Veggie snacks: health, flavour and new trends

Daniel Sanz, Francesc Castells, Xavier Casemajor, Llorenç Freixanet, Josep Lagares

INTRODUCTION

The snacks market has now reached a level of maturity, particularly when it comes to vegetable snacks. All the same, annual consumption continues to grow, partly due to arrival of dehydrated versions that offer an alternative to the fried snacks that still account for the highest percentage of this type of product on shelves.

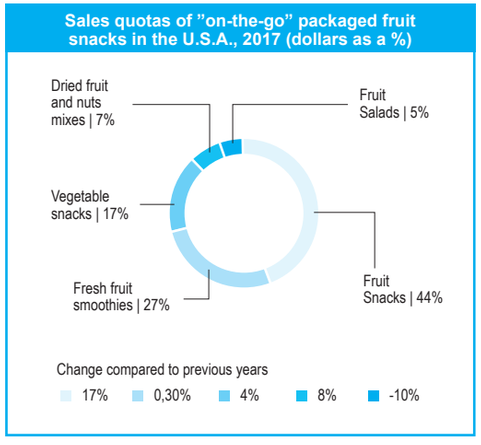
The market includes vegetable chips that are sliced and then oven baked or fried (from mixed chips made from sweet potato, beetroot, carrot, and parsnip, to the traditional and ubiquitous fried potato chips).

▲ **Figure 1.** Current vegetable chip types: Carrot, parsnip, and beetroot crisps (top), lentil and soy chips (bottom).

Some recently launched alternatives include expanded lentil or chickpea snacks, prepared using flour from the pulses as the main ingredient, along with other flours and starches (see Figure 1). Compared to traditional fried potato crisps, these products have a high protein and fibre content and a lower fat content. Greater awareness among consumers about leading a healthy diet and consuming less sugar and fat, along with a sales format that better suits their needs, has derived in the gradual growth of sales in this new product category and they are even stocked by major retailers.

Fresh fruit smoothies "On-the-go" packaged fruit snack sales represent 2.4% of fresh fruit sales in volume in the United States of America. Packaged vegetable snack sales represent 0.9% of the total fresh vegetable sales volume. Therefore, as shown in Figure 2, fresh fruit, fresh vegetable, and dried fruit snacks showed the biggest increase in sales between May 2016 and May 2017.

A market research survey undertaken by the British analysts, *Technavio*, forecasts that the worldwide market for vegetable chips would grow by around 10% during the 2017-2021 period. Vegetable snacks, therefore, definitely represent an outstanding opportunity.



▲ **Figure 2.** Snacks sales growth by type in 2017 in the U.S.A. (Source: Nielsen Perishables Group FreshFacts® 52 Weeks Ending May 27, 2017). The Nielsen Company.

Types of vegetable snacks: dehydrated fruit and vegetables

Most of today's vegetable snacks actually derive from one of the oldest forms of preserving foodstuffs. This involves dehydrating harvest surpluses, whether sun drying different fruits (grapes, plums, or apricots to obtain raisins, prunes, etc.), or combining sun drying with prior toasting to dry nuts (almonds, walnuts, hazelnuts...).

Sun-based drying processes lead to poorer quality products and increased contamination, as V. R. Sagar and P. Suresh Kumar described in their article, *Recent advances in drying and dehydration of fruits and vegetables*: a review (Journal of Food Science & Technology. 2010 Jan; 47(1): 15–26.). The article also examines the published literature on current dehydration technologies for fruits and vegetables, and how a process is effective if it reduces drying time while causing minimal product damage.

The aforementioned products are very well known and consumed worldwide, but more dehydrated products have recently become available with such a low residual moisture level that they end up with a crunchy texture. They form part of a natural progression towards a snack type product that aims for a louder and crispier texture, providing a similar sensation to a fried potato chip, but with a nutritional content containing less fat and more fibre. They are generally prepared using acidic fruits (apple, strawberry, pineapple...), with the toughest parts removed first (seeds, rind, stalks), before slicing and subsequent drying.

Traditional technologies

Although a wide range of dehydration ovens are currently available for this type of application, mainly based on heat pump systems, achieving truly crispy textures requires long drying times. This prolonged exposure to drying air inevitably leads to a certain amount of enzyme-derived browning, with the product darkening because of the effect of the enzyme, polyphenol oxidase, which

▲ **Figure 3.** Current types of dehydrated fruits and vegetables.

occurs naturally in this type of fruits. Chopped fruits are normally soaked in antioxidant solutions prior to the drying process to minimise this defect.

Other applications, such as freeze-drying, enable dehydration with better colour retention and really crunchy textures, but the energy cost and system's productivity means that its application is basically restricted to topping type products that are added to other products (mainly dairy products, mass produced pastries, and biscuits).

QDSnacks® technology and its application for vegetable products

QDSnacks® is a patented technology that was initially developed for quick drying meat snacks, using only air under precisely controlled conditions, with the product's texture and flavour conserved by keeping temperatures low during the process (QDSnacks®, the future of meat snacks here and now).

This technology, however, also offers the option of developing vegetable snacks, and even a combination of plant and meat raw materials to create a product high in biological protein content combined with the nutritional benefits of the fruit or vegetable (a source of fibre, reduced fat, slow absorbing sugars...).

The QDSnacks® system operates using automatic product loading onto a continuous conveyor belt that moves the product through the different drying

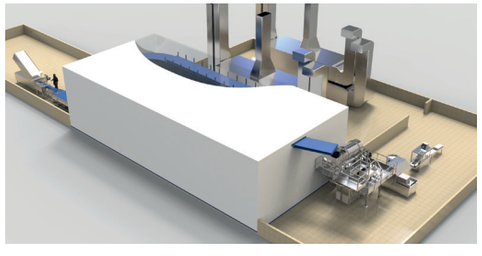
▲ Figure 4. Dehydrated fruit snacks produced using QDSnacks technology. Apple chips (top). Banana chips and pear nachos (bottom).

areas in the form of a spiral, where the environmental conditions can be varied and sequential in order to adjust the process to each product's requirements.

Being able to use different temperature and humidity conditions for the drying air during the process itself, along with the potential adaptability for each stage, gives rise to an essential production and development tool for creating new product lines and concepts. The aim is always to ensure that the snacks produced remain stable at room temperature and have a flavour, aroma, and texture that meet the needs of each consumer.

New dehydrated fruit and vegetable chip concepts using QDSnacks®

The experience gained through producing meat-based crispy chips using *QDSnacks*® technology has been



▲ Figure 5. QDSnacks® Industrial.

put to use to produce restructured meat blocks (like salami), containing a mix of different sourced meats processed with suitable ingredients. These can be sliced very thinly before dehydration in order to produce thin crunchy slices that are similar in both appearance and flavour to traditional meat products (salami, chorizo, or cured ham, for example).

This production concept can be transferred to manufacturing crunchy fruit and vegetable snacks, using different plant-based ingredients to create restructured logs that can be sliced into thin slices using industrial slicing machines, for subsequent dehydration until they reach maximum crispiness. The initial ingredients for preparing vegetable chips may be starch-based, such as different cereal flours (Figure 8), or hydrocolloids and purées if producing fruit chips (Figure 4).

The raw material used to obtain the paste can be sourced from fresh and frozen fruits and vegetables, as well as purées and concentrates. Gelling agents are

▲ Figure 6. Vegetable crisp preparation using QDSnacks® technology

also required, derived from rice, corn, or potato flours for example, or hydrocolloids such as Xanthan gum, locust bean gum, or agar-agar can also be used.

The entire process from receiving the raw material to product output takes under 6 hours. Figure 6 is a process flow diagram showing the different steps involved when manufacturing this new plant-based crispy chips concept.

As opposed to restructured meat logs that gain their consistency through meat protein coagulation (whether via acidification to the isoelectric point of the proteins or denaturation using heat), the logs for producing vegetable crisps need to reach a certain temperature to achieve the solubilization that will create the right consistency to enable processing once the product has cooled.

The cooking time and temperature need adjusting based on the restructured log diameter so that the centre of the product reaches the correct temperature. Once that temperature has been reached, they need to be cooled quickly so that they gel and obtain the firmness required for slicing. This is called the solubilization temperature, at which the paste's gelling agent molecules restructure, enabling the structure to retain the water from the mix to form gels and remain stable once the gelling temperature is reached (20-50ºC).

Table 1 shows the solubilization temperatures for different gelling agents. As can be observed, each

Gelling agent	Solubilization temperature
Potato starch	60ºC
Wheat starch	64ºC
Rice starch	85ºC
Corn starch	90ºC
Agar-agar	100ºC

▲ Table 1. Solubilization temperatures for different gelling agents.

starch requires a different temperature. These differences depend on the composition, size, and form of the starch granules, which vary for each type of flour. Large granule starches need a lower temperature in order to gel as they absorb more water. Smaller grain flours, however, such as rice flour, need to reach a higher temperature (Y. Chen *et al*, Effects of starch chemical structures on gelatinization and pasting properties). Agar-agar, on the other hand, is obtained from seaweed and needs to reach the boiling point of water to solubilize.

The QDSnacks® technological process

The first step involves reducing the vegetable particles (using a cutter o colloidal mills) once the other ingredients have mixed in. Then, the resulting paste is stuffed through a vacuum filling machine to fill plastic casing of the required diameter. Once sealed using a clipper, the logs are cooked by immersion into kettles containing hot water at a controlled temperature or hung on sticks with trolleys in steam ovens. The filling process must be done with vacuum to ensure that the logs do not break the plastic due to the paste expansion during cooking.

The next step involves quickly cooling the log pieces to enable them to gel, and once cooled to a sufficiently low temperature whereby an industrial knife can penetrate without breaking the structure, the pieces are thinly cut using an industrial slicer (Figure 7) and a retractable automatic unloading system distributes the slices onto the QDSnacks® drying belt. This is when the QDSnacks® drying parameters are adjusted. These are the relative humidity, temperature, airflow, and drying time.

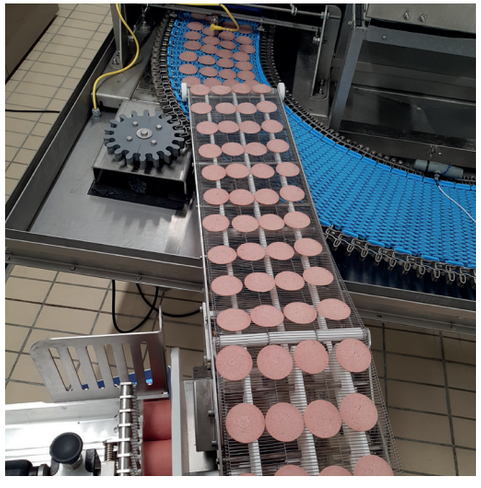
The thickness of the slices determines the texture of the chips. Drying slices less than 1 millimetre thick produces crispy chips in up to 30 minutes. Thicker slices require more time and take up to 60 minutes. The product will dehydrate during this processing time until the final humidity content is equal to or less than 5%, with reductions of 50 to 80% compared to the initial weight of the slices prior to drying.

After drying, the surface of the chips can be coated with spices, aromas, herbs, or natural extracts using a continuous seasoning system, as such that a common base can be used to create all types of variants, making it easy and cheap to expand the range of each product line. The chips can be previously sprayed with oils to make it easier for these final ingredients to adhere.

Lastly, product is packaged in bags made of metallised film containing a nitrogen-modified atmosphere to provide greater mechanical resistance and ensure a longer shelf life for the product at room temperature.

Nutritional aspects of vegetable snacks developed using QDSnacks® technology

Vegetables have a high water content, which is why the QDSnacks technology was developed to obtain water content reductions of up to 90% and water activities of less than 0.4. The water activity value (Aw) is a vital threshold when conserving any food, given that it is a fraction of the available total free humidity that can favour microbial growth and physiochemical instability in foods. Values under 0.85 indicate pathogenic



▲ **Figure 7.** Slicing vegetable product logs on the QDSnacks® drying belt in the Metalquimia pilot plant.

▲ **Figure 8.** Vegan chips produced using QDSnacks® technology: Broccoli chips (left) and Vegetable chips (right). Different diameters.

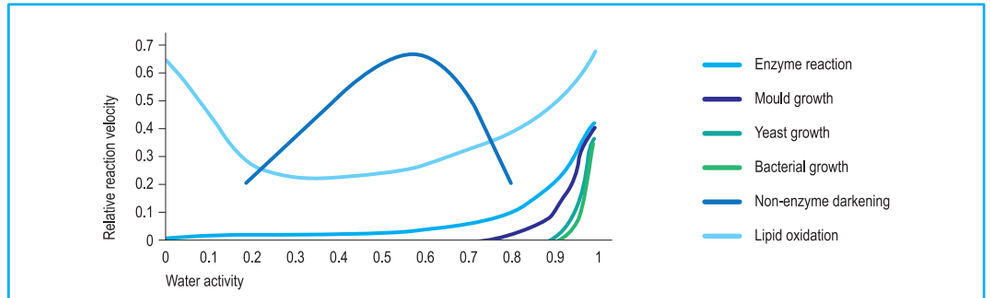
bacteria growth inhibition and guarantee the product's texture, although truly crunchy textures are only achieved with values under 0.4.

Figure 10 shows the different reactions that occur in foods as a function of their water activity. As can be observed, the factors requiring control in this type of product are essentially lipid oxidation and enzyme reactions. The former can cause the product to go rancid. The latter is caused by enzymes in fruit and vegetables, which are responsible for forming unpleasant aromas and compounds that change the colour.

Non-enzyme derived darkening caused by the Maillard reaction tends to occur only at very high operating temperatures (over 160°C) in products containing carbohydrates and proteins.

All these parameters ensure the stability, safety, quality, and shelf-life of the product. Table 2 compares

▲ **Figure 9.** The SFSC compact seasoning application system (Image courtesy of TAV, SL).



▲ **Figure 10.** Physical, biological, and chemical changes in snacks as a function of water activity.

the water activities for different snack types. Vegetable and fruit chips are between 0.2 and 0.4, similar values to traditional fried potato chips.

Nutrient concentrations are different after drying as the initial water content varies according to the type of fruit or vegetable (table 3). Dehydration leads to higher proportions of fibre, protein, minerals or vitamins, an interesting aspect when it comes to positioning the product on shelves.

No added sugars is also appealing to consumers given that despite the high level of sugars naturally present in dehydrated fruit and vegetable snacks, these are generally low glycaemic index products. The fibre present in vegetables and fruit delays the absorption of sugars into the digestive system, slowing down the rate of increase of blood glucose level. The amount of sugars present in packaged dehydrated fruit weighing 60 grams, for example, represent around 40% of the recommended daily amount for this nutrient. This represents high calorie content, so these are energy products from a nutritional standpoint.

Future possibilities for new plant-based product formats developed in the QDSnacks®

Although vegetable products are a healthy alternative to fried snacks given their lower fat content, combining them with high protein content ingredients enables their composition to be balanced, with snack products developed that are not only easy to consume, but also provide very significant amounts of protein and fibre.

Using the same base process presented in the previous section, plant protein isolates (soy, pea, rice) can be added to both increase the final protein content and give the product a more fibrous texture in the mouth so that it somewhat simulates the spongy texture of meat during chewing. Extruded soy pellets are an ideal ingredient for this application, whereby with the right particle size in the initial paste, they

Food group	Water activity
Potato chips	0.2 - 0.3
Fruit chips	0.2 - 0.3
Fried vegetable chips	0.3 - 0.4
Crackers	0.3 - 0.4
Pulse and starch chips	0.3 - 0.4
Ham chips	0.4 - 0.5
Energy bars	0.5 - 0.6
Jerky	0.7 - 0.85
Meat sticks	0.7 - 0.85
Sliced salami	0.87 - 0.91
Cured ham	0.91 - 0.95
Fresh vegetables and meat	0.95 - 1.0

▲ **Table 2.** Average Aw values for different foods Source: Water Activity Values of Select Food Ingredients and Products.

Product and presentation	Energy (Kcal)	Carbs. (gr.)	Sugars (gr.)	Proteins (gr.)	Fats (gr.)	Fibre (gr.)
Banana	89.0	22.8	12.2	1.1	0.3	2.6
Dehydrated banana	346	88.3	47.3	3.9	1.8	9.9
Fresh peach	59.0	13.5	8.4	0.8	0.2	1.5
Dehydrated peach	371	88.5	24.0	5.7	0.1	8.6
Fresh apple	52.0	13.8	10.4	0.3	0.1	2.4
Dehydrated apple	353.6	94.8	81.2	1.0	1.6	11.8
Fresh pear	57	15.2	9.8	0.1	0.2	3.1
Dehydrated pear	333	83.3	50.0	0.3	0.6	16.7

▲ **Table 3.** Nutritional composition of different fresh fruits and their dehydrated snacks. Values expressed based on 100 grams of the end product (Source: **USDA Food Composition Databases**)

can emulate the behaviour of meat fibre in the mouth when chewing the dehydrated chip.

In line with this application, combining plant based products with meat based raw material creates a synergic effect when developing more healthy and palatable snacks. In both cases, the ingredients by themselves lack significant content of one of the nutritional groups recommended for daily consumption as part of a balanced diet.

The lack of dietary fibre and the presence of fat and cholesterol in meat is compensated by including fruits and vegetables in the product composition. Equally, the surplus of sugars and practically zero protein content improves by adding meats and derivatives into the formula. Balancing the composition this way also enables the use of meat cuts and mechanically separated meats that are generally destined for lower added value products, which then increase in value given their protein and iron content.

Continuing with this concept of a balanced product that is rich in the main nutrients of a balanced diet, QDSnacks® technology can be used to develop vegetable and fruit vegan bars, or they can be combined with different types of meat. Producing a healthy snack and a nutritional dietary supplement that can be consumed between meals without providing empty calories through the surplus of fats and sugars in their composition.

▲ **Figure 11.** Beef and rice crisps produced using QDSnacks® technology.

Using legume protein isolates, such as soy or chickpea, vegetables, and other binding ingredients, it is possible to form bars of a specific thickness that can be dehydrated using the QDSnacks®. Fibre, natural gelling agents, and fruit purées can be moulded, cut, and quickly dried using the QDSnacks® to develop energy-type bars that maintain the flavour and texture of the original ingredients, as it involves mild dehydration at low temperatures.

It is also possible to use an extruding head with the QDSnacks® system to distribute the prepared paste with the required thickness onto the QDSnacks® drying belt. They are then cut to the adjusted size as required. Having adjusted the temperature, relative humidity, airflow, and drying time conditions, they are dried until the correct texture is achieved with a sufficiently low humidity content to ensure they remain stable at room temperature, which when combined with modified-atmosphere or vacuum packaging, produces the necessary shelf life.

CONCLUSIONS

Market research surveys indicate that healthy snacks are here to stay and QDSnacks® technology represents a great opportunity for both the meat and snack industries, and knowing how to understand and anticipate changing customer needs is essential, both for traditional meat companies and snack producers. Diversification is undoubtedly the way forward to continue growth within a very competitive market.

▲ **Figure 12.** Aubergine and soy vegan bars produced using QDSnacks® technology.

Preserving the nutrients, the flavour, and the colour of the snacks, without needing to add aromas and colourants is the main challenge for manufacturers, meaning labels do not have to contain as many unfamiliar references for the consumer. Snack manufacturers also have to decide which processing methodology and machinery best preserver the raw material's original sensorial and nutritional qualities. Processes such as frying in oil, toasting, or high temperature extrusion, can be replaced by the convective drying of QDSnacks®, which keeps the product's original flavour and texture better, and can be used to develop other vegetable snack categories and combinations with meat ingredients.

BIBLIOGRAPHY

• THE NIELSEN COMPANY. August 2017. On-The-Go Produce Snacking: A Billion Dollar Industry and Growing. Available at: https://www.nielsen.com/us/en/insights/news/2017/on-the-go-produce-snacking-a-billion-dollar-industry-and-growing.html

▲ **Figure 13.** Metalquimia QDSnacks® low pressure extruder (Girona, Spain).

• TECHNAVIO. January 2018. Top 3 Drivers of the Global Vegetable Chips Market. Available at: https://www.businesswire.com/news/home/20180105005643/en/Top-3-Drivers-Global-Vegetable-Chips-Market

• U.S. FOOD AND DRUG ADMINISTRATION. January 2015. Water activity in foods. Available at: http://www.fda.gov/ICECI/Inspections/Inspectionguides/Inspectiontechnicalguides/ucm072916.htm

• J. Bemiller and R. Whistler. 2009. Starch Chemistry and Technology. Elsevier. Food Science and Technology International Series.

• Shelly J. Schmidt and Anthony J. Fontana, Jr. Water Activity in Foods: Fundamentals and Applications. Appendix E: Water Activity Values of Select Food Ingredients and Products. 2007, Blackwell Publishing and the Institute of Food Technologists.

• V. R. Sagar and P. Suresh Kumar. Recent advances in drying and dehydration of fruits and vegetables: a review. Journal of Food Science and Technology. 2010 Jan; 47(1): 15–26.

• D. Sanz, *et al*. 2016. QDSnacks®, the future of meat snacks here and now. Metalquimia: Technological articles. p 245.

• D. Sanz, *et al*. 2016. QDS Process® technology as an exponential R&D driver for cured meats. Metalquimia: Technological articles. p 259.

• Fiona S. Atkinson, Kaye Foster-Powell, and Jennie C. Brand-Miller. 2008. International tables of glycemic index and glycemic load values: 2008. Diabetes Care, Vol. 31, number 12, pages 2281-2283.

ACKNOWLEDGEMENTS

We would like to thank every member of Metalquimia's Engineering and Programming Department for their dedication and input to the project, as well as every member of Metalquimia's Technological Department for their invaluable collaboration in developing each product category.