Scientific Papers. Series A. Agronomy, Vol. LXV, No. 2, 2022
ISSN 2285-5785; ISSN CD-ROM 2285-5793; ISSN Online 2285-5807; ISSN-L 2285-5785

CHANGES IN THE QUALITY OF FOOD DURING STORAGE AND THE MAIN DETERMINING FACTORS

Elena BONCIU, Cătălin Aurelian ROȘCULETE, Aurel Liviu OLARU, Elena ROȘCULETE

University of Craiova, Faculty of Agronomy, 19 Libertatii Street, Craiova, Romania

Corresponding author email: rosculeta2000@yahoo.com

Abstract

Food products have a vital importance for consumers because providing the energy requirements and nutrients. Through their properties, these products can improve, maintain or affect human health. Storage is the most important aspect of the food supply chain that ensures food security and round-the-year quality food supply of a country. During storage, the food quality can undergo significant changes, as most food products are characterized by a relative stability over time, influenced by both internal and external structural factors, which can modify their fundamental properties, through some degradation, alteration, chemical or microbiological processes, impurification with foreign substances, etc. Storage conditions, the microclimate and hygiene of the warehouses, environmental factors, gas composition, the nature of the packaging, the nature of other products present in the warehouse, management practices etc. affect the shelf life and quality of food products to great extent. Storage in a controlled atmosphere can slow down the loss of food quality and is an important alternative to chemical preservatives and pesticides. For example, reducing the oxygen content in a warehouse slows down the degradation of stored food. Controlled atmosphere systems maintain the organoleptic characteristics of the food and reduce losses due to pathogens.

Key words*: food quality, storage, chain; biochemical, microbiological.*

INTRODUCTION

The planet's population will reach 9.3 billion in 2050, according to a study conducted by the French Institute of Demographic Studies (INED, 2020). Facing a demographic explosion, it is essential that agriculture and the food industry find a balance between food production, energy production, resource protection and food waste reduction, while satisfying consumer demand.

The food industry is a priority area of the economy, because foods are of strategic importance (Fen, 2018; Sadiku et al., 2019). Sustainable intensification of agricultural crop production is one of the links in ensuring food security through modern genetic and biotechnological measures. The result is the sustainable production of a larger amount of food using the same area of land and at the same time reducing the negative effects on the environment, in favourable social and economic conditions (Roșculete et al., 2018; Bonciu, 2020; Bonciu et al., 2020).

Climate change is affecting food security by reducing the production of agricultural raw materials, but also by degrading agricultural land. It is very likely that the stability of the food supply will continue to decline as extreme weather events will intensify.

Food needs to be stored in special conditions, as it is prone to rapid spoilage. The alteration consists in the change, in a negative sense, of the initial properties of the food product, so that the respective product degrades, registers losses of the nutritional value and accumulates some toxic components.

Improper food storage is one of the causes that contribute massively to the phenomenon of food waste. Proper food storage does not mean simply storing products in the refrigerator or storage space; how food is arranged in these spaces and storage conditions are important to keep food in optimal condition for consumption.

Food systems have a critical impact on people's lives, health and well-being. They also have a fundamental influence on the planet's natural resources and ecosystems. Biodiversity and food systems are highly interdependent. Biodiversity decline and mismanagement of chemicals and waste poses a serious threat to long-term food production capacity and the resilience of food systems. Urgent action is

needed to combat the direct and indirect factors of biodiversity decline in the context of food production and consumption. In this regard, it is essential to reduce pesticide dependence and nutrient overuse (Roșculete et al., 2019; Olaru et al., 2020; Partal and Paraschivu, 2020).
A systemic understanding of how agriculture, economy, consumer's health and also environmental health are interconnected is essential for food security and food safety ensuring (Paraschivu et al., 2020; Durău et al., 2021; Paraschivu et al., 2021). The Covid-19 pandemic continues to affect food systems and to endanger the global population's access to balanced nutrition. The global food crisis has caused not only major supply chain disruptions and a significant downturn in the global economy, but also the emergence of uneven steps towards recovery, which has led to an imbalance in the supply of food to the population (Paraschivu and Cotuna, 2021).
Chemical Changes During Processing and Storage of Foods provides researchers in the fields of food science, nutrition, public health, medical sciences, food security, biochemistry, pharmacy, chemistry, chemical engineering, and agronomy with a strong knowledge to support their endeavours to improve the food we consume (Rodriguez-Amaya and Amaya-Farfan, 2021).
Storage is the most important aspect of the food supply chain that ensures food security and round-the-year quality food supply of a country. During storage, the food quality can undergo significant changes, as most food products are characterized by a relative stability over time, influenced by internal and external structural factors, which can modify their fundamental properties, through some degradation, alteration, chemical or microbiological processes, impurification with foreign substances, etc.

MATERIALS AND METHODS

The purpose of this paper was to point out some of the changes in the quality of food during storage and the main determining factors of these changes.
The topics followed in this research were: an overview of the changes in the quality of some main food products during storage; the main factors that influence the safety of stored food and some modern and sustainable ways to extend the shelf life of food.
The used methods included the searching of various databases and hand searching of specialized literature with the latest publications in the field and identification of some relevant results. The main databases were Web of Science and Google Scholar as well as FAO (The Food and Agriculture Organization) and EFSA (European Food Safety Authority). Some relevant information was transposed in the form of adapted figures and tables.

RESULTS AND DISCUSSIONS

The production of raw material for food and food storage at the national or global level is important due to its multifunctional roles of enhancing food access, nutrition, and income security at the national, community and household levels (Paraschivu et al., 2015; Owach et al., 2017; Paraschivu et al., 2019).
Food spoilage is caused by different types of microorganism such as: bacteria, fungus, yeasts etc. Spoiled foods usually have an unpleasant appearance, aroma, and taste. Sometimes, however, spoilage can be difficult to detect, such as when staphylococci deposit exotoxins in food or when few bacteria are present to cause a perceptible change.
Contaminating microorganisms can be transmitted to foods in several ways. Airborne pathogens can fall onto fruits and vegetables and then penetrate the product through an abrasion of the skin or rind, whereas crops carry soil borne bacterial pathogens to the processing plant. Shellfish concentrate pathogens by straining contaminated water and catching the microbes in their filtering apparatus, and rodents and arthropods transport pathogens on their feet and body parts as they move about among foods.
Human handling of foods also provides a source for transmission. For example, bacterial pathogens from an animal's intestines can be transmitted to and contaminate meat handled carelessly by a butcher (Pommerville, 2018).
Because food is basically a culture medium for microorganisms, the chemical and physical properties in and surrounding the food have a significant impact on the type of

microorganisms growing on or in the food. Several intrinsic and extrinsic factors (Figure 1) determine whether foods are likely to spoil quickly or resist spoilage (https://microbiologynotes.org/food-spoilage-intrinsic-and-extrinsic-factors).

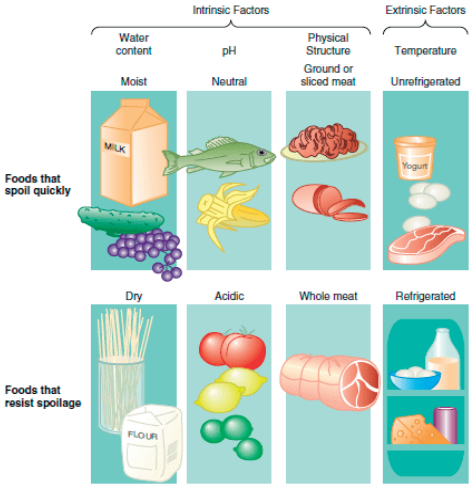

Figure 1. The intrinsic and extrinsic factors which determines foods spoilage (Pommerville, 2018)

Conditions naturally present in foods that influence microbial growth are called intrinsic factors (water, pH, physical structure, nutrients content, etc.). Thus, one of the prerequisites for all life is water. Therefore, food must be moist, with a minimum water content of 18% to 20% before contamination by microorganisms and spoilage can occur (Pommerville, 2018).

Most foods fall into the slightly acidic range on the pH scale, and numerous bacterial species multiply under these conditions. In foods with a pH of 5.0 or below, acid-loving molds often are the spoilage organisms. Extreme pH affects the structure of all macromolecules. The hydrogen bonds holding together strands of DNA break up at high pH. Lipids are hydrolyzed by an extremely basic pH. Citrus fruits, for example, generally escape bacterial spoilage but are susceptible to mold contamination (Pommerville, 2018).

The optimum growth pH is the most favourable pH for the growth of an organism. The lowest pH value that an organism can tolerate is called the minimum growth pH and the highest pH is the maximum growth pH. These values can cover a wide range, which is important for the preservation of food and to microorganisms' survival in the stomach. For example, the optimum growth pH of *Salmonella* spp. is 7.0-7.5 but the minimum growth pH is closer to 4.2 (Jin and Kirk, 2018).

The food's nutrients can contribute to microbial growth. Fruits support organisms metabolizing sugars and carbohydrates, whereas meats support protein decomposers. Starch-hydrolyzing bacterial cells and molds often are found on potatoes, corn, and rice products. Environmental conditions surrounding the food (food storage and packaging) are extrinsic factors influencing microbial growth and food spoilage (Pommerville, 2018).

Microbial spoilage causes the loss of more than 25% of food products before consumption and wastes a considerable amount of food each year (Faour-Klingbeil and Todd, 2020). Using active packaging and antimicrobial additives for food preservation are two important target areas to protect and extend the shelf-life of perishable foods by preserving them from external environmental impacts and contamination (Faour-Klingbeil and Todd, 2020).

In the bakery and flour products units, the flour is stored in specially arranged spaces, with appropriate conditions of temperature, relative humidity and light. The storage aims at: improving the quality of the flour (as a result of the maturation process), the formation of mixtures from batches with different qualities (so as to introduce into the manufacture flour of the most homogeneous qualities, over a longer period of time), as well as ensuring the quantity necessary for the continuity of the production. The storage of the flour in improper conditions leads to the deterioration of the quality or even to its alteration, causing significant losses (Feng et al., 2020).

In normal quality flours, the microbiota is predominantly made up of bacteria and in smaller quantities yeasts and molds are found. The amount of microorganisms in the flour also depends on the conditions of transport and storage, the quality of the packaging and other factors. *Salmonella*, coagulase-positive staphylococci and other human pathogenic bacteria must be absent from the normal flour micro biota. The presence of such bacteria proves an inadequate degree of hygiene and contamination of these products by rodents.

The most common types of microbial spoilage of flour are molding, heating and the flour souring. Most common species of molds are *Aspergillus*, *Rhizopus*, *Mucor* and *Fusarium*. A significant aspect of spoilage of molds is production of mycotoxins, which may pose danger to health (Kabak et al., 2006; Duarte et al., 2010; Omotayo et al., 2019).

Compared to cereals, flour is a less microbiologically stable product. Because the flour lacks the existing defence systems in the whole grain, the representatives of the grain micro biota that reach the flour come in direct contact with the nutrients it contains and for this reason, with the appearance of favourable conditions of humidity and temperature they proliferate and this is how the flour deterioration phenomenon occurs.

Some volatile compounds formed during food photo-oxidation are toxic to humans, such as 1.4-dioxane, benzene, toluene, and lipid peroxides. Some researchers suggest that the toxic action of oxidized lipids is due to the accumulation of peroxides, aldehydes, ketones, polymers, oxypolymers, aromatic compounds and other substances that form at high temperatures (Sies, 2015; Chircă et al., 2020).

Temperature can cause many physical and chemical changes in all food constituents. Sometimes these changes can be beneficial, other times they can cause health problems. Oxidation reactions are often the cause of unwanted food changes. One such reaction is oxidative rancidity due to the peroxidation of fats and oils from various foods. In addition, many vitamins, pigments, and some amino acids and proteins are sensitive to oxygen (Chircă et al., 2020).

The packaging can control two variables in terms of oxygen and these have different effects on the rates of oxidation reactions in food. Therefore, the selection of smart packaging is necessary to ensure adequate food protection.

Meat is one of the most commonly eaten foods in a diet. Given the diversity of origin (of cattle, pigs, sheep, poultry, etc.) special attention must be paid to the receipt, storage and marketing of this product.

During storage, the dominant microbiota can cause the deterioration and release of volatile compounds or slime formation; as a consequence, the product becomes unacceptable for human consumption (Iulietto at al., 2015). Thus, according to the cited authors, the main factors which affect the shelf-life of meat products and favour some bacterial strains rather than others, are: packaging (aerobically, vacuum or modified atmosphere), storage temperature, the composition of the products (Table 1)

Table 1. The main factors which affecting the shelf-life of meat (Iulietto at al. 2015)

Intrinsic factors	Extrinsic factors
Species, breed, age and feeding of the animal of origin	Quality management system
Initial microbiota	Packaging system
Chemical properties (pH, a_w, redox potential, peroxide value)	Temperature control
Product composition	Processing conditions and hygiene
Antimicrobial components	Storage types
Biopreservation systems (bacteriocinogenic LAB cultures and/or their bacteriocin)	Relative humidity, atmospheric gas composition and ratio

Regarding the fruits and vegetables, the factors that cause alteration are: temperature, non-ionizing radiation, water, oxidation process, microorganisms and enzymes.

After harvest, fruits and vegetables continue to show vital attributes through the processes of respiration and perspiration, degradation of substances with more molecular weight as well as the synthesis of flavours. On the other hand, the lifespan of these products is limited by their composition and the interaction between its components and environmental factors (Silva, 2008).

Because of this, especially under the influence of temperature and humidity, the activity of enzyme systems leads to profound changes in the nature of chemical components, a change that results in the loss of the state of fragility and freshness, by the loss of its colour, the weakening and even disappearance of the aroma, structure and textural firmness and natural resistance to various microorganisms.

Maintaining crop quality after harvest is an important consideration for any fresh market produce grower or handler. Because of the significant effect of temperature on respiration, the amount of time a harvested product is exposed to heat should be minimized; the fruit or vegetable should be quickly brought to its optimal storage temperature (Silva, 2008).

Harvested fruits and vegetables of different plants have different rates of respiration (Table 2).

Table 2. The different rates of respiration to fruits and vegetables (Silva, 2008, after Wilson, 1999)

Respiration Rates	Types of Fruits and Vegetables
Very low	Dried fruit and nuts
Low	Apples, garlic, grapes, onions, potatoes (mature), sweet potatoes
Moderate	Apricots, cabbages, carrots, figs (fresh), lettuce, nectarines, peaches, pears, peppers, plums, potatoes (immature), tomatoes
High	Artichokes, Brussels sprouts, cut flowers, green onions, snap beans
Extremely high	Asparagus, broccoli, mushrooms, peas, sweet corn

Molds such as *Penicillium* sp*., Aspergillius* sp. and *Sclerotinia* sp., causes spoilage of fruits and vegetables, both before and after harvest. Alteration becomes faster as the microorganisms come in contact with the cell juices and as the temperature, relative humidity of the air and its oxygen content are more favourable to the living conditions of the microorganisms.

Increasing the shelf life for perishable fruit can be achieved by applying some sensor-equipped monitoring devices. In this way, concrete and ultra-fast information can be obtained about the actual conditions in which the respective foods were stored and transported. The unique identification of each food product is possible by combining sensor-based technologies with radio frequency identification (RFID) markings, which allow the interpretation of environmental data on a chip. These modern technologies allow the use of guaranteed quality declarations, the supply of ready-to-eat products to supermarkets, as well as the application of logistical concepts such as FEFO (the first to expire, the first to leave).

In the supply chains for processed and fresh food products, the partners have a shared responsibility of minimizing quality losses to deliver high-quality products to end users. In spite of their efforts, a large portion of what is produced is never consumed (Hertog et al., 2014).

Food storage should be done under conditions that prevent changes in nutritional, organoleptic and physico-chemical properties, as well as microbial contamination. For this purpose, the food will be stored in rooms or in specially arranged spaces, protected from insects and rodents, equipped with the necessary installations and equipment to ensure the control of temperature conditions, humidity, ventilation, etc., established by normative acts in force.

In order to prevent food spoilage, an important factor is the duration of the transport, which must be as short as possible. During transport, the food must not change its qualities. Maximum efficiency is an essential condition in preventing food contamination or spoilage.

CONCLUSIONS

In the process of cultivation, collection, transportation, storage, slaughter, processing, production of raw materials and food, their contamination can take place. In addition, improper food storage is one of the leading causes of food waste.

Foods need to be stored in special conditions, as they are prone to rapid spoilage. The alteration consists in the modification, in a negative sense, of the initial properties of the food product, so that the respective product registers losses of the nutritional value and accumulates some toxic components. Depending on the nature of the contaminants, they are classified into: physical, chemical and microbiological contaminants.

During storage, the food quality can undergo significant changes, as most food products are characterized by a relative stability over time. There are several parameters which are optimal considered to control the food quality: water activity, pH, temperature, light, and the partial pressures of oxygen and carbon dioxide.

A modern concept for preventing food spoilage is the design of smart food packaging based on these parameters. Such packaging has the advantage of helping to maintain the safety and quality of food in conditions of durable environmental protection.

REFERENCES

Bonciu, E. (2020). Aspects of the involvement of biotechnology in functional food and nutraceuticals. *Scientific Papers. Series A. Agronomy*, *LXIII*(2), 261–266.

Bonciu, E., Olaru, A.L., Rosculete, E., Rosculete, C.A. (2020). Cytogenetic Study on the Biostimulation Potential of the Aqueous Fruit Extract of *Hippophae rhamnoides* for a Sustainable Agricultural Ecosystem. *Plants*, *9*. 843.

Chircă, C., Croitoru, O.C., Mititelu, M. (2020). Modificări fizico-chimice suferite de nutrienţii din

alimente în timpul depozitării şi procesării termice (Physico-chemical changes in food nutrients during heat storage and processing*). Farmacist.ro*, *197*(6).

Duarte, S., Pena, A., Lino, C. (2010). A review on ochratoxin A occurrence and effects of processing of cereal and cereal derived food products. *Food Microbiol*., *27*. 187–198.

Durău, C.C., Sărățeanu, V., Cotuna, O., Paraschivu, M. (2021). Impact of the grassland management planning application on some features of the grassland vegetation from Western Romania – Case Study. *Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development*, *21*(3), 325–331.

Faour-Klingbeil, D., Todd, E.C.D. (2020). Prevention and Control of Foodborne Diseases in Middle-East North African Countries: Review of National Control Systems. *Int. J. Environ. Res. Public Health*, *17*. 70.

Fen, K. (2018). System of management of economic safety of food industry enterprises. *Formation of market relations in Ukraine*, *4*. 115–119.

Feng, W., Ma, S., Wang, X. (2020). Quality deterioration and improvement of wheat gluten protein in frozen dough. *Grain & Oil Science and Technology*, *3*(1), 29–37.

Food Spoilage: Intrinsic and Extrinsic Factors. Available on: https://microbiologynotes.org/food-spoilage-intrinsic-and-extrinsic-factors. Accessed at February 27, 2022.

Kabak, B., Dobson, A.D., Var, I. (2006). Strategies to prevent mycotoxin contamination of food and animal feed: a review. *Crit Rev Food Sci Nutr*., *46*. 593–619.

Hertog, M.L.A.T.M., Uysal, I, McCarthy, U., Verlinden, B.M., Nicolaï, B.M. (2014). Shelf life modelling for first-expired-first-out warehouse management. *Phil. Trans. R. Soc. A*., *372*, 20130306.

INED (2020). Population growth. Available on https://www.ined.fr/en/glossary/population-growth. Accessed at January 25, 2022.

Iulietto, M.F., Sechi, P., Borgogni, E., Cenci-Goga, B.T. (2015). Meat Spoilage: A Critical Review of a Neglected Alteration Due to Ropy Slime Producing Bacteria. *Italian Journal of Animal Science*, *14*. 3.

Jin, Q., Kirk, M.F. (2018). pH as a Primary Control in Environmental Microbiology: 1. Thermodynamic Perspective. *Front. Environ. Sci*., *6*. 21.

Olaru, A.L., Rosculete, E., Bonciu, E., Rosculete, C.A., Sarac, I. (2020). Evaluation of the cytogenetic effects of Quantis biostimulant in *Allium sativum* cells. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, *48*(2), 681–691.

Omotayo, O.P., Omotayo, A.O., Mwanza, M., Babalola, O.O. (2019). Prevalence of Mycotoxins and Their Consequences on Human Health. *Toxicol Res*., *35*(1). 1–7.

Owach, C., Bahiigwa, G., Elepu, G. (2017). Factors influencing the use of food storage structures by agrarian communities in northern Uganda. *Journal of Agriculture, Food Systems, and Community Development*, *7*(2), 127–144.

Paraschivu, M., Cotuna, O. (2021). Considerations on COVID 19 impact on Agriculture and Food Security and forward-looking statements. *Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development*, *21*(1), 573–581.

Paraschivu, M., Cotuna, O., Sărățeanu, V., Durău, C.C., Păunescu, R.A. (2021). Microgreens - current status, global market trends and forward statements, *Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development*, *21*(3), 633–639.

Paraschivu, M., Ciobanu, A., Cotuna, O., Paraschivu, M. (2020). Assessment of the bacterium *Erwinia amylovora* attack on several pear varieties (*Pyrus communis* L.) and the influence on fruits sugar content. *Agricultural Sciences & Veterinary Medicine University, Bucharest, Scientific Papers. Series B. Horticulture*, *LXIV*(1), 163–168.

Paraschivu M., Cotuna, O., Paraschivu, M., Olaru, L. (2019). Effects of interaction between abiotic stress and pathogens in cereals in the context of climate change: an overview. *Annals of the University of Craiova - Agriculture, Montanology, Cadastre Series*, *XLIX*/2, 413–424.

Paraschivu, M., Cotuna, O., Paraschivu, M., Durau, C.C., Damianov, S. (2015). Assesment of *Drechslera tritici repentis* (Died.) Shoemaker attack on winter wheat in different soil and climate conditions in Romania. *European Biotecnology Congress*, *Journal of Biotechnology*, *208*. S113.

Partal, E., Paraschivu, M. (2020). Results regarding the effect of crop rotation and fertilization on the yield and qualities at wheat and maize in South of Romania. *Agricultural Sciences & Veterinary Medicine University, Bucharest, Scientific Papers. Series A. Agronomy*, *LXIII*(2), 184–189.

Pommerville, J.C. (2018). Fundamentals of microbiology. Burlington, USA: Jones and Bartlett Learning,

Rodriguez-Amaya, D.B., Amaya-Farfan, J. (2021). *Chemical Changes During Processing and Storage of Foods.* Sao Paolo, Brazil: Academic Press Publishing House.

Rosculete, C.A., Bonciu, E., Rosculete, E., Olaru, A.L. (2019). Determination of the Environmental Pollution Potential of Some Herbicides by the Assessment of Cytotoxic and Genotoxic Effects on *Allium cepa*. *Int. J. Environ. Res. Public Health*, *16*(1), 75.

Rosculete, E., Bonciu, E., Rosculete, C.A., Teleanu, E. (2018). Detection and Quantification of Genetically Modified Soybean in Some Food and Feed Products. A Case Study on Products Available on Romanian Market. *Sustainability*, *10*(5), 1325.

Sadiku, M.N.O., Musa, S.M., Ashaolu, T.J. (2019). Food Industry: An Introduction. *International Journal of Trend in Scientific Research and Development*, *3*(4), 128–130.

Sies, H. (2015). Oxidative stress: A concept in redox biology and medicine. *Redox Biol*., *4.* 180–183.

Silva, E. (2008). Respiration and ethylene and their relationship to postharvest handling. In: *Wholesale success: a farmer's guide to selling, postharvest handling, and packing produce* (Midwest edition). Available online at: http://www.familyfarmed.org/retail.html