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NUTRITIONAL QUALITY OF HORTICULTURAL PRODUCTS

Current trends and importance in food chain

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"Enhancing practical skills of horticulture specialists to better address the demands of the European Green Deal"

Bucharest, 2025

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Introduction

The nutritional quality, as an extended definition, refers at the value that one product has for the consumer's physical health, growth, development, reproduction and psychological or emotional well-being. This value can be conferred by the substance itself, considering all the mineral and organic components of foods (all ingredients, compounds either beneficial or harmful) and the feelings, the state of well-being/indisposition that foods can cause in consumers (Köpke, 2005). Otherwise said, the nutritive quality is an indicator of the contribution of a food to the nutrient content of the diet. The food value depends on the quantity of a food which is digested and absorbed and the amounts of the essential nutrients (protein, fat, carbohydrate, minerals, vitamins) which is contained by that ingested amount of food. Food quality has a great importance in our diet, and most important in the diets associated with chronic diseases. Nutrients are not consumed in isolation, but as components of whole foods and in an infinite number of combinations.

Foods contain a myriad of chemical substances, of which some play a major role, some a secondary role, while some either serves no role in human metabolism or their role has not yet been elucidated. In order to develop individual diet recommendations, that are nutritionally adequate for a better human health and well-being, there is a continue need for learning and understanding the nutrient composition of food products. Continuous research is being carried out on food with high nutritional value, that needs to be valorized accordingly and the last decades were full of new superfood placed into the market. There is a continuous necessity and an opportunity for teaching staff and master students to practically learn the analytical methods used for the identification and quantification of nutrients and the bioactive compounds with increased nutritional value. These aspects are largely presented on the first module, entitled “Current trends and importance in food chain”.

For being in direct relation with people safety and health, the nutritional quality aspects of horticultural products have been included in the EU regulations and international or national standards. To apply the quality standards for vegetables and fruits, different criteria, specific to each product are used, and the normative acts differentiate the quality of fruits and vegetables by three categories: extra, quality I and quality II. The international organizations responsible for food safety and quality are: Food and Agriculture Organization (FAO), World Health Organization (WHO), European Food Safety Authority (EFSA) and national bodies.

For countries that don't have the resources or infrastructure to develop their own safety evaluations and regulations, the Joint FAO/WHO Food Standards Programme, known as the Codex Alimentarius, was developed. These aspects are largely presented on the first module, entitled "Regulations on nutritional quality of horticultural products".

Horticultural products have their quality traits in direct relation with soil and climate variations, with cultivars/varieties/species, with the applied cultivation technology or specific agricultural practices, etc. (Köpke, 2005) and the values of each component can be affected by the soil and growing conditions, handling and storage, and processing. Recently, it has been claimed on social media, in an intense debate, that our food is far less nutritious than it used to be (McGrath & Shewry, 2020) and that the vanishing nutrients it's just a hazard of climate change (Suglia, 2018).

Sellers of vitamins also claim our food doesn't contain all the nutrients it once did. This might be due to soil depletion, cold storage, food ripening off the vine, and global transport of out-of-season foods as the foods contain the greatest amount of nutrients when they are eaten right after the harvest.

According to recent research, rising carbon dioxide levels are and they will continue making our food less nutritious, with less essential vitamins available to human development. Wheat, maize, soybeans and field peas contained less protein, zinc, and iron when grown under levels of carbon dioxide expected by 2050, in a study conducted by Medek et al, 2017. A study comparing modern plants with historical herbarium specimens and found that levels of all minerals, including zinc, iron and calcium, closely tracked carbon dioxide levels through time (Suglia, 2018). Another one found that concentrations of essential nutrients decreased in 18 strains of rice, while B vitamins as riboflavin and folate, dropped by as much as 30 percent, after being exposed to increased carbon dioxide levels in an experiment (Zhu et al., 2018). Actually, the amount of CO2 in the atmosphere makes plants to grow faster and rise the content of carbohydrates, but at the expense of other nutrients, so in percentage terms the amount of nutrients are actually declining. So, is it true? The question become even more serious when we ask ourselves if it possible to starve our body of nutrients while we simultaneously gaining weight? The key facts reminded by WHO, tell us that worldwide obesity has nearly tripled since 1975, that more than 1.9 billion adults, 18 years and older, were overweight in 2016, and over 650 million were obese, 39 million children under the age of 5 were overweight or obese in 2020 and over 340 million children and adolescents aged 5-19 were overweight or obese in 2016 (WHO, 2021).

Are these frightening figures also related with the nutritional quality of food? Is our food becoming less nutritious? On the other hand, other scientists claim the mineral nutrient composition of vegetables, fruits and grains is not declining, the idea of decline due to agricultural soil mineral depletion is unfounded, the changes are within natural variation ranges and are not nutritionally significant, and that eating the recommended daily servings provides adequate nutrition (Marles, 2017).

Also watch https://www.youtube.com/watch?v=Yl_K2Ata6XY

Who is right?

How can we solve this debate in the near future? The answer relies in proper skills and proper analytical methods to test the nutritional quality of food and its effects on human health. These aspects are largely presented on the modules “Food nutritional quality” and “Tricks and tips in analysis methods of nutritional values”.

The nutritional quality of horticultural products may also differ in time. Fruits and vegetables usually undergo different treatments during harvest and post-harvest period, that can be form a simple hand harvest and to harvest with specialized equipment or treatments with sophisticated processing methods (long term controlled atmosphere storage, drying, lyophilization, frying etc.). In every step of those procedures, different parameters must be considered, so that a fine final product can be guaranteed. Those parameters can be environmental, biological, mechanical, chemical etc. factor that can alter the final product, with direct impact to its nutritional and market value. Still, even all the necessary specifications are respected, in order to achieve the best quality and quantity of the final product, the quality analysis still plays an important role. Specific aspects related to most common protocols used to analyse the nutritional quality are presented on the module “Laboratory methods for nutritional quality analysis”.

Food provides human body essential nutrients to sustain life. In some cases, when food is contaminated with pathogens, the effect can be opposite, and can either harm or even kill us. According to the **World Health Organization** (WHO), more than 200 diseases are caused by eating food contaminated with bacteria, viruses, parasites or chemical substances (Liou, 2021). Since consumers cannot measure the nutritional quality by themselves, or see, taste or smell the threat of contaminated food, the food safety laboratories tend to prevent the negative effects of harmful agents of diseases. Through routine testing, surveillance and involvement in epidemiological investigations, food safety laboratories can detect pathogens and identify emerging pathogens. These aspects also need to be considered when talking about nutritional value, but it will be further presented in a similar online course, entitled **"Sustainable use of pesticides and their residues monitoring".**

Especially for horticulture specialists, it is important, to understand why quality control and quality assurance is essential when dealing with food, especially with fruits and vegetables and their derived products. Enhancing the practical skills of students, master students and even doctoral students to better understand the implication the nutritional quality of horticultural products can have on people's life is of maximum importance, especially in the context of the new demands of the **European Green Deal**.

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Module No. 1 Current trends and importance in food chain

Summary

In this module, aspects related to nutritional quality, including definitions, terms related to nutritional quality, terms relating to horticultural products and different types of horticultural products are presented, as well as an overview of the framework that is governing the nutritional quality, as goals, directions, strategies (*Farm to fork*, *European Green Deal*, 17 UN goals, EFSA). The third unit of this module present aspects related to the influences on nutritional quality along the food chain, as the pre-harvest technologies, the selection of fruit and vegetables selection for processing, the postharvest technologies and how the nutritional quality of fruits and vegetables is changing during storage, the processing technologies, and the importance of the last step before marketing, the fruit and vegetables packaging.

Learning outcome descriptors

By the end of the module, the trainees should be able to prove they acquired both general and transferable skills and knowledge, understanding and professional skills.

General and transferable skills

1	Plan a research task.
2	Work independently or with a minimal guidance where appropriate.
3	Work in team with minimal guidance where appropriate.
4	Show good written and oral communication skills.
5	Demonstrate computer literacy
6	Perform online (computer) search to develop information technology skills in order to retrieve information from a variety of sources.

Knowledge, understanding and professional skills

1	Specify the importance and the main characteristic features of nutritional quality of fruits and vegetables
2	Understand and define the factors that influence the nutritional quality of fruits and vegetables
3	Elaborate/List the benefits, economic and social impact of different horticultural technologies on nutritional quality of fruits and vegetables

Unit 1.1: What does nutritional quality means?

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To assure sufficient nutritional quality of horticultural crops is one of the major challenges for the near future given their importance for the well-being and health of consumers. Horticultural products are an important source of essential nutrients.

1.1.1 Nutritional quality definitions

Generally, the nutritional quality can be evaluated through:

1. Primary essential nutrients: water, fiber, proteins, fats, carbohydrates, amino acids, nucleic acids, vitamins, dry matter, and minerals.

2. “Secondary metabolites” or “phytonutrients” in plants classified in major four categories of polyphenols, terpenes, alkaloids, and sulfur containing compounds (Bansal, 2017).

'Your diet is a bank account. Good food choices are good investments.'
Bethenny Frankel

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1.1.2 Framework (goals, direction, strategies - *Farm to Fork,* European Green Deal, 17 UN goals, EFSA)

Sustainable Development Goals

In 2015, the Heads of State and Government and High Representatives, meeting at the United Nations Headquarters in New York, have decided on new global Sustainable Development Goals of the *2030 Agenda for Sustainable Development*.

2030 Agenda is a plan of action focused on people, planet, prosperity, peace and partnership. The 17 goals are listed below:

The UN 2030 Agenda envisages “a world of universal respect for human rights and human dignity, the rule of law, justice, equality and non-discrimination”.

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17 Goals of the 2030 Agenda for Sustainable Development

End poverty in all its forms everywhere

Reduce inequality within and among countries

End hunger, achieve food security and improved nutrition and promote sustainable agriculture

Make cities and human settlements inclusive, safe, resilient and sustainable

Ensure healthy lives and promote well-being for all at all ages

Ensure sustainable consumption and production patterns

Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all

Take urgent action to combat climate change and its impacts*

Achieve gender equality and empower all women and girls

Conserve and sustainably use the oceans, seas and marine resources for sustainable development

Ensure availability and sustainable management of water and sanitation for all

Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss

Ensure access to affordable, reliable, sustainable and modern energy for all

Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all.

Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels

Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation

Conserve and sustainably use the oceans, seas and marine resources for sustainable development

Source: https://sdgs.un.org/publications/transforming-our-world-2030-agenda-sustainable-development-17981

Some of the objectives

> By 2030, end hunger and ensure access by all people, in particular the poor and people in vulnerable situations, including infants, to safe, nutritious and sufficient food all year round.

> By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality.

European regulation

Farm-to-fork

The *European Green Deal* is an integral part of the Commission's strategy to implement the United Nation's 2030 Agenda and the sustainable development goals.
In EU, the *European Green Deal* was announced by the European Commission in 11 December 2019.

European regulation

There are 6 commission priorities for 2019 – 2024 period

A European Green Deal.
Europe aims to be the first climate-neutral continent by becoming a modern, resource-efficient economy.

A Europe fit for the digital age.
The EU's digital strategy will empower people with a new generation of technologies.

An economy that works for people.
The EU must create a more attractive investment environment, and growth that creates quality jobs, especially for young people and small businesses.

A stronger Europe in the world.
The EU will strengthen its voice in the world by championing multilateralism and a rules-based global order.

European regulation

There are 6 commission priorities for 2019 – 2024 period

Promoting our European way of life.
Europe must protect the rule of law if it is to stand up for justice and the EU's core values.

A new push for European democracy.
We need to give Europeans a bigger say and protect our democracy from external interference such as disinformation and online hate messages.
The elements of the Green Deal are listed in Figure 1.

European regulation

European Green Deal components

Figure 1. Green deal components
Source: https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52019DC0640&from=ET

European regulation

The European Green Deal key actions are:

1. Increasing the EU's climate ambition for 2030 and 2050.
2. Supplying clean, affordable and secure energy.
3. Mobilizing industry for a clean and circular economy.
4. Building and renovating in an energy and resource efficient way.
5. Accelerating the shift to sustainable and smart mobility.
6. **From 'Farm to Fork': designing a fair, healthy and environmentally-friendly food system.**
7. Preserving and restoring ecosystems and biodiversity.
8. A zero-pollution ambition for a toxic-free environment.
9. Mainstreaming sustainability in all EU policies.
10. The EU as a global leader.
11. Time to act - together: a European Climate Pact.

European regulation

The 6th strategic key action 'Farm to Fork' is focused on "Greening the Common Agricultural Policy". It highlights the following objectives:

- European food is famous for being safe, nutritious and of high quality. It should now also become the global standard for sustainability.

- Measures, including legislative, to significantly reduce the use and risk of chemical pesticides, as well as the use of fertilizers and antibiotics.

- European farmers and fishermen are key to managing the transition (efforts to tackle climate change, protect the environment and preserve biodiversity - at least 40% of the common agricultural policy's overall budget and at least 30% of the Maritime Fisheries Fund would contribute to climate action).

European regulation

The ‘Farm to Fork Strategy’ will also contribute to achieving a circular economy (It will aim to reduce the environmental impact of the food processing and retail sectors by taking action on transport, storage, packaging and food waste. This will include actions to combat food fraud and to launch a process to identify new innovative food and feed products, such as seafood based on *algae*.

Lastly, the ‘Farm to Fork Strategy’ will strive to stimulate sustainable food consumption and promote affordable healthy food for all. (Imported food that does not comply with relevant EU environmental standards is not allowed on EU markets (The Commission will explore new ways to give consumers better information, including by digital means, on details such as where the food comes from, its nutritional value, and its environmental footprint. The ‘Farm to Fork Strategy’ will also contain proposals to improve the position of farmers in the value chain.

European regulation

Figure 2. Farm to fork objectives areas
Source: https://ec.europa.eu/food/horizontal-topics/farm-fork-strategy_en

European regulation

The Farm to fork goals for 2030 are illustrated in Figure 3:

Figure 3. The aims of Farm to fork strategy
Source: https://food.ec.europa.eu/horizontal-topics/farm-fork-strategy_en:

European regulation

The actions for this action will focus on:

- The creation of a healthy food environment which makes the healthy and sustainable choice the easy choice.
- Food labelling to empower consumers to choose healthy and sustainable diets.
- Stepping up the fight against food waste, Halving per capita food waste at retail and consumer levels by 2030.
- Research and innovation, EUR 10 billion under Horizon Europe will be invested in R&I related to food, bioeconomy, natural resources, agriculture, fisheries, aquaculture and environment. Knowledge transfer will be essential.
- Promoting the Global transition.

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Unit 1.2: Importance of nutritional quality (conventional and organic)

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The “nutritional value” represents the nutrient composition of various products, and the nutritional quality of a product is measured according to the possibility of covering the plastic or energy needs of organisms. Each country has established its recommended nutritional values for the daily requirement of nutrients: proteins, carbohydrates, lipids, vitamins, and minerals.

The term "nutritional quality" is constantly evolving and changing. At the beginning, the emphasis was on product quality, and was represented by quantifiable and measurable parameters, but today we are dealing with a much broader approach that includes aspects related to product safety, aspects concerning products health, the biological value of the product, etc.

We have been witnessing a continuous growth in terms of concern for organically grown foods and ecological farms (which produce certified organic products). Also, in recent years, ecological processing technologies have been developed, ensuring the storage and transport conditions in accordance with the rules of healthy nutrition.

Figure 4. The relation between nutritional quality and conventional and organic agriculture

On the one hand, from a nutritional point of view, the product' s value is given by the presence of valuable components, but also by the absence or presence in small quantities of pesticide residues, nitrates, and nitrites. The term "organic" is the way in which horticultural products are grown and processed. In order for the products to fall into the category of organic food, they must comply with a series of requirements specific to organic crops such as: cultivation in soils without chemicals or synthetic pesticides, without oil-based fertilizers, or sewage sludge.

A topical issue for debate is the nutritional quality achieved by organic farming, compared to the conventional one, highlighting the advantages and disadvantages of each cultivation method with a bigger impact on human health. Most consumers believe that organic foods are more efficient, due to the lack of artificial ingredients or chemical residues, and also safer, as they can prevent certain diseases. For this reason, certain customers are willing to pay an additional cost to reap the benefits of the quality of organic products.

There is evidence that organic foods have low levels of residues, pesticides, nitrogen, and a better flavour compared to conventionally grown ones. Besides it has been found that some organic foods have resulted in additional amounts of nutrients, antioxidants, vitamins, polyunsaturated fatty acids such as Omega 3, and lower quantities of compounds with a negative impact on nutrition, such as mycotoxins, residues of pesticides, heavy metals, and glycoalkaloids (Niggli, 2009).

A product with a good nutritional quality has in its composition a lot of dry matter, vitamins, carbohydrates, minerals, and phenolic acids. Following the analysis of nutritional quality by the *French Food Safety Agency*, a higher amountof dry matter was found in products from organic crops than in the conventional ones, these results being consistent with other reports (Rembiałkowska et al,. 2001; Rembiałkowska, 2003). Moreover, a higher total of dry matter was found in the case of leafy vegetables (spinach, white cabbage) from organic crops (Woese et al.,1997). The presence of a greate rdry matter content in organic crops can be explained by the fact that fertilization is less intense in organic farming, and thus fruits and vegetables are smaller in size and contain less water than expected.

In a scientific review of the comparison of nutritional quality and food security of organic vs. conventional productions Yu et al. (2018) concluded that in the prevailing number of studies the dry matter is 7-20% higher in organic plants, although in several studies was found differences between organic and conventional plants.

In our human bodies **vitamins** play a fundamental role in achieving various metabolic functions, and determine a proper functioning of the immune system. Following the analysis of 13 studies on vitamin C content, it has been observed that in 7 of them, the sum was significantly bigger in organic crops compared to the standard ones, and in the other 6 studies the content was insignificant in terms of vitamin C content. (Heaton, 2001). Of all studied species (organic vs. conventional), the maximum vitamin C content was recorded for blackcurrant juice (160.60 mg 100 g-1 FW / 161.20 mg 100 g-1 FW), followed by apple (10.50 and 7.95 mg 100 g-1 FW) and beets (8.03 mg 100 g-1 FW / 7.75 mg 100 g-1 FW) (Gąstoł et al., 2011).

In the 27 studies analyzed by Woese et al. (1997), in which the measures of vitamins in organic horticultural products were compared to the usual ones, there has been found the same level of vitamin A/ beta-carotene in both of them. The same result was shown for vitamins belonging to group B (B1 and B2). Differences were recorded in vitamin C, where a higher value of it was discovered in organic crops. The studies were performed using carrots and potatoes as research material.

> The sugar content of horticultural products is also an index of quality (they taste better and ensure the quality of technological processing).

They have an energetic role, and are constituted (the sugar plants) from glucose, fructose and sucrose. In the case of aminodophilic plants, they are represented by starch. The total sugar content varied significantly for organically grown fruits, compared to fruits coming from normal farms. According to Lester (2007) and Wang (2008) the quantity of sugars obtained from organically grown grapefruit and blueberries was bigger than in the opposite case.

The studies conducted by Gąstoł et al. (2011) showed that the total sugar content in apples is 9% and 7.9% respectively (conventional vs. organic), followed by beetroot 8.4% and 5.9% respectively (organic vs. conventional), whereas the lowest content of sugar was recorded for celery 0.6 and 1.3, respectively (conventional vs. organic).

Similarly, in the case of tomatoes, carrots and potatoes which were organically obtained, a more advanced figure of total sugars was reported compared to those conventionally grown, but the differences were not statistically suggestive (Rembiałkowska, 2003; Hallmann and Rembiałkowska 2008).

Significantly higher, titratable acidity was observed in organically grown crops (Dangour et al., 2009), and some studies found a more titratable acidity for organically grown tomato juices (Hallman and Rembiałkowska, 2008).

Lipids are usually reserve substances for oil plants. Horticultural products contain several fatty acids (palmitic, oleic, linoleic, linolenic, erucic, etc.) that help the growth and development of the human body, the regulation of cholesterol and inflammatory processes. They can be saturated or not to varying degrees, and can contain from 4 to 26 carbon atoms. Oleic and linoleic acids seem to be the most common. Fats rich in monounsaturated fatty acids, such as olive oil, can lower the cholesterol and protect the body from high-density lipoprotein (HDL) cholesterol. Fatty acids are beneficial to the human body in regulating the blood pressure.

> Organically grown vegetables contain less protein, but these proteins are of higher quality due to the content of essential amino acids.
>
> Worthington 2001; Bordeleau et al. 2002

Eating foods rich in Omega 3 and 6

- can reduce blood pressure in hypertensive people;
- fluidizes the blood contribute to the correct functioning of the nervous system;
- strengthens the immune system;
- controls inflammatory reactions.

Phytosterols and steroids are present in greater amounts in vegetable oils.
Sources of phytosterols are nuts, vegetables and seeds.

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Proteins, in addition to their plastic role, can also play an energetic part, their content of vegetables and fruits varying a lot (0.2% - 6.5%/Burzo, 2015).

A very important source of protein is represented by the leguminous plants.

The nitrogen from any type of fertilizer influences the quantity and quality of plant proteins (Worthington, 2001). Furthermore, following the studies performed, it has been concluded that in organic crops the quantity of protein is lower than in the conventional ones, and the quality of proteins (measured by the amino acid content) is better in organic crops than in the rest.

According to some researchers, the total protein content was largely higher for conventional cultures (Magkos et al. 2003; Rembiałkowska, 2004; Amarante et al. 2008). Some research made by Gąstoł et al. (2011) shows that the juice obtained from conventional beet culture had a significantly upper level of N-protein (0.21%) than the juice from an organic culture (0.162%).

Mineral compounds (magnesium (Mg), iron (Fe), phosphorus (P), calcium (Ca), etc.) are vital for the development and good functioning of the bone system and beyond.

The content of mineral elements influences the quality of horticultural products, too.

The appearance of changes in the t**exture, colour and taste** of horticultural products may be based on deficiency or excesses in some elements (iron (Fe), calcium Ca), manganese (Mn).

The decrease of the water content leads to the modification of the turgidness, and to the appearance of wilting and wrinkling in the case of fruits, roots, etc.

It has been found that an extraordinary phosphorus (P) content helps to grow tomatoes, the absence of P and potassium (K) decreases fruit firmness (Sams, 1999), while the lack of calcium(Ca) increases firmness (Weston and Barth, 1997).

Phosphorus fertilizers promote fruiting and accelerate the maturation process. Excessively applied magnesium (Mg) fertilizers intensify the bitter pit attack.

Deficiency of minerals in apple. Lack of nitrogen, potassium. Iron deficiency chlorosis.

Young tomato fruits affected by blossom end rot caused by calcium deficiency.

Intervene chlorosis caused by iron and nitrogen Deficiency on a grape wine.

Grapevine with chlorosis and rust.

The content of minerals and trace elements in crops may vary, depending on the method of fertilization, and on the effects, which are not the same for all compound elements. Studies have shown that potassium (K) and phosphorus (P) can be found in a higher amount in organically obtained potatoes (Woese et al., 1997). Regarding the Fe content, according to the research, an equal amount of it was found in both organic and conventional vegetables, but there were also situations when its volume was greater in organically obtained products (Woese et al 1997).

Potassium (K) fertilizers contribute to increasing firmness (structure-texture), improving the taste; it also increases the value of titratable acidity by changing the sugar/acidity ratio. A higher nitrogen (N) and ash content was obtained for conventionally grown potatoes and carrots, and organically grown vegetables had a higher potassium (K) and sodium (Na) content (Kumpulainen 2001).

The higher amount of potassium (K), that dissolves in the soil from synthetic fertilizers, make difficult magnesium (Mg) absorption from soil, and the less amount of magnesium (Mg) in plants leads to less absorption of phosphorus (P). This leads to a lower content of these two elements in conventionally produced vegetables (Worthington 2001). On the other hand, increased potassium (K) content leads to increased levels of vitamin C, while potassium (K) deficiency in tomatoes reduces the amount of lycopene, but increases beta carotene in fruits. (Vincente et al., 2014).

Nitrates and nitrites represent basic nutrients in a plant growth. Recent research has shown a higher presence of nitrates and nitrites in products from conventional crops, which is due to the use of fertilizer with chemical composts. In products obtained conventionally, a better nitrate content was observed, especially in leaves, roots and tubers (Woese et al. 1997).

Organic crops had a lower nitrate content, more vitamin C and more sugars compared to conventional ones (Rembiałkowska 2000, 2003, 2004; Rembiałkowska et al., 2001; Hallmann and Rembiałkowska, 2008).

Food Safety Pesticide and Nitrate Testing of Apples in Laboratory

Microelement fertilizers influence the enzymatic, hormonal activity, regulate vital processes, participating in the formation of organic compounds in plants. The influence of microelements on the quality of vegetables and fruits is reflected in the increase of carbohydrate, in the accumulation of protein substances, and ascorbic acid (Gherghi et al., 2001). Of the macronutrients, magnesium (Mg), in addition to being important in human nutrition, also has an effect on the accumulation of beta-carotene in carrots (Welch, 2003).

Calcium (Ca) deficiency can affect the quality of produce both during cultivation and later, during storage. Although there are different opinions about this effect, it is claimed that calcium deficiency is the cause not only of peak rot on tomatoes, which occurs on the first fruits, but also on peak rot in leaves (salads and cabbage), cracking in carrot roots and black core of celery (Vincente et al., 2014).

Organic stimulants provide the plants with all the necessary mineral elements, thus ensuring productions with superior nutritional quality, and a good storage capacity.

When **organic fertilizers** are used, the nutrients are gradually released from the activity of microorganisms.

The protein content in the production is lower, but they are of higher quality due to more essential amino acids. The lower content of proteins in plants leads to a higher content of carbohydrates from which vitamin C is synthesized.

Fertilization with organic fertilizers also increases the content of vitamin B. All this increases the quality of products from organic vegetable production (Worthington, 2001; Workneh and Osthoff, 2010).

Phenolic substances in plants have a strong antioxidant activity. The polyphenol content was more significant in organic products, according to studies by Weibel et al. (2000). It was also found that organic apples contained 18.6% more phenolic compounds than in the common fruits. Among the species analysed by Gąstoł et al. (2011), the black currant, with the greatest level of phenols, (7.00 g GAE l -1) was noted.

From the category of **environmental factors** that can influence the nutritional composition of products we can mention: **climatic conditions** (temperature, rain, light), **soil type**, **soil moisture**, **soil pH**, **soil health**, **geographical area**, and **degree of pollution** (Hornic, 1992).

Climatic factors influencing the quality of horticultural products:

Temperature: low summer temperatures slow down the ripening rate, and decrease the amount of carbohydrates. High temperatures during autumn adversely affect the synthesis of anthocyanins and flavones, speed up the maturation process, and thus reduce the ability to store fruit.

Rain: insufficient quantity influences the increase in volume of fruits and vegetables, changes the ratio of the main minerals (K + Mg / Ca), which can lead to the appearance of bitter pit disease. The presence of excess rain leads to an increase in fruit size, a decrease in firmness (structure-texture), a poorly developed aroma, and a reduction in storage capacity.

Light: by directly influencing the process of photosynthesis, causes the accumulation of a higher quantity of carbohydrates in fruits. The researchers Salunke and Desai (1998), Weston and Barth (1997), Hornick (1992) and Knorr and Vogtmann (1983) found that light intensity influences the content of vitamin C, B1 and beta-carotene in vegetables and fruits, having a greater influence on green leafy vegetables.

In the case of leafy vegetables, the location of the leaves also has an effect - whether they are external (exposed to the sun) or hidden in the rosette leaves. Those exposed to the sun accumulate more **antioxidants** (Vincente et al., 2014). The light intensity over the wavelengths used in photosynthesis, and the low temperature can negatively influence the quality of fruits and vegetables.

One of the important factors that can directly affect the nutritional quality of fruits and vegetables, and indirectly the physiological processes that take place in plants, is *fertilization*. The application of fertilizers aims to improve the growing and maturing conditions of vegetables and fruits. Nitrogen fertilizers increase the **chlorophyll content**, the **cell size**, intensify the **respiration process**, and increase the sensitivity of fruits and vegetables to **storage diseases**.

It has been shown that in some crops, the quality of protein falls with the increasing measure of nitrogen fertilizers (Knorr and Vogtmann, 1983; Weston and Barth, 1997 and Rembiałkowska, 2000). Fertilization increases the concentration of nitrogen, with the exception of free amino acids, which explains the quantity of nitrates in vegetables (Weston and Barth, 1997 and Rembiałkowska, 2000), Workneh and Osthoff, 2010), especially in the case of green leafy ones (Lee and Kader, 2000).

There have also been studies where no changes in protein levels have been found (Knorr and Vogtmann, 1983 and Weston and Barth, 1997). It has been found that higher levels of nitrogen fertilizers decreased the glucose quantity of vegetables (Knorr and Vogtmann, 1983) and cabbage fibers (Weston and Barth, 1997). It has also been discovered that the level of nitrogen has a great influence on the content of vitamins in fruits and vegetables.

Nitrogen fertilization increases beta-carotene in vegetables (Weston and Barth (1997). Welch (2003) notes that except high levels of nitrogen fertilizers, beta-carotene increases and with later harvest dates. The increase of nitrogen determines the decrease of firmness (Sams, 1999) and taste (Knorr and Vogtmann, 1983; Lee and Kader, 2000 and Mattheis 1999).

The quality of fruits and vegetables is also influenced by the harvesting and storage conditions. The time of harvest can significantly affect the nutritional quality of fruits and vegetables, especially the concentration of **vitamin C** in fruits.

In the case of apricots and immature apples, the content of vitamin C (ascorbic acid) is lower. Also, fruits in the early stage of ripening have a lower flavor compared to fruits harvested at full maturity. Some studies attest to a better or equal preservation of organic and conventional products (Heaton, 2001).

Among the advantages of organic products, we list: higher number of vitamins and proteins, and a reduced number of chemical residues.

In order to highlight the benefits of organically obtained products, compared to conventionally acquired ones, it is necessary for them to be grown in similar soils and climatic conditions, to be collected at the same time, and the laboratory analyses to use the same methods and equipment. It is necessary to call attention to the nutritional quality of the products got organically, and to take into account the following main parameters: vitamins, proteins, minerals, carbohydrates, dry matter, acidity, chemical control of pesticides, toxins, nitrates, heavy metals, secondary metabolites, and microbial contamination.

The estimation of the flavours of fruits and vegetables obtained organically varies, depending on the preferences of each person. In general, the nutrient content is higher in organic crops (Worthington, 1998).

The quality of horticultural products is established according to the laboratory analyses, through which their physical and chemical properties are evaluated.

In order to get a high production with a superior qualitative value, it is necessary to ensure optimal conditions for growing vegetables and fruits. All these conditions are part of the **agrotechnical measures** for cultivation and maintenance of crops, and include: soil maintenance works, application of irrigation systems, carrying out pruning works on trees, application of fertilizers, and so on.

The soil maintenance works influence the water regime in the soil, the porosity of its surface layer, the development of microorganisms, etc., all of these leading to a good development of horticultural plants, with great results in terms of both quantitative and qualitative production.

If we choose to keep a soil in the form of unworked soil in orchards (apples for example), it will have the effect of more intense colouring of fruits, with an increase in their phosphorus content, achieving the necessary storage conditions.

The use of **irrigation systems** ensures that horticultural plants have a favourable effect on the growth and maturation processes. Under the conditions of a balanced irrigation, according to the water requirement, there is an increase in both the volume and the quality of fruits during the storage period. An excessive use of irrigation increases the water content in plants, decreasing the content of soluble dry matter (Gherghi et al., 2001), and the nutritional values, especially those related to taste.

It is possible to grow vegetables with impaired watering, but when exactly watering will be shortened should be very well planned. Drought in carrots at the beginning of their cultivation leads to poor quality products that do not withstand long-term storage. Water stress at the beginning of tomato development also adversely affects both yield and production (Workneh and Osthoff, 2010). In cabbage, water deficiency is unfavorable during the formation and growth of heads.

The **pruning work** on trees aims to create the framework for the best possible biological development, and to maintain a balance between their leaves and fruits. If the cuts are too severe, then there will be a smaller number large size fruits, with a higher content of soluble dry matter and a lower value of acidity. The pigmentation of these fruits is more intense, the storage capacity is lower, and they can reach maturity earlier than usual. If the tree branches have been cut, the fruits will be larger in number, but smaller in size, and low in carbohydrates.

The quality of horticultural products is reflected both in the properties of the product to meet the food requirements of the population, and in the economic aspects of processing and use of products.

Quality is born in the research stage. It is developed in the production course, and is highlighted in the consumption process.

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Unit 1.3: Influences on nutritional quality along the food chain

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The nutritional quality of food along the food chain is a dynamic interplay of numerous factors. Researchers in this field aim to understand and address these influences to ensure that food remains a reliable source of essential nutrients for the global population. The development of sustainable and nutritionally sound food systems is a crucial focus in addressing food security and public health concerns.

1.3.1 Pre-harvest technologies. Cultivation technology influence on nutritional quality

Quality of fresh vegetables and fruits are conducted by many factors (Siddiqui, 2015). Regarding the pre-harvest factors and cultural practices, a lot of studies demonstrated their influence on the postharvest physiology, quality and storage life, event true the time, has been given less importance to this aspect (Kader, 2002; Salami et al., 2010; Siddiqui, 2015).

According Tyagi et al. (2017), the post-harvest quality of fruit crops can be affected by many aspects such as **genetics**, **environmental factors**, **cultural practices** and **physiological factors**.

The pre-harvest activities are essential in ensuring that agricultural practices are environmentally sustainable, economically viable, and contribute to ending hunger and improving livelihoods worldwide.

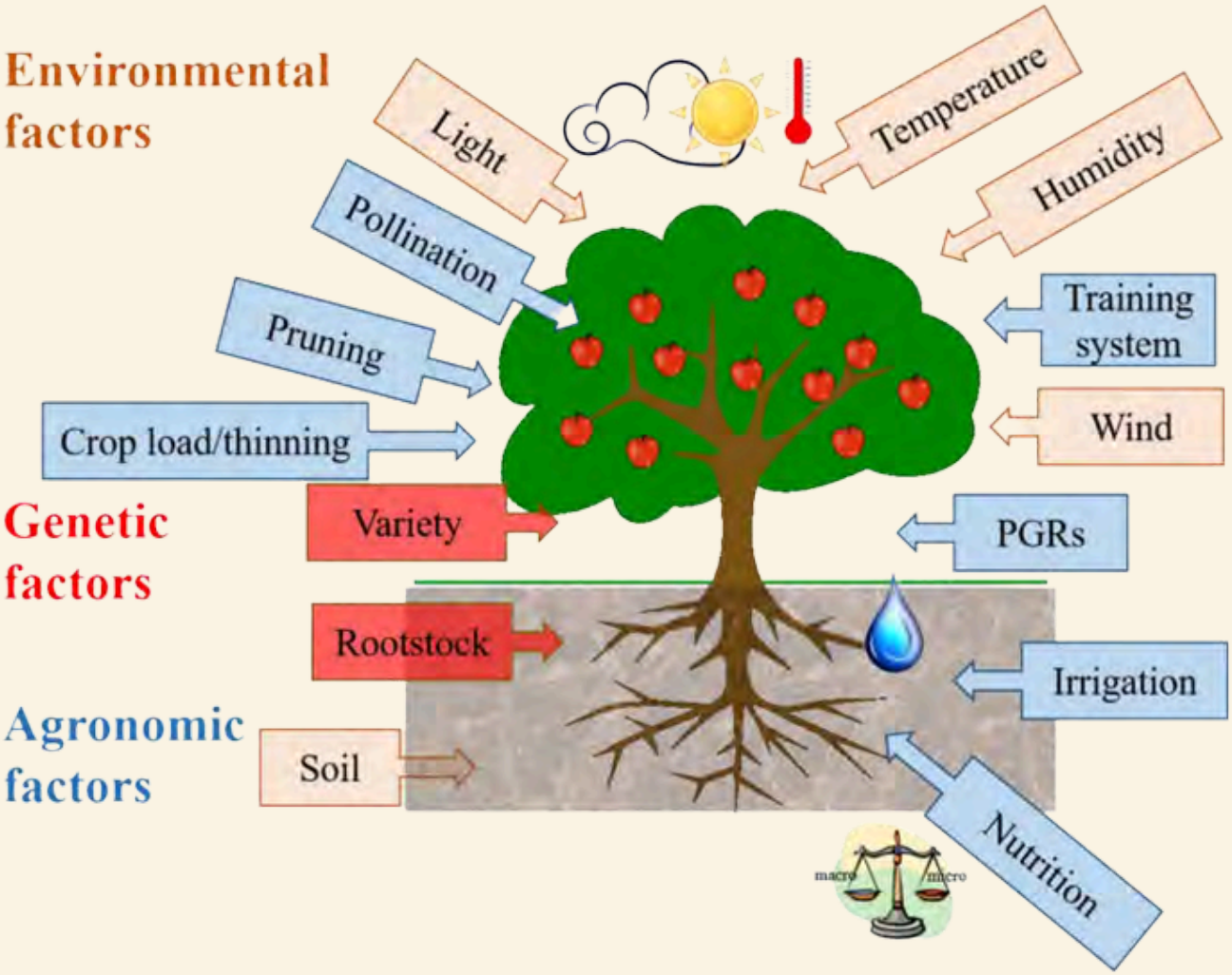


Figure 5. Factors affecting apple quality grouped in genetic, environmental and agronomic (Source: Musacchi et Serra, 2018)

The studies conducted by Musacchi et Serra (2018) showed that environmental and agronomic factors along all the growing season strongly affect the final apple quality including the nutraceutical aspects (Figure 5). Temperature and light contribute to several modifications of external and internal apple quality like red overcolor and dry matter accumulation, but also can trigger unwelcome disorders like sunburn.

Orchard design, training system and pruning can dramatically impact the skin overcolor and the maturity of the fruit. Crop load and thinning can determine physiological adjustments that benefit the dry matter accumulation in the fruit. Irrigation and nutrition can modify the overcolor and the chemical composition of the flesh.

Genetic factors are represented especially by species, cultivar and rootstock (Musacchi et Serra, 2018; Tyagi et al., 2017). Several parameters of quality, such as colour, shape, size, weight and biochemical composition, are controlled genetically (Musacchi et Serra, 2018; Scalzo et al., 2010; Tyagi et al., 2017). Cordenunsi et al. (2005) reported significant differences in chemical composition among different strawberry cultivars (Table 1). Cultivar and specie selection is therefore critical to the postharvest qualities of fruits (Cordenunsi et al., 2005; Tyagi et al., 2017).

CONSTITUENT	CULTIVAR					
	MAZI	OSO GRANDE	DOVER	PAJARO	TOYONOKA	CAMPINEIRO
Water (%)	91.2 ± 0.2	90.5 ± 0.3	93.1 ± 0.1	90.8 ± 1.3	89.7 ± 0.2	92.8 ± 0.2
Soluble solids (%)	7.5	8.0	5.4	9.0	9.4	6.0
Glucose (mg/100 g)	713 ± 108	1713 ± 23	1520 ± 82	951 ± 52	1495 ± 271	1371 ± 389
Fructose (mg/100 g)	1327 ± 35	1928 ± 37	1852 ± 99	1232± 66	1591 ± 18	1547 ± 37
Sucrose (mg/100g)	661 ± 12	1803 ± 67	908 ± 30	807 ± 48	1316 ± 21	847 ± 29
Citric acid (mg/100 g)	600	590	680	ND	590	710
Total ascorbic (mg/100g)	50.9 ± 0.4	63.3 ± 2.3	40.1 ± 5.5	69.3 ± 2.1	55.6 ± 3.8	85.3 ± 0.8
Anthocyanin (mg/100 g)	54.9 ± 5.6	42.2 ± 8.3	52.2 ± 6.6	21.2 ± 2.0	19.1 ± 1.5	13.4 ± 2.3
Total phenolics (mg/100 g)	174.3 ± 2.3	249.8 ± 0.7	219.7 ± 0.6	233.1 ± 2.1	158.6 ± 3.0	289.2 ± 8.7

Table 1. Chemical composition of some strawberry cultivars harvested at the ripe stage
Source: Tyagi et al., 2017; Cordenunsi et al., 2005

Leafy vegetables have higher concentrations of nutrients that are less mobile in the plant (e.g., calcium) and depend on direct water flow rather than recycling from older leaves. Mineral concentrations may vary widely among cultivars (Vicente et al., 2022).

Environmental factors include radiation, temperature, carbon dioxide (CO2) and ozone (O3) concentrations, rainfall, wind, frost, hailstorm, pollution and also harvesting season and time (Barman et al., 2015; Siddiqui, 2015; Tyagi et al., 2017), besides geographical area, as well as soil type, moisture, pH and health (Hornic, 1992).

Radiation interception in the field have been associated with modifications in the level of nutritional composition and antioxidant capacity of fruit (Tyagi et al., 2017). Sun-exposed sides of fruits have higher levels of phenolic and vitamin C than shaded regions (Lee et Kader, 2000). Studies performed by Woolf et al. (1999), with some avocado shown that fruit produced with exposed to the sun contained higher dry matter, higher levels of calcium, magnesium and higher oil content than shady fruit.

In leafy vegetables, there are 10 times more flavonols in surface leaves than in internal leaves. (Vicente et al., 2022). When tomato plants are exposed to more light, the content of total phenols, carotenoids and ascorbic acid increase. Increasing temperature from 21 to 26°C reduced total carotene content without affecting lycopene content.

When further temperature increased from 27 to 32°C reduced ascorbate, lycopene, and its precursor's content, but enhanced rutin, caffeic acid derivates, and glucoside contents. Both excessive solar radiation and temperature (> 30–35°C) inhibit lycopene biosynthesis in tomato and stimulate the oxidation of both lycopene and β-carotene (Gautier et al., 2008).

The exposure of fruits to **excessive sunlight** results in the occurrence of sunscald in several fruit crops (Barman et al., 2015). The direct exposure of the sunlight on the fruit surface results in pigment degradation in the affected surface area of the fruit.

Further, cellular death and collapse of the affected tissue occurs if the duration of exposure of sunlight or its intensity is higher than adequate or optimum levels. This influence of high sunlight exposure causing stress to the fruits is mainly thermal in nature, although some bleaching of the chlorophyll pigment can also occur.

Some examples of quality degradation due to exposure to excessive or insufficient sunlight are detailed in the Table 2 9 (Source: Barman et al., 2015).

Specific disorders like water core in apple, flesh translucence in pineapple, stylar-end breakdown in lime were also reported by various workers due to weak and insufficient light presence (Barman et al., 2015).

NAME OF THE FRUIT	REFERENCE	SYMPTOMS
Persimmon	George et al. (1997)	Sun Scald
Mandarin	Myhob et al. (1996)	Sun Scald
Pomegranate	Panwar et al, 1994	Sun Scald
Blueberry	Caruso (1995)	sun Scald
Pineapple	Lutchmeah (1992)	Sun Scald
Apple	Campbell et Marini (1992) Sibbett et al. (1991)	Low sunlight intensity reduces the color development Sun Scald
Banana	Wade et al. (1993)	Sun Scald
Strawberry	Osman and Dodd (1994)	Insufficient light typically results in smaller size fruit and decreases the surface glossiness in strawberry

Table 2. Quality deterioration due to excess or insufficient sunlight in various

Temperature represents an important parameter, because most of the vegetable and fruit crops have specific temperature requirements for the optimum development of yield and quality parameters (Tyagi et al., 2017). Temperature influences the uptake and metabolism of mineral and nutrition by plant. Increasing temperature increase the transpiration, while lower temperature influences the flower sex and fruit setting. During the development stage of fruit, variation in temperatures can affect photosynthesis, respiration, aqueous relations and membrane stability as well as levels of plant hormones. High temperatures can increase the rate of biochemical reactions catalyzed by different enzymes and affect the mineral accumulation.

Fruits like grapes and apple contain higher sugar and lower acid content when grown under high temperature (Musacchi et Serra, 2018). Wurr et al. (1996), reported that kiwi grown under higher temperatures matured earlier that the same crops grown under lower temperatures.

High temperature also increases sunburn and cracking in apples, apricot and cherries and increase in temperature at maturity will lead to fruit cracking and burning in litchi (Kumar et Kumar, 2007). Higher temperatures can increase the capacity of air to absorb water vapors and, consequently, generate a higher demand for water.

Higher evapotranspiration indices could lower or deplete the water reservoir in soils, creating water stress in plants during dry seasons. For example, exposure to elevated temperatures can cause morphological, anatomical, physiological, and, ultimately, biochemical changes in plant tissues and, as a consequence, can affect growth and development of different plant organs. These events can cause drastic reductions in commercial yield (Wang and Zheng, 2001).

Preharvest exposure of fruit and vegetables to direct sunlight leads to a number of postharvest physiological disorders among which, sunburn or solar injury is the most prevalent temperature-induced disorder in fruit and vegetables (Table 3).

FRUIT	DISORDER	SYMPTOMS	REFERENCE
Apple	Sunburn	Skin discoloration, pigment breakdown	Bergh et al. (1980), Wünsche et al. (2000)
Apple	Watercore	Water soaking of flesh	Marlow and Loescher (1984)
Avocado	Sunburn	Skin browning	Schroeder and Kay (1961)
Pineapple	Flesh translucence	Water soaking of flesh	Paull and Reyes (1996); Chen and Paull (2000)
Lime	Stylar end breakdown	Juice vesicle rupture	Davenport and Campbell (1977)
Cranberry	Sun scald	Tissue breakdown	Croft (1995)

Table 3. Disorders associated with preharvest exposure of fruit to high temperature or direct sunlight.

Source: Barman et al., 2015; Woolf and Ferguson, 2000

Factors like **high light intensity**, **high ambient temperature** and **moisture stress** increase the propensity of sunburn. Initial symptoms of sunburn include bleaching or yellowing of the peel in apple (Bergh et al., 1980) and corky or rough fruit surface in avocado (Schroeder and Kay, 1961).

Temperature is the main factor influencing the growth and development, as well as the quality of vegetables. Vegetable species have different temperature requirements: tomatoes are heat-loving and carrots are cold-resistant. Worknehand and Osthoff (2010) summarizes that carrots grown at high temperatures have been found to have a higher total sugar content, while those grown at low temperatures are sweeter, especially due to the higher sucrose content.

Carbon dioxide (CO_2) and ozone (O_3) concentrations in the atmosphere are changing during the last decade and are affecting many aspects of fruit crops production around the globe (Felzer et al., 2007; Lloyd et Farquhar, 2008). Ozone concentration in the atmosphere is also increasing which can potentially cause postharvest quality alterations in fruit crops. Stomata conductance and ambient concentrations are the most important factors associated with ozone uptake by plants. Ozone enters plant tissues through the stomates, causing direct cellular damage, especially in the palisade cells (Mauzerall et Wang, 2001).

The damage is probably due to changes in membrane permeability and may or may not result in visible injury, reduced growth and, ultimately, reduced yield (Krupa et Manning, 1988). The direct impact of climate change, and more specifically the increased CO2 content, is more pronounced on C3 plants. Initially, it was found that increased CO2 concentrations also increased the yield of these plants, but long-term studies have shown that yields gradually begin to decline over the years, with increasing CO2 concentrations. Increasing the CO2 concentration by 250 ppm also increases the yields, being higher in legumes than in leafy vegetables. When CO2 levels increase above 400 ppm, yields decrease (Scheelbeek et al. 2018; Leisner 2020).

The effect of the concentration of carbon dioxide on the content of vitamins and minerals has not been proven, but it is believed to increase the level of antioxidants (Scheelbeek, et al. (2018).

In general, elevated concentrations may play the role of 'foliar fertilizer' as it is ingested through the leaves and tissues of plants, but some species are deficient in macro and micronutrients, proteins and other nutrients useful to humans. Consumption of such plants, which are depleted of nutrients, leads to increased deficiencies of vitamins and minerals in humans. This is how the so-called "**Hidden hunger**" (DaMatta et al. 2010; Leisner, 2020).

The term "hidden hunger" means an insufficient supply of vitamins and minerals such as zinc or iron, even though a person eats enough calories (Müller et al. 2014). The products themselves, which are present on the table, have a reduced content of these substances

Rainfall affects the water supply to the plant resulting influences the composition of harvested fruits (Tyagi et al., 2017). Fruits are more susceptible to mechanical damage during shipment. Rain increased the susceptibility of fruit to handling damage. During prolonged periods of rain fruit quality may revert to that prevailing prior to the start of the rain event. High rainfall and the consequences on fruit growth also increase incidence of skin cracking disorders, such as found in cherries (Sekse, 1995) and in apples (Opara et al., 1997).

Wind can cause damage to the fruit and vegetables, during growing season (Barman et al., 2015). Damage by winds can be grouped into two categories: damage caused by less frequent severe storms; and that caused by frequent winds of intermediate strength. High velocity winds result into damage of leaves and defoliation in leafy vegetables, which cause severe damage in product appearance and market ability (Kays, 1999). In fruit crops, defoliation leads to smaller size fruit (Eckstein et al., 1996) and development of poor fruit color in citrus (Ogata et al., 1995). Mild winds may cause wind scarring disorder due to rubbing of fruits against twigs.

The injured fruit develop some silvery patches which increase in size with the advancement of maturity. It may also cause friction marks on kiwifruit (McAneney et al., 1984; Lizana et Stange, 1988), wind rub on persimmon (George et al., 1997) and wind scab of French prune (Michailides et Morgan, 1993). Therefore, use of windbreaks is advocated for production of fruit and vegetable in areas subjected to excessive wind (Holmes et Koekemoer, 1994).

Hailstorm during fruit growth causes direct damage to the crop by increasing percentage of deformed fruit (Hong et al., 1989) and anatomical alteration (Visai et Marro, 1986; Fogliani et al., 1985). It also causes indirect damage by increasing incidence of diseases, like bacterial spot in pepper (Kousik et al., 1994).

The severity of damage depends upon factors like hail stone size, growth stage of crop and duration of exposure (Duran et al., 1994). Damage of hails can be minimized by use of hail nets over trees of fruit crop, for example in apple, pear plantations (Reid et Innes, 1996) or covering the fruit bunches, in banana pantation (Eckstein et al., 1996).

Pollution can be produced by excess of air pollutants such as ozone, sulfur dioxide, fluoride and nitrogen oxides and can cause severe damage and reduce quality of fruit and vegetables during their growth (Barman et al., 2015).

During the summer season when high temperature and solar radiation prevails the production of ozone in the atmosphere generally increases due to increase in nitrogen species and emission of volatile organic compounds (Mauzerall et Wang, 2001). Ozone enters into the plant system through stomata and causes cellular damage by increase in membrane permeability and may cause injury (Mauzerall et Wang, 2001). Higher concentration of ozone in the atmosphere also affects the photosynthetic and respiratory processes in plants which ultimately affects postharvest quality in terms of overall appearance, color, flavor and increase turnover of antioxidant systems (Grulke et Miller, 1994; Tjoelker et al., 1993; Percy et al., 2003).

Elevated atmospheric concentrations of ozone may also lead to yellowing or chlorosis in leafy vegetables, blistering in spinach, alter sugars and starch content in fruit and tuber crops and reduce fruit size by decrease in biomass production (Kays, 1999; Felzer et al., 2007).

Fluoride causes discoloration in peach fruit. Similarly, higher concentration of nitrogen dioxide in the atmosphere results in marginal and interveinal collapse of lettuce leaves (Kays, 1999). Apart from air pollutants, ions of heavy metals like silver, cadmium, cobalt, magnesium, manganese, nikel, zinc etc. which may enter into the plant system through soil amendments, runoff, or contaminated irrigation water also can cause deterioration in quality of fruits and vegetables (Kays, 1999)

Harvesting season and **time** influences the quality of fruits and vegetables (Tyagi et al., 2017). When fruits are harvested in off season give more remunerative price to the grower. Harvesting during or immediately after rains should not be carried out since it creates most favorable conditions for multiplication of microorganisms. Harvesting at improper maturity leading to lower eating quality, failure to ripen or excessive softening. Fruits should be harvested when temperature is mild because, higher temperature leads to faster respiration. Non climacteric fruits like cherry, strawberry, grapes pine apple, pomegranate should be picked at full ripe stage, because they are producing very small quantities of ethylene and don’t respond to ethylene treatments.

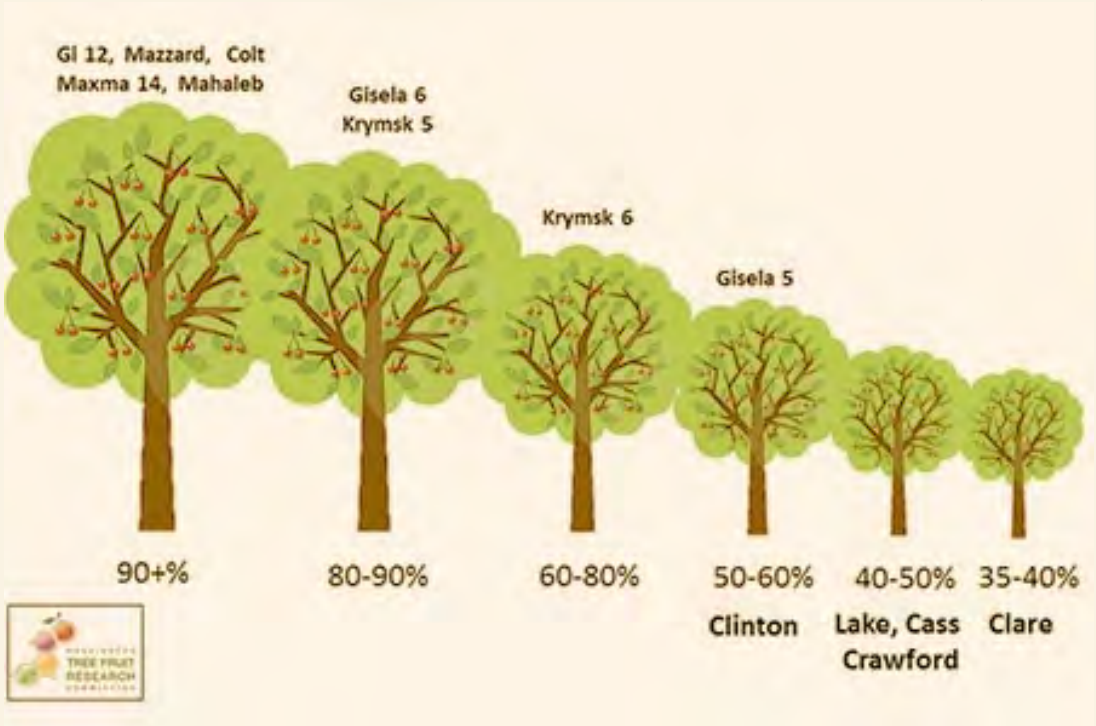
Non climacteric fruits like cherry, strawberry, grapes, pine apple, pomegranate should be picked at full ripe stage, because they are producing very small quantities of ethylene and don't respond to ethylene treatments. **Climacteric fruits** like apple, mango, papaya, pear, peach sapota etc. produce larger quantities of ethylene and it should be picked at full maturity stage. Nagy (1980) reported that immature citrus fruits contained the highest concentration of vitamin C, whereas ripe fruits contained the least.

Non climacteric fruits

Climacteric fruits

Cultural practices can be root stock scion relationship, trunk cross sectional area of rootstock, pruning, thinning and girdling, planting density, canopy position, plant growth regulators, irrigation, mineral nutrition, organic production, soil maintenance, fruit bagging (Barman et al., 2015; Siddiqui, 2015; Tyagi et al., 2017).

The rootstocks in tree fruit crops are used to influence precocity, tree size, fruit quality, yield efficiency, mineral uptake, and to withstand adverse environmental conditions. Rootstock effect is clearly identifiable in the development of fruit firmness, fruit weight, and biochemical composition such sugars, acids, polyphenols, anthocyanins, vitamins (Calves et al., 2005; Kremer-Köhne and Köhne, 1992; Spinardi et al., 2005).



Rootstocks for Cherry
Source: https://treefruit.wsu.edu/web-article/cherry-rootstocks/

Trunk cross sectional area of rootstock, influenced the fruit quality in terms of total soluble solids, acidity and leaf nutrients contents (Dalal et Brar, 2012). According Kumar et al. (2008) trunk cross-sectional area of tree fruit crops may be a useful index for estimation of growth, yield and quality of fruits. Kumar et al. (2016) reported at apricot, positive relationship between TCSA and yield.

Pruning reduce the vegetative buds and increase the development of new shoot and attributes to altered hormonal conditions better nutritional translocation in more number of new shoots and canopy frame work (Tyagi et al., 2017). In competition between vegetative and reproductive growth observations fruit are dominance sink and reproductive sink have a higher priority for water and nutrient than other plant parts. Pruning treatment appears to be an alternative strategy to obtain better yield and quality in densely populated old mango orchards (Asrey, 2013). Fruits of severe and medium pruning had more TSS content in ber (Khan et Hossain, 1992). Shoot pruning is also helpful in reducing the tree size and improving the fruit quality of guava (Lal et al., 2000).

Thinning reduces the competition between fruits or plants and thus promotes a good balance between the vegetative and fruit parts and improves quality (Tyagi et al., 2017). In case of grapes over cropping can reduced fruit quality in current season and can also result in poor bud break, delayed growth and reduced fruit yield in the following season (Somkuwar et al., 2014).

Fruit thinning is one of the most efficient and widely used methods of obtaining high quality apples (Basak, 2006). BA treatments for fruit thinning led to fruit elongation, decreased fruit firmness and starch index, increased soluble solids content in apple (Milic et al., 2013). Flower bud thinning was more effective in enhancing the fruit size, weight and quality as compared to flower and fruits thinning in kiwifruit (Thakur et Chandel, 2004).

Girdling (removal of bark) can improve the balance between vegetative and fruit growth in a tree (Barman et al., 2015). Girdling of grapes is practiced commercially in vines that have extra vigor and produced poor quality fruit. It increases the size and shape of berry and delays its ripening by lowering sugar: acid ratio and color intensity. In case of peach and nectarines, girdling 4–6 weeks before harvest increases the size of fruit and advances its maturity (Day, 1997). But, if girdling is done too early during pit hardening, it causes splits in pits of peach and nectarine. These fruits soften more quickly than intact fruits and are highly susceptible to decay (Crisosto et Costa, 2008).

Planting density can decrease fruit quality if it high, because increases competition between plants and reduces light availability (Tyagi et al. 2017). The average light intensity and temperature during the fruit season has been reported to affect the post-harvest quality of strawberry (Cordenunsi et al., 2005).

Total soluble solids were decreased with increasing plant density in muskmelon (Mendlinger, 1994). Poor **management of fertilizers** will increase physiological disorders in fruit crops due to deficiencies of some minerals or increase of other leading to toxicity. Increasing planting density decreased fruit quality (fruit weight, colour, soluble solids, sucrose, glucose, fructose, sorbitol, malic and citric acid) in apple (Stampar et al., 1998). **Canopy position** (inside/outside or southern part/northern part) can influence the fruits quality in terms of appearance (size, shape, color) and sensorial (texture, sugar, acid content). For example, apples (cv. Aroma) produced outside the canopy contain higher level of dry matter, soluble solids and soluble sugars than those produced inside the canopy (Nilsson et Gustavsson, 2007). These fruits also develop a darker red peel color while, those produced inside canopy remain green. This is due to higher light intensity on the outside canopy, which facilitates accumulation of soluble sugars like fructose, glucose and sucrose and also synthesis of anthocyanin pigments in the fruit.

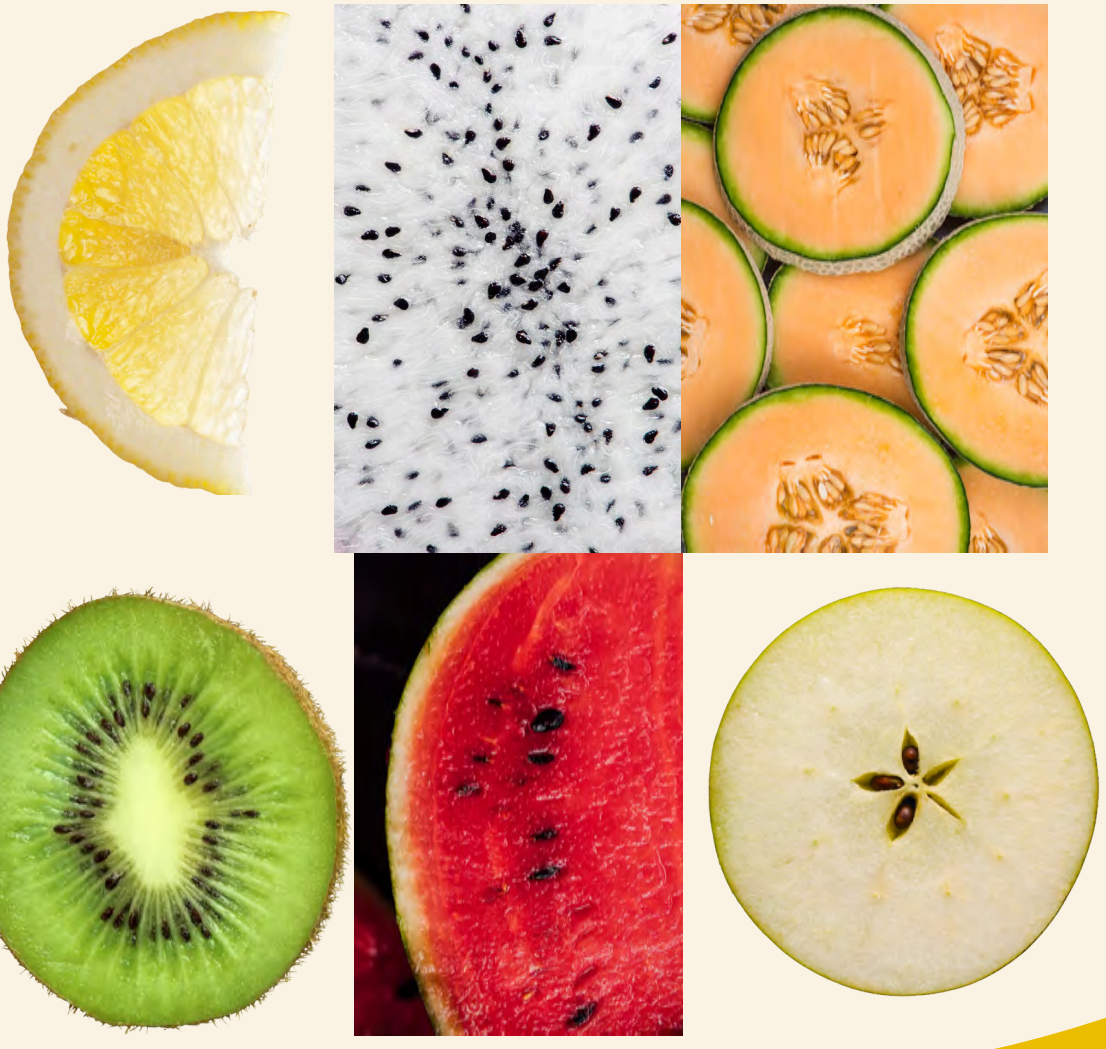
Plant growth regulators can provide significant economic advantage to the growers when used in appropriate concentration, as these have proven effective in stimulating a number of yield and quality parameters (Tyagi et al., 2017). For increase yield it is necessary to increase the fruit set. The growth regulators also contribute towards fruit growth and development.

Some of the plant growth regulators and chemicals are synthesized **endogenously** but occasionally they need to be supply minted **exogenously** for the intended purpose of improving fruit set, quality and yield. Application of synthetic gibberellins is widely known to improve fruit set in apple and pear, according with Gill et al. (2012). **Gibberellins** are used for increasing fruit size and firmness of cherries and peaches (Canli et al., 2015; Lurie, 2010). Increase in flowering may lead to more fruit and coupled with increasing in fruit size may be determine by cell increased, cell layer formation and cell division with increase sink strength of fruit. Fruit size increase due to **cytokine** and gibberellins application to apple and grapes was suggested to be cause by increased cell division and elongation and cell wall extensibility (Emongor et al., 2001; Yu et al., 2001).

Irrigation it is important for a good production and quality fruits and vegetables (Tyagi et al., 2017). It is well documented that water stress not only reduces crop productivity but also tends to accelerate fruit ripening (Henson, 2008).

Pre-harvest water stress caused increased post-harvest browning potential in avocado and also interacted adversely with restricted ventilation (Bower et Cutting, 1987). Decreasing fruit moisture loss during storage significantly decreased the incidence of pathological and physiological disorders (Bower et Cutting, 1987). Moisture stress also increase sunburn and cracking in apples, apricot and cherries and increase in temperature at maturity will lead to fruit cracking and burning in litchi (Kumar et Kumar, 2007). Irrigation influences the water and nutrient supply to the plant and can affect the nutritional and antioxidant capacity of fruit. In the case of peaches, it has been shown that lower levels of irrigation results in higher density of fruit surface trichomes and consequent lower weight losses in storage (Crisosto et al., 1995).

Mineral nutrition has significant impacts on fruit quality (Tyagi et al., 2017). These include effects on fruit color, texture, disease susceptibility, juice composition, and the development of physiological disorders (Singh et al., 2013). Fruit quality usually improves as soil moisture and nutrients increase from deficient to optimum, levels that produce maximum yield may not always correspond to those that result in the highest fruit quality and maximum quality retention (Mark et al., 2002). Poor management of fertilizers will increase physiological disorders due to deficiencies of some nutrients or increase of other leading to toxicity.



Plant protection products (PPP) can deeply affect the nutritional quality, but the most known effects are not directly affecting the content of different components, but lead to different contamination with chemicals. After countless studies, pesticides have been linked to cancer, Alzheimer's Disease, ADHD, and even birth defects. Pesticides also have the potential to harm the nervous system, the reproductive system, and the endocrine system (Jakuboski, 2011). Still, some research indicate that nutritional quality may be affected, as the research on “Incredible” sweet corn variety (Zea mays L. var. rugosa) treated with different herbicides, where authors discovered that disruptions in biochemical pathways in plants due to pesticides have the potential to alter the nutrient quality, taste, and overall plant health associated with edible crops (Cutulle et al., 2018).

Organic production is a form of agriculture which excludes the use of synthetic fertilizers and pesticides, plant growth regulators and genetically modified organisms (Singh et al., 2009; Stockdale et al., 2001). Continues use of chemical fertilizers without organic manures cause problems to soil health and decrease the quality of produce. Living mulch and straw mulch increase earth worm and increase cation exchange capacity. A sawdust mulch reduced physiological disorders in apple fruit and increased the Ca and K concentrations in the leaves (Lang et al., 2001). Organic management in apple may delay on-tree fruit ripening and also improve the fruit eating quality (Eman et al., 2007).

The increasing demand of consumers for fruit quality coupled with unsustainable productivity, organic farming is claimed to be most alternative. In this situation, the use of organic manures and biodynamic become important for quality improvement of fruits and vegetables.

Organic vs. unorganioc apples

Pre-harvest packaging in fruit crops protects the fruit from the attack of pest such as fruit fly and guava weevil (Siddiqui, 2015; Tyagi et al., 2017). Different types of bagging material are used like Kraft type paper, baking paper, polyethylene, poly propylene spun bond fabrics (PSF), Bio degraded films. The variation in temperature, humidity, wind and sunlight are main factor responsible for mechanical injury and the increase in film rigidity, probably due to degradation of cross links. Photo degradation and cross linking are main causes of structural changes, the loss of resistance, increase in fragility of films. Poly propylene spun bond fabrics (PSF) having good mechanical resistance and bio-degradability.

Kudachikar et al. (2000) reviewed that the shelf life of berry fruits can be extend by coating the fruits in wax followed by packing in polythene bags. Maniwara et al. (2015) observed that the MAP-2 plastic showed the best results in maintaining fruit quality, gas composition, and extension of storage life (up to 51 days) in passion fruit.

Physiological factors involved that influenced the fruit quality are auxins, respiration and transpiration processes, ethylene synthesis, water loss etc. (Tyagi et al., 2017). Fruit size in general is negatively correlated with firmness and amount of berry phenolics (Ali, 2012). Fruit size can be improved either by increasing carbohydrates availability to fruit or by increasing fruit sink strength (Agusti et al., 2002). When the synthetic auxins are applied at the onset of cell enlargement stage fruit sink strength is increased and carbohydrates accumulation in the fruit enhanced (Agusti et al., 2002).

Smaller fruits are firmer as they have the same number of cells as larger fruit, giving a greater density to the plant tissue (Ali, 2012). The relationship between ripening period and temperature is due to fruit respiration. Fruit respiration depends on many enzymatic reactions, and the rate of these reactions increases exponentially with increase in temperature. Fruit bearing order may also have a significant effect on the bioactive compounds in berry crops like mulberry (Ali, 2012). The phenolic content is reported to be increased by 10-25% from primary to tertiary fruits (Anttonen et Karjalainen, 2009). Water loss causes fruit to lose its firmness, the peel or pulp becomes soft and shriveled, and ripening period reduces (Paull, 1999).

Conclusions

- The pre–harvest factors, such climate change and cultural regime are directly and indirectly influence the production and quality of fruit crops grown in different climates around the world.
- Lack of cultural practices leading to undesirable fruit quality with non-uniform maturation.
- Temperature can directly affect crop photosynthesis, and a rise in global temperatures can be expected to have significant impact on postharvest quality by altering important quality parameters such as synthesis of sugars, organic acids, antioxidant compounds and firmness.
- Rising levels of carbon dioxide and Increased levels of ozone in the atmosphere can lead to detrimental effects on postharvest quality of fruit crops.
- Nutrition management and organic fertilization in fruit crops significantly influences the level of different bioactive compounds in fruits, so optimized fertilization is very important for marketability of fruits after harvest.
- Finally, the use of new cultivars of fruits crops tolerant to high temperature, resistant to pests and diseases, short duration and producing good yield under stress conditions, as well as adoption of hi–tech horticulture and judicious management of natural resources can be good strategy for improvement in post-quality of fruit crops.

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https://treefruit.wsu.edu/web-article/cherry-rootstocks/

1.3.2 Fruit and vegetables selection for processing

Fruit and vegetables can be either used for direct consumption or for processing. Usually, the best fruits are chosen for imediat marketing while the products that show some signs of alterations are redirected for processing. Still, the selection of fruits and vegetables is highly dependent of the final destination of the processed product.

The selection of fruits and vegetables for processing is a critical step in the food industry, and it involves several scientific considerations to ensure the quality and safety of processed products.

- Avoid fruits and vegetables with cuts, bruises, insect holes, mold or decay signs. But, remember that the size or shape does not alter the taste or chemical composition, therefore, all shapes and sizes make great fruit and vegetables.

- Avoid the fruits and vegetables that are being kept fresh for a long period of time, as the quality tend to decrease during storage and transportation time. During the wintertime, fruits imported from faraway countries may have weaker quality than the same frozen local products. Fresh produce is best when bought in its season and locally for maximum flavor and nutrition. Canned fruits and vegetables are also nutritious, the value for human body depends also on the quantity of added salt, sugars syrup, other additives.

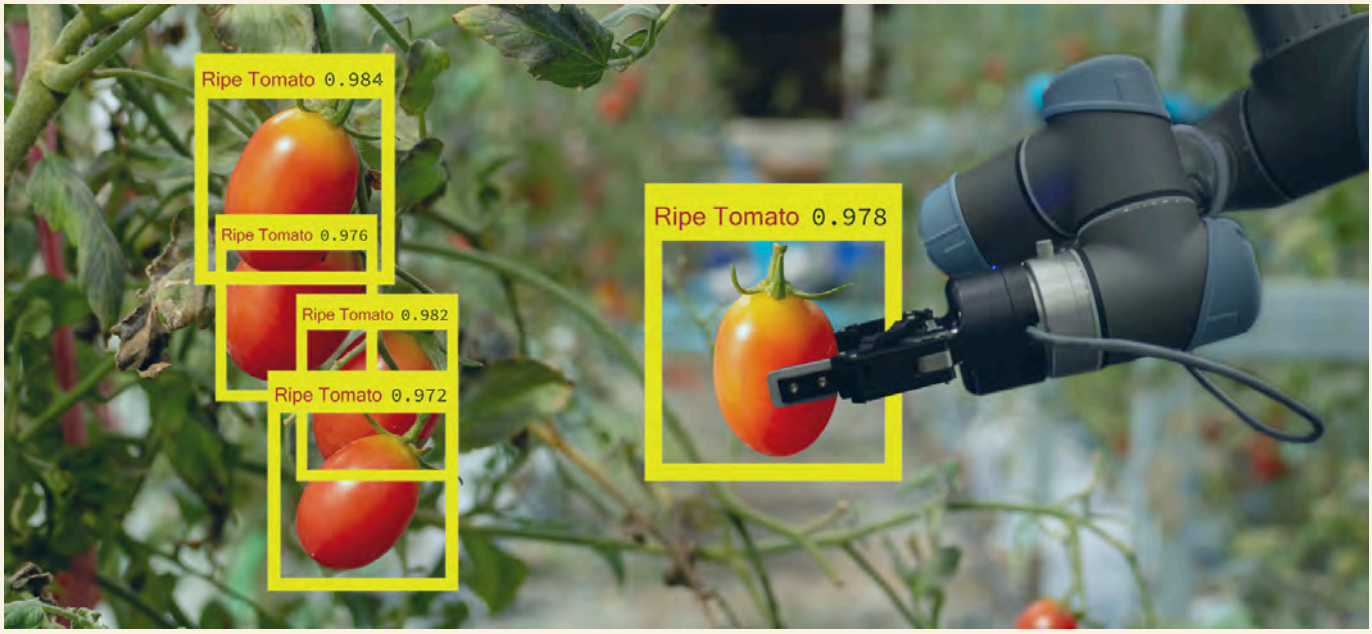
- Avoid the unripe fruits. When fruits ripe, they softens and change the color, but the ripening process depends on the fruit. For example, oranges and grapefruit will not get any sweeter once picked, peaches and bananas will change color and get sweeter, but they bruise easily in shipment, so they should be picked unripen.

- Avoid the products that are limp and starting to turn brown, and prefer instead the crisp and colorful one, when the vegetables are in their season.

1.3.3 Postharvest technologies – Variation of nutritional quality of fruits and vegetables during storage

After harvest, there is a finite period of time in which fruits and vegetables maintain their fresh-like appearance while also becoming increasingly susceptible to a decrease in their nutritional value (Velderrain-Rodríguez et al., 2019).

Investigations in this area are essential for advancing storage and management techniques that preserve the nutritional integrity of fruits and vegetables. Such research plays a vital role in enhancing food security and elevating public health standards.



The postharvest phase is a critical stage in the life cycle of fruits and vegetables. Once harvested, these commodities enter a vulnerable period where the retention of their nutritional qualities becomes a significant concern. While the primary focus has often been on extending the shelf life of produce, there is an increasing emphasis on ensuring that the nutritional content is also preserved. This capter explores the multifaceted role of postharvest technologies in maintaining the nutritional quality of fruits and vegetables during storage, emphasizing the underlying science and technological advancements in the field.

Nutrient Degradation

Many studies focus on how the nutritional content of fruits and vegetables changes during storage. Vitamins, such as vitamin C and B vitamins, can degrade over time. Antioxidants like polyphenols may also be affected.

Nutrient degradation refers to the process by which essential nutrients in foods, such as vitamins, minerals, and other bioactive compounds, deteriorate or diminish in quantity and quality. This degradation can occur due to various factors, including exposure to light, heat, oxygen, and time. Understanding nutrient degradation is crucial in food science, nutrition, and food preservation. Here are some key points related to nutrient degradation:

Mineral Retention

Some minerals are more stable during storage and essential minerals like potassium and magnesium in various fruits and vegetables are important for fruit quality.

Respiration Rate

The respiration rate of fruits and vegetables is an important factor that influences nutrient changes during storage and different storage conditions can impact respiration and subsequent nutrient degradation.

Temperature and Humidity

Storage temperature and humidity levels play a critical role in maintaining the nutritional quality of produce. Studies assess the optimal conditions for different types of fruits and vegetables to minimize nutrient loss.

Modified Atmosphere Packaging (MAP)

This technology can help maintain nutritional quality by controlling oxygen and carbon dioxide levels.

Effect of Light

Light exposure can lead to the degradation of certain nutrients, particularly in leafy greens and some fruits and impact nutrient loss during storage.

Freezing and Drying Methods

The choice of freezing or drying methods can have a significant impact on nutrient retention in various food products. This is an important consideration for both food preservation and maintaining the nutritional quality of foods.

Postharvest Treatments

The choice of freezing or drying methods can have a significant impact on nutrient retention in various food products. This is an important consideration for both food preservation and maintaining the nutritional quality of foods. Some of postharvest treatments, such as irradiation or controlled atmosphere storage are used to extend the shelf life while minimizing nutrient loss.

Variability Among Produce

It's well-established that different fruits and vegetables have distinct rates of nutrient loss over time. Understanding these variations is essential for optimizing storage and handling practices to preserve the nutritional quality of various produce items.

1.3.4. Processing technologies

In this chapter we are learning about variation of nutritional quality of fruits and vegetables with the processing technologies (drying, juice and concentrated products, freezing, dehydration, canning, minimal processing so on) - comparative result with fresh products

The term "**minimal processing**" refers to the use of one or more methods, techniques, or procedures to transform either plant- or animal-derived foods into ready-to-eat products while maintaining the original nutritional and organoleptic qualities.

The successful application of minimal processing delays nutrient loss and undesirable changes in texture, color, flavor, and aroma related to ripening or microbial spoilage. The development and successful implementation of MP methodologies requires great efforts; for example, any changes made to a fruit or vegetable must be invisible or barely noticeable or it may decrease consumer acceptance.

Likewise the use of chemical additives should be avoided, as they are commonly perceived as "artificial, unnatural, or dangerous" by most consumers (Velderrain-Rodríguez et al., 2019).

Current conventional procedures used for minimal processing food, such as freezing, smoking, or heating, may lead to losses of up to 40% of fruit and vegetable products.

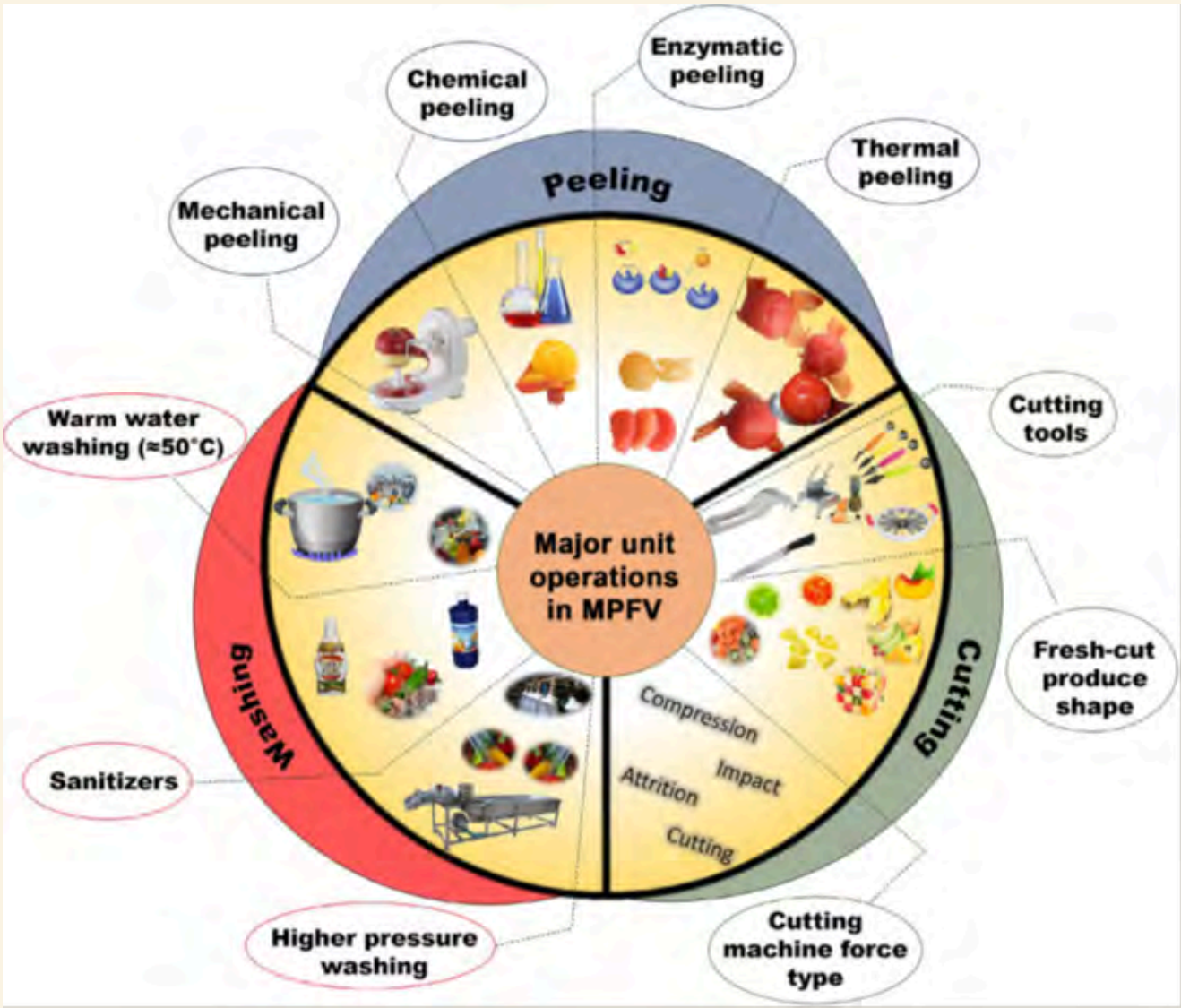


Figure 6. Major operation units used in minimal processing of fruits and vegetables (MPFV)
Source: Velderrain-Rodríguez et al., 2019

One of the first activities that must be done after harvesting the produce is pre-cooling the fresh fruits and vegetables. The goal is to reduce their temperature as quickly as possible to slow down the breathing process, which leads to a decrease in their quality.

The technology includes several stages:

- correct selection of the picking time - mainly in the morning, when the weather is cool, or at night, if the produce will be transported at night to the markets;
- cooling in suitable premises (room and forced air cooling, hydrocooling, icing, vacuum cooling);
- suitable packaging. (Aked, 2002).

1.3.5 Fruit and vegetables packaging– integrated vs. organic technologies (for both fresh and processed fruits and vegetables)

Fresh fruits and vegetables are very perishable products with relatively short postharvest lives. and can be easily affected by climatic conditions due to highly perishable nature and it is important to understand their biology.

Fresh fruits and vegetables are very perishable products with relatively short postharvest lives. They are living tissues with high water content and are subject to continuous change after harvest ending with senescence. Senescence is the final stage in the development of the plant organ, characterized by the breakdown and death of the cells. Harvesting is the first step in the postharvest system and affects subsequent operations such as packing, handling, transport, and preservation of the crop.

Because of their perishability the harvesting and packing speed of fresh horticultural products is of great importance as soon as the optimum stage of maturity is reached. During packing, all the operations should be well controlled, and the inspection and quality control team must pay special attention to maturity, color, shape, and size, as well as freedom from skin blemishes and external materials when grading, sorting, and packing the products (Ait-Oubahou et al., 2019a).

Fruits and vegetables can be easily affected by climatic conditions due to highly perishable nature and it is important to understand their biology. In developing or choosing a packaging system it is necessary to take in consideration **respiration** and **moisture** of horticultural products (Kumar and Morya, 2019).

During respiration process, **oxygen** is used and **carbon dioxide** is released. The product deterioration is directly influenced by a high respiration rate. Horticultural products can be grouped, depending on the intensity of their respiration at 10°C, into four categories (Beceanu and Chira, 2002):

- with low respiratory intensity (less than 5 $cm^3/kg/h$) are dried onions, autumn potatoes, melons and cucumbers;
- with average respiratory intensity (5-10 $cm^3/kg/h$) are most of the roots, melons, peppers and eggplants, cabbage, apples, pears, plums and peaches;
- high respiratory intensity (10-20 $cm^3/kg/h$) have moon radish, pea pods and lettuce;
- very high respiratory intensity (over 20 $cm^3/kg/h$) have bean pods, peas, dill, parsley, green onions, green garlic, mushrooms, okra, cauliflower (Beceanu and Chira, 2002).

The choice and application of **post-harvest practices** is influenced by the pattern of plant respiration and ethylene production. Depending on the differences between them, fruits and vegetables are classified into two categories: (1) climacteric and (2) non-climacteric fruits and vegetables (Rees et. al 2012).

Climacteric are those whose ripening is accompanied by an increase in the frequency of respiration and increased production of ethylene, ethylene being the natural ripening hormone in plants. After peak respiration and ethylene production (climacteric peaks), both decline significantly.

Controlled Atmosphere Systems
http://pennrefrigeration.com/services/controlled-atmosphere-systems/

In non-climacteric, the rate of respiration undergoes a gradual decrease during ripening and senescence and there is no increase in ethylene. Climacteric plants (Table 4) can be picked ripe or immature and left to ripen. Non-climacteric cannot ripen after harvesting and are therefore left to ripen on the plants. (Watson et al., 2020).

	CLIMACTERIC	NON-CLIMACTERIC	REFERENCE
Fruits	apricot, apple, avocado, mango, banana, guava, jackfruit, muskmelon, papaya, pear, plum, peach, tomato, kiwi fruit.	raspberry, pomegranate, blackberry peas, pepper, pineapple, cherry, orange.	Kumar and Morya, 2019
Fruits	apple, pear, peach, apricot, plum, blueberry, yellow melon, green melon and tomato.	cherry, sour cherry, raspberry, strawberry, grape	Beceanu and Chira, 2002
Vegetables	pottato	cucumbers, pepper, eggplant, okra, pea, leafy and root vegetables	Beceanu and Chira, 2002
Vegetables	onion, cabbage, moon radish, pea pods, salad bean pods, peas, dill, parsley, green onions, green garlic, mushrooms, okra, cauliflower and most of the roots		Beceanu and Chira, 2002

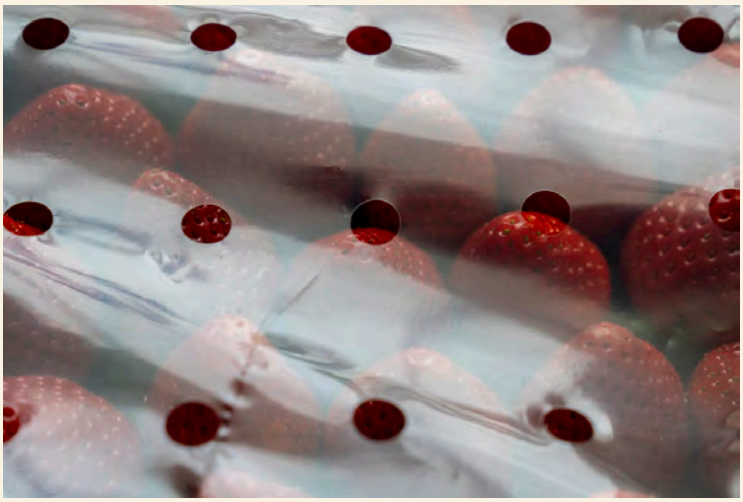
Table 4. Fruits and vegetables classification according to their respiratory behavior

Packaging can be defined as any outer layer, such as a carton or tray made of wood, plastic or cardboard that holds the commodity, along with packing materials. In addition to containing, protecting, transporting, and distributing the product, the package is called upon to persuade, stimulate, and idealize the contents (Ait-Oubahou et al., 2019b).

When it comes to fresh commodities, packaging should strictly meet various challenges in order to be able to preserve fruits and vegetables for longer periods during transport and avoid contamination resulting from foodborne pathogens. (Bodbodak and Rafiee, 2016).

Packaging has been traditionally assumed to have **four basic functions**:

1. protection
2. communication
3. convenience
4. containment



Requirements for effective food packaging

- The package's material must not contain any typesof toxic chemical;
- The packageshould permitrapid cooling of the products;
- The package should be stable to high humidity and moisture;
- The package must encounter handling and marketing requirement in term of size, shape, strength and weight in accordance with international standards;
- The package must have the appropriate mechanical strength to protect the products;
- The package should be inter-lockable and stackable;
- For easy disposability package should bere-usableand recyclable;
- The package should be cost effective;
- The package should be easily open;
- The package should be of suitable standard depending on the market demand;
- The package should be compatible with food .

Packaging materials

The packaging materials might be rigid, such as wood boxes, plastic crates, boxes and bins, jars, pottery, bamboo baskets, reed baskets, date palm leaves baskets, willow weaving baskets etc. providing more physical protection to their content.

Flexible packaging is made of materials including plastic films, mesh bags, sacks, paper, fabrics, and vegetable fibers playing largely basic functions of containment for easy displacement and storage, such as ensure the physical protection of the content, increase user convenience, and serve as a marketing tool of produce presented nicely in a well-designed package to entice customers to buy the product.

With other words, the nature of materials used for packaging of horticultural products is diverse and include natural fibers, molded fiber, paper, cardboard, wood, plastic, and many other sources and materials (Ait-Oubahou et al., 2019b)

Natural Fiber

If a few years ago containers made from palm leaves, sisal, bamboo, straw, jute, and other stiff fibers were represented by buckets, baskets, creels, bags, and sacks with a woven structure that is closed or made of netting (Figure 7c), in recent time, due to increased plastic pollution, eco-friendly and zero waste necessity the food and packaging industries developed new food packaging disposable utensils, containers, tableware, etc. (Figure.7a, b).

a) food disposable utensils made by bamboo

b) food disposable utensils made from cardboard and paper

c) palm leaves baskets

Figure 7
Organic packaging materials: bagasse, palm leaves and bamboo as well as cardboard and paper from sustainably managed forests (https://www.interpack.com/(left) (https://www.alamy.com/eco-friendly (right))

Plastic Containers

Packages made of plastic are the most commonly used because of their many advantages and considerations; for example, they are reusable and can be used many times within several years. Plastic containers can be made in different shapes, weights, and sizes with different thicknesses in flexible or rigid plastic.

Plastic containers are easily cleaned, washed, and disinfected using appropriate machinery, which is nested when empty and stackable when full, without the risk of damaging the commodity unless the containers are overloaded (Ait-Oubahou et al., 2019b).

Figure 8. Plastic containers
Source: https://www.google.com/search?q=plastic+container

Watson et al., (2020) points out that depending on the products, fiberboard cartons fitted with anti-moisture barriers to prevent the liquids from penetrating the fiberboard can also be used. The main substance applied to the fiberboard to prevent moisture from entering or leaving the carton is wax, but this makes the cartons difficult to recycle.

Corrugated Cardboard

Corrugated cardboard is similar with plastic and can come in different flute sizes or with a different number of flute layers (i.e., single, double, or triple wall board), to provide the desired mechanical strength, which increases with the number of the wall board and type and size of flutes. Cardboard boxes and crates at the bottom of stacking pallet are susceptible to distortion and crushing due to the heavy load of the packages of the upper layers of the pallet.

They can also be damaged by high moisture during transport, in storage rooms, or when it is in contact with water during precooling (hydro- or ice-cooling) or when exposed to heavy rain. Despite some of the above drawbacks, cartons are the dominant packaging material in the horticulture industry because of their reduced transportation cost due to lightweight of the unit; also, they can be custom made to cut and shape for any wanted configuration, such as robust and stiff if corners are reinforced to avoid any distortion during stacking, ease of handling, best material for lettering and printing, and recyclable (Figure 9).

Figure 9. Corrugated cardboard containers
Source: https://www.google.com/search?q=ambalare fructe

Cardboard sheets are also used for separating and holding trays for fruits, such as apples, pears, and oranges, which are packed in corrugated boxes. The fruits are packed in layers in the corrugated boxes for long-distance transport or for export purposes (Ait-Oubahou et al., 2019b).

Wood

Wooden packages (Figure 10) are common for bulk transportation due to their high stacking strength and ability to withstand water. They can have different forms, such as crates, boxes, and bins. Wood has the advantages of strength and defense against high humidity, and they can also be reused. It is used for fruits and vegetables such as oranges, mandarins, apples, grapes, stone fruits, tomatoes, potatoes, and snap beans. However, the reuse of these wooden crates raised concerns related to sanitation and potential source of cross-contamination.

Figure 10. Wooden containers

The main disadvantages of wooden containers are environmental issues as the wood comes from natural forest, difficult to obtain uniformity of weight of the boxes and not easily returnable for reuse. In addition, for sanitary concerns, some countries are imposing restrictions on the introduction of wooden packages

Wooden packages are generally assembled using staples, wires, and nails, which can sometimes cause injuries to the packaged products if no protection like separators and inserts are used. Similarly, damage of packaged produce can be caused by wood packages with sharp edges and splinters if they are not well polished (Ait-Oubahou et al., 2019b).

Requirements for effective food packaging

- The package's material must not contain any types of toxic chemical;
- The package should permit rapid cooling of the products;
- The package should be stable to high humidity and moisture;
- The package must encounter handling and marketing requirement in term of size, shape, strength and weight in accordance with international standards;
- The package must have the appropriate mechanical strength to protect the products;
- The package should be inter-lockable and stackable;
- For easy disposability package should bere-usableand recyclable;
- The package should be cost effective;
- The package should be easily open;
- The package should be of suitable standard depending on the market demand;
- The package should be compatible with food.

Packaging classification based on level of packaging

Levels of packaging affects how products are packed and shipped. There are so many ways that a product can potentially be damaged during shipping, during stocking in the store, and even while the customer is taking the product at home. That's why it's critical to strike a balance between the levels of packaging to keep your product looking great and properly protected. The reare three levels of packaging i.e.primary, secondary, tertiary and unit load.

Types of packages

Over time, several types of packaging have been identified depending on their utilization and today we can even make a classification of them, like:

- packages used in field and transport;
- packages used for transport and storage;
- packages used for consumers;

Packages used in field and transport

Packages used in field are represented by rubber, plastic or wooden buckets, baskets and crates, or metal basin used for picking operation (Figure 11).

Figure 11. Types of packages used in field and transport (Source: https://www.emag.ro/cos, http://news-roman.ro, https://www.stiriagricole.ro)

For bulk shipping from one location to another are used plastic crates, boxes, and bins ping, and also for the storage of their contents before they undergo packing operations.

Packages used for transport and storage

Transportation can occur from farm to warehouse or to wholesale or retail markets, as well as from wholesale to retail markets. Today, plastic or wooden crates and bins are extensively used as the packages that can resist the pallet's load and the effect of high relative humidity in the storage rooms.

At different stages in the supply chain, the packaging material and form need to support the needed weight or size per unit packs. The most suitable types of packaging for the handling and transportation of fresh produce are nestable plastic crates (Ait-Oubahou et al., 2019b).

Packages used for consumers

Besides the basic packaging functions the consumer package takes into consideration the aesthetic values such as ease of display and storage in home refrigerators for short durations before final consumption. These are mainly made of low-cost packaging material per kilogram of produce, such as low-density polyethylene (LDPE), Kraft paper, or plastic netting, depending on the commodity.

Minimally processed horticultural produce requires additional packaging precautions, which may translate onto packaging the produce in consumer packs as a primary packaging, then packed in corrugated box or plastic crates for shipping. Today, recyclable and degradable consumer packaging bags or nets are used in all countries (Ait-Oubahou et al., 2019b).

Active packaging

Consumer demands and market trends are under continuous change in favor of convenience foods, which need mild preservation and should have fresh-like qualities. Fact that created the need for changes in distribution practices intended for foods distributed over increased distances and stored for longer periods (Bodbodak and Rafiee, 2016). Ščetar and Kurek, (2010) summarized that the active packaging employs a packaging material that interacts with the internal gas environment to extend the shelf-life of a food. Such new technologies continuously modify the gas environment (and may interact with the surface of the food) by removing gases from or adding gases to the headspace inside a package.

Taking these demands into consideration, the concept of active packaging has been introduced as an innovative food-packaging concept. A packaging interacting with food and the environment with a dynamic role in extending shelf life, improving safety, and enhancing sensory properties while maintaining the quality of the food is usually said to be active (Scully, 2009).

Active packaging is defined as packaging aimed at enhancing the performance of the package system by deliberately including subsidiary constituents in either the packaging material or the package headspace.

Active packaging includes various aspects such as:

- physiological processes (respiration of fresh fruit and vegetables);
- chemical processes (lipid oxidation), physical processes (dehydration);
- microbiological aspects (spoilage by microorganisms) that may be influential in determining the shelf life of packaged fruits (Bodbodak and Rafiee, 2016).

Techniques for preservation and improving quality and safety of foods in active packaging can be put into three categories:

- absorbing systems (ie, scavenging). Undesired compounds such as oxygen, carbon dioxide, ethylene, excessive water, taints, and other specific compounds are removed through absorbing (scavenging) systems.
- releasing systems actively add or release compounds such as carbon dioxide, antioxidants, and preservatives into the headspace of the package or to the packed food.
- other systems involve varied tasks, such as self-heating, self-cooling, and preservation. Today, oxygen scavengers, moisture absorbers, and barrier packaging are the technologies dominating more than 80% of the market (Bodbodak and Rafiee, 2016; Robinson and Morrison, 2010).

MAP (Modified atmosphere packaging)

The creation in the package of a modified atmosphere (MA) can be done in two ways: active and passive. Active modification involves pulling a slight vacuum on the package and then replacing the atmosphere with the desired gas mixture. **Absorbers** (active packs) of CO2, O2 or ethylene can be incorporated into the pack to control the concentration of these gases.

ADVANTAGES	LIMITATIONS
More convenient products with higher	Each F&V requires specific optimum gas composition;
Quality and shelf life;	Risk of spoilage due to improper packaging or temperature abuse; low respiration rate products, often cannot achieve optimum atmosphere prior to end of their shelf life, whereas high respiration rate products can be exposed to anoxia;
Little or no need for chemical preservatives;	Risk of spoilage due to improper packaging or temperature abuse; low respiration rate products, often cannot achieve optimum atmosphere prior to end of their shelf life, whereas high respiration rate products can be exposed to anoxia;
More natural and healthy way of product	Necessary temperature control;
Preservation;	Product safety to be established;
Delay in ripening with reduction in respiration of the product;	Plastic films may be environmentally undesirable unless effective recycling is installed;
Reduction in weight loss and consequently retardation of softening and compositional changes;	MAP loses all its benefits once the consumer opens the package or if it is damaged;
Reduced fungal growth and chilling injury;	MAP may raise limitations to storage (for instance, no stacking of packages on top of each other), which increases logistics costs;
Easy display of fruit inside the package;	
Reduction in production and storage cost due to better utilization of labor, space, and equipment	

Table 5. Advantages and limitations of MAP
Source: Sousa-Gallagher et al., 2016

In passive modification (Table 5), the atmosphere is achieved by breathing the commodity into the package, and the equilibrium in the atmosphere depends on both the characteristics of the packaged product and the package (Ščetar and Kurek, 2010).

Not every package is suitable for a MAP. Various packaging materials are being tested developed and improved – as low-density polyethylene (PE-LD) and linear low density polyethylene (PE-LLD) packaging. Edible coatings and films are beginning to be tested and included in fruit and vegetable packaging; also **Antimicrobial packaging**; **Smart or intelligent packaging**, **biodegradable packaging**, etc. In the near future, packaging will increasingly resemble smart systems, incorporating both smart and conventional materials, adding value and benefits throughout the packaging supply chain.

For smart materials to be used in packaging, they must be inexpensive relative to the value of the product, reliable, accurate, reproducible in their range of action, and environmentally friendly and safe for food contact. Ščetar and Kurek, (2010)

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