

## MULTIVAC White Paper on HPP

# **Shelf life improvement for fruit and vegetables with suitable packaging technology: High pressure processing**

### **The situation**

The food industry today faces essentially four great challenges:

1. Reducing food waste
2. Raising the level of food safety and consumer protection
3. Handling resources sparingly
4. Developing and using needs-based packaging solutions, which meet current and future trends.

This is because around 1.3 billion tons of food are wasted or lost every year. In terms of fresh fruit and vegetables, the wastage is as high as between 40 and 55 percent of cultivation. Viewed over the whole added value chain, there is food waste from the point of harvesting and production, right through to the processing and storage of food, as well as during transport, and this also occurs in the retail chain and at the consumer.

There are various causes. They depend to some extent on the state of development of the particular country and on people's food habits. In developing countries, food wastage occurs primarily during manufacture, in other words at the start of the added value chain. The reasons for this are unfavourable framework conditions during harvesting or further processing, as well as the sub-optimal infrastructure, inadequate storage and chilling capacity, and unsuitable packaging and marketing concepts. People lack suitable machines, technology and materials to be able to give shelf life to the food and to make it safe. The food therefore spoils before it reaches the consumer.

In developed and emerging countries on the other hand, food waste occurs primarily in households and the retail chain. Food is thrown away, even though it can still be enjoyed - usually when the use-by date has been reached, or because it no longer meets the standards or has become unattractive in appearance, or because it can no longer be sold at a profit.

The damage to the environment, the food industry, the retail trade and consumers is enormous. From the economic perspective, the costs arising from the destruction and disposal of spoilt food run to billions throughout the world. Around 70 million tons of food land in the rubbish bin in the European Union alone. In addition to this, there is the waste of water and use of CO<sub>2</sub> equivalents, which are employed in cultivating the food as well as processing and subsequently destroying it.

The trends, which influence consumer behaviour, also have an effect on the utilisation rates of fruit and vegetables. Society and family structures are changing. There are an increasing number of singles in all age groups - and already around half the inhabitants of large cities now live in single-person households. Many families need two incomes to be able to pay for their living costs. In addition to this, we are living and staying fit longer, but we also have to battle against the symptoms of many diseases and are increasingly changing our eating habits to suit the circumstances of modern life. The overall trend towards needs-based food products is therefore continuing - and the focus is on food that is suitable for children and seniors, as well as functional, natural food of the highest quality, together with convenience products and ready meals, which can be prepared quickly without great effort or consumed on the way to work, during the lunch break or while playing sport.

The food industry has to face all these challenges. This means that measures for better utilisation of fresh or delicate food have the absolute top priority. An important factor in this is the packaging procedure. This is because packaging contributes to extending the shelf life of packed products and increasing food safety. It is however a matter of using the technology, which is suitable for the particular food, but which is also economically viable for the particular producer, meets his needs and is within his control.

### **Specific properties of fruit and vegetables**

In the case of vegetables and salads, and in particular with ready-to-eat or cook assortments, which are the focus of current trends, the risk of microbial spoilage is very high. This is because the protective layer, such as the skin for example, is missing from the product's interface with the ambient atmosphere.

In the case of fruit, the distinction between climacteric and non-climacteric fruits is a significant aspect, since the type of fruit has considerable effects on its shelf life, processing possibilities and storage. Due to the two- or three-fold increase in respiration, in other words oxygen absorption and carbon dioxide release, the climacteric condition also has an effect on biochemical changes such as for example the degradation of cell wall pectins and the hydrolysis of starches. Metabolism therefore continues to work after harvesting, and the ageing process of the fruit begins. The consequences are ripening, fermentation, discoloration and then finally spoilage due to decay of the cellular structure, as well as the growth of mould and other undesirable microorganisms.

The ripening gas, ethylene, is one of the materials, which can accelerate the ripening process - and it presents a particular challenge not only in the processing and packaging procedures but also for the consumer at home. It is absorbed as the gaseous phytohormone, ethene, and it stimulates the ripening of fruit by converting stored enzymes into sugar and energy. This means that the fruit becomes sweet but also soft. Ethylene is gaseous and has a stimulating effect on other food in the vicinity.

As a basic principle, whole and undamaged products can generally be kept longer than cut product. Depending on the product variety and degree of ripening as well as the processing, packaging material and packaging technology, there can very quickly arise the onset of discoloration, mould and liquid accumulation, even before the best-before date has expired.

### **Processes primarily used for extending the shelf life**

MAP and EMAP packs have primarily been used up to now for extending the shelf life of fruit and vegetables. In the case of MAP packs (Modified Atmosphere Packaging), the natural atmosphere in the sealed pack is replaced by a modified atmosphere or gas mixture appropriate for the particular product. It usually consists of carbon dioxide, nitrogen or oxygen. Its precise composition is based on the product variety, the storage temperature and the nature of the product, as well as its degree of ripening, state of reduction and many other factors. In the case of EMAP packs (Equilibrium Modified Atmosphere Packaging), a modified atmosphere is created through targeted micro-perforation of the packaging film, which permits an exchange between the pack and the ambient environment. This means that CO<sub>2</sub> gets out and O<sub>2</sub> gets in. An equilibrium atmosphere prevails in the pack and this also prevents the pack from swelling for example. The density of the perforation is matched to the respiration activity of the product. Thanks to the interaction of respiration and film permeability, the inside of the pack creates an atmosphere that promotes the food's shelf life.

## **The high pressure processing (HPP) of food**

### **Uses, areas of application**

High pressure processing is one of the most promising procedures for extending the shelf life of delicate food products, and it also makes a future-proofed contribution to increasing food safety worldwide. The main areas of application are ready meals, meat and sausage products, as well as fruit and vegetables. High pressure treatment is also however applied to seafood and fish, as well as juices and other drinks.

This process, which is very gentle on the product, deactivates or even eliminates undesirable microorganisms in the food, such as salmonella, listeria, mould fungus and harmless bacteria like lactic acid bacteria, which occur naturally to some extent in products, but which can have a negative effect on taste and visual appearance. Unlike heat treatment, the vitamins and other sensitive substances in the food are largely retained. Also the taste does not change, or barely at any rate, since the small molecules, which for example form the aroma of food, withstand the high pressure.

Consumers benefit from this process, since fresh and processed food or very popular high-quality ready-meals can be stored without additives or heat treatment and then consumed over an extended period of time.

## **History**

As far back as the end of the 19th century, Bert H. Hite was investigating alternative processes for extending food shelf life at the Agricultural Research Station of West Virginia. In 1897 he succeeded in finally obtaining proof of the effect of hydrostatic pressure in extending the shelf life of milk, fruit juice and meat without any visible impairment of the product. This approach was not however seized upon by the food industry at the time. But in the 1980's however, the high pressure process was finally rediscovered as a gentle method of preserving food and extending its shelf life. In 1991 the first high pressure treated fruit juices and jams were launched on the market in Japan, and these appeared for the first time in 1996 in Europe and the USA. Since 2010 the process has experienced an enormous boost in many developed countries. The reasons lie in the changed habits of consumers: "bio" is considered to be "in", and consumers are increasingly appreciating natural food, while at the same time not wanting to see any reduction in quality, appearance and shelf life. Due to changing social, household and family structures, the trend is also moving towards fruit preparations, purees and smoothies, as well as ready-meals and prepared fruit, salad and vegetable assortments, which have to be largely free of additives and preservatives.

## **High pressure processing in concrete terms**

As a matter of principle, only packaged food in solid, liquid or paste-like form are high pressure treated. This requires special properties for the packaging material. Generally trays, composite films or PET bottles (in the case of liquid products such as juices and smoothies) are used. In order to achieve the optimum result for each product, the process within the HPP system must be matched to the optimum degree to the product, packaging material and pack shape, and the process has to be precisely controlled. The pack design in particular is of great significance in order to prevent mechanical damage and deformation of the packs during the process of high pressure treatment. The pressure level used, the pressure holding time and the type or recipe of the food product, as well as the particular type and quantity of bacteria and microorganisms, have an influence on the success of high pressure processing.

HPP systems usually consist of a pressure chamber, a loading system with so-called loading crates, high-pressure pumps, a water circuit and a control system. Loading is frequently by hand. In automated packaging lines on the other hand, the packaged products are placed in the corresponding loading crate by means of a handling module. The loading crate is cylindrical in design and can therefore withstand high pressure, because the pressure is distributed evenly over the surface.

The packs are then subjected to a very even pressure of up to 6,000 bar (87,000 psi) for a defined holding time, which is generally several minutes, in a liquid-filled container with a piston or lid that can be tightly sealed. The pressure is exerted from all sides during compression. There are no shearing forces, so that most products hardly show any changes afterwards. Colour, freshness, aroma and taste are retained, while undesirable microorganisms such as bacteria, harmful yeast and mould fungus are reduced or eliminated. In the case of meat products for example, the pressure and starting temperature selected for the product being treated must be kept sufficiently low, so that the natural red meat colour is retained.

So that the stress on the food product and packaging material is kept as low as possible, so-called hold times are built in, during which the materials can be regenerated. This also enables reliable high pressure processing of MAP packs to be achieved. After processing is completed, the pressure is released through depressurisation valves. The loading crates are then moved out of the pressure autoclave, dried and if necessary marked or labelled.

### **Synergy effects from a combination of MAP and HPP**

The growth of microorganisms can in fact be further delayed with a combination of MAP and HPP, which means that the storage stability and shelf life of the food products are further improved. Consumers benefit from significantly improved food safety and shelf life. The combination of both processes also provides significant benefits for the food industry and retailers, since the products can be presented more attractively at the point of sale and a greater degree of convenience can be achieved.

While vacuum packs can generally be subjected to high pressure processing without any great problems, modified atmosphere packs present particular challenges as regards their pack design and processing. This is because the risk of deformation, reduced barrier properties or delamination is very high with multi-layer packaging materials, when the packs are subjected to high pressure. Thanks to a patented process, MULTIVAC is able to ensure that modified atmosphere packs can withstand the high pressure process without damage.

When analysing the effects of high pressure processing on the polymers, their barrier properties and the polymer structures of film materials, the HPP experts at Wolfertschwenden established that films under certain conditions and with very even pressure from all sides were not damaged at all or only very slightly. As regards the barrier properties of the packaging materials subjected to high pressure, it was evident that the permeation coefficient of the individual polymers was temporarily lowered during high pressure processing - the barrier effect therefore increases during the pressure holding time.

The success of the process is essentially an interaction between the process itself and the packaging concept. The packaging process requires that it is matched precisely to the particular product, so that mechanical stress on the product is kept as low as possible - one aspect that MULTIVAC focuses on particularly.

### **Expertise and range of services from MULTIVAC in the HPP treatment of food**

MAP and HPP - in recent years MULTIVAC has systematically faced this challenge. The leading manufacturer worldwide of thermoforming packaging machines has many years of experience in the development of packaging solutions with MAP and EMAP. Comprehensive analysis and the research conducted by Dr Tobias Richter, Head of the HPP Center at MULTIVAC in Wolfertschwenden, as part of his dissertation have brought about significant improvements in technology as well as a higher level of efficiency for the whole HPP process.

In 2011 as a result of several new patented developments, MULTIVAC succeeded in integrating high pressure processing into automated packaging lines and also applying this to MAP packs. Up until that point, the HPP process had mostly been performed separately from the packaging procedure. One year later, MULTIVAC's own HPP Test Center was put into operation at the company headquarters in Wolfertschwenden. Here MULTIVAC combines HPP technology, packaging know-how, automation expertise and analysis under one roof.

### **Integration of HPP systems in automated packaging lines**

Thanks to the integration of HPP technology in automated packaging lines, throughput and product flow can be significantly improved. At the same time, process costs per pack are reduced - which means that overall efficiency is therefore increased. Appropriate preconditions are however necessary for a smooth packaging procedure:

1. MULTIVAC developed a concept, which has also been patented, for the loading crates that have to be specially designed for automatic loading and unloading. The loading crates fold open automatically in two halves and then close again automatically after loading. This means that they are easily accessible for the handling units.
2. Since the degree of filling for the loading crates has a significant impact on the throughput of the HPP system, pack-specific loading patterns are defined and stored in the machine control of the packaging line. It is also specified in the patterns, which pack is placed by the gripper robots in the loading crates and how it is placed. This guarantees optimum and efficient loading of the high pressure chamber.

3. In order to achieve the optimum result, the production output of the HPP systems must be specifically designed to the output of the packaging machines.

### **The HPP Test Center at MULTIVAC**

In conjunction with Uhde HPT, various types of system were conceived for testing different products. Uhde HPT undertook the technical implementation of the systems.

In MULTIVAC's HPP Test Center, a HPP 035 single-chamber system with a volume of 35 litres is available to customers - this is a special design size that can be used very flexibly. The system was originally conceived for a higher operating pressure of 7,000 bar, but tests are currently performed at the industrial standard pressure of 6,000 bar. As with the other systems, the HPP 035 has the equipment and processes, which have been patented by MULTIVAC, for reliably treating both vacuum packs and modified atmosphere packs with high pressure. The special double cladding of the high pressure chamber enables the system to be tempered with a liquid heat medium, so that the different production conditions at user companies can be simulated as closely as possible.

Test users can therefore convince themselves of the quality of the high pressure treated products in the Center itself. In addition to this, MULTIVAC also provides various packaging machines in its HPP Test Center, so that it can react flexibly to customers' wishes on site.

The technology leader from the Allgäu region of Germany also offers other services such as performing shelf life tests and giving advice on the design of customised packaging concepts for high pressure processing. Pack samples, which are produced in the Innovation Center, can be high pressure processed in the HPP Test Center. MULTIVAC also provides contact if necessary with packaging material manufacturers and, thanks to impartial accredited test laboratories in the immediate vicinity, is able to facilitate independent testing of the relevant parameters of the HPP treated product samples. Even storage tests with periodic testing of product quality features and microbiology are possible.

### **Summary**

High pressure processing, which is suitable for treating vacuum packs and modified atmosphere (MAP) packs, offers overall many benefits when compared with shelf life extension through heat treatment: while vitamins are lost or destroyed during heat treatment, and in most cases the heat is not evenly distributed, the HPP non-thermal process retains the vitamins and other delicate substances, while at the same time reducing or eliminating undesirable microorganisms. Consumers benefit from high pressure processing, since fresh and processed food or ready-meals of the highest quality can be stored without additives and consumed over an extended period of time.