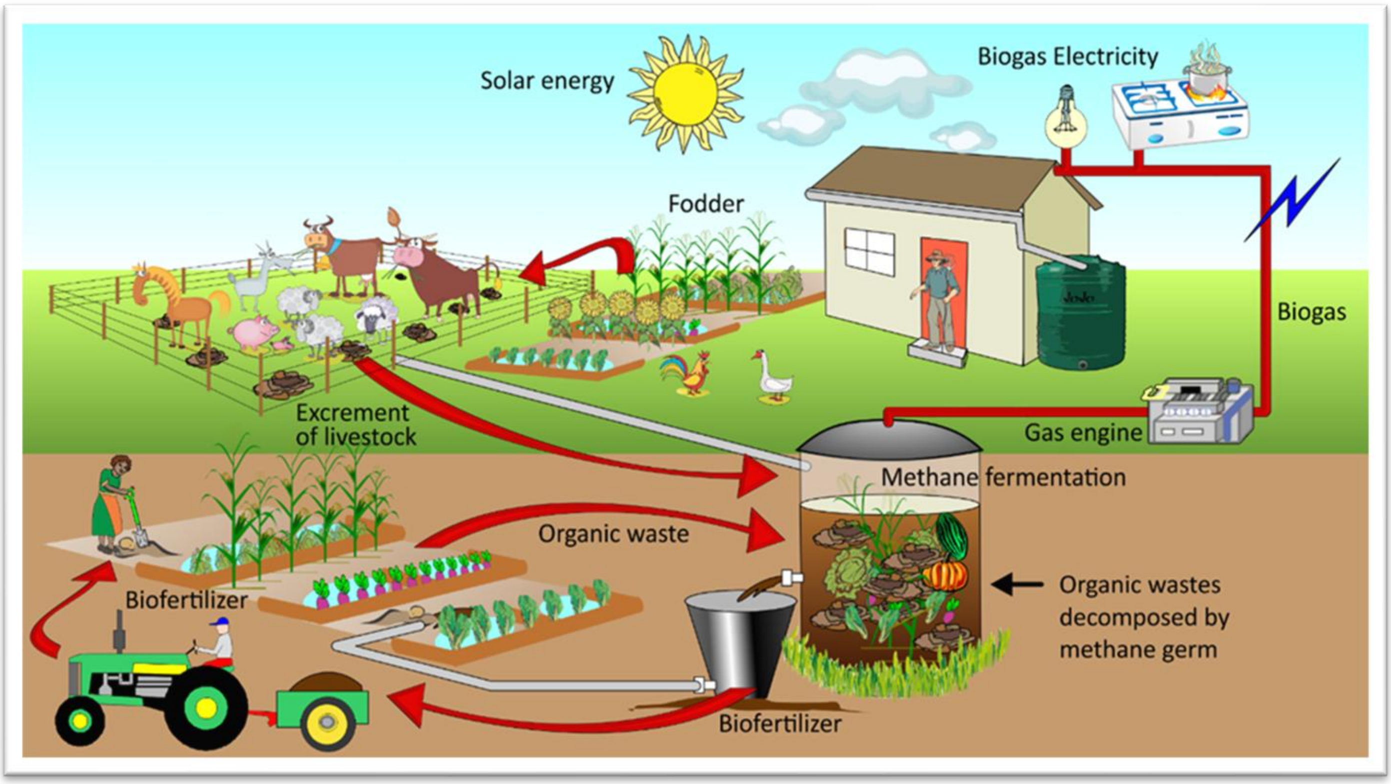

Illustration of an integrated food and energy system (IFES) implemented in a rural community

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System Components

Biogas digester

The biogas system installed at each project site consists of a 6 m^3 dome-shaped digester designed to process livestock manure and kitchen waste to produce methane gas. The gas is used primarily for cooking and heating, significantly reducing dependence on firewood and paraffin. The digester supports the anaerobic decomposition of organic material, resulting in two main outputs: clean, combustible gas and nutrient-rich slurry. The slurry is an effective organic fertilizer that is used in the vegetable gardens to enhance soil fertility and crop productivity.

Complete biogas digester connected to the gas stove

Operational gas stove – status at 18 months post-installation, indicating well fed biogas digester with good pressure

Biogas meter and analyser for monitoring biogas production

Rainwater harvesting system

Each household was equipped with a 5000 litre storage tank that captures and stores rainwater runoff from rooftops. The water is primarily used for household cleaning, feeding the digester and irrigating the vegetable garden. The rainwater harvesting system is equipped with filtration to ensure clean storage, as well as a booster pump for use when the water level is below 25% capacity for irrigation purposes.

Rainwater harvesting tank with booster pump

Drip-irrigated vegetable garden

To enhance local food production, each project site maintains a 72 m^2 vegetable garden equipped with a drip irrigation system which is powered either by gravity from the tank or a booster pump, depending on the level of water in the rainwater storage tank. Crops grown include spinach, tomatoes, carrots, onions, peppers, lettuce, beetroot and other vegetables vital for household nutrition. The use of drip irrigation conserves water by delivering it directly to the plant roots and reduces weeding and disease incidence due to minimal water contact with foliage and soil surfaces.

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Vegetable garden fitted with drip irrigation system – status at 11 months post-installation

Application of digestate (bio-fertilizer) in the vegetable garden – status at 18 months post-installation

Impact areas:

- **Reduction in greenhouse gas emissions and deforestation**
  The project has significantly contributed to climate change mitigation by capturing methane from decomposing organic waste through biogas digesters. This not only prevents the release of a potent greenhouse gas into the atmosphere but also replaces traditional cooking fuels like firewood and paraffin. As a result, there has been a noticeable reduction in deforestation and indoor air pollution, promoting healthier households and ecosystems.
- **Improved soil fertility and reduced chemical dependency**
  Application of bio-slurry from the biogas process has enhanced soil fertility in household gardens. The organic fertilizer improves soil texture, moisture retention and nutrient content, leading to healthier and more productive crops. This has reduced the need for chemical fertilizers, lowering input costs and minimising environmental degradation from agrochemicals.
- **Enhanced food security and nutrition**
  The establishment of drip-irrigated vegetable gardens has enabled year-round food production. Households are now growing a range of vegetables such as spinach, tomatoes, onions and carrots, regardless of rainfall variability. This has increased the availability of nutritious food, diversified diets and improved household food security.
- **Increased water use efficiency**
  The integration of a 5000 litre rainwater harvesting tank and drip irrigation system has improved water management practices at household level. These systems provide a reliable water source during dry periods and minimise water loss through evaporation and runoff. This has resulted in more efficient use of water, essential in water-scarce rural communities.
- **Strengthened household and community resilience**
  By integrating food, water and energy systems, the project has improved households' ability to withstand climate-related shocks such as droughts and energy shortages. The synergy among system components supports a more self-reliant and adaptive way of life, reducing vulnerability and increasing community sustainability.
- **Economic savings and income generation**
  Households have reported a decrease in spending on cooking fuel and vegetables due to the availability of biogas and homegrown food. Additionally, surplus vegetable produce has provided income-generating opportunities through local market sales, supporting rural livelihoods and fostering micro-enterprise development, particularly among women and youth.

Conclusion

The integrated food and energy systems implemented across six provinces in South Africa demonstrate a scalable and sustainable approach to addressing climate change challenges while improving food and energy security. The biogas digester, rainwater harvesting system and drip-irrigated vegetable garden work in synergy to form a resilient rural development model that can be replicated nationwide. However, continued support, community engagement and policy integration are vital to scaling and sustaining this impact. ■

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Training University of Venda students on evaluating the performance of irrigation systems

– by Dr Macdex Mutema, Mr Fanie Vorster, Ms Sandisiwe Mahlamvu, Mr Milton Petersen and Mr Karabo Moreme

ARC-NRE Agricultural Engineering trained 32 students from the University of Venda on 19 May 2025 on evaluating the performance of drip and sprinkler irrigation systems in the laboratory. The students are registered for a module on Fluid Mechanics at UNIVEN and the practical exposure was useful for their studies. The training was conducted by staff from the Irrigation and Agricultural Infrastructure Engineering division at the ARC-NRE Silverton campus. ■

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Mr Milton Petersen and Dr Mutema explaining the dripper test bench to the students

Dr Macdex Mutema giving a theoretical lecture to the students

Mr Petersen explaining the sprinkler test bench to the students

Group photo of the University of Venda students

ARC-NRE exhibited at Nampo 2025

– by Ms Elmarie Stoltz

The ARC-NRE Agricultural Engineering (AE) and Soil, Climate and Water (SCW) campuses jointly exhibited, along with the other ARC campuses, at the 57th Nampo Harvest Day held in Bothaville, Free State, from 13-16 May 2025. ARC-NRE showcased its research activities and services to clients and farmers, with the emphasis on marketing its laboratory services which include the testing of soil and water samples, irrigation equipment and tractors.

Nampo 2025 was attended by ±67 945 visitors and 920 exhibitors. Good collaboration and discussions took place with stakeholders and clients during this event. ■

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From left: Ms Elmarie Stoltz, Ms Mmakgabo Matlou and Ms Nwabisa Masekwana at the ARC-NRE exhibition stand at Nampo 2025

Ms Manoshi Mothapo attending to a visitor at the ARC-NRE-AE stand

Ms Elmarie Stoltz asking learners to guess how much the bull weighs at the ARC-NRE-AE stand

Ms Mmakgabo Matlou explaining the soil testing laboratory to visitors at the ARC-NRE-SCW stand

Ms Nwabisa Masekwana explaining the research activities of ARC-NRE-SCW to students and learners at Nampo

ARC-NRE exhibited at G20 MACS event – by Ms Elmarie Stoltz

South Africa hosted the G20 Meeting of Agricultural Chief Scientists (MACS) in Polokwane, Limpopo from 26-28 May 2025 for a 3-day summit aimed at advancing global leadership in agriculture, research and innovation.

The gathering brought together top agricultural scientists from G20 member nations to discuss critical issues such as food security, sustainable farming and climate change resilience. This event served as a key precursor to South Africa's first-ever G20 Leaders Summit, scheduled for November 2025 in Johannesburg.

Four ARC-NRE Researchers were nominated to be part of the scientific demonstration team at the G20 MACS event. ■

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The ARC exhibition stand at the G20 MACS event

Dr Goodman Jezile (left) and Mr Philani Apleni exhibiting the mobile soil laboratory at the G20 MACS event

Mr Johan van Biljon (left) and Dr Tingmin Yu exhibiting drones at the G20 MACS event

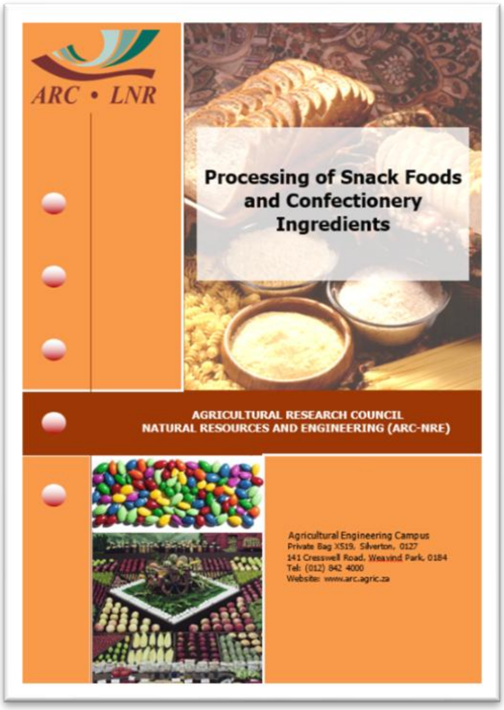
Mr van Biljon explaining the function of the drones to a visitor at the exhibition stand

New publication

Processing of Snack Foods and Confectionery Ingredients

Authored by Ms Theresa Siebert

Published: June 2025



Snack foods can be defined as small portions of food which are often eaten between meals and include a wide variety of foods:

- Pre-packaged items such as chips, crackers, pretzels, dried fruit, etc.
- Fresh fruit and vegetables.
- Dairy products such as yogurt.
- More complex dishes including ice cream, pizza, etc.

Confectionery refers to sweets and chocolates, while confectionery ingredients refer to any substance that is used in the preparation of confectionery, such as sugars, cocoa products, dairy ingredients, etc.

Some of the processing options for snack foods and confectionery ingredients covered in this publication are the following:

- Cocoa butter is used in the production of both white and milk chocolate.
- Maize chips and snacks are manufactured using an extrusion-based process like that of puffed maize snacks. They are cooked at relatively low temperatures and then sheeted out, cut into shapes and fried.
- Tortillas and tacos are flat, circular, light-coloured bread, about 1-3 mm thick and 15-30 cm in diameter. Tacos are tortillas that are allowed to undergo starch degradation and then formed into a "U" shape and fried.
- Roasted pumpkin seed is a by-product from various other pumpkin products where the flesh is processed and the seeds discarded. The seeds are dried, cleaned and roasted.
- Ice cream is a frozen or partially frozen dairy product made from a homogenised mixture containing fresh cream, butter, milk, sweetened condensed milk and milk powder. ■

Ice cream

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Chocolate sauce and ice cream