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Advanced Packaging for Transport of Local Produced Food (Vegetables and Fruits)

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Abstract According to the production of a country, agriculture occupies the first place in terms of importance, so the maintenance and placement of agricultural products should be constantly present and the model of international transport should be constantly adapted to the contemporary market demands. This is especially true for fruits, vegetables, meat and live animals. In order to transport the goods safely, to store them and deliver them to the final consumer, they must be placed in a specific packaging. The packaging protects the load from scrapes, damage, external influences (moisture, light). In addition to its protective purpose, the packaging presents aesthetic appearance and allows a constant quantity and a safe declaration on the original packaging. In addition, the packaging plays a commercial role and improves product sale, which is why packaging design is one of its most important properties (often more important than content). The main task is to provide the customer or the consumer fresh, healthy, mature and preserved goods in the appropriate packaging that suits the taste and purchasing power of the consumer, whether it is a national or international sales market.

Keywords: • agriculture • vegetables and fruits • transport • packaging • production •

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1 Introduction

Fruit and vegetables play an important role in healthy nutrition and are high on the list of consumer priorities. However the major obstacle of purchasing ready-to-eat fresh-cut fruits and vegetables is their short shelf life, leading to quick degeneration and decomposition of the product and undesirable look and negative palatability (Ščetar 2010).

Quality and good packaging must protect the goods against the deterioration and damage. The final buyer (consumer) must be assured that the goods will get to it as goods were produced and that the environment could not have a negative impact on it.

Processing and packaging are the two important phases of operations in the food industry. The final phase is the packaging stage. A great deal of automation strategies are constantly being utilized in every phase of processing and packaging.

The correct packaging enables processors to pack fresh and fresh-cut fruit and vegetables and extend their shelf life. The important parameters for this shelf life extension are temperature, moisture and a modified atmosphere (oxygen, carbon dioxide and ethylene). If both temperature and packaging are optimal, ageing of fruit and vegetables can be slowed down significantly.

It is essential to minimise physical damage to fresh produce in order to obtain optimal shelf-life.

This study will explain the importance of packaging fruits and vegetables, show us types of packaging, and also conditions under which fruits and vegetables need to be transported and stored. Study will explain some of the advanced packaging technologies used to extend shelf life of vegetables and fruits and labeling of products.

2 Packaging functions

a) Function of protection

Good packaging must protect and guard against spoiling the contents stored in it. The end buyer (consumer, customer) must be assured that content will get to it as it was produced and that the environment could not have a negative impact on it.

b) Logistic function

The role of logistics is to ensure the storage of packaged goods in the required quantity and the prescribed durability without loss of value, while protecting the environment and saving costs. The packaging must ensure the storage of the packaged goods on the way to the final customer. Depending on the nature of the material, they are packed in suitable packaging, stored in silos, in an open storage space, in a covered, closed warehouse or in an air-conditioned warehouse. Therefore, the choice of packaging materials or packaging also depends on storage and transportation.

c) Marketing function

The end customer looks at the packaging as a part of the product. The packaging must attract the buyer and give him/her practical information. The commercial-selling function of the packaging consists in attracting the customer through its appearance, providing basic information about the product, providing consumers with easy identification of products on the market, creating an image of product, manufacturer, retailer, distributor and originality, and encouraging consumers to repurchase.

In addition, packaging can (Almenar 2016):

- Add value to produce,
- Strengthen brands,
- Monitor produce and environment changes during storage,
- Be a tracking tool,
- Provide anti-theft prevention,

- Allow unique identification and communication with consumers,
- Increase consumer satisfaction,
- Reduce food waste.

3 Deterioration

Deterioration includes any reduction in the quality of food, reducing their nutritional value, deteriorating their taste, smell, color, consistency and appearance, changing the chemical composition, physical characteristics and their contamination.

Figure 1: Defected pepper and strawberry;
(Source: http://www.fao.org/docrep/008/y4893e/y4893e06.htm)

The most common causes of food deterioration while in transport and in the store are:

- Defective product that has left the factory being defected,
- Improper transportation, handling and sale,
- Damaged packaging,
- Non-hygienic conditions of production, transport and handling of the product,
- Correct and defective (spoiled) products being mixed together,
- Keeping food in the vicinity of food or goods of strong odor,
- Exceeded the shelf life of the food.

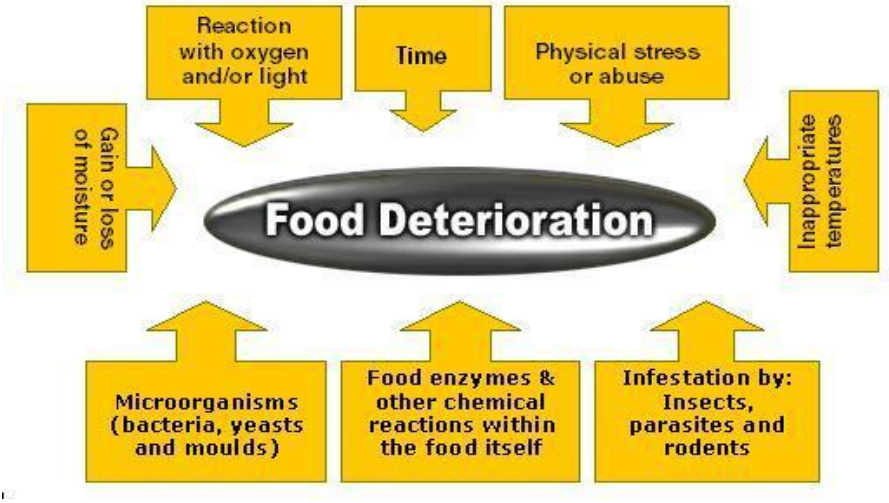

Figure 2: Illustration of causes of food deterioration.
(Source: http://ecoursesonline.iasri.res.in/mod/page/view.php?id=1706)

Depending on the type of food and the cause of the defect, deterioration of the food can be slow or very fast. Most common defects happen because of elevated temperatures, increased air humidity, elevated pressure, hitting, friction, irradiation, dust and other contaminants.

Beside outer causes, food can defect itself from inner causes, such as changing color, taste and consistency, physical and chemical reactions, reaction or contamination of packaging and microorganisms.

4 Transport, manipulation and storage of vegetables and fruits

The globalization of the market and the growth of the trade in vegetables and fruits are placing increasingly complex tasks on producers. The goal is to supply nutritional products as soon as possible to satisfy more demanding consumers, bearing in mind that it is only a satisfied customer a guarantee on market and winning the competition.

The production process management system, in most of the food-producing companies, is efficient due to the use of fully automated, modern production and control technologies and experienced and well-trained employees. On the other hand, distribution processes involving storage and transport of products are

often critical links in the food chain. One of the reasons is the dynamism of these processes; the product should be delivered from one location to another in the shortest possible time.

Vegetables and fruits are temperature-sensitive, ie they require a certain temperature regime. Therefore, special attention should be paid to this type of product in order to preserve their health and quality.

Each product in time loses on quality. However, the loss is much faster and higher if the product is exposed to unhealthy temperature. The highest number of bacteria that cause food poisoning grows best at a temperature of 37°C. Many microorganisms that cause food poisoning can not propagate at temperatures below 5°C. This means that in all parts of the cold chain the temperature should be below 5°C, and should not exceed 8°C.

Table 1: Recommended gas mixtures

Fruits	O_2 (%)	CO_2 (%)	N_2 (%)	Vegetables	O_2 (%)	CO_2 (%)	N_2 (%)
Apple	1–2	1–3	95–98	Artichoke	2–3	2–3	94–96
Apricot	2–3	2–3	94–96	Beans, snap	2–3	5–10	87–93
Avocado	2–5	3–10	85–95	Broccoli	1–2	5–10	88–94
Banana	2–5	2–5	90–96	Brussels sprouts	1–2	5–7	91–94
Grape	2–5	1–3	92–97	Cabbage	2–3	3–6	81–95
Grapefruit	3–10	5–10	80–92	Carrot	5	3–4	91–95
Kiwifruit	1–2	3–5	93–96	Cauliflower	2–5	2–5	90–96
Lemon	5–10	0–10	80–95	Chili peppers	3	5	92
Mango	3–7	5–8	85–92	Corn, sweet	2–4	10–20	76–88
Orange	5–10	0–5	85–95	Cucumber	3–5	0	95–97
Papaya	2–5	5–8	87–93	Lettuce (leaf)	1–3	0	97–99
Peach	1–2	3–5	93–96	Mushrooms	3–21	5–15	65–92
Pear	2–3	0–1	96–98	Spinach	Air	10–20	–
Pineapple	2–5	5–10	85–93	Tomatoes	3–5	0	95–97
Strawberry	5–10	15–20	70–80	Onion	1–2	0	98–99

Source: https://www.researchgate.net/publication/210280254

By increasing the temperature, all the processes within the plant's fruit/vegetable flow faster, and with the lowering of the temperature all processes in fruit/vegetable are slowed down. By cooling fruits and vegetables, it is achieved to slow down or stop the action of microorganisms and to isolate water as another cause of the defect. Today, in a cool and frozen state, almost all kinds of perishable goods (fruits, vegetables, meat, fish, ready meals, etc.) are transported and sold.

Cooling involves maintaining and storing fruits and vegetables at a temperature of 0 to +4 °C. Exceptions are some types of fruits and vegetables that can be stored and transported at slightly higher temperatures (eg. citrus fruit at 12°C and bananas up to 15°C).

The cooling process is essentially a way of storing fruit and vegetables that can not be changed for a shorter time. For some types of fruits and vegetables it is necessary to regulate the humidity of the space and the intensity of ventilation.

Apart from cooling, products can be frozen. Freezing is the process of cooling the product to the fading of the liquid content and is kept at very low temperatures for a long time, with a minimum change of basic natural and nutritional properties and product value.

To maintain transport and storage of food, it is necessary to have adequate storage and transport conditions related to the arrangement and equipment of the premises and vehicles, in accordance with the requirements of good storage practices.

Storage spaces must therefore be appropriately maintained and sufficient for the proper storage of various types of products. It is necessary to provide protection against dust accumulation and lifting, particle deposition on packed products, prevention of condensation or mildew development on walls and surfaces and good hygiene practices, including protection against various pollutants, and in particular pests

Storage atmosphere must be controlled by reference parameter control (CO_2, O_2, temperature, relative humidity), which are characteristic of each type of vegetables and fruits, including a variety of vegetables and fruits (Table 1).

4.1 Cold storage warehouses for vegetables and fruits

Warehouses are used for storage of goods, which are built as solid material objects with the required sewage and the ability to control the conditions. Warehouses can be universal - for storage of various types of food and specialized warehouses for storing certain types of foods.

Refrigerators are storage facilities for storing food at low temperatures (Figure 3). They are used to store both fresh and frozen foods. Cold rooms are mostly constructed as ground-based buildings. Specialized refrigerators are built around the food processing plants (slaughterhouses, frozen fruit and vegetable production plants, ready meals, fish, frozen bakery products, etc.) in which refrigeration or freezing is an integral part of the technological process.

The refrigerator walls must be as thick as possible and with as less openings as possible to achieve the best thermal isolation. The chambers are isolated by flocculant, glass wool or other insulators. Each chamber must be provided with a ventilation device that has natural or artificial air flow. Production and maintenance of the cold in warehouses for the storage of deteriorating goods is an essential part of the technology of work. It is achieved with compressors located in a special engine room, most commonly separated in their own building with a refrigerator.

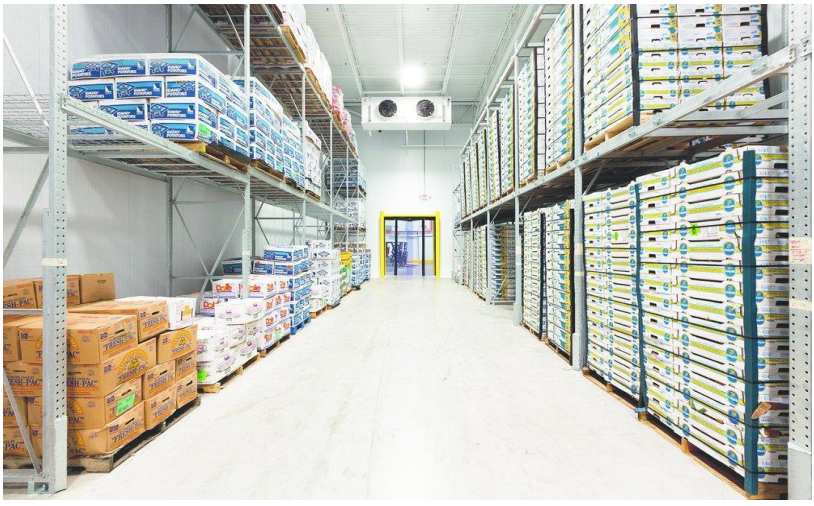

Figure 3: Cold storage warehouse.
(Source: https://www.reonomy.com/blog/post/the-rise-of-us-cold-storage-facilities)

By preserving fruits and vegetables in refrigerators, their use is extended for a certain, relatively short time. During that period, fruits and vegetables are in a lively condition. When storing fruits and vegetables, it is important to separate them because some types of products, due to their poor mutual influence, may cause the product to change the odor, to become inflammable, to transmit toxicity.

4.2 Transport of vegetables and fruits

For the transport of fruits and vegetables on longer distances, ships are used, and for shorter trucks and wagons. Some means of transportation differ in terms of protection, have a ventilation system, they are thermally insulated or cooled, kept out of the influence of outside temperatures, etc. In transport, cooling of fruits and vegetables is possible by means of a refrigerating machine, ice, dry ice or chilled air.

For the simplicity of manipulation and the entire transport process, most fruits and vegetables are palletised. Palletisation is the application of pallets in freight transport. The pallet is a wooden base or plastic base made out of panels of certain standardized dimensions to which the goods are placed.

The pallet is a kind of auxiliary equipment that allows the formation of a compact and solid package, complex of various types of piece goods (Figure 4). The loading and unloading of palletised goods is carried out by a forklift truck. If the goods are not palletised, loading and unloading requires additional workforce engagement and it takes more time to achieve the same amount of shredding as in palletised goods.

Figure 4: Plastic pallet with reusable plastic container.
(Source: https://nortpalet.com/en/info/fruit-and-vegetables-processing/)

Single use packaging generate a lot of unnecessary waste. Nowadays the consumers are demanding more recyclable packaging.

The Reusable Plastic Container is a returnable packaging without packaging waste because the containers are disinfected and cleaned after recollection. Damaged containers that can not be repaired are 100% recycled and used for the production of new plastic containers (Figure 5).

Reusable plastic containers' high levels of ventilation create the ability to more quickly cool products and control temperature in transit, prolonging shelf life. These containers can significantly reduce product damage. The design of containers make the handling process easier. The containers interlock exact and protect the foods from damaging.

Figure 5: The life cycle of plastic reusable containers at IFCO Company.
(Source: https://www.ifco.com/ee/en/food-safety/c3239543720887eb)

With the development of container transportation of fruit and vegetables is increasingly taking place in refrigerated-containers (reefers) transported by sea transport, and at the landing port of fruits and vegetables, it is directly loaded into trucks - refrigerators or wagons - refrigerators.

The benefits of transporting fruit and vegetables in containers are multiple, they protect products from external influences and allows simpler and more flexible application of temperature monitoring or regime. Frigo containers have a temperature control range of -35°C to + 12°C (Figure 6). Fruits and vegetables transported in fridges are packaged in boxes of various sizes and dimensions, weighing 10 to 50 kg. Container load was not palletised to make the container storage space as good as possible.

Figure 6: Inside and outside look of a reefer.
(Source: http://www.chassisking.com/images/products/regular/reefer-containers-20-hc-reefer-container-440v.jpg)

5 Packaging for vegetables and fruits

Consumption of food is one of the basic needs for human beings and its quality and safety is essential for leading a healthy life. Owing to the ever-increasing globalization of markets, foods being processed, distributed, and consumed in the same locality where they are produced are becoming less common. This worldwide integration of the food supply chain requires new approaches and systems for assuring food safety and quality since, during harvesting, handling, processing, and storage, food quality is compromised due to various biotic and abiotic factors. Therefore, it is important to monitor routinely the quality and safety of foods at different points in the supply chain. (Ashok 2018)

5.1 The Modified Atmosphere Packaging

The MA packaging technique (Figure 7) consists of the enclosure of respiring produce in polymeric films in which the gaseous environment is actively or passively altered to slow respiration, reduce moisture loss and decay and/or extend the shelf life of the products. (Ščetar 2010)

Figure 7: The Modified Atmosphere Packaging of fresh cut fruits.
(Source: https://www.chemarc.com/content/modified-atmospheric-packaging-map-technology-for-fruits-and-vegetables-an-overview/590196c484583c4676851674)

The Modified Atmosphere Packaging can be created in two ways, active and passive.

With active modification, the natural atmosphere in the sealed package is replaced with a modified atmosphere or gas mixture matched to the respective product. This modified atmosphere consists of **carbon dioxide**, **nitrogen** and **oxygen**.

Carbon dioxide is a natural gas that is low in the air. CO_2 prevents the growth of most aerobic bacteria and mold. The Carbon dioxide is the most important element in this packaging method. In general it can be said that the higher the CO_2 concentration, longer the shelf life of the perishable foods. It needs to be considered, fat and water are easily absorbed by carbon dioxide gas, but excessive

carbon dioxide concentration causes loss of quality in taste, moisture and concentration of packaging.

Nitrogen (N_2) is inert gas used to exclude air, especially to displace atmospheric oxygen in packaging. Oxygen's presence is precondition the growth of aerobic microorganisms. As a result, O_2 is usually excluded from modified atmosphere packaging. Vegetables and fruits need oxygen to stay alive and keep fresh in the packaging, thus require oxygen concentration, that prevents the spoilage.

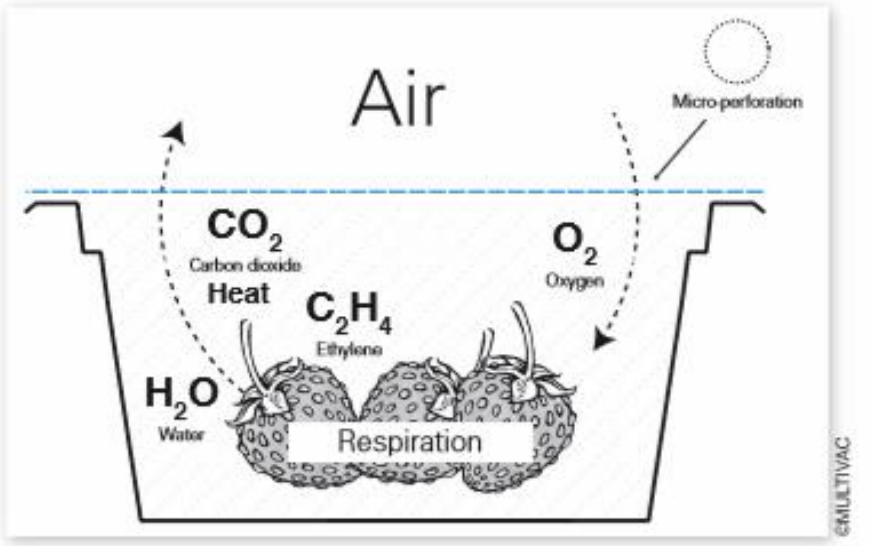

Figure 8: Passive Modified Atmosphere Packaging respiration diagram.
(Source: https://www.dlg.org/fileadmin/_processed_/1/f/csm_Packungsatmosphaere_Gleichgewichts-e_7f133437a5.jpg.)

The passive modified atmosphere packaging (Figure 8) has specific micro perforations that enables an exchange of the atmosphere between the package and the environment. The micro perforation, which is made by a special laser, are miniature holes that invisible for human eyes. In this packaging method, the carbon dioxide flows outward and the oxygen is inward. As a result in balanced air in the packaging takes the advantage of the natural respiration of fruits and vegetables for controlling the atmosphere in the packaging.

Figure 9: Testing the atmosphere in a plastic bag of carrots.
(Source: https://en.wikipedia.org/wiki/Modified_atmosphere)

The difference between the two methods is that active MAP use inert gases to form a static atmosphere, while in passive MAP the oxygen can entry and the carbon dioxide can exit. Figure 9 shows an atmosphere testing in a plastic bag of carrots.

5.2 The Intelligent Packaging as an innovation of the future

In Intelligent Packaging, the intelligent device or system is always part of the material that forms the package and is never placed inside the package along with the product. Examples of systems used currently to communicate produce quality and/or safety or to extend shelf life include indicators (time-temperature indicators, quality indicators, leak detectors), tracking devices (radio requency identification devices) and temperature-compensation membranes. (Almenar 2016)

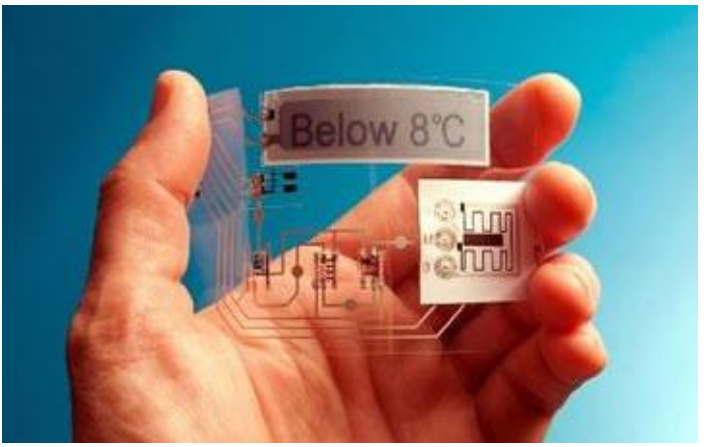

Figure 10: Thinfilm Electronics technology device for intelligent packaging.
(Source: http://www.fdbusiness.com/intelligent-packaging-sends-alerts-when-food-is-spoiled/)

Smart packaging can be categorised into two types, those which incorporate integrated circuits (IC's) (Figure 10) and does which do not incorporate IC's otherwise known as chipless smart packaging (Figure 11). Packaging that incorporate diagnostic indicators are also included in smart packaging. These can be used for such functions as monitoring vibration, acidity, tilt, shock, humidity, light, heat, time chemicals, virus or bacteria as they develop or as they are contacted. (Ščetar 2010)

Smart packaging uses features of high added value that enhance the functionality of the product, notably mechanical, electronic and responsive ink features, for example electronic and mechanical dispensers in which drugs are supplied and the prepared meal that automatically tells the microwave how it should be cooked. (Ščetar 2010)

Using intelligent packaging, it is possible to record a wide variety of time and temperature of product, products can be read by standard barcode readers and Android and Apple smartphones. Unique serial ID for each products can be used, enabling rich Track & Trace functionality.

Figure 11: BarCode being used for Intelligent Packaging of products.
(Source: https://www.smitherspira.com/industry-market-reports/packaging/active-intelligent-packaging-to-2023)

5.3 Biodegradable packaging

Prior to recent years, nearly all packaging for food, produce, and supplies were sold in plastics that were oil-based, made from petroleum. Because of the rising costs of oil, petroleum is a non-renewable resource and growing problem of waste disposal, there is growing attention to biodegradable packaging.

As a solution the consumer products industry is working on the development of biodegradable packaging (Figure 12). The materials of biodegradable packaging break down and return to the nature without causing harm. In order for packaging products or materials to qualify as biodegradable, they must completely break down and decompose into natural elements within a short time after disposal – typically a year or less.

Figure 12: Biodegradable packaging for fruits from palm.
(Source: http://www.sunpack.com/earthcycle-biodegradable-packaging-alternative/)

The compostable packaging consist of a group of polymers that derived from renewable raw materials like lactic acid, cellulose, soy protein, starch (e.g. corn, potato), it is not harmful to the environment and decompose back into carbon dioxide, water, biomass etc.

In the short term, bio based materials will most likely be applied to foods requiring short-term chill storage, such as fruits and vegetables, since bio based materials present opportunities for producing films with variable CO2/O2 selectivity and moisture permeability. (Ščetar 2010)

5.4 Labels on the packaging

One key area is the right labelling of the packaging. Labelling regulations also depend on packaging form. If we use the MAP methods for packaging – the primary packaging will be a closed pack. The text on the label must be written in one of the official languages of an EU member state and be comprehensible, in readable font size (minimum 1,2 mm) for the consumer.

Nowadays the conscious consumer would like to know more about the products, not just how fresh is the fruit or vegetables. He is interested in producing circumstance. The label is mandatory and include: the regulated product name and general description; the place of origin; the Trade's or Packer's full name and address; the quantity in the prepacked package is expressed as net weight (in grams or kilograms), production lot number and GTIN number (Figure 13).

The packaging have to be declare if the packaging contains gas, e.g. packed in protective atmosphere“ label. Additionally the trade's can declare information about the fruits' or vegetables' size, quality class, etc. The use of best-before-date is highly recommend, but is not mandatory for fresh unprocessed fruits and vegetables.

Figure 13: Label on the packaging.
(Source: http://www.freshplaza.com/2018/0117/tomatopack.jpg)

6 Conclusion

The average consumer rarely thinks about how their strawberries, asparagus, potatoes, apples and other fruits and vegetables got to the supermarket shelf. Customers simply decide what products they want and select them. But those strawberries, potatoes, apples and others, have been on a journey of many steps, considerations and challenges to arrive fresh and ripe on supermarket shelf.

Because of the many variables involved in packaging and shipping, getting perishables from point A to point B is one of the most challenging aspects of food manufacturing. Buyers – whether it's a grocery store or the end-consumer – expect a safe, attractive, fresh product.

Preservation of goods in a fresh and orderly condition from the place of production to the place of consumption is conditioned by the professional and proper preparation of the goods for transport. It is of utmost importance that each product is properly prepared, processed and preserved in a fresh and orderly state, up to the time the product is placed on the market.

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