Module 2.3

Quality and safety indicators for fruits and vegetables
- conventional versus organic -

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Learning Outcomes

The module "Quality and safety indicators for fruits and vegetables, conventional versus organic" provide information about the quality of fruits and vegetables, quality and safety regulation

The skills acquired relate to the identification of quality and safety of fruit and vegetables suitable for human consumption.

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Introduction

Nowadays, **in the EU and worldwide**, agriculture and food industry face new trends of developing green alternatives. This agriculture sector emerged as a result of people concerns about health and environment due to the intensification of agriculture technologies, and uses of chemicals, in both agriculture and food processing industry (Jeločnik et al., 2015).

Organic farming is a dynamic system, also, in Romania and in 2016, the total area cultivated in organic was 226309 ha.

As everybody know, **fruits and vegetables** are a class of foods with high nutritional intake, which offers us a balanced and healthy diet. Moreover, represent the basic raw materials for the food industry.

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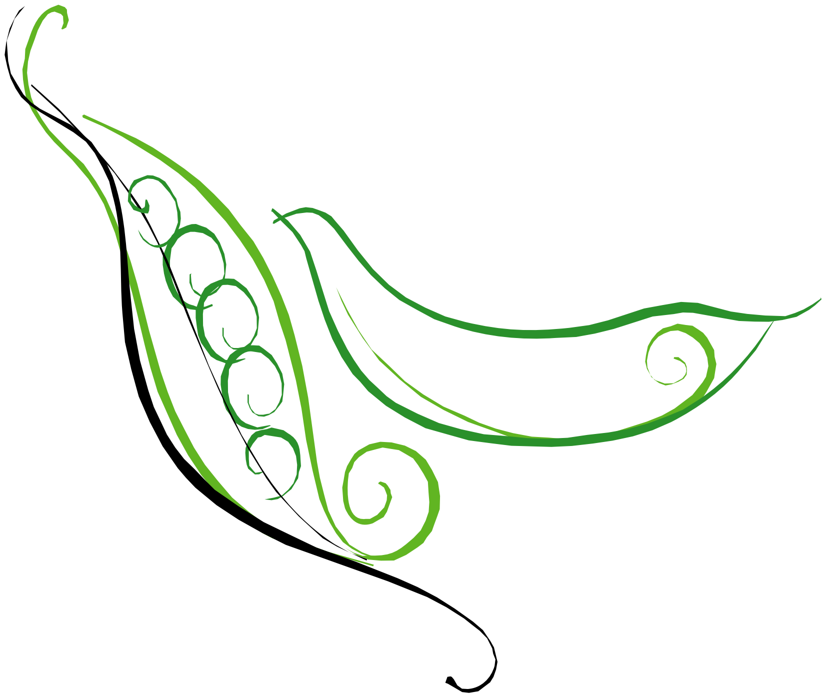
The quality of fruits and vegetables



Module: Sustainable processing for organic food products

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Quality parameters

Quality of fruit and vegetables is a combination of attributes, properties or characteristics that determine the value for the consumer.

Quality parameters include:

- appearance,
- texture,
- flavour/aroma
- nutritional parameters like: vitamin C, phenolic compounds, antioxidant capacity, carotenoids, dietary minerals, etc.

The relative **importance** of each quality parameter depends upon the commodity and whether it is eaten fresh or minimally processed. Consumers judge quality of fruits and vegetables on the basis of appearance and freshness (`best before' date) at time of purchase.

Quality parameters

Quality of fresh fruit and vegetables depends on:

- the cultivar,
- pre-harvest practices,
- climacteric conditions,
- maturity at harvest,
- harvesting methodology
- post-harvest conditions,

making shelf life prediction a difficult task when compared with other food products.

Quality parameters

Handling procedures, conditions and time impact on the quality of fruit and vegetables, and consequently the quality of products.

Additional factors that influence the quality of fruits and vegetables include:

- **method of preparation** (sharpness of cutting tools, size and surface area of the cut pieces, washing/treatment, and removal of surface moisture) and
- **subsequent handling conditions** (cooling rate, sanitation conditions, packaging, maintaining optimum conditions of temperature and relative humidity during distribution) (Gallagher et. all. 2011).

Nutritional value

Possible relationships between stresses, cropping practices and accumulation of nutritional compounds in organic cultivation. Source: Orsini et. al., 2016

Stress	Cropping practice	Cause	Qualitative response	Reference
Nutrient deficiency	Organic fertilization	Nutrient availability affected by mineralization speed; Difficulties in covering plant need with balanced nutrition.	Reduced NO_3 in leaves Antioxidants accumulation	Williams, 2002; Maggio et al., 2013; Velikova et al., 2000; Sharma et al., 2012; Hermans et al., 2006; Zhao et al., 2009; Vallverdú-Queralt et al., 2012
Drought	Organic mulching, Weed control, Organic pest management	Organic mulching less effective in preserving soil water; uncontrolled water loss through damaged tissues (mechanical weeding, pathogen attacks).	Antioxidants accumulation Osmotin accumulation Polyamines accumulation Increased sugars	Bandyopadhyay et al., 2012 Aghaei et al., 2008; Anssour and Baldwin, 2010; Abdin et al., 2011 Orsini et al., 2011 Sperdouli and Moustakas, 2012; Keunen et al., 2013
Wounding	Weed control, Organic pest management	Wounds caused by mechanical weeding; partial pest outbreak; nematodes	Antioxidant accumulation Osmotin accumulation Polyamines accumulation	Robson et al., 2010 Abdin et al., 2011 Hussain et al., 2011
Disease outbreak	Disease management	Occurrence of disease outbreak due to inefficient control practices; Increased biodiversity; nematode presence	Oxidative burst Antioxidant accumulation Osmotin accumulation	Davies et al., 2006 Wszelaki et al., 2005; Zhao et al., 2009 Chen and Guo, 2008

Nutritional and healthy value

Response of main antioxidant components to organic cultivation practices. Source: Orsini et. al., 2016

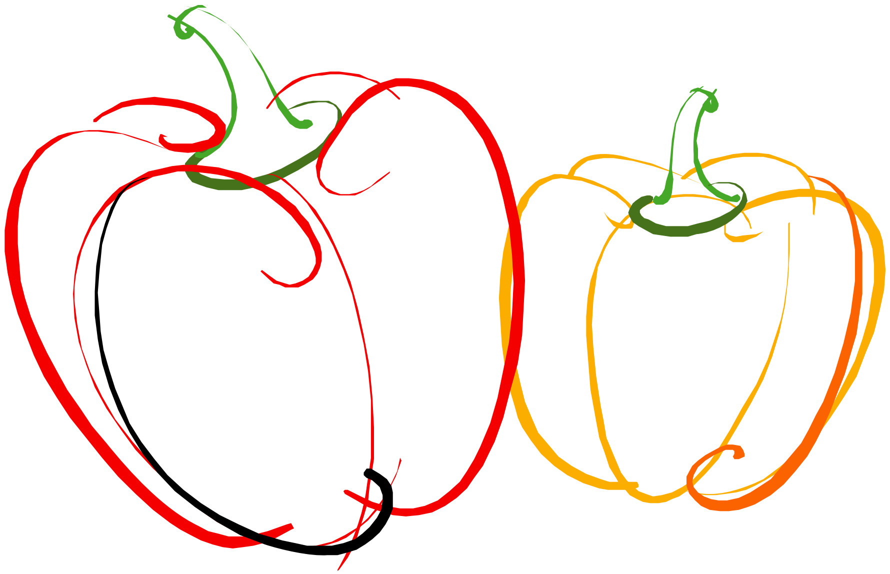
Compound	Crop	*Latin name*	Response to organic cultivation protocols	References
β-Carotene	**Carrot**	*Daucus carota*	= ↑	Stracke et al., 2009; Søltoft et al., 2011; Sikora et al., 2009
	Lettuce	*Lactuca sativa*	=	Ismail and Fun, 2003; Durazzo et al., 2014
	Pepper	*Capsicum annum*	↓ ↑	Del Amor, 2007; Hallmann and Rembiałkowska, 2012
	Spinach	*Spinacia oleracea*	=	Ismail and Fun, 2003
	Strawberry	*Fragaria x Ananassa*	=	Cardoso et al., 2011
	Tomato	*Solanum Lycopersicum*	↑	Caris-Veyrat et al., 2004
Ascorbic Acid	**Cabbage**	*Brassica oleracea*	↑	Worthington, 2001
	Carrot	*Daucus carota*	↓↑	Worthington, 2001; Sikora et al., 2009
	Cauliflower	*Brassica oleracea, L., subsp. Botrytis*	↑↓	Picchi et al., 2012
	Chinese mustard	*Brassica juncea*	=	Ismail and Fun, 2003
	Lettuce	*Lactuca sativa*	↑	Worthington, 2001; Ismail and Fun, 2003
	Pepper	*Capsicum annum*	↑	Hallmann and Rembiałkowska, 2012
	Potato	*Solanum tuberosum*	↑	Fischer and Richter, 1986; Pither and Hall, 1990; Nelson et al., 1993; Worthington, 2001
	Spinach	*Spinacia oleracea*	= ↑	Ismail and Fun, 2003 Worthington, 2001; Koh et al., 2012
	Tomato	*Solanum Lycopersicum*	↑	Pither and Hall, 1990; Caris-Veyrat et al., 2004
	Strawberry	*Fragaria x Ananassa*	=	Barbieri et al., 2015

Nutritional and healthy value

Response of main antioxidant components to organic cultivation practices. Source: Orsini et. al., 2016

Compound	Crop	*Latin name*	Response to organic cultivation protocols	References
Phenolics	Chinese Cabbage	*Brassica rapa subsp. pekinensis*	↑	Ren et al., 2001; Lima and Vianello, 2011; Lima et al., 2012
	Carrot	*Daucus carota*	↑	Sikora et al., 2009
	Cauliflower	*Brassica oleracea, L., subsp. Botrytis*	↑ =	Picchi et al., 2012
	Lettuce	*Lactuca sativa*	↑	Young et al., 2005
	Pepper	*Capsicum annum*	↑	Hallmann and Rembiałkowska, 2012
	Potato	*Solanum tuberosum*	=	Hajˇslová et al., 2005; Søltoft et al., 2010
	Spinach	*Spinacia oleracea*	↑	Ren et al., 2001; Koh et al., 2012
	Tomato	*Solanum Lycopersicum*	↑	Caris-Veyrat et al., 2004

Extending the shelf life of fresh fruit and vegetables



Module: Sustainable processing for organic food products

Shelf-life & fresh vegetables

Fruit and vegetables shelf life is best defined as the period within which the product retains acceptable quality for sale to the consumer.

Different quality criteria are important depending on the specific type of commodity and whether it is to be sold fresh as a whole or fresh-cut (minimally processed).

For the fresh fruit and vegetables market, specific minimum quality standards exist in many countries and there is a trend towards international standardization of quality grades.

Biological processes like respiration, transpiration and biochemical transformations continue also during post-harvest period.

Shelf-life & fresh vegetables

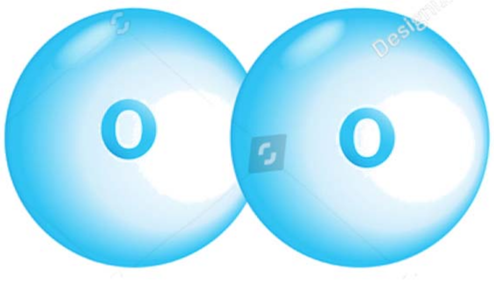
By manipulating different factors such as **temperature, relative humidity (RH)** and the concentration of **O_2**, **CO_2** and **ethylene** in fresh fruit and vegetables it can be reduce the decay risk.

Temperature

- low temperatures slow down metabolic processes such as respiration and transpiration;
- delay the development of post-harvest diseases by inhibiting host ripening, by prolonging disease resistance associated with immaturity, and by directly inhibiting the pathogen.

The storage/shelf life of fresh produce is considerably extended if respiration can be slowed down using refrigeration.

Shelf-life & fresh vegetables



Oxygen

- lowering of the O_2 concentration greatly reduces the respiration rate;
- as the O_2 concentration decreases, respiration rate decreases until the O_2 concentration reaches the extinction point, which is the transition point between aerobic and anaerobic respiration, leading to loss of tissue integrity and off-flavors.

Carbon dioxide

- generally enhances the retardation effect of low O_2 concentrations.

- **commonly used** atmospheres of about 2±4% O_2 and 5±7% CO_2 suppress respiration and delay ripening of fruit and vegetables.
- **optimum ranges** of O_2 and CO_2 levels can result in several advantages to the fruit and vegetables;
- **unfavorable atmospheres** can induce physiological disorders and enhance susceptibility to decay.

Shelf-life & fresh vegetables

Humidity

- water is lost as water vapor from the internal air spaces within the fruit and vegetables (intercellular spaces) to the surrounding atmosphere.
- too much water vapor can lead to the development of molds;
- the **recommended RH** for storing or shipping for most of fruit and vegetables is in the range of **85±95% or slightly higher**.

Ethylene

- if ethylene is removed from storage rooms the shelf life of climacteric and non-climacteric fruit and vegetables may be beneficially affected.
- the challenge lies in the fact that even at very low concentration (<0.1 ppm), induce ripening or cause physiological disorders in some horticultural products.

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Shelf-life & fresh vegetables

The greatest utility and value in producing fresh perishable commodities come from the ability to extend their supply over and beyond the harvest season.

There are two types of technologies that have evolved in order to provide this benefit:

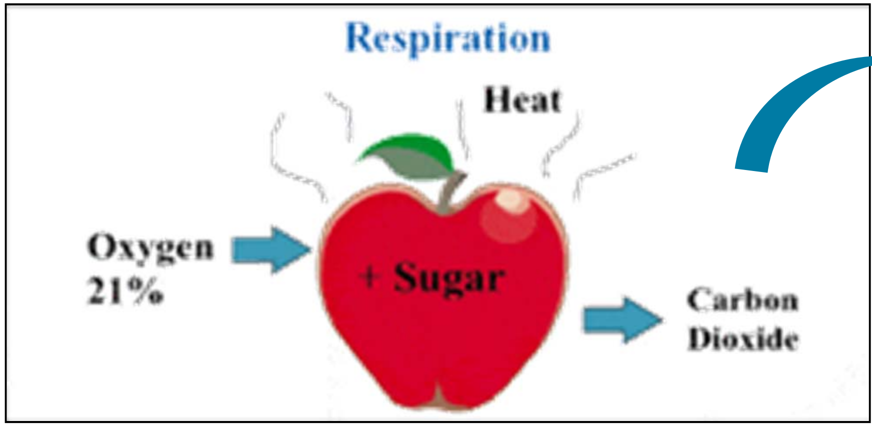
- **controlled atmosphere (CA) storage,**

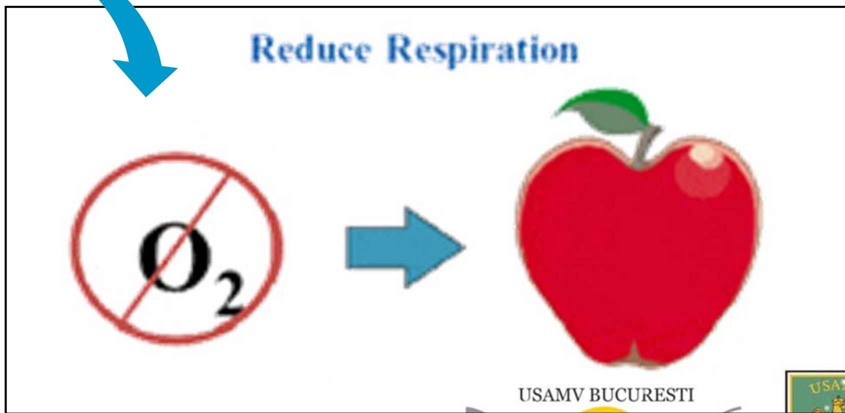
- **modified atmosphere packaging (MAP).**

Shelf-life & fresh vegetables

Controlled atmosphere (CA) storage

CA has its most beneficial effects on climacteric fruit and vegetables at the pre-climacteric stage by prolonging this stage. The effects are less marked in climacteric fruit and vegetables at its ripening stage and in non-climacteric fruits at any stage. Climacteric fruits such as apples and pears are by far the leading crops for which CA technology has been adopted, and to a lesser extent to cabbages, sweet onions, kiwifruit, avocados, persimmons and pomegranates.





Shelf-life & fresh vegetables

The major advantages of CA storage are:

· substantially **reduces the respiration rate** of fruit and vegetables (~50% of that in air at the same temperature);

· **decreases** not only **production of ethylene**, but also the rate of response of the tissues to ethylene;

· **alleviates certain physiological disorders** such as chilling injury of various commodities;

· **affects post-harvest pathogens** directly or indirectly and consequently retards decay incidence and severity;

· useful tool for insect control in some commodities;

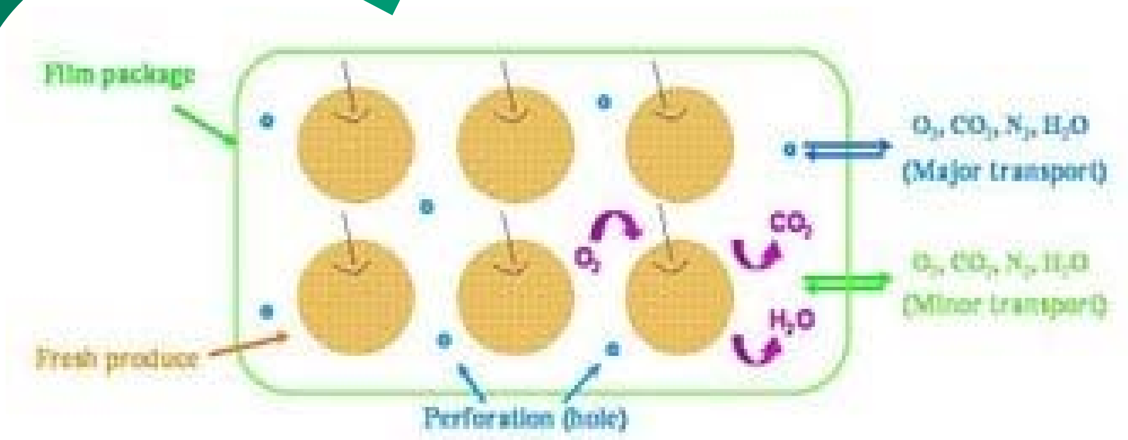
· increases the availability of F&V even during off season.

Shelf-life & fresh vegetables

Modified atmosphere packaging (MAP)

MAP of fresh produce relies on modifying the atmosphere inside the package, achieved by the natural interplay between two processes: the respiration of the product and the transfer of gases through the packaging, which leads to an atmosphere richer in CO_2 and poorer in O_2.

The single most important factor is respiration rate of the product.



Shelf-life & fresh vegetables

Freezing (see also Ch. 7)

Fruits and vegetables are mostly harvested seasonally and usually localized or restricted in certain geographic region and requires availability of effective preservation techniques.

Quick freezing has been considered to be one of the most important preservation technologies available for preservation of fruits and vegetables (Awad et al., 2012; Kiani and Sun, 2011, Xin et. al., 2015).

Quick freezing lowers temperature of fruit and vegetable to their freezing point within a very short time while hardly changing their nutritional quality and sensory characteristics.

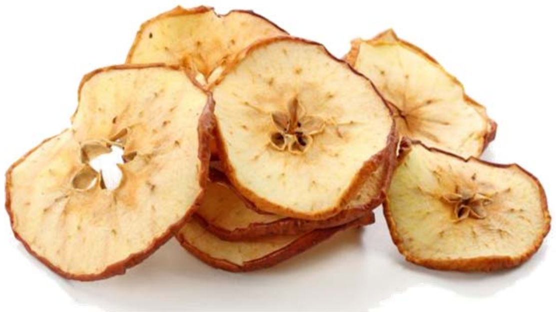
The prevailing low temperature effectively reduces microbial and enzymatic activities and weakens the oxidation and respiration of harvested fruit and vegetable.

Due to increased urbanization the consumption of frozen fruits and vegetables is increased mainly for convenience, time-saving and other practical reasons.

Shelf-life & fresh vegetables

Drying (see also Ch. 4)

- is among oldest and most widespread of all postharvest operations;
- is an effective and viable preservation process;
- It significantly extends the shelf-life and nutritional quality of fruit, vegetables, spices and herbs;
- It reduces the amount of free-water, to slow down deteriorative processes, which are principally caused by microbial growth, chemical reaction and/or enzymatic activity;
- it can reduce the cost of storage and transport, due to the loss of the original shape and weight (Raponi, 2017);



Quality and safety regulations

Module: Sustainable processing for organic food products

Quality and safety regulations

According to IFOAM (2014), organic agriculture should sustain and enhance the health of soil, plant, animal, human and planet as one and indivisible.
The role of organic agriculture, whether in farming, processing, distribution, or consumption, is to sustain and enhance the health of ecosystems and organisms from the smallest in the soil to human beings.

In particular, organic agriculture is intended to produce high quality, nutritious food that contributes to preventive health care and well-being. In view of this it should avoid the use of fertilizers, pesticides, animal drugs and food additives that may have adverse health effects.

Quality and safety regulations

IFOAM Principles and Standards and EC Regulations reflect the common understanding within the organic sector. By combining these and the outcomes of the consultations with stakeholders in the organic sector, five major underlying *principles* for organic food production and food quality were identified: naturalness, health, sustainability, process and product orientation, and system approach.

Naturalness

The EC Regulation 834/2007 defines organic agriculture and food production as a management system that respects nature systems and cycles (Article 3a)(ii). It aims at producing products of high quality.

In their overall principles (Article 4) naturalness is based on:

(a) natural substances and processes' (EC, 2007, Article 3)

(b) an appropriate design and management of biological processes based on ecological systems, using natural resources which are internal to the system by methods (Article 4).

Health and sustainability

IFOAM defines four overarching principles for organic agriculture; one of which is the principle of health (http://www.ifoam.org/growing organic/definitions/doa/index.html).

The health principle also includes a description of sustainability.

Sustainability, according to IFOAM, refers to the health of soils, ecosystems and people.

Quality and safety regulations

Process and product orientation

- Concepts of organic food quality involve both the product- and the process-oriented quality assessment of food. Yet the descriptions of different current main regulations of organic agriculture and food production, like the EC Organic Regulations (EC Regulations 834/2007, 889/2009), IFOAM Basic Standards, as well as the Codex Alimentarius Guidelines for organic food, are process oriented.
- This means that principles, standards and rules are defined for the production process rather than for the produced food itself. The most important aspects for organic food to be successful on the market are sensory quality, freshness, regionalism, careful processing and minimum use of additives.
- Methods (e.g. life cycle assessment) evaluating the process oriented quality of organic food are able to assess the social, economical or ecological aspects that are linked to the production of organic food. Quality assessment of the food itself includes the product aspects. The outcome of the consultations among many stakeholders in the organic sector is that when organic food quality is defined and evaluated, both the process- and product-related aspects should be considered.

Quality and safety regulations

System approach

Organic food production is defined as a system approach (EC Regulation 834/2007, Articles 3 and 4 (934), or holistic approach (EC Regulation 889/2009). Along the food chain, there are many factors influencing the quality of the food.

A conceptual framework for organic food quality has to consider a system approach for defining and evaluating the quality of the food.

A clear definition of a system approach for food products is still lacking, but should be deduced from an understanding of an organism and not just its components. All foods come from living organisms and undergo several treatments, from the method of production in the field, to the fork and the plate.

Organic food and its quality definition and evaluation need:

(a) a whole food chain approach from field to fork, oriented towards the consumer expectations;

(b) a whole food approach which focuses on food as the fundamental unit and not just as a sum of single nutrients;

(c) an understanding of a living organism and its fundamental aspects in relation to food and the health of the consumer.

Quality and safety regulations

The system of HACCP (Hazard Analysis of Critical Control Point) is a science-based, systematic tool for identifying and evaluating hazards that are significant for food safety and for establishing systems of control and measures to ensure food safety.

The use of the HACCP system in agricultural production is somehow limited. When fruits and vegetables are to be consumed fresh, there are no steps that can eliminate or reduce biological hazards to acceptable levels once contamination has occurred.

Basically, controlling contamination through application of GAP (Good Agricultural Practices) and GMP (Good Manufacturing Practices) is the only way to reduce such hazards. Although HACCP has limited usefulness in agricultural production of fruits and vegetables, hazard analysis is a useful process for reducing hazards when produce is processed, since there are steps in the production chain where hazards can be minimized. http://unctad.org/en/docs/ditccom200616_en.pdf

Conventional vs. Organic

Module: Sustainable processing for organic food products

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Conventional *vs*. Organic

Definition

Organic agriculture is characterised to be **healthier** and **more sustainable for the environment** (Hughner et al., 2007; Canavari and Olson, 2007; Stolz et al., 2011; Carlson and Jaenicke, 2016; Mie et al., 2016; EC, 2017).

Weeds are controlled through crop rotation, mulching, cover crops, hand weeding, and mechanical methods such as flame weeding.

Pest control relies on agro-ecological practices (i.e. crop rotation, intercropping, soil management), biological control agents (i.e. predators, parasitoids, pathogens, and competitors) (Gomiero, 2017).

Conventional agriculture use synthetic fertilizers, insecticides, herbicides, fungicides, etc.

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Conventional *vs*. Organic

Productivity and environmental impact

- **Organic** agriculture is with 20–30% lower than the **conventional** counterpart, depending on the crops, agro-ecological context and practices (Gomiero et al., 2011a; Seufert et al., 2012; de Ponti et al., 2012; Ponisio et al., 2015; Gomiero et al., 2011b).

- **total management costs** were not significantly different for organic and conventional agriculture, but labor costs were significantly 7–13% higher with organic farming practices.

- **profits** in organic agriculture were about 20–30% lower than conventional agriculture when organic premiums were not accounted for, organic agriculture was significantly more profitable (22–35%) than conventional agriculture when actual premiums were applied.

Conventional *vs*. Organic

Productivity and environmental impact (cont.d)

- As regards **soil health, biodiversity and reduced contamination** from agrochemicals, there seems to be a general agreement on the fact that organic practices perform much better than their conventional counterparts (Bengtsson et al., 2005; Gomiero et al., 2011a; Gomiero, 2013, 2015a; Bellon and Penvern et al., 2014; Lorenz and Lal, 2016; Reganold and Wachter, 2016).

- regarding **GHG emissions**, N leaching, etc., some meta-analysis (e.g., Mondelaers et al., 2009; Tuomisto et al., 2012) found that organic farming scores better than conventional farming when expressed per production area, but due to the lower yield of organic crops, when performances are expressed per unit of product such positive effect is considerably reduced or not present at all.

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Conventional *vs*. Organic

Consumers attitude

Consumers buy organic foods because they are believed to be:

- healthier than conventional foods
- with a higher nutritional value compared with conventional ones
- free from agrochemical residues and potentially unhealthy chemicals added in the food processing phase,
- free from added hormones and antibiotics (Hughner et al., 2007; Stolz et al., 2011; Kahl et al., 2012; Mie et al., 2016).

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Conventional *vs*. Organic

Consumers attitude (cont.d)

Other than health, they include:

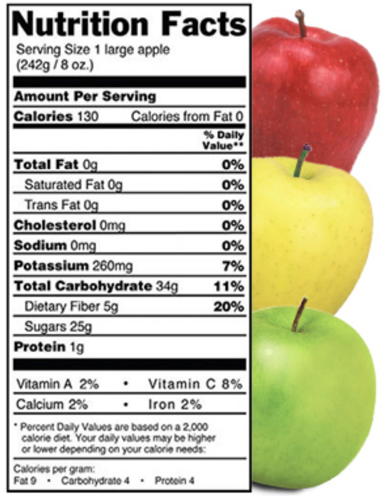
- a broad concern for environmental sustainability and food system resilience,
- risk perception,
- cultural norms,
- ecological, ethical and political beliefs (*cf. Honkanen et al., 2006; Ruiz de Maya et al., 2011; Aertsens et al., 2009 Kahl et al., 2012 Læssøe et al., 2014)*.

The overall level of health and environmental concerns and the level of education (and income) also seem to strongly affect the likelihood of consumers buying organic products (Honkanen et al., 2006; Dimitri and Dettmann, 2012; Baudry et al., 2016).

Conventional *vs*. Organic

Nutritional value

- differences in composition between organic (O) and conventional (C) crops/crop-based foods (Barański et al., 2014):
  - (O): higher antioxidant activity;
  - (O): higher concentrations (18–69%) of a various nutritionally desirable antioxidants/(poly)phenolics and other plant secondary metabolites;
  - (O): lower (up to 75%) concentration of agrochemical residues;
  - (O): lower concentration of Cadmium (Cd), a toxic heavy metal;
  - (O): Lower concentration of total nitrogen and toxic nitrogen-based compounds were also in organic crops compared to conventional crops (total nitrogen: −10%; nitrates:−30%; nitrites:−87%).
  - (O): up to 50% less nitrates than their conventional counterpart, (Lairon (2009).



Conventional *vs*. Organic

Sensory properties

- no significant differences in taste and organoleptic quality, nor does it find that organic products are considered to taste better than conventional food (*Theuer, 2006*).

- organic strawberries ware found to taste better than conventional strawberries (*Reganold et al., 2010*);

Conventional *vs*. Organic

Residues in food

- organic food is reported to contain a **much lower amount of residues** than conventional food;

- such residues have **a lower toxicity** (Baker et al., 2002; Winter and Davis, 2006; Hoogenboom et al., 2008; Lairon, 2009; Barański et al., 2014; EFSA, 2016a).

Conventional *vs.* Organic

Residues in food

The overall results reported by EFSA (2016a) are summarised in table below.

Produce with residues below or at the **limit of quantification (LOQ)** and above the LOQ (data from EFSA, 2016a and own elaboration).

Produce category	Total sample size	Sample below the LOQ figure	Sample above the LOQ figure
Total sample (%)	82,649	44,333 (53.6)	38,316 (46.3)
Conventional* (%)	77,857	40,193 (51.6)	37,664 (48.4)
Organic (%)	4792	4140 (86.4)	652 (13.6)

(*) own elaboration on EFSA (2016a), as in the report the figures for the total sample includes organic produce, which, however, show a higher percentage of samples with no quantifiable residues.

Conventional *vs*. Organic

Residues in food

Residues detection rate below and above permitted Maximum Residue Levels (MRL) in organic and conventional food above the Limit of Quantitation (LOQ) (data from EFSA, 2016a,).

	Samples with residues below the MRL (as% of total samples)		Samples with residues above the MRL (as% of total samples)	
Food typology	Conventional	Organic	Conventional	Organic
Total	45.3	12.4	3.0	1.2
Fruits and nuts	69.4	9.6	2.8	0.7
Vegetables	39.8	12.7	3.5	0.5
Cereales	34.3	12.5	1.4	0.4
Animal products	14.4	22.0	0.8	0.5
Other plsnt products	32.0	22.3	9.5	4.2
Baby food	6.5	5.2	1.1	1.2

The largest difference concerned fruits and nuts, where 69.4% of conventional products contained residues, against only 9.6% of organic products.

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Conventional *vs*. Organic

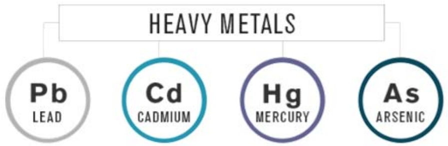
Heavy Metals

Food contamination with heavy metals (taken up from the soil by plants) and mycotoxins is of serious concern in terms of food safety.

Organic produce contained a lower level of cadmium (Cd) compared to conventional produce (Hoogenboom et al., 2008; Barański et al., 2014).

It has been argued that this might probably be because many phosphate fertilisers used in conventional agriculture are significantly contaminated with Cd (Barański et al., 2014; McCarty, 2014).

Cadmium is emerging as a major cause of vascular disorders, various common cancers, kidney disease, osteoporosis and other health disorders and diseases. The fact that organic produce has lower Cd levels is certainly good news (McCarty, 2014). However, it has to be pointed out that Cd content in crops depends also on its native concentration in the soil.



Conventional *vs*. Organic

Mycotoxins

- are toxic by-products of certain moulds;
- under some environmental conditions, certain moulds may colonise crops in the field and/or food produce during storage;
- because resist decomposition and are not broken down in digestion, they persist in the food chain and can end up in meat and dairy products;
- is no evidence to support the claim that organic farming leads to an increased risk of mycotoxin contamination (Lairon, 2009; Smith-Spangler et al., 2012).
- no difference in contamination risk between organic and conventional produce (Smith-Spangler et al., 2012)

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Conventional *vs*. Organic

Mycotoxins

In the Netherlands, Hoogenboom et al. (2008) carried out a large comparative study focusing on organic and conventional wheat, lettuce, carrots, potatoes, pigs, cows and hens, and concerning mycotoxins the authors found no difference between organic and conventional crops.

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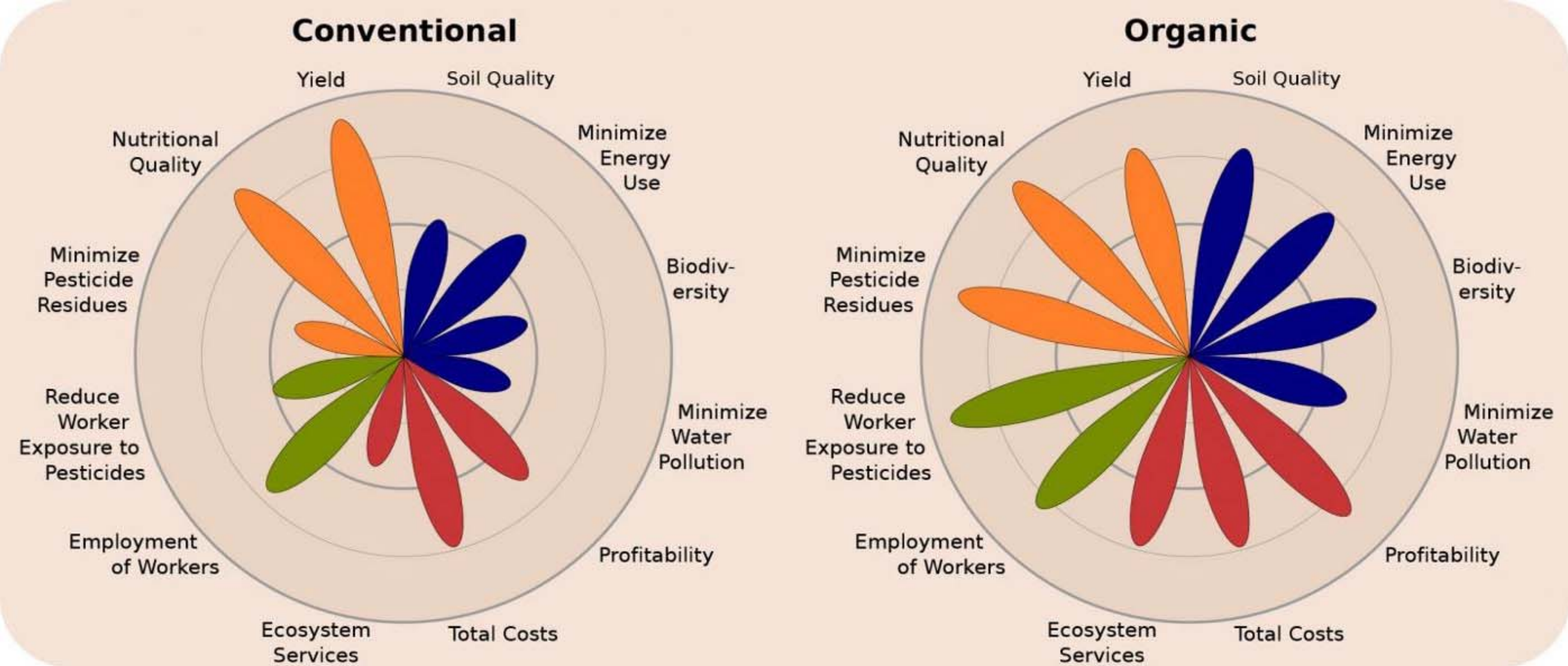
CENTRUL DE CERCETARE PENTRU STUDIUL CALITATII PRODUSELOR AGROALIMENTARE

Overall...



Source: https://medium.com/food-is-the-new-internet/washington-state-university-organic-farming-is-a-double-win-more-profitable-and-more-sustainable-f881cedded7