Food Science eBook

A healthy helping of science in every bite

eBook

VAISALA

Table of contents

Introduction

Food was never mere fuel. It is a source of nourishment and inspiration, a social bond, that has existed and will exist for millennia.

Currently, we stand at the threshold of a food revolution. Never has the need for sustainable, high-quality, and safe food been so great. And as improved and wholly new production methods are coming on line, we are moving from science fiction to science reality. The future is about overcoming new challenges on our way to feeding the planet's increasingly urban populations.

On one hand, it's about fearlessly helping to bring forth better meat alternatives or growing your next steak dinner in a bioreactor tank. On the other, it's a quest for improving and even rethinking greenhouses, adopting vertical farming methods, and repurposing disused subway tunnels into underground farms.

And in yet another way it's about realizing new, regenerative farming techniques and enabling the food and beverage industry to become a truly end-to-end circular economy where nothing ever goes to waste.

This is what Vaisala Food Science is all about. The data we provide is helping to make old and new production methods more efficient and more sustainable — resulting in healthier, more nutritious diets — while being laser-focused on flavor.

Value-adding data for a tastier tomorrow

This is the future, but it is also happening today. None of these improvements can happen without accurate and reliable data, and this is where we come in. Far more than a mere supplier of measurement instruments, we are in the business of providing value-adding data that supports more informed decision making. We are your expert partner throughout the entire logistics chain – from the farms to the processing and storage facilities, we are there to help you ensure food safety, extend shelf-life and make food more accessible to all. Join the growing number of food manufacturers from all around the world who trust Vaisala's technologies and expertise to help them make sure food grows safe, stays safe, and tastes great.

With our space-proof technology, we make sure that in every bite, there is a healthy helping of science and a whole lot of flavor.

We call this Vaisala Food Science.

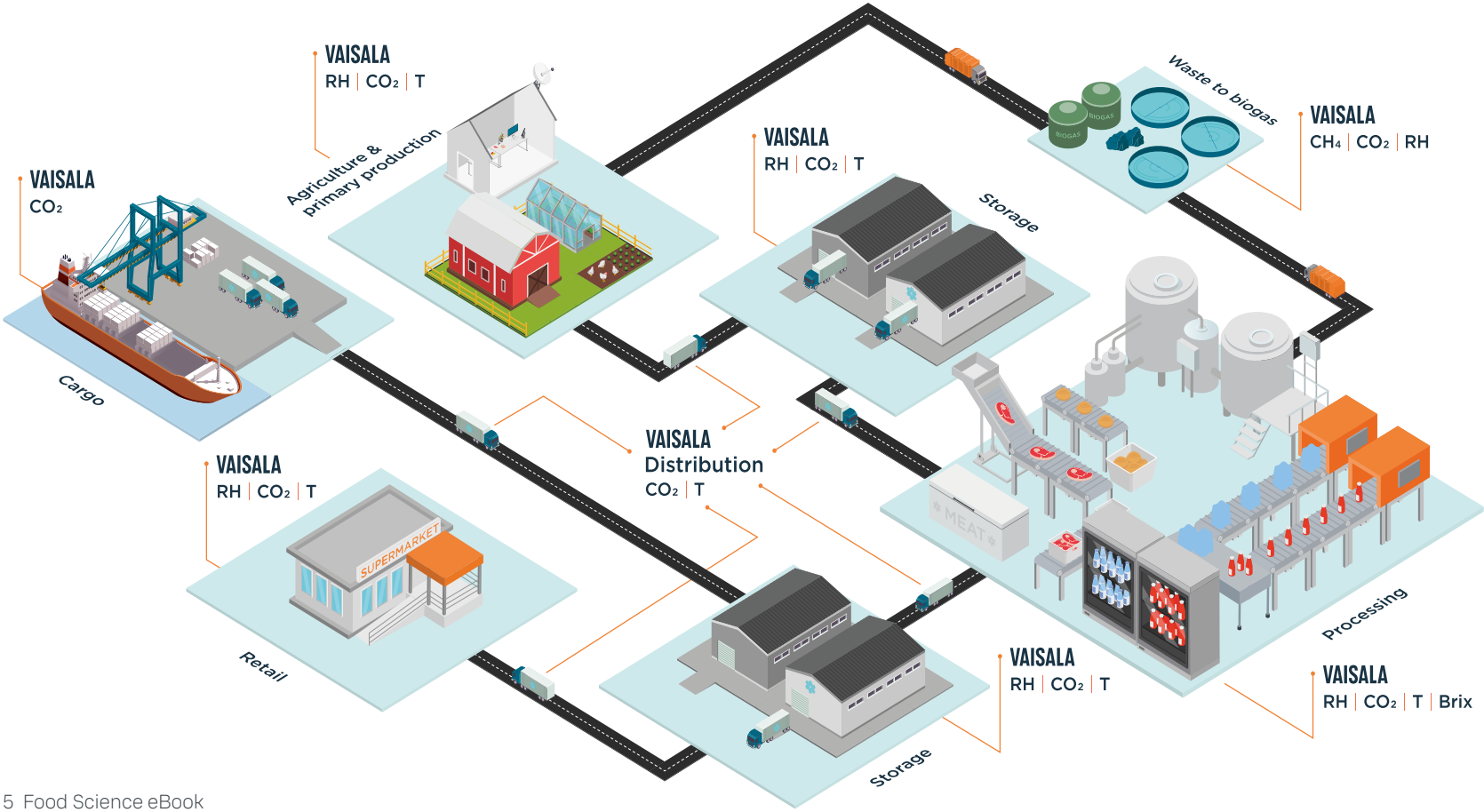
Vaisala's solutions cover your entire value chain. We can support you at every single step – from primary production through transportation, processing and storage, and all the way to creating a truly circular economy through processing food waste into biogas and biomethane.

About Vaisala

Vaisala is a global leader in industrial and environmental measurements that provide customers with data for making better decisions, increasing safety, and improving efficiency.

Reliable and accurate measurement data for multiple parameters is required at every stage of the food chain – from primary production, distribution, and storage through food processing to retail.

In this eBook, we review the most critical conditions and process measurement parameters required for ensuring high product quality, increasing safety, improving taste, optimizing shelf-life, and improving the overall sustainability of the food chain.



Primary production

Raising productivity and quality with optimized carbon dioxide in greenhouses

Optimizing carbon dioxide concentrations not only raises productivity by as much as 40% in the darkest time of the year, but it also improves the quality of the produce.

Optimizing carbon dioxide levels requires continuous and accurate information from both the indoor and outdoor environments. Typically, carbon dioxide, relative humidity, and temperature are measured inside greenhouses; outside measurement parameters include wind speed and direction, precipitation, and solar radiation. The optimal carbon dioxide conditions depend on the plant and the light conditions in the greenhouse. It is essential to maintain the right carbon dioxide level, which lies in the range of 800 to 1000 ppm, as using too much increases costs unnecessarily and can be harmful for the crop. The greenhouse control system that automatically controls and adjusts the carbon dioxide concentration can be equipped with a carbon dioxide probe.

The optimal temperature in a greenhouse varies between 15–24 °C (60–75 °F), depending on the plant species grown and the desired level of photosynthetic activity. Optimal relative humidity also depends on the plant species grown, with a typical range varying between 50% and 70%.

How all these growth factors interact must be considered to ensure the wellbeing of the plants. Carbon dioxide fertilization also works in the dark season, enhancing the effect of artificial light and compensating for the lack of light that would otherwise hamper plant growth. This is crucial in greenhouse cultivation, especially in northern Europe. With the right carbon dioxide concentration, plants will start producing fruit earlier than normal. This type of fertilization produces no toxic byproducts and creates no excessive moisture, just healthy plants and a good yield.

Tips for greenhouse transmitter placement

- Select a carbon dioxide sensor location that represents the greenhouse climate well
- Do not place sensors near vents or exhaust ducts
- Place temperature sensors close to plants otherwise they won't accurately monitor the climate around the plants
- Do not place humidity sensors close to heaters, heating pipelines, fans, walls, or irrigation water sprays

Read our customer case

Why climate control systems provider Damatex chose Vaisala sensors for their greenhouse customers.

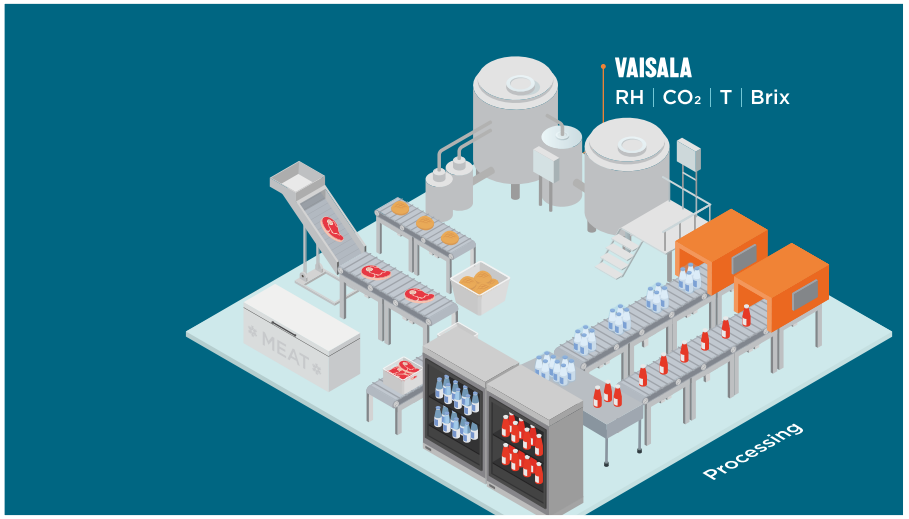
Industrial food processing

Data-driven food processing operations

The world's population is expected to grow to almost 10 billion people by 2050, while the demand for food is expected to increase by more than 50%. At the same time climate change is a key driver to optimize energy usage, decrease emissions, and avoid food waste.

Current food processing systems must be as efficient as possible to meet these growing demands, with a fully traceable and transparent value chain.

Accurate and reliable data is required in food processing to avoid poor energy efficiency, low end-product quality, and equipment corrosion. Finding and maintaining the optimal conditions is the key to lower cost and increased energy efficiency. Here, measuring parameters such as relative humidity, temperature, carbon dioxide, and liquid concentration or Brix and dry solids offers significant benefits. The food processing sector plays a vital role in providing the growing world population with enough food, ensuring that it is safe to consume and easy to access. To do this, food items need to have sufficient shelf life, withstand transportation and storage, and not compromise on high product quality or taste.



Critical measurements for process optimization and control in food and beverage production:

- Relative humidity for streamlining drying processes
- Temperature for optimizing process conditions
- Carbon dioxide for keeping employees safe and goods fresh
- In-line Brix or dry solids for product quality control and remote process diagnostics

Humidity measurement in food drying

Drying plays an important role in improving global food production and security. When moisture is removed to a safe level, drying can prevent microbial growth and reproduction, reduce moisture-induced biochemical reactions, and reduce packaging, storage, and transportation costs. Proper drying also extends the shelf life of products.

Accurate humidity measurement helps to achieve exactly the right balance – drying the product sufficiently to keep it safe while optimizing input volume and drying time to minimize energy usage and maintain quality. Sustainable drying using accurate measurement devices to control the process is a cost-effective way to enhance food quality and yield.

Applications such as the drying of demineralized whey can be optimized by measuring the humidity and temperature in the dryer inlet and outlet air. For example, a Finnish dairy company increased its production capacity by 20% without increasing its energy consumption just by updating its dryer controls.

Fluid bed drying

Fluid bed drying is a very effective method of solid particle drying. Accurate humidity monitoring of the drying air is needed to optimize the drying process.

Read more about fluid bed drying monitoring on our website.

Spray drying

Spray drying is widely used in food production to prevent microbial growth and keep products safe. To ensure efficient spray drying, it is necessary to monitor relative humidity or dew point levels. Our interactive drying simulator will help you understand how accurate humidity measurement can improve both energy efficiency and yield.

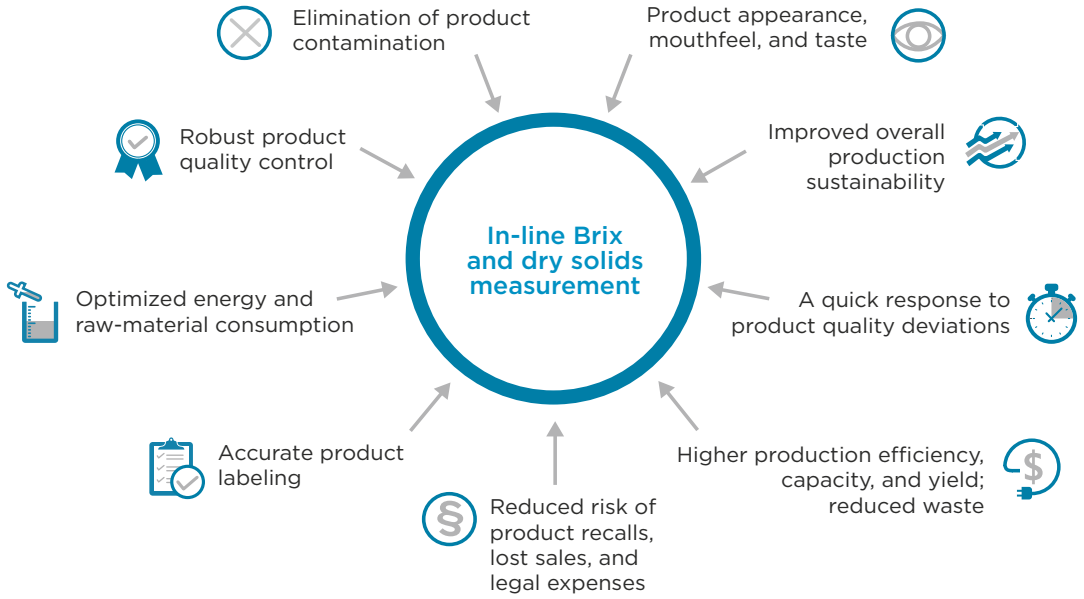
Baking oven monitoring

In applications such as bread baking and cereal manufacturing, the humidity level in dryers and ovens must be carefully controlled to maintain quality and yield. Read more about baking oven monitoring and download our application note here.

Real-time, continuous process and product quality control with in-line Brix measurement

In-line Brix concentration measurement helps manufacturers to successfully perform food and beverage production tasks by allowing for real-time, continuous, automated process control without compromising measurement accuracy. The figure on the right summarizes the benefits.

Traditionally, process and product quality control would be done by collecting samples manually and analyzing them in a laboratory – a costly, time-consuming procedure that results in a significant delay between sampling and the result being available. Consequently, any products that fall outside of acceptable values are likely to have travelled throughout the process before an alarm can be raised, and this may result in significant product wastage.

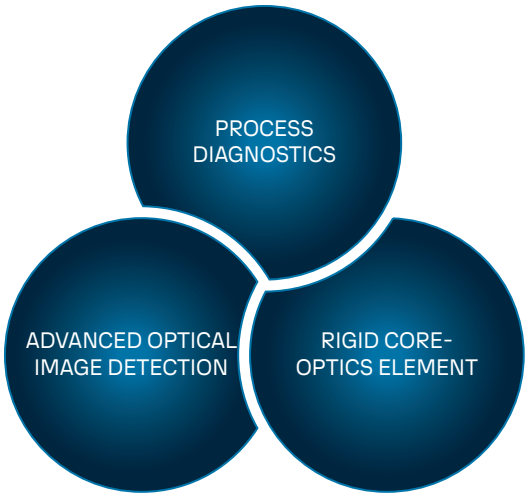


In-line Brix and dry solids measurement enables reliable process and product quality control

Future-proof your process today

In food and beverage production, changes in liquid concentration take place in many operations. Continuous in-line monitoring of concentration using Vaisala's sanitary refractometer brings benefits throughout a processing plant's operations, from product intake to product processing and wastewater treatment, substantially improving the plant's overall sustainability and resource efficiency.

Unlike time-consuming and laborious sampling, which poses a risk of product contamination, in-line measurement of Brix concentration allows for real-time continuous process control without compromising measurement accuracy. Moreover, automated in-line measurement does not require operators to be physically present on site.



Distinctive features of the in-line Vaisala K-PATENTS sanitary refractometer that enable remote process control and diagnostics

Accurate in-line Brix measurement that is not affected by color, air bubbles, particles, fruit pulp, flow or pressure changes, vibration, or temperature shocks.

No laborious sampling or measurement errors. Operators can now concentrate on other important tasks.

More information

Visit our dedicated web page on **in-line process refractometers** for industrial process instrumentation and control applications to learn more.

Evaporation

Juice, instant coffee and tea, powdered and condensed milk, tomato paste, and pectin production are just some examples of products that use evaporation. In the evaporation process, in-line concentration measurement is required at the evaporator outlet. The signal is then connected to the controller, which adjusts the evaporator inlet flow and regulates the concentration value.

In evaporation processes Vaisala's sanitary refractometer:

- Optimizes performance
- Reduces energy (steam) consumption
- Ensures the target concentration is achieved
- Enables real-time monitoring of evaporator efficiency

Dilution, dissolving, and blending (mixing)

These are typical operations when producing drinks by mixing water, concentrated juice, alcoholic beverages, or soft drinks. For a dissolving operation, sugar, salt, or powder are required.

The in-line refractometer can be used in dilution, dissolving, and blending to help achieve and maintain the desired final concentration of a liquid. Measurement performance is not affected by air bubbles in sugar solutions.

In these processes the sanitary refractometer:

- Prevents excess consumption of raw materials
- Ensures high and consistent product quality
- Enables automated operations
- Ensures stable measurements regardless of the presence of suspended particles

CUSTOMER CASE

A producer of ready-to-drink beverages from tea extract in the USA had had difficulties finding a Brix measurement device that would withstand the vibration from RO units. After they installed Vaisala's sanitary refractometer with an integrated high-pressure wash nozzle they saw measurements stabilize and eliminated the problem of prism fouling.

Spray-drying

The importance of spray-dryer monitoring can be explained using the example of a powdered infant formula production process. In this process it is crucial to maintain the dry solids content at a specified level as a too-low solids content will result in a small particle size, poor wettability, and a shorter product shelf life. On the other hand, an excessively high dry solids content increases the viscosity of the milk, which results in larger particles and affects spray-dryer capacity.

In spray drying, the in-line sanitary refractometer:

- Ensures correct solids concentration to the spray dryer, resulting in the correct particle size
- Ensures efficient drying operation, resulting in smooth, accurate product packaging
- Ensures a completely dry product with a longer shelf life
- Reduces energy consumption
- Improves product quality

Solid-liquid extraction

Extraction is commonly used in food and beverage applications to obtain ingredients from natural raw materials, e.g. pectin extract or ready-to-drink tea.

The in-line refractometer can be used to detect the amount of extracted substance (dissolved solids) in the liquid after the extraction process. Measurement performance is not affected by undissolved solids in the liquid, making it an ideal tool for monitoring extraction efficiency. In-line measurement enables process adjustments to be made in real time in order to increase productivity and reduce costs. The refractometer can also help to ensure that the correct amount of dry solids continues to the next processing step.

CUSTOMER CASE

An Italian producer of extracts from spices and plants for use as food ingredients installed a Vaisala sanitary refractometer to ensure that their products reach the desired concentration after evaporation. They also use the measurement for in-line control of recovered alcohol concentration.

CUSTOMER CASE

A cereals producer in the USA improved their product quality, eliminated sugar losses, and reduced their waste treatment costs by optimizing sugar slurries control with in-line Brix measurement using the Vaisala sanitary refractometer.

Quality control

As all liquids have a unique refractive index value, the in-line refractometer can determine the final quality of the liquid and ensure that the product meets the required specifications. Real-time detection provides timely warnings about process disturbances and potential quality variations.

Examples of quality control using a sanitary refractometer include carbonated soft and alcoholic drinks production and egg separation.

Low-concentration beverages

Diet soft drinks and flavored water are low-sugar-concentration beverages whose production requires high measurement accuracy and repeatability. Process variations are low and operating ranges are limited to 0–30 Brix and 4–30 °C. The Vaisala K-PATENTS Sanitary Refractometer can be used to detect concentration variations in these types of products with good measurement accuracy and repeatability, enabling advanced process control.

CUSTOMER CASE

A soft drinks producer in Finland uses the Vaisala K-PATENTS Sanitary Refractometer to ensure accurate and repeatable in-line Brix measurements for blending and product interface detection in the manufacture of products such as flavored mineral water and diet drinks.

CUSTOMER CASE

By replacing manual sampling with the in-line refractometer for control of dry solids in liquid egg processing, another Vaisala customer in the USA improved their process efficiency and gained better control over product quality. The measurement helps them to adjust the dry solids in standardized egg yolk and whole egg by adding the necessary amount of egg white.

Cooking

In the production of jams or sugar confections a mixture containing sugar is cooked to achieve the right concentration.

A sanitary refractometer can be used for continuous in-line monitoring of the Brix concentration during batch preparation to determine the end-point for the process and to increase yield and efficiency. In-line measurement eliminates the need for batch sampling and off-line analysis, improves product consistency and quality, ensures that product labeling specifications are met, and optimizes sugar usage.

Learn more

Learn more about in-line Brix concentration measurement in jam cooking in our **application note**.

CUSTOMER CASE

A German jam producer was able to significantly improve their manufacturing process, make more efficient use of raw materials, and eliminate the need for off-line sampling at the cooking and packaging stages with the help of an in-line refractometer. The device was installed directly in their open cooking pan to continuously monitor the Brix concentration and ensure it remained within the desired limits for reduced-sugar and standard product types.

Alcoholic fermentation

Alcoholic beverages such as wine, beer, and cider are produced through a fermentation process. The alcoholic fermentation determines the strength and quality of the final product. It is therefore very important to monitor the overall fermentation process in order to achieve the desired product quality.

The in-line sanitary refractometer ensures flawless product manufacturing by monitoring the Brix content at different stages of fermentation. At the start of the fermentation process the Brix content indicates the starting gravity of the feed that is fed into the fermenter. In the fermentation vessel or in the by-pass to the fermentation vessel the Brix content determines the degree of fermentation as alcohol is produced.

At the final stage of the fermentation process, when installed after the fermenters, the sanitary refractometer monitors the quality of the final product in real time and helps to determine when the batch is ready as well as if the target alcohol level has been achieved.

Learn more

Read more in our optimized alcoholic fermentation **application note**.

CO_2 monitoring in fermentation and brewing

Enzymes, antibiotics, amino acids, and alcohols are all produced by fermentation in strictly controlled environments. CO_2 is the most important gaseous metabolic product in fermentation and is also used for the carbonation of beverages. CO_2 can be a safety hazard and monitoring it is essential to avoid accumulation and ensure employee safety.

CO_2 safety measurement is especially needed in beverage production because fermentation tanks have pressure relief valves. If the pressure in the tanks builds up too high, the gas will exit through these valves. There is also the risk of gas leaking from the tanks or pipelines. Excessive levels of CO_2 can displace oxygen, causing tiredness, unconsciousness, or even death.

Workplaces where carbon dioxide can rise to dangerous levels include wineries, breweries, fermentation facilities, and carbonated drinks production facilities.

Most countries have set workplace exposure limits for CO_2. For instance, in the United States, OSHA (Occupational Safety & Health Administration, U.S. Department of Labor) requires the general exposure to CO_2 to not exceed 5,000 ppm during an eight-hour working shift.

Read about monitoring CO_2 in Chateau St. Jean in Sonoma Valley, California.

Alcohol distillation

Distillation is commonly used to purify alcoholic beverages. The process takes place in a distillation column, which separates the feed into two or more product streams, one of which must meet product specifications.

The in-line sanitary refractometer provides automatic control over the separation of the binary mixtures. Continuous concentration measurements of top and bottom products help to maintain optimal operation and allow for adjustment of product concentration by reflux or boilup control. Accurate measurements help to ensure that the product meets specifications, which translates into optimal performance and reduced costs and energy consumption.

Learn more

Read more in our rum distillation **application note**.

Product interface detection

Processing plants with multi-product lines and clean-in-place (CIP) operations require product-to-product, product-to-water, and product-to-CIP liquid identification. The Vaisala sanitary refractometer's optical detection of the liquid's Refractive Index can be used as a "fingerprint" for interface detection. Automated monitoring and control of the CIP process allows products to be switched without the need for a shutdown, increasing productivity without compromising end-product quality.

Learn more

Read more about product monitoring in product-to-CIP liquid interface detection **here**.

CUSTOMER CASE

After installing the Vaisala sanitary refractometer, a European dairy, which previously produced around one million liters of waste product per year during product changeover on filling lines, was able to cut its 15-minute product changeover time to the legal minimum of five minutes, reducing waste by two thirds.

CUSTOMER CASE

A beverage producer in Spain reduced product losses resulting from inefficient product-to-CIP interface control by replacing conductivity meters with the highly accurate Vaisala sanitary refractometer, which had the added benefit of being able to withstand high temperatures during the CIP cleaning process.

Organics monitoring in effluent streams

The sustainability of food, beverage, and brewing production facilities is directly related to their side-streams and wastewater treatment practices. Organic pollutants from food and beverage production include oils and fats, alcohol, proteins, and carbohydrates. Wastewater from production must be monitored to ensure compliance with environmental regulations. Moreover, high concentrations of organic materials must be quickly detected to ensure proper operation of the water treatment system.

Traditional methods of monitoring chemical oxygen demand (COD) and total organic carbon (TOC) in wastewater can be expensive to maintain and calibrate, and do not provide continuous real-time information. The Vaisala in-line refractometer enables industrial food and beverage production facilities to monitor and treat their effluent streams before discharge. In-line water quality control and organics content monitoring provide fast and accurate data in real time.

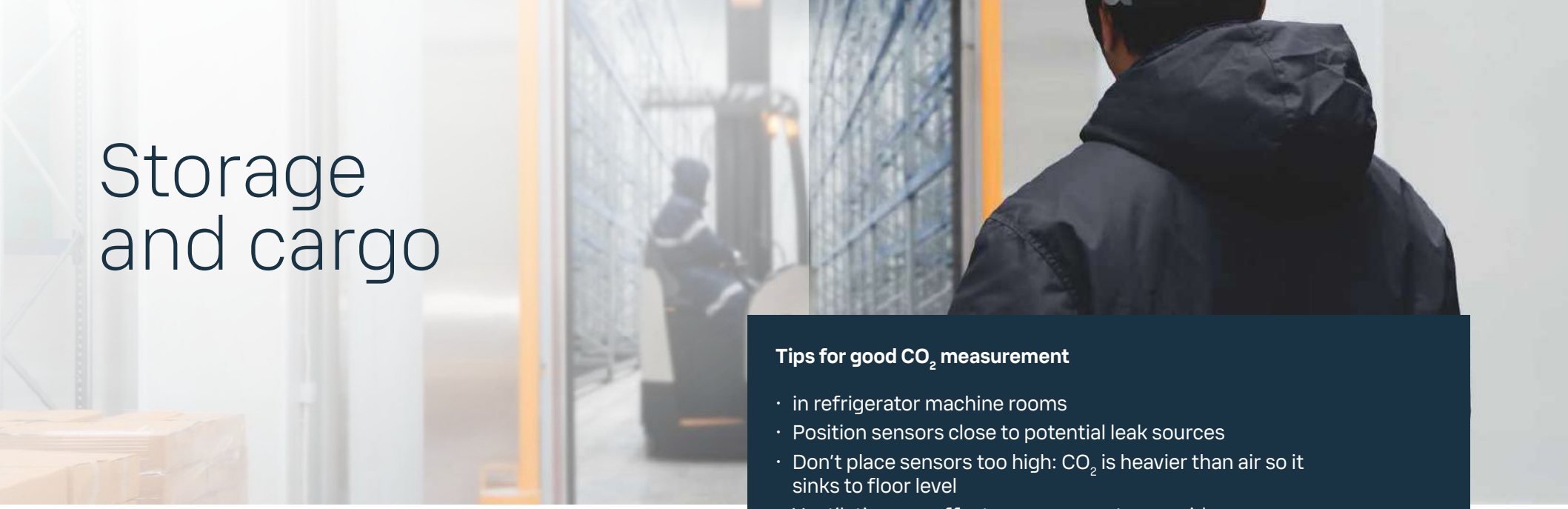
For more information on organic waste processing, jump to the section From waste to value.

The Vaisala in-line process refractometer has a range of benefits for effluent control in food production waste streams:

- Direct in-line measurement of total dissolved solids (TDS)
- Measurement does not drift and instrument requires no recalibration
- Real-time control over wastewater treatment plant loads and optimized plant operation
- Continuous water quality monitoring
- Helps eliminate product losses with timely alarms
- Improves overall plant cost efficiency by adjusting incoming load, reducing treatment costs, and improving cost-efficiency of environmental compliance

Read more about how this is done here.

Storage and cargo



Carbon dioxide refrigerant monitoring

CO_2 refrigeration has found numerous applications in food and industrial processing, cold storages, and food retail and transportation.

Measuring CO_2

All living organisms produce carbon dioxide, which is an important part of photosynthesis. In food logistics and production, CO_2 needs to be maintained at the right level in order to ensure process safety, productivity, and product quality.

In the food industry, CO_2 needs to be monitored in storage facilities, ripening rooms, freezers, refrigerators, transportation vehicles, retail outlets, breweries, wineries, logistics hubs and terminals, and during dry ice storage and transportation.

Tips for good CO_2 measurement

- in refrigerator machine rooms
- Position sensors close to potential leak sources
- Don't place sensors too high: CO_2 is heavier than air so it sinks to floor level
- Ventilation can affect measurement, so avoid installing sensors close to air inlet vents
- Open doors and windows change the CO_2 concentration
- Temperature variations might affect CO_2 measurement
- Avoid installing CO_2 detectors close to vibrating engines or actuators

In fruit and vegetable storage and transportation, the right level of CO_2 is important to keep produce fresh, ensure the safety of personnel, and prevent machinery damage. The CO_2 level can be controlled to slow down aging or to ripen produce.

Benefits of reliable CO_2 measurement in storage facilities

- Better control leads to higher, more consistent quality
- Increases safety
- Over-cooling consumes a significant amount of energy and money
- To ensure optimal refrigerator performance, refrigerant levels are important
- Locating leaks as soon as possible saves both energy and refrigerant

Learn more Read more in our blog: Why is CO_2 measuring important?

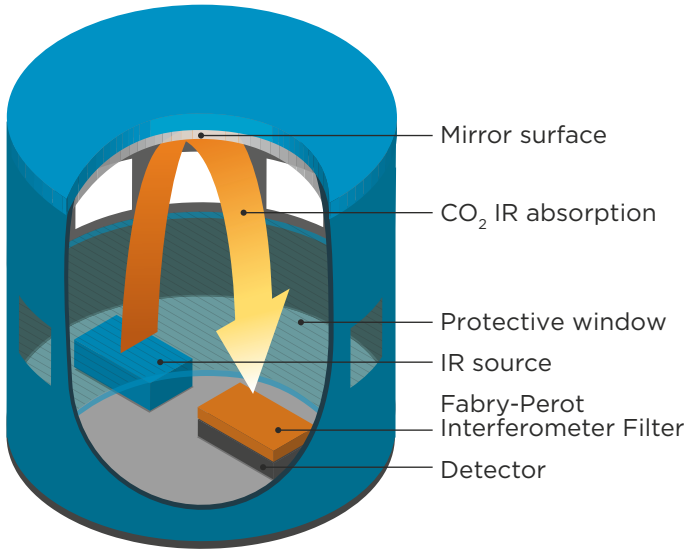
Detecting CO2

CO_2 is a non-toxic and non-flammable gas. However, exposure to elevated concentrations of CO_2 can induce a risk to life.

Unlike ammonia, without proper sensors it is impossible to detect if CO_2, which is colorless and odorless, is leaking from the refrigeration system. To ensure the safety of personnel in a CO_2 refrigerated facility, CO_2 transmitters should be installed in every human occupied space and as close to potential leakage points as possible. The number of transmitters should be based on risk assessment. Ventilation and air flow should be considered when planning transmitter installations. Carbon dioxide is twice as heavy as air so it sinks and pools close to the ground, displacing oxygen in the air. Transmitters should therefore be installed at floor level.

The Vaisala CARBOCAP® Carbon Dioxide Probes GMP251 and GMP252 are intelligent, stand-alone probes, especially designed for harsh and humid environments. The operating temperature range of the probes is specified as -40 ... +60 °C. The GMP251 has a measurement range of 0 ... 20% CO_2 while the GMP252 is intended for ppm ranges and has a measurement range of 0 ... 10 000 ppm CO_2.

The probes are easy to mount outside of refrigerated rooms. Vaisala CARBOCAP® sensors are accurate and durable with excellent long-term stability that will reduce lifetime maintenance costs. They enable reliable carbon dioxide detection for the wellbeing of people working in CO_2 refrigerated spaces or people enjoying the excitement of an ice hockey game in a CO_2 refrigerated ice stadium.



Watch our video

Watch our video to learn more about Vaisala CARBOCAP® technology.

From waste to value

Realizing a circular food and beverage economy

Even the most optimized food production process creates byproducts that we can recycle, upcycle, and reuse in farming or energy production.

Biogas from farms

Greenhouses and livestock produce waste which can be turned into biogas through the process of anaerobic digestion (AD). Compostable materials, feedstock, sub-standard produce, animal waste, and more are fermented in an oxygen-free process to create raw biogas. This is then used to fuel a combined heat and power engine (CHP) which generates electricity for the farm, as well as heat for warming greenhouses, animal shelters, and other buildings.

The solid byproducts of AD are a directly usable, all-natural, and high nutrient-content fertilizer, reducing the use of resource-heavy fertilizers.

Biogas from municipal and food processing waste

Landfills have for the most part transformed completely. No longer places to hide waste, they have become active parts of a greener economy. Compostable waste is used to produce biogas that drives large-scale boiler plants — generating both electricity and district heating. Municipal water treatment plants are also now regularly both creating biogas and upgrading it to biomethane.

Upgrading biogas to biomethane

The conversion of raw biogas to fuel-grade biomethane is making the green biogas economy truly profitable. Slated to replace fossil-based natural gas in many leading economies from 2035, biomethane is already transforming the way green energy is produced and used.

CUSTOMER CASE

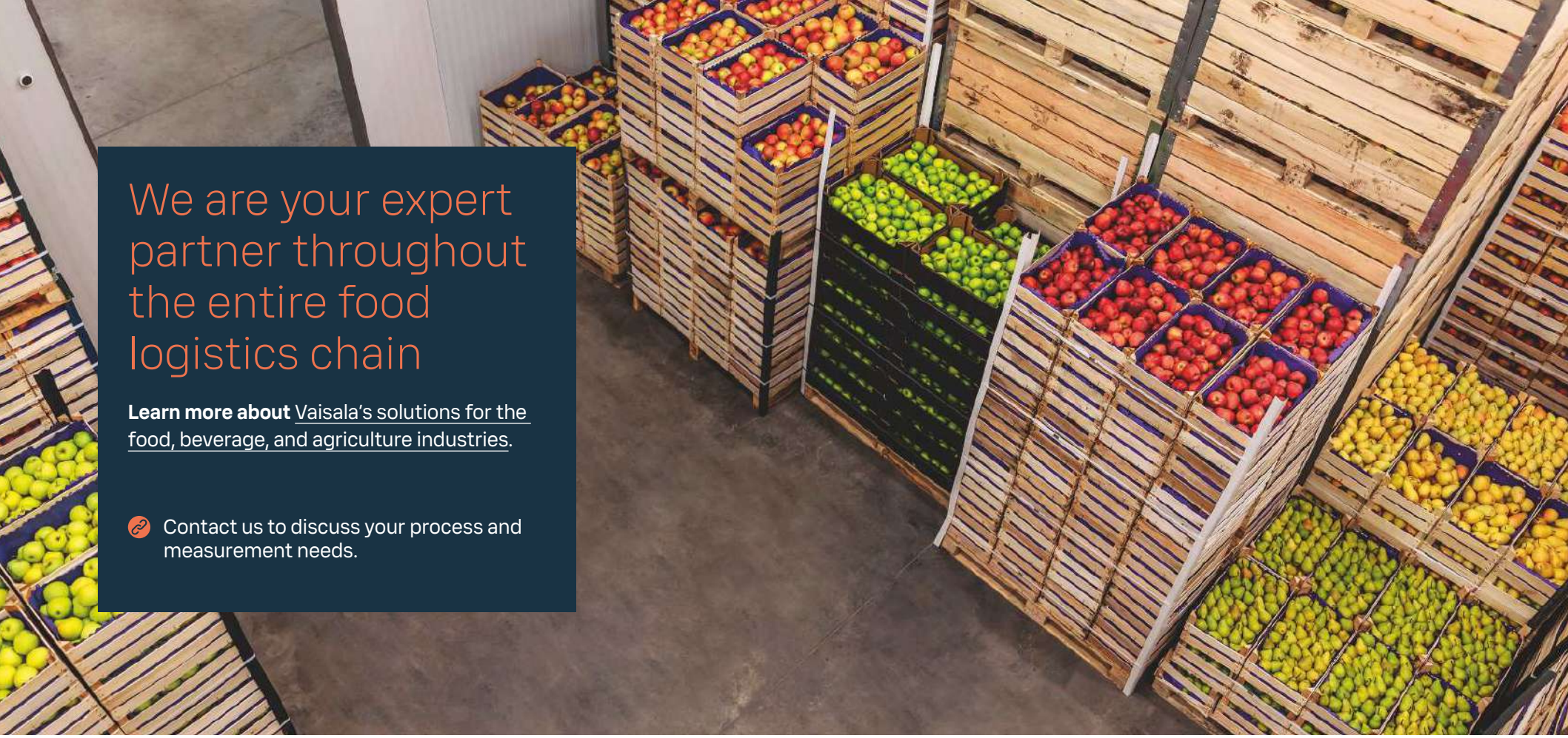
Japanese company JFE Environment Technology Co., Ltd uses the Vaisala MGP261 to monitor the quality of raw biogas and to optimize biogas production at the Miura Biomass Center.

Read more about the case here or download the full story here.

It is a direct substitute for natural gas and is used as a fuel in applications such as heating, transport, and electricity generation.

Our instruments for the smart control of biogas and biomethane quality include the Vaisala MGP261 and Vaisala MGP262 multigas probes. These products offer superior stability of measurement, low maintenance, and low cost of ownership, and are built with easy installation and operation in mind.

For more information on how Vaisala can help you create value from waste, visit the biogas section of our website.



We are your expert partner throughout the entire food logistics chain

Learn more about Vaisala's solutions for the food, beverage, and agriculture industries.

Contact us to discuss your process and measurement needs.

Vaisala is a global leader in measurement instruments and intelligence for climate action. We equip our customers with devices and data to improve resource efficiency, drive energy transition, and care for the safety and well-being of people and societies worldwide. With almost 90 years of innovation and expertise, we employ a team of over 2,300 experts committed to taking every measure for the planet. Vaisala series A shares are listed on the Nasdaq Helsinki stock exchange.

VAISALA

www.vaisala.com

Please contact us at
www.vaisala.com/contactus

Scan the code for more information