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food processing &
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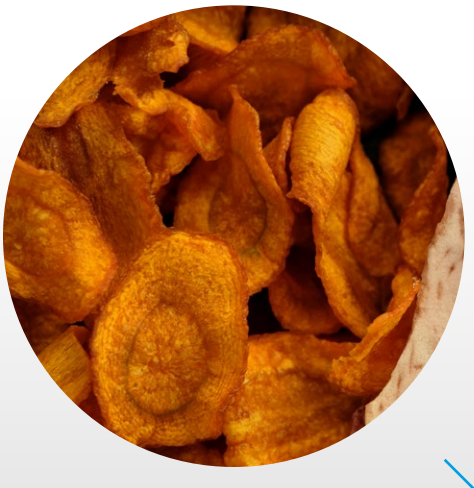
a new generation of fried foods

how innovative frying technology can help create healthier snack products with real consumer appeal



a tna white paper

About the author:

Arnaud Jansse

applications engineer, product development
tna solutions

Arnaud has more than 25 years of expertise in product development, quality assurance and research and development (R&D) for applications including beverages, dairy, fruit and vegetables, meat and functional ingredients. He is responsible for further developing **tna**'s equipment and processes to meet the needs of the company's growing customer base around the world. In addition, Arnaud also manages **tna**'s Food Technology Centre. Here, **tna** provides ongoing consultative support for customers, using in-depth application knowledge to trial R&D, run simulations on-site and advise on how to achieve optimal line performance for a range of applications including, potato chips, french fries and pellets, amongst other fried products.

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introduction

Frying is a popular cooking method worldwide with many cuisines across the world developing fried specialties for a wide range of applications. At the same time, consumer demand is gradually reshaping the way manufacturers are processing foodstuffs. With the trend toward health and wellness continuing at pace, consumers' increasingly health-conscious attitudes mean they are making more considered food choices than ever before – looking at how products are prepared or cooked before buying. This growing awareness of health and wellness has led to increased popularity for plant-based ingredients, such as quinoa, maize or corn: according to research from the Plant Based Foods Association (PBFA), US retail sales of plant-based foods were up 90 per cent in mid-March 2020 compared to the previous year. In addition, protein-based snack products, such as pork rinds, are also on the rise.

As shoppers continue to monitor labels, the type, quality and amount of oils and fats used to create their favourite fried foods are also coming under scrutiny. Palm oil, for example, has attracted growing concerns over the sustainability of its production, despite recent positive steps made in this area. Alternative ingredients such as rapeseed, cottonseed and coconut oil varieties are rising in popularity as a result, with consumers perceiving them as healthier, environmentally friendly and a more natural alternative to traditional oils. It is a trend that is not expected to slow any time soon; the global coconut oil market, for example, is expected to reach US$ 5537.9 million by 2026.

Meanwhile, consumers are becoming more discerning and refined in their preferences too. In addition to healthier products, they want food that's readily available, tastes great and is appealing with a desirable colour and texture. This is leading to new levels of innovation and new product development (NPD) across the food processing industry to address these demands and provide multiple benefits to consumers, both in terms of pre-processing solutions and frying innovations.

1 Plant Based Foods Association (PBFA), "New Data Shows Plant-Based Food Outpacing Total Food Sales During COVID-19." Press release, May 26 2020.
2 Market Reports, 'Global Coconut Oil Market Report, History and Forecast 2015-2026, Breakdown Data by Manufacturers, Key Regions, Types and Application', 2020.

1 health and fried foods

During the frying process, fats and/or oils can be absorbed by food. As a result, food processes and nutrition labels are subject to an increasing number of regulatory policies. For example, in the US and other countries, fat content on nutrition labels is broken down into fat types including healthy fats (polyunsaturated and monounsaturated) and unhealthy fats (saturated and trans-fat). The World Health Organisation (WHO) recommends reducing saturated fat intake to less than 10 per cent, and trans fats to less than 1 per cent, of total energy intake for adults, thus promoting a move away from processed foods containing high amounts of these macronutrients.[3] As a result, manufacturers are relying on alternative methods to minimise the absorption of unhealthy fats into food during processing.

Starting with a complete review of their frying process, manufacturers can identify numerous opportunities to optimise their overall frying systems. This includes an evaluation of their oil management programme, regular maintenance of frying equipment – with emphasis placed on temperature controls, heating and heat transfer surfaces – and a comprehensive sanitation programme to ensure all food contact points are free of build-up. In addition, the quality of the oil itself is intrinsic to creating a healthier end product. The selection of a quality, high-stability frying oil can help minimise or remove trans fats entirely, as well as providing additional benefits such as prolonged shelf life and superior taste.

Producers are also looking toward new ingredients as a possible solution to improving the healthfulness of their products. The snack category is particularly ripe for innovation as manufacturers formulate with alternative ingredients such as ancient grains, including quinoa, lentils and whole seeds. At the same time, the fruit and vegetable chip market is experiencing significant growth, with apple, mango and jackfruit chips becoming increasingly popular amongst consumers.

Aside from the uptake of healthier ingredients, the introduction of Commission Regulation EU 2017/2158 in 2018, means that manufacturers must meet requirements for reduced acrylamide – a chemical that has been shown to possess carcinogenic properties – in fried and baked foods. For instance, quantities in potato chips must not exceed 750 parts per million (ppm).

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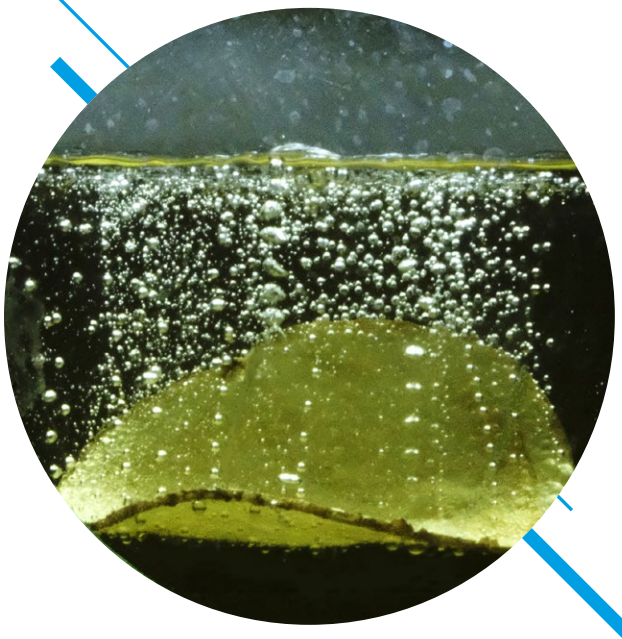

3 World Health Organisation – Healthy diet, September 2015. From: http://www.who.int/mediacentre/factsheets/fs394/en/

2 what is acrylamide?

Acrylamide is a chemical that can be formed in food via the reaction of asparagine (an amino acid), reducing sugars (particularly glucose and fructose) and reactive carbonyl compounds at temperatures higher than 120 degrees Celsius during frying, baking, roasting, toasting and grilling. The amount of acrylamide formed depends on the final cooking temperature, cooking time and amount of asparagine and reducing sugars in the product. Potatoes and other root vegetables including sweet potatoes, beets and yams, for example, naturally contain both macronutrients. This means the formation of acrylamide is more common in chips produced using these types of raw materials. Other major contributing food groups include French fries, coffee, biscuits, pastries and bread.[4]

Due to the health concerns associated with acrylamide, leading bodies such as the WHO and the Food and Agriculture Organisation (FAO) of the United Nations continue to explore the risk of dietary acrylamide exposure, stating the levels of acrylamide in foods pose a "major concern".[5] This, combined with the introduction of widespread stringent regulation means manufacturers are looking for new and innovative technologies that can simultaneously help them reduce acrylamide levels in their foodstuffs, while creating winning products that consumers will love.

3 the rise of innovative processing techniques

A number of techniques have been developed to successfully reduce the levels of acrylamide in fried products, as well as create products lower in saturated and trans fats. These include pre-processing techniques, such as blanching and pulsed electric field (PEF) technology, and innovative frying equipment, including vacuum and multi-stage, as well as oil management methods.

3.1 blanching & hot washing

Blanching is a processing technique that is often considered the most important tool for controlling reducing sugar levels in raw materials, and thus lowering the formation of acrylamide during cooking. A traditional heat processing technique, blanching has been improved and optimised over time for industrial and commercial purposes. As a result, it is a popular method for pre-processing products containing naturally high levels of sugar – to reduce sugar before frying. By placing the product in water of 80-90 degrees Celsius, the sugar is partly removed from the cells. When blanching root vegetables, such as potatoes, beetroot, sweet potato and carrot, for example, this can result in a reduction of sugar content by up to 50 per cent, depending on slice thickness. This allows manufacturers to offer consumers healthier and more appealing options.

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At the same time, manufacturers have optimised the blanching process over time to make way for new techniques, like hot washing, aiding snack producers to achieve the highest product quality for different fried food varieties. Pre-processing products which are typically cut into smaller / thinner slices, such as potato chips, at temperatures higher than 90 degrees

4 Food & Agriculture Association of the United Nations - Code of practice for the reduction of acrylamide in foods, July 2013. From: www.fao.org/input/download/standards/11258/CXP_067e.pdf
5 Food and Agriculture Organization of the United Nations. World Health Organization. Summary report of the sixty-fourth meeting of the Joint FAO/WHO Expert Committee on Food Additives (JECFA). Retrieved July 24, 2008, from: http://www.who.int/entity/ipcs/food/jecfa/summaries/summary_report_64_final.pdf

Celsius can result in pre-cooking. This can have a negative impact on the end product's textural stability, making it become soft or rubbery, and is therefore not ideal for chip manufacturers looking to create a crispy, dry texture. As such, producers increasingly use hot washing to reduce the sugar in chip slices. The slices are washed at lower temperatures (50-75 degrees Celsius) to prevent pre-cooking and in doing so, firm up the plant fibres and cell structure to create a more stable product for frying.

In addition, processing at temperatures of 90 degrees Celsius or more can also reduce the mineral and vitamin content of the end product by removing important salts, vitamin C or vitamin A in carrots. This lowers the product's perceived healthfulness, while also resulting in a bland colour and taste that's not very appealing to consumers. Hot washing at a lower temperature can help overcome these issues. For instance, hot washing leafy green vegetables leads to the expulsion of air to give a brighter green colour for enhanced appearance and freezing capabilities.

Meanwhile, as pre-processing technology continues to evolve, non-thermal technologies represent a novel area of food processing and are currently being explored on a global scale. Pulsed electric field (PEF) technology is one such example.

3.2 PEF technology

Unlike blanching and hot washing techniques, PEF technology is a relatively recent development which does not rely on heat treatment. A much gentler process, the technology works by using pulses of electricity to puncture cell membranes and allow fluid to exit. As a result, moisture is removed from the cells, including the small molecule nutrients like sugars. This enhanced sugar extraction results in reduced acrylamide formation during cooking, while also allowing the use of all potato varieties, including those with high sugar levels / late season potatoes, and other root vegetables. For example, vast acrylamide reductions have been achieved in PEF-treated vegetable chips (see figure 1).

processing benefit

As a non-thermal processing technology, the product also remains raw throughout, maintaining the product's structure for improved texture and crispiness. At the same time, PEF treatment also improves cutting by reducing the force required by up to 50 per cent, resulting in a smoother surface. This in turn means reduced mechanical damage to knives, less starch wash-out on the surface, and fewer chips sticking together during deep-frying, eliminating the need to reject them. Meanwhile, manufacturers have the opportunity to develop new cuts and shapes (e.g. thin lattice cuts), helping their products stand out on the supermarket shelves.

In addition to enhanced texture, PEF technology also aids the development of products with the visual appeal consumers expect. Colour, for example, is often determined by the amount of reducing sugars in the product. When processed at high temperatures, these sugars caramelise and burn, leading to browning. Their part removal or reduction via PEF treatment reduces the effects of

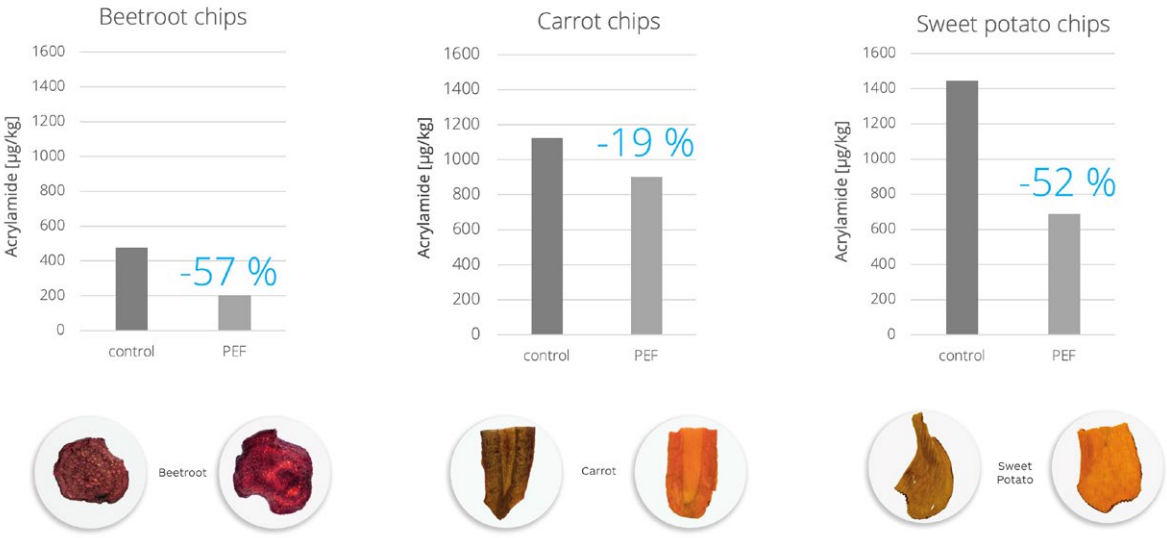

Figure 1: Acrylamide reduction in PEF-treated vegetable chip varieties.

Orange & purple sweet potato | Sweet potato & golden beetroot | Purple sweet potato & carrot

Figure 2: Vast colour retention of PEF treated vegetable chips

caramelisation, maintaining the original vibrant colour of the raw ingredients and optimising overall appearance (see figure 2).

PEF treatment also has a direct impact on oil uptake by food, including chips, thanks to improved cut smoothness. Conventional potato slices for example, usually exhibit a feathered edge made up of larger, and often broken cells that acts as an open door for oil absorption. In contrast, the perfectly smooth surface of a PEF-treated slice, with smaller, intact cells, inhibits excessive oil uptake while maintaining crispiness. Trials have shown, for example, that untreated potato chips typically exhibit 33 per cent oil content, whereas in PEF-treated varieties this can be reduced to 28 per cent[6]. This allows for the production of natural, low-fat snacks, as well as delivering a texture which consumers desire.

At the same time, PEF technology can also lead to reduced frying time. Unlike conventional potato chips, the cells in PEF-treated chip slices are opened to allow the release of moisture prior to frying. In contrast, untreated slices possess a high moisture content, meaning that a longer frying time is required to evaporate the moisture from the chip.

Trials demonstrate that the incorporation of PEF technology can translate to a possible 10 per cent reduction in frying time for potato chips (see figure 3), in conjunction with a 5 per cent increase in batch size, leading to an increased production capacity of 15 per cent.[7] This means manufacturers are better equipped to increase product throughput to meet growing demand for convenience foods.

An additional benefit of this new technology is that it is electrically powered and thus a clean and energy efficient process, using approximately only one tenth of the energy used by traditional (steam heated) pre-heaters.[8] For manufacturers this means added cost savings, as there is no additional loss of energy due to ambient heat radiation, as well as being able to demonstrate their products have "green" credentials – e.g. by using green sun or wind energy to power the PEF unit.

While advancements have been made in the development of pre-processing technologies, equipment manufacturers also continue to look for new and innovative ways to enhance their frying equipment.

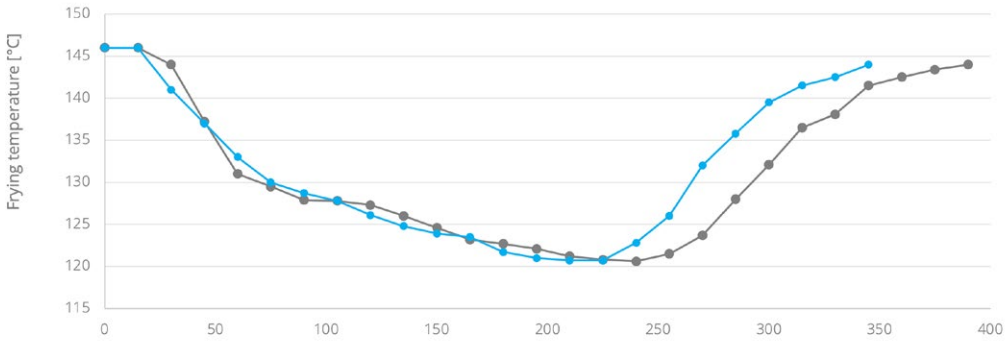

Figure 3: Frying process adaptation using PEF

6 ELEA, 2018
7 ELEA, 2018
8 ELEA, 2018

3.3 vacuum frying

Vacuum frying works by continuously cooking products under low temperature and low-pressure conditions, from start to finish. With this cutting-edge frying technology, the frying vessel is enclosed, and pressure is reduced so that the boiling point of water is reduced to below 100 degrees Celsius. This means dehydration (the purpose of frying) can be driven by a lower oil temperature. At these low temperatures, the degradation of the product's surface structure is reduced, lowering the amount of oil absorbed. Significant fat reduction can therefore be achieved with minimal impact on product quality. Meanwhile, the use of high quality, flavourful, zero trans-fat oil varieties is also possible. Oil oxidation is reduced due to lower frying temperatures and the lack of oxygen present in the system, leading to a much longer shelf life and cost savings. As a result, manufacturers can create consumer appeal by improving the perceived healthfulness of their snack products, using oil types including canola, sunflower, olive oil, coconut and corn oil.

In addition, vacuum frying systems are ideal for producing chips from fruit and vegetables that are high in natural sugars, such as parsnips, beets, carrots, apples, kiwifruit or mango, since temperature-related reactions, such as acrylamide formation and caramelisation, are slowed down significantly and in some cases do not occur. This is a particularly important development for potato and root chip manufacturers, since no matter what the reducing sugar level of the raw material, high quality end products are achievable. Potatoes containing 0.3 per cent or more of sugars for example, are often considered to be low quality. However, applying the vacuum frying technology, the same high quality end product can be achieved as using products with lower sugar content.

While vacuum frying enables producers to meet consumer trends for healthier and low-fat products, it also allows them to develop goods with positive organoleptic properties, such as authentic taste, improved texture and appealing appearance. At high frying temperatures, the sugars that are present in food will caramelise, which leads to browning, influencing the colour of the final product. At low temperatures however, the colour of the raw ingredient is much easier to maintain since caramelisation does not develop very fast in comparison to atmospheric frying. Therefore, processors have much more control over the product's final colour.

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As vacuum frying is a gentle processing technique, it also helps to deliver improved texture and crispiness in snack products. At higher temperatures, fast heat transfer occurs, whereby moisture evaporates quickly, which damages the internal cell structure. This can result in a hard texture. Reducing the pressure of a frying system therefore lowers the temperature required for evaporation to take place. Consequently, the moisture gently evaporates from the product, producing the characteristic crispy texture for which chips are known. Furthermore, because the movement of moisture is less forceful during vacuum frying, products are able to retain more of the flavour inherent in the raw ingredients.

3.4 multi-stage frying

Multi-stage frying (also referred to as two-stage frying) is a more cost-effective alternative to straightforward vacuum frying and is mainly used for potato chips. This tailor-made approach is broken down into two stages, the first of which is atmospheric pre-frying and the second, vacuum frying. During the initial stage, the product is fried at a high temperature for a short amount of time (around 30-300 seconds) to accelerate the evaporation of plus/minus 80 per cent of the moisture. The process is then completed at a low temperature for 30-120 seconds in a vacuum fryer, which reduces acrylamide formation and ensures a safer, healthier end product.

Thanks to a much gentler process of vacuum frying, the end product upholds the natural qualities of the raw material, including nutritional value and colour, without the need for additives or colourants – for superior fried products. This is because the breaking down of important vitamins and minerals and natural

colouring components is reduced. At the same time, the process gives enough control to prevent discolouring such as browning or caramelisation. As a result, snacks are produced that have a recognisable taste and enhanced visual appeal to stand out in an increasingly competitive market.

3.5 oil management

Ensuring efficient oil management, filtration and selection have become top priorities for potato chip manufacturers looking to create products that are simultaneously nutritionally appealing, as well as taste great and have a desirable color, texture. Oil quality maintenance is therefore intrinsic to creating such high quality, healthful snack products. That's because cooking oil can quickly degrade during frying due to a number of factors, such as oil type, temperature and the processing method. Not only does this reduce oil quality, but also disrupts cooking efficiency, making it harder to clean the fryer and ultimately compromising product quality. Frying with degraded oil can also trigger serious health-related side effects due to the increased levels of fatty acids, oxidised lipids and acrylamides in the product.

did you know?

In most frying operations, the fatty acid level of the oil will rise to an unacceptable level if the total volume of oil in the system cannot be turned over within a set time. Turnover occurs by the pickup of oil into the products as they pass through the fryer. Depending on their physical characteristics, most products absorb oil during the initial stages of frying, lowering optimum oil levels. Potato slices, for example, can absorb anywhere between 24 per cent and 35 per cent of oil. For this reason, a fresh oil infeed is necessary for oil levels to return levels to 100 per cent and ensure the product is cooking in the freshest oil possible for optimum quality.

Oil turnover is directly impacted by the quality of cooking oil used, since some oils are less resistant to heat than others. Sunflower oil, for example, is much less stable at the heating stage than coconut oil. An oil that is more resistant to heat will have a higher oil turnover than one that is less stable. Selecting the right type of oil has therefore become a key consideration for potato chip manufacturers looking to maintain oil integrity for longer.

At the same time, the accumulation of debris can also accelerate cooking oil degradation. This occurs when small pieces of the sliced potato break away and burn and carbonize within the fryer kettle. Consequently, oil quality decreases and can result in off-flavours and an uneven colour and appearance.

processing benefit

Well-designed frying systems should also address a variety of needs, such as maintaining oil integrity. The most innovative frying technology incorporates continuous oil filtration systems to help remove particulate material, left behind from sliced products, during cooking. Typically, the oil is passed through a filtering system to remove both large and fine particles. If left in the oil, these particles continuously produce polymers and other polar compounds that create an off-taste in the product, and degrade the frying oil, impacting organoleptic properties, including crunchiness. The sooner and more effectively the particles are removed, the better the oil quality.

The filtered oil is then blended with fresh oil and pumped back into the machine to return oil levels to the optimum amount. The repeated refreshing of oil helps mitigate the generation of free fatty acids, as well as other polar compounds and ensure the chips are cooked in the freshest oil for the highest possible quality.

summary

While frying remains a popular cooking method around the world, consumers continue to seek healthier products that are readily available, but still exhibit a desirable taste, texture and appearance. As such, snack food manufacturers in particular, are seeking new ways to differentiate their product offering by improving the healthfulness of their products. Whether it's via the incorporation of new ingredients or advanced pre-processing, frying and oil management techniques, there is a multitude of options available for creating healthier convenience foods. As such, it is important to work with a supplier that has the technological expertise and know-how to find the right solutions to fit individual production requirements. Partnering a leading processing solutions supplier, such as **tna**, gives food manufacturers the ability to do just that and ultimately stand out from the competition in this dynamic and constantly evolving market.

With over 60 years of experience in the food processing industry, Florigo, a **tna** company is widely known for its ability to boost capacity, improve quality and increase efficiency with its wide range of innovative food processing technology. The company specialises in the design, manufacture and servicing of high-performance processing equipment for the snacks industry, including washing, de-stoning, peeling, slicing, blanching, drying, frying, cooling and freezing equipment. Florigo's cutting-edge patented vacuum frying and de-fatting technology helps food manufacturers around the world to develop healthier snacks with unique consumer appeal.

About **tna**

tna is a leading global supplier of integrated food processing and packaging solutions with over 35 years of industry experience and 14,000 systems installed across more than 120 countries. The company provides a comprehensive range of products including materials handling, processing, cooling and freezing, coating, distribution, seasoning, weighing, packaging, inserting and labelling, metal detection, verification and end of line solutions. **tna** also offers a variety of production line controls integration & SCADA reporting options, project management and training. **tna**'s unique combination of innovative technologies, extensive project management experience and 24/7 global support ensures customers achieve faster, more reliable and flexible food products at the lowest cost of ownership. **tna**'s inclusive growth agenda underscores its business ethos, to support those less fortunate; especially children, through the humanitarian initiatives undertaken by the Nadia and Alf Taylor Foundation.

tna solutions Pty Ltd., 24 Carter Street, Sydney Olympic Park NSW, 2127, Australia
Email: info@**tna**solutions.com Facebook Twitter LinkedIn YouTube