SCIENTIA AGROPECUARIA

Scientia Agropecuaria

Web page: http://revistas.unitru.edu.pe/index.php/scientiaagrop

Facultad de Ciencias Agropecuarias

Universidad Nacional de Trujillo

REVIEW

Indicator values for food shelf life prediction: A review

Teófilo Espinoza-Tellez[1*]; Roberto Quevedo-León[1]; Oscar Diaz-Carrasco[1]

[1] Departamento de Acuicultura y Recursos Agroalimentarios, Programa Fitogen, Universidad de Los Lagos, Avenida Alberto Fuchslocher 1305, Región de los Lagos, Osorno, Chile.

* Corresponding author: teofilo.espinoza@ulagos.cl (T. Espinoza-Tellez).

Received: 14 December 2023. Accepted: 5 July 2024. Published: 16 July 2024.

Abstract

The short time that people have to cook their own food has led industries to satisfy the need for ready-to-eat products. This has motivated a progressive increase in studies that can determine the time at which the product can be safely consumed (shelf life). There are several methods for determining the shelf life of products; but regardless of the method used, the key is to know the minimum and/or maximum values of the indicators that define their deterioration. These values of spoilage indicators can change according to the compositional conditions of the food or the conditions under which it is stored during its shelf life. This review provides values for indicators used in tests for the determination of food shelf life, according to their nature, and environmental conditions, as way to be used by researchers as a reference in their predictions. The results of this research show scientific evidence through published articles about indicator values, their changes, referring to food shelf life kinetics. These values can be used for the prediction of food shelf life, for comparison purposes with their respective studies. It will be of importance for consumers, who will be able to use these values as a reference in the storage of these products. Shelf life indicator values for foods not considered in this work should be evaluated or experimented with in future work.

Keywords: Food; indicators of spoilage; shelf life; maximum values; minimum values.

HTTPS://DOI.ORG/ https://doi.org/10.17268/sci.agropecu.2024.032

Cite this article:

Espinoza-Tellez, T., Quevedo-León, R., & Diaz-Carrasco, O. (2024). Indicator values for food shelf life prediction: A review. *Scientia Agropecuaria*, *15*(3), 429-448.

1. Introduction

The shelf life of a food is defined as the time in which the product has lost its minimum quality characteristics, these can be physical, biochemical, microbiological and sensory (Bassey et al., 2022; Kato et al., 2017; Carrillo & Reyes, 2014; Pedros-Garrido et al., 2020; Singh, 2000). After a period during shelf life storage, foods will inevitably reach their expiration date; after this date, it cannot be consumed (Andrade et al., 2023; Wang & Teplitski, 2023). Quality encompasses many aspects of the food, such as its physical, chemical, microbiological, sensory and nutritional characteristics. Some indicators are more directly associated with the health and safety of products (for example, microbiological indicators); while others define only the loss of quality without necessarily affecting the safety of the consumer. A food generally has several indicators that define its shelf life and must be monitored in stability experiments over time. These changes may not be detected by consumers; for examples, the loss of bioactive compounds such as some vitamins during their shelf life is a characteristic that is not generally observed by consumers. Other changes manifest quickly at the level of sensory perception and can be taken more quickly as an immediate control response (Gyawali et al., 2022; Kahlon et al., 2021; Kebeya et al., 2021; Li et al., 2023).

In addition to the information provided to the consumer, it is equally important that the producer is aware of the changes that may occur in the product over time, as well as the factors that produce these changes (Van der Vossen-Wijmenga et al., 2022). This information serves as a basis for making decisions regarding the type of packaging, care during distribution, and the process that must be carried out according to the target market. With this information, the minimum shelf life that is needed for an adequate market cycle can be visualized from the planning stage, since the cost of replacing the product at the point of sale or the consumer rejection due to perceived sensory changes in the product is extremely high (Clodoveo et al., 2021; Forsido et al., 2021; Halloub et al., 2022; Lee & Robertson, 2022; Liu et al., 2022).

Finally, it must be considered that, if the food is assigned a shelf life that is significantly shorter than the actual life of the product, there is a risk of reducing the marketing time and removing a product from the market that is still suitable for consumption (Bressan & Toledo, 2020; Zielinska et al., 2020). On the contrary, an overestimated shelf life can result in consumers receiving a product not suited for consumption. Therefore, knowing with greater certainty the shelf life of a product and predicting its marketing and consumption cycle is fundamentally important in reducing food loss, hence the importance of this type of study (An et al., 2023; Ktenioudaki et al., 2022; Manthou et al., 2019; Tarlak, 2020).

The length of time a product can remain suitable for consumption without changes in quality or safety may depend on several factors, such as the selection of raw materials, the formulation of the food product, the inhibition of spoilage reactions, the material packaging selected and product storage conditions (Ahari & Naeimabadi, 2021; Bonciu et al., 2022; Fadiji et al., 2023; Ghoshal et al., 2023; Lomate et al., 2021; Moradi et al., 2023; Pedros-Garrido et al., 2018; Pivovarov et al., 2021).

Numerous investigations have been conducted and published in the literature to ascertain the shelf life of foods, using accelerated or non-accelerated methods. The shelf life of a product is a generic concept and relative to the environmental conditions until it reaches the final consumer. The objective of this review is to show the different values of shelf life and time indicators, which have been used in recent years and during different investigations; to be compared with the studies themselves. Figure 1 shows an abstract of the review of shelf life indicators in foods.

2. Most used shelf life indicators

In general, many indicators associated with food spoilage can be described, however, a few indicators have been recurrently used to determine shelf life transversally to the type of food under study (dairy, meat, milk, cereals, etc.). Although there is no generic standard that allows the selection of representative indicators of the deterioration of a food, since they depend on the characteristics of the product to be studied (compositional factors, environmental factors, packaging used, among other relevant factors); if there are criteria that can be used (Sistková & Cizková, 2024).

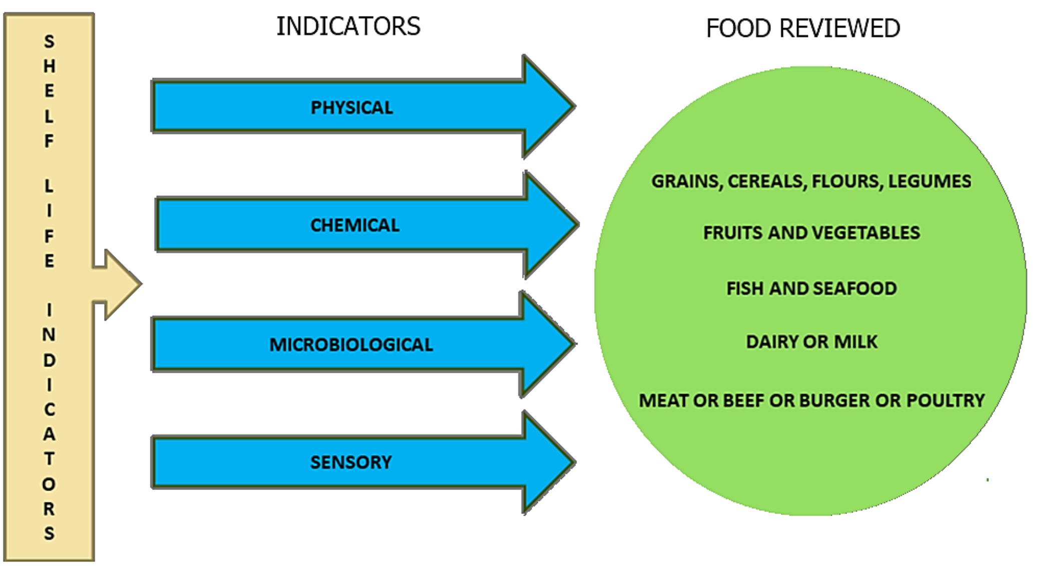

Figure 1. shows an abstract of the work on the review of shelf life indicators in food.

Table 1
Values for Shelf life indicators in grains, cereals, flours, legumes

Product	Physical	Chemical	Microbiological	Sensorial	Experimental Conditions	References
Raw Cornmeal	Color (CIELab) L^* 80.82 - 81.87 a^* 4.24 to -3.84 b^* 30.54 to -29.67	Lipase Activity (U/mL): 0.24 - 0.17 Peroxidase activity (U/g): 148.57 - 71.86 Total carotenoids (μg/g): 16.33 - 16.94 Moisture (% wb): 1.4 - 12.6	Not reported	Not reported	300 gauge (LDPE) bags. Accelerated Test at 38 ºC, 90% RH for 60 days.	(Deepa & Hebbar, 2017)
Rice grains variety M206	Total Rice Yield (TRY)% 66.52 - 69.22 Husked Rice Yield (HRY)% 56.07 - 61.29 Whiteness Index (WI): 38.37 - 30.29	Moisture content % dry base (db): 25.03 - 16.15 Free Fatty Acids (FFA)%: 2.87 - 9.57 PV: milliequivalent peroxide /1000 g: 5.72 - 12.80 Iodine Value (IV): 104-98 g I_2 /100 g	Not reported	Not reported	Rice grain with husk 20 kg Packed in paper bags ambient air dried (AAD) Accelerated test at 35 ºC, 65% RH for 10 months	(Ding et al., 2015)
Snacks	% Swelling 26.54 Puncture force (N) 7.15 -16 CIELab L* 8.78 a* 34.27 b* 63.39	Moisture % (wb) 2.36 - 2.39 PV 0 - 470 meqO_2/Kg	Not reported	4 point scale Rancidity 1-3 Texture 1-3	Fried wheat-based snacks in safflower oil and heated up to 195 ºC. Packed in polypropylene bags (PP) (15 × 20 cm) Stored at 25 ºC, 60% RH for 310 days	(Kosegarten et al., 2022)
Biscuits	Firmness (N) 21,13 - 23,80	Antioxidant Capacity DPPH (μmol TROLOX/g): 0.439 - 0.407 PV < 0.5 mmol oxygen/kg W_a 0.53 - 0.62	Fungi and Yeast < 2 UFC/g Mesophilic Bacteria (RAM) < 3 UFC/g Total Coliforms < 3 MPN/g	Texture Honey-free filling Firmness (N): 7.94 - 37.50 Adherence (J): 0.09 - 0.18 Cohesion: 0.10 - 0.10 Elasticity: 0.47 - 2.11 Relaxation time (s): 0.10 - 0.09	Biscuit with honey filling Packed in polypropylene bags (PP) Stored at 20 ºC for 6 months	(Patrignani, Battaiotto, & Conforti, 2022)
Fresh noodles	Final water activity: 0,96	Moisture 36 - 22,5%	RAM 6.24 - 6.63 log CFU/ g Yeast 3-8.5 log CFU/g Molds 1.5 - 8 log CFU/g	Not reported	Sterile bags (10 g/bag) Stored at 25 ºC for 7 days.	(Guo et al., 2022)
Bread	Specific Volume (SV) mL g^{-1} 3.5 - 6 0.89 -0.87	Moisture (%) 37.85 - 36.37 pH 5.1 - 5.2	Molds y yeast (log CFU g^{-1}) 4,69 - 5.58 *Staphylococcus aureus* (log CFU g^{-1}) 2.62 - 5.12	9 – point hedonic scale (control sample and bread fortified with 2% SPI) Appearance 6.37 - 5.65 Flavour 6.53 - 5.84 Softness /Hardness 6.84 - 6.14 Texture 6.63 - 6.02 General acceptance 7.09 - 6.10	900 g sample Stored at 25 ºC, RH 75% for 7 days.	(Chang, Chang, & Chuang, 2023)
Merengue	Specific Volume (SV) (ml/g): 2.63 - 4.17 W_a 0.38 - 0.46 CIELab: L* 88.81- 89.05; a* 0.49 to -0.29; b* 16.92 to -15.74	Not reported	Not reported	Hedonic scale evaluation 1-9 Appearance 4 - 4 Smell 4 - 4 Texture 5 - 5 Flavour 5 - 5	Packaging in dry plastic package Stored at 23 ºC for 90 days.	(Yuceer & Caner, 2022)

	Hardness (g): 3271 - 7814 Viscosity: -2.63 to −1.93 Chewiness (g): 31.46 - 19.69 Cohesion: 0.07 - 0.07 Fracturability (g): 1020 - 939 Gumminess (g): 286 - 197 Resilience: 0.03 - 0.04 Elasticity: 0.08 - 0.06					
Cake	W_a 91.2-0.85 Hardness (g): 3.21- 5.83 Fractureability (g): 0.45-3.18 Cohesion: 0.44-0.34 Adhesiveness (gs): -24,04 to -54.85 Chewiness (gmm): 1,01-1.31 L* 72.51 - 66.36 a* −3.52 to −2.04 b* 63.23-56.58	pH 7.74 -7.66 Moisture 33.9 -23 %	RAM (log CFU g^{-1}) 2.50 -5.41 Enterobacteria (log CFU g^{-1}) 0.33- 0.48 Molds y yeast (log CFU g^{-1}) 0- 4.72	9 –point intensity evaluation scale Firmness 3.2 - 2.8 Thickness 4.1 - 1.3 Yellow Color 6 - 4.6 Brilliant 3.5 - 3.3 Porosity 4.8 - 4.1 Cohesiveness 5 - 4.9 Moisture 3.5 - 3.0 Freshness 6.5 - 2.0	7 cuts per box (± 70 g/cut), covered with a sheet of parchment paper and stored in cardboard boxes. Stored at 22 °C for 10 days.	(Moura-Alves et al., 2022)
Granola bar	Energy (Kcal 100 g $^{-1}$) 386.71 - 394.81 CIELab: L* 45 - 50 a* 11 to -10.9 b* 22.8 - 24.8 a_w 0.36 - 0.45	Moisture (g 100 g $^{-1}$) %: 6.5 -6.54 Ash %: 2.3 - 2.08 Protein %: 14.5 - 17.27 Fat %: 4.63 - 5.89 Carbohydrates %: 71.76 - 68.18 PV (millieqv./kg sample): 1 - 8 Free Fatty Acids (FFA as % oleic acid): 1.07 - 1.49 TBA (mg MDA/kg sample) 0.01 - 0.21	RAM 10 UFC g^{-1}	Taste 8.10 - 7.18 Initial texture 8.40 - 793 Scent 7.60 - 7.3 Color 8.10 - 7.3 Acceptability 8.0 - 7.58	Granola bar composition 32.5% cereal base mix (oats, wheat, flattened rice, corn flour and corn flakes) and 17.5% nuts (peanuts, cashews, almonds, dates, and raisins). Stored at 28 ºC for 30 days.	(Sarika et al., 2019)
Semolina	CIELab L* 65.08 - 79.86 a* 11.52 - 8.96 b* 35.76 - 11.20 Chroma (*) 65.98 – 31.60 Hue angle (h): 75.98 -63.77 Dimension (16.5 cm × 12.1 cm) Thickness (mm) 50 Breaking length (m) 3.466 Breaking length (width)(m) 2.455 Burst resistance (kg/cm^2) 2.4 Tear index (longitudinal) (mN m^2/g): 17.0 Tear Index (width) (mN m^2/g): 19.8 Traction index (longitudinal) (Nm/g): 33.9 Traction index (known width) (Nm/g): 23.8 OTR (cc/[m^2 × day × atm]) (27 ± 2 °C y 65 ± 2 % RH): 618.75 WVTR (g/cm 2 /24 h/mm) (27 ± 2 °C y 65 ± 2 % RH): 0,00009 % opaqueness: 4.25	Moisture 14.65 - 12.73 Fat (g/100 g bs) 6.40 - 5.11 Protein (g/100 g bs) 10.0 - 7.9 Ash 1.05 Carbohydrate 73.21 Lutein content (µg/g D.W) 0.75 - 0.2 Antioxidant activity (mM FeSO 4 equivalent/g DW) 100 - 50 Aflatoxins (µg/kg): 1.74 - 1.46 Actividad de captación de radicales TPC (mg GAE/g D.W) 3.5 - 1.0 Reducing sugar content (mg dextrose equivalents/g DW) 6.0 - 8.95	Not reported	General Appearance 7 - 5 Color 8 - 4 Smell 7 - 5 Texture 7 - 4 Flavour 7 - 5 Taste 6- 5	50 µm thick pure polypropylene (PP) bag 150 g raw corn grits Stored at 23 ºC, 80% RH for 120 days	(Pal & Bhattacharjee, 2018)

For example, products where the amount of water and the way it is available in the food (available or bound water) are important to consider; this is the case of fruits and vegetables. Figure 2 shows the frequency of use of some of the most used indicators in shelf life studies, according to the type of food; during the last 5 years. Certain indicators are more frequent in a type of food. Thus, moisture content is more frequently used in shelf life studies in the case of cereals, flour, baking products, fruits and vegetables. Other indicators such as texture and pH are more frequently used in foods with good protein structure, such as meat and seafood products.

3. Physical deterioration indicators

A relevant indicator that affects the shelf life is water content, which can be expressed as water contained in per every 100 grams of food (fresh or dry). Similarly, water activity (W_a), which measures the amount of free water in the food within a value between 0 to 1 (without dimensional value), has been widely used to measure it stability. Water, as the universal solvent of life, is responsible for deterioration of food by serving as a means of transport and an element of life in chemical and microbial reactions (Fennema & Tannenbaum, 2008). Other indicators in this category are the mechanical properties of the food; which in turn can be affected by both the moisture content; as well as by modifications of other compounds inside. Among these indicators are the texture (measured in g or newton) and the viscosity (Pa·s) of the food (depending on its solid or liquid state). These indicators can be measured instrumentally or sensory through a panel of judges.

Color measurement is a transversal physical indicator to be considered in food shelf life studies, and it is widely used to improve food quality. There are several ways to express color in food. Instrumentally, predetermined color spaces are used, and their value scale depends on the chosen space (RGB, CIELab; HSV, among others). Color can also be measured sensory.

Other indicators, depending on the nature of the product, may be density, water uptake, water loss, particle agglomeration, respiration (in the case of fruits and vegetables), among other physical indicators.

4. Chemical deterioration indicators

Chemical changes inevitably occur during food deterioration. These can arise during handling, processing and storage. Changes in composition often occur; for example, in the acidity content (measuring pH or % acidity %), in the degradation of proximal compounds such as lipid content, sugar content (brix) and/ or proteins. Furthermore, these degradations can generate secondary compounds such as volatile nitrogenous bases (associated with microbial activity), triethylamine, biogenic amines and/ or formaldehyde formation.

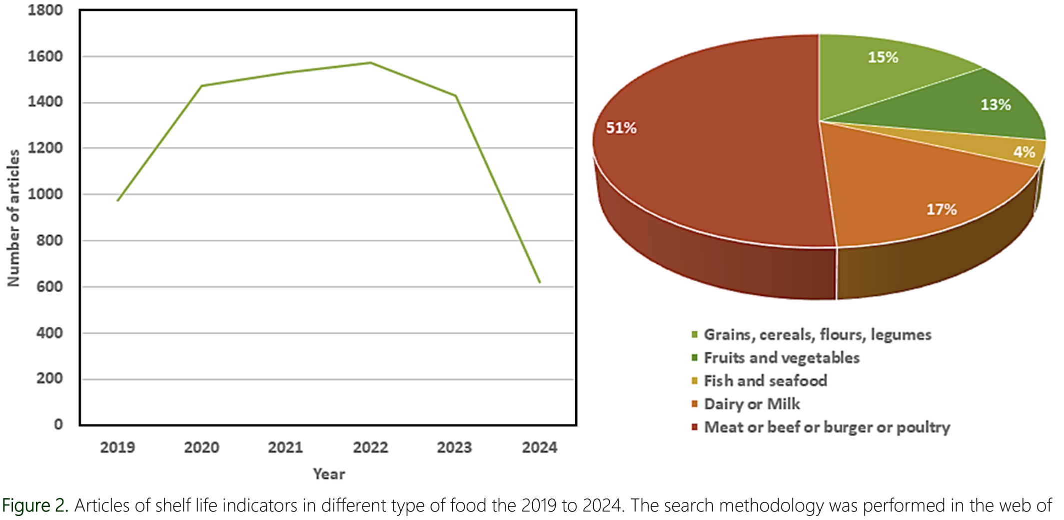

Figure 2. Articles of shelf life indicators in different type of food the 2019 to 2024. The search methodology was performed in the web of science database (scielo, scopus, wos), by subject and the keywords used were: shelf life; type of food (grains, cereals, flours, legumes; fruits and vegetables; fish and seafood; dairy or Milk; meat or beef or burger or poultry) and indicators (moisture, water activity, peroxide value, microbiological, texture, thiobarbituric acid, pH, antioxidant capacity, CIELab, sensory evaluation).

Other types of chemical deterioration during product storage are browning and oxidation of compounds. Browning is an oxidation reaction that can occur by both enzymatic and non-enzymatic action and the best way to quantify it is using color as an indirect indicator of the reaction. Directly, the enzymatic activity of enzymes responsible for catalyzing the reaction can be quantified. Enzymatic browning disrupts compounds responsible for antioxidant capacity, for example, the content of phenols which have been associated with such bioactive property (Anand et al., 2018; Mayookha et al., 2023; Sikora & Swieca, 2018; Yang et al., 2022). Oxidation is another deterioration indicator widely used in shelf life studies; mainly there are the oxidations of lipid compounds, which can be qualified by measuring the peroxide value (POV, an indicator of early lipid oxidation) as well as the content of terminal oxidation compounds can also be oxidized, for example myoglobin in red meat or vitamins in fruits and vegetables. Indicators of chemical importance with bioactive capacities have been included as indicators in the recent years, including the quantification of properties such as antioxidant, anti-inflammatory and carcinogenic capacity.

5. Microbiological deterioration indicators

Pathogenic microorganisms cannot be present in foods for consumption, the indicators taken into account in shelf life studies are: the content of viable mesophiles (RAM); psychrophile content (Santos et al., 2020), total coliform content, enterobacteria; molds and yeasts. Units are usually expressed in logarithmic units in base 10 of viable cells (CFU) per gram or milliliter. In general, in the case of viable mesophilic content, the maximum permissible limit has been established at value of 107 CFU/g or ML; except for those products that, due to their nature, may contain higher values (fermented products among others).

6. Sensory deterioration indicators

The quantification of sensory aspects of foods is one of the very useful and necessary aspects in most food shelf life studies. They can be used to corroborate appreciable changes in sensory aspects detected by consumers. Aspects of flavour, color, texture, smell, among others, have been considered in shelf life studies. In this case, such sensory indicators need to be carefully measured through strict evaluated protocols (generally using a Likert scale), due to human subjectivity in evaluation. Since there is no predetermined scale for these evaluations, it is sometimes difficult to make comparisons between studies for the same product, due to the differences in the protocols during the measurement (Freitas & Costa, 2006; Kebeya et al., 2021; Lauteri et al., 2023). Table 1 to 5 report start to end values for shelf life indicators in different foods arbitrarily grouped according to their affinity, and according to the conditions used in the experiments conducted recorded by the scientific literature during the last 5 years.

7. Values for Shelf-life indicators in grains, cereals, flours, legumes

Values of indicators used in physical, chemical, microbiological and sensory shelf life tests for intermediate moisture products such as bread and some cereals (Pande et al., 2024; Wickramaarachchi et al., 2024), as well as those with low free water content such as flours; are shown in Table 1. Whole or partially sifted flours have limited storage stability, while degermed flour is often stable for up to 3 months (Gwirtz & Garcia-Casal, 2014). The shelf life of flour can be very variable depending on the origin and degree of processing (Sylchuk, Tsyrulnikova, Zuiko, & Riznyk, 2021), however, a shelf life of 90 days is estimated for flours with lipid content (>10%). After three months, integral, whole grain or semi-whole grain flours lose quality. Refined flours (<10% fat) can have up to more than a year of shelf life. Bakery and confectionery products considered as intermediate humidity products, fresh are losing their shelf life due to microbiological growth, crumb hardening (retrogradation and moisture loss), less resilient crumb, loss of flavour and rancid aroma. The use of freezing in these products is a current trend, and it is one of the ways to guarantee a product with a longer shelf life to the end consumer, with few changes in its appearance, taste and aroma as long as cold chains are not broken in the storage process.

8. Shelf lie indicators in fruits and vegetables

Values of indicators used in physical, chemical, microbiological and sensory shelf life tests for fruits and vegetables with good free moisture content are shown in Table 2. The expected deterioration of a fruit or vegetable begins because after the optimal ripening point, the tissues damaged by the fruits own enzymatic activity allow the entry and attack of bacteria, fungi and molds. The process leads to the visual change from a ripe vegetable to a rotten one. To control the deterioration of fruits and vegetables, it is necessary to store them in cool, dry and dark place. The speed of enzymatic reactions increases the higher the temperature, the amount of water present in the plant itself and the environmental humidity (Qi et al., 2022; Romanazzi & Moumni, 2022; Zambon et al., 2023). To keep fruits and vegetables fresh for longer periods, it is good to keep them in environmentally friendly packaging that complies with further extending the shelf life of perishable foods (Palanisamy et al., 2024) and to implement simple practices such as avoiding damaging a perishable product and having clear storage temperatures ideally at 5 °C without affecting their texture and flavor without affecting their texture and taste (Burdon et al., 2017; Fischer et al., 2011; Inestroza-Lizardo et al., 2018; Liplap et al., 2013; Ogura et al., 1975). The use of semipermeable containers in the care of vegetables such as lettuce, chard, broccoli, or basil that prevent dehydration or loss of water from the products is common. For example, by using perforated bags that have a level of ventilation or opening. Practically all available fruits tolerate a temperature of 5-6 °C in refrigerators, the only exception being bananas, which are best kept out of the refrigerator (Faradilla et al., 2017; Sanchez-Rivera & Bello-Perez, 2008; Yang et al., 2008).

9. Shelf life indicators in fish and sea foods

Worldwide, at least 10 million tons of seafood products are spoiled or damaged each year during transport or storage. Monitoring the freshness of seafood products in real time has become especially important (Cui et al., 2024). Values of indicators used in physical, chemical, microbiological and sensory shelf life tests for seafood (fish and shellfish) are shown in Table 3. Seafood is a highly perishable food product due to microbiological, chemical and enzymatic reactions, which are adapted to function even at low temperatures; and which are the main causes of the rapid deterioration of its quality (Tavakoli et al., 2022). Currently, refrigeration and frozen storage are the most common methods for preserving fish. However, refrigeration alone cannot provide prolonged shelf life periods, and freezing, although extending shelf life, may worsen sensory characteristics. Therefore, there is a need to preserve seafood for long periods without exposing it to sub-zero temperatures (de Rezende et al., 2022).

10. Shelf life indicators in dairy products

Values of indicators used in physical, chemical, microbiological and sensory shelf life tests for dairy products are shown in Table 4. Milk is a nutritious food that has a short shelf life and requires careful handling. It is a highly perishable food because it is an excellent medium for the growth of microorganisms, especially bacterial pathogens, which can cause product deterioration and illness in consumers. Processing milk allows it to be preserved for days, weeks or months and helps reduce foodborne illnesses. The shelf life of milk can be extended by several days through techniques such as cooling (which is the factor most likely to influence the quality of raw milk) or fermentation. Pasteurization is a procedure by which, through heat treatment, the useful life of milk is prolonged, and the number of possible pathogenic microorganisms is reduced to levels that do not represent a serious danger to health. Milk can be further processed into easily transportable, concentrated, high-value dairy products with long shelf life, such as butter, cheese and ghee (clarified butter). Other studies have been conducted by adding chestnut shell extract to cheese to improve the nutritional benefits and shelf life of fresh cheese, while reducing food industry waste (Ferreira et al., 2024).

11. Shelf life indicators for meat products

Values of indicators used in physical, chemical, microbiological and sensory shelf life tests for meat products are shown in Table 5. Fresh red meats are highly perishable and their stability depends on intrinsic factors, such as their composition and initial microbial load (Dusková et al., 2024); and extrinsic factors, such as packaging and storage temperature, which, in the end, is the most important condition for their deterioration (González et al., 2014). Lipid oxidation is another variable that can affect the shelf life of meat, and can be detected by changes in flavour, color, texture, nutritional value and the formation of possible toxic compounds (Bassey et al., 2022; Bottegal et al., 2023).

Table 2
Values for shelf life indicators in fruits and vegetables

Product	Physical	chemical	Microbiological	Sensorial	Experimental conditions	References
Mangoes	L*: 61.5 - 53.4 Chroma (C*): 61.5 - 53.4 Hue angle h^0: 88.8 - 85.9 Firmness (N) 04 - 0.2	SST (%) 13.1 - 10.5	RAM: 1.3 - 4.7 log CFU/g *B. psychrophiles*: 1.0 - 3.1 log UFC/g Molds and yeast: 1.7 - 4.3 log UFC/g Total coliforms: 1.0 - 2.7 log UFC/g	Hedonic scale 6 - 9 Smell: 7.7 - 2.6 Appearance: 7.9 - 2.9 Brightness: 8.4 -3.0 Color: 7.8 - 2.7 Firmness: 8.8 - 4.2 Flavour: 8.8 - 4.3 Sweetness: 9.0 -6.2	Mangoes peeled and cut into cubes 2.5 cm on each side. 250 mL polyethylene trays were packed with 80 g of cubes, sealed. Stored at 100 °C for 18 days	(Salinas-Hernandez, Gonzalez-Aguilar, & Tiznado-Hernandez, 2015)
Oranges	Weight 7.5% - 40% Loss of weight PP 0.0% - 38.2% Firmness N 15.09 - 1.02 Breathing frequency (Mg/kg.h) 13 - 16	Polyphenol oxidase activity (U min^{-1} g^{-1}) PPO: 0.5-3.2 Peroxidase activity (U min^{-1} g^{-1}) PO: 0.5 - 4.0 Respiration rate: 12.03 - 16.20 mg/kg.h Titratable acidity TA: 0.99 - 0.11 pH: 4,13 - 4,09 SST: 12.03% - 24.03% Antioxidant %: 70 - 42 ascorbic acid (ug ascorbic/mg) 42 - 30 Decomposition rate %: 20 - 76	RAM (log CFU/g) 1.30 - 8.75 Yeast (log CFU/g) 2 - 8.75	Not reported	Stored at 4 °C for 20 days	(Dulta et al., 2022)
Almonds	Not reported	PV: 0.57-1.26 (meq peroxide/kg oil) AGL: 0.21 -0.21 (% oleic) Conjugated dienes: 0.213 - 0.302 (%) α-tocopherol: 435 - 334(mg/kg oil) β- + γ-tocopherol: 34.3 - 31.7 (mg/kg) - δ-tocopherol: 9.38 – 8.24(mg/kg)	Not reported	Average consumer hedonic score 8 – 4 (10th Month)	of Lightly toasted almonds (LR) 300g husked almonds, raw Nonpareil almonds with skin. The beans were roasted under two different conditions: 115 ± 6 °C for 60 min and 152 ± 6 °C for 15 min to produce a "light" and "dark" degree of roasting, respectively. Stored at 150 °C, RH 39% at 1 to 12 month intervals.	(Franklin et al., 2017)
Tomatoes	Loss of weight (%) 100 - 94	petunidin 3-(p-coumaroyl-rutinoside)-5-glucoside mg L^{-1}: 25 - 150 Carotenoids mg kg^{-1}: 20 - 125 pH: 4.08 - 4.14 Acidity (%): 6 - 5.9 SST %: 4.5 - 5	Not reported	Not reported	The tomatoes were placed in an incubator, with a photoperiod of 16 h/8 h, photon flux density of 80 µmol m^{-2} s^{-1} Stored at 12 °C + luz, RH 70% for 3 weeks in 0.5 L transparent plastic boxes.	(Petric, Kiferle, Perata, & Gonzali, 2018)
Avocados	L* 37.44 - 24.44 a* -12.56 - 5.63 b* 18.3 - 3.83 Firmness (N): 143.13 - 14.61 Weight loss (%): 0 - 4.04	Total soluble solids (TSS) % 15.6 - 3.52 pH 6.68 - 7.08 Lipids (bs) %: 27.29 - 33.30 CO_2: (mmol $kg^{-1}d^{-1}$): 11.34 - 78.38	Not reported	Deterioration index (scale 1-5) 1 - 4.80	Hass Avocado Packaging in macro-perforated polyethylene bags (Soiplast Ltda., Bogotá, Colombia). The bags were 10 × 12 cm with a thickness of 0.25 mm and 5 mm perforations distributed in squares every 6 cm. Fruit weight 200.05 g Stored at 9 °C, 80% RH for 35 days	(Sierra et al., 2019)
Lettuce	Exudate measurement %: 16 - 10 Firmness: 0.0026 - 0.0025 CIELab L* 85.62 - 59.70 a* 6.97 - 11.06 b* 23.12 - 28.87	pH 7 - 6 Acidity %: 0.02 - 0.05 Moisture %: 95.7 - 92.53 Chlorophyll (mg/g) 0.038 - 0.019	*Escherichia coli* in 10 days (Log CFU/g) 9.35 - 7.57 Molds and Yeast in 15 days (Log CFU/g) 0.00 - 3.18	Smell 1.40 - 3.40 Flavour 1.20 - 3.20 Appearance 1.40 - 5.00 Crunch 1.40 - 3.00 Browning 1.20 - 3.20	100 g of freshly cut lettuce were packaged in lightweight polypropylene nano-packs. Stored at 4 °C for 12 days	(Farahanian et al., 2023)
Chickpeas	Respiration rate RR (ml kg^{-1} h^{-1}) RRO2 (Oxygen respiration rate) 21.43 - 5	Phenols (mg/100 g) 87.19 - 125,66	RAM (log CFU/g): 4.8 - 10	Not reported	Green chickpeas Whole pods	(Kaur et al., 2022)

	RRCO2 (Carbon dioxide respiration rate) 21.66 - 7 Firmness (g_f) 2069.4 - 2480 Color change: 3.4 - 7.5 Transpiration rate (g H_2O kg^{-1} h^{-1}) 65% RH 0.690 85% RH 0.212 Physiological loss of weight (PLW, %): 1 -3.97	Chlorophyll (mg/100 g) 26.01 - 24,21 Ascorbic acid (mg/100 g) 46.88 - 33.65 O2 (%) (oxygen level) 20 – 5 CO_2 (%): 5 - 9			Packaged in 38 µm LDPE perforated films oxygen permeability (cm^3 µm/m^2*rh*atm) 7708 Water vapor transmission rate (WVTR) to 37,8 °C and 90% of RH (g µm/m 2 day) 400 Weight filler packs (g) 250 Stored at 5 °C, RH 80% for 12 days.	
Carrots	Firmness (N): 6.58 - 1.27 Loss of weight %: 0 - 14.29	Beta carotene (mg/kg) 86.23 - 21.69	Not reported	Not reported	Samples in trays Stored at 28 ˚C for 28 days	(Nguyen, 2020)
Apples	Respiration rate % 9.18 - 8.47 Firmness (g): 7682 - 7401 Puncture force(g) 394 – 273 CIELab L* 40.19 - 37.12 a* 42.11 - 47.35 b* 18.29 - 16.04	Loss of weight (%): 0.00 - 9.83 SST (%): 12.29 - 15.17 Acidity (%): 0.26 - 0.18 Catechin: 27,13 - 26,47 (mg/100 g bs) Epicatechin: 109.24 - 108.05 (mg/100 g bs) Chlorogenic acid: 90.62 - 89.37 (mg/100 g bs) Floridzina: 23.55 - 22.45 (mg/100 g bs) Quercetin (3- O - galactoside) 9.88 - 8.91 (mg/100 g bs)	Not reported	Not reported	Combination packaging of biaxially oriented polypropylene (BOPP) and polyvinyl chloride (PVC) film with a thickness of 30 and 50 µm. 1 kg of apple Stored at 2 °C for 180 days.	(Mangaraj, Thakur, & Nishad, 2023)
Bananas	Firmness (N) 36 - 10 L* 80.01 - 55.01 Loss of weight (%) 4 - 7.3	Total antioxidant activity (%): 60.01 - 58 Total phenol content (mg GALg^{-1}FW) 190 - 175 Ascorbic acid (mg/100grF.W): 10.03 - 5.0 Polygalacturonase activity (PA) (mmol kg^{-1}s^{-1}): 1.52 - 2.53 SST (%). 11.02 - 20.07 Acidity (%): 0.23 - 0.58 Ethylene (ng kg^{-1}s^{-1}) 0.02 - 0.036	RAM (Log CFU/g): 3.2 - 3.7	Not reported	Cavendish banana cultivation The selected fruits were healthy and had no physical damage or fungal contamination, and were uniform in shape, size, color and state of ripeness. Stored at 15 °C, RH 90% for 20 days	(Hosseini, Zahedi, Abadia, & Karimi, 2018)

Table 3
Values for Shelf life indicators in fish and sea foods

Product	Physical	Chemical	Microbiological	Sensorial	Experimental Conditions	References
Salmon	CIELab L*: 49.55 - 53.03 a*: 12.43 - 11.74 b*: 15.41 - 16.90 Loss of weight (%): 2-5.17 Water retention (%): 95.59 - 75	pH: 6.40 - 7.32 TBA (µg MDA/g de salmon): 0.02 - 0.3 TVB-N (mg N/100 g de salmon): 12.83 - 60	Not reported	Scale 1 - 5 Smell: 2 - 5 Acceptability: 4 - 1	Fresh Atlantic Salmon 23 fillet weight 1500g Stored at 4 °C for 13 days with packaging of 8% biological antioxidant macerated in ethanol from carob seeds (CSE).	(Ouahioun et al., 2022)
Rock mullet (*Mullus surmuletus*)	Not reported	TVB-N: 27 - 41 (mgN/100g) PV: 0.04 - 1.02 (mmole CPO/kg) TBA: 0.02 - 8.2 (mg MDA eq/kg) Cadaverine: 0 - 19 (mg/kg)	Not reported	Rejection score, simple linear model score (5 -15): 0.02 - 9	Mullet salmon fillets Specie (*Mugil cephalus*) Stored on ice at 0 °C for 13 days	(Pilavtepe-Celik & Buzrul, 2021)

			Putrescine: 0.1 - 17 (mg/kg)				
Trout	Common packaging (CP)	Not reported	TBA: 0.07 - 1.11 mg MDA/kg TVB-N: 10 - 20 mg/100 g	Aerobic plate count (APC): 3.53 - 6.5 log UFC/g	Not reported	Rainbow trout A 30 g sample was packed in a 120 × 170 mm low-density polyethylene ziplock bag. Raw rainbow trout, pieces 1 cm thick, with an approximate weight of 10 g Stored at 4 °C for 12 days.	(Yin et al., 2022)
	Vacuum packaging (VP)	Not reported	TBA: 0.07-0.2 mg MDA/kg TVB-N: 9 - 18 mg/100 g	Aerobic plate count (APC): 3.53 - 6.52 log UFC/g	Not reported		
	Modified atmosphere packaging (MAP)	Not reported	TBA: 0.07-1.3 mg MDA/kg TVB-N:10-17 mg/100 g	Aerobic plate count (APC):3.53-7.0 log UFC/g	Not reported		
Shrimp (*Litopenaeus vannamei*)		Hardness 14.68 - 2.32 N Elasticity: 0.7 - 0.1 mm	pH: 7.62 - 8.98 Thiobarbituric acid index (TBA): 0.4-2.10 mg MDA/kg Peroxide value (PV): 0.2-2.44 meq/kg Volatile basic nitrogen compounds (TVB-N): 10,05-54.05 mg/100 g	Total plate count (TPC): 2.31-10.04 log CFU/g	Sensory score (0 - 12 days) 9.00 - 2.64	Average weight of a shrimp was 18 ± 2 g Packaging plastic bags Stored at 4 °C for 20 days	(Liu et al., 2022)
Clam		Not reported	TVBN (mg/100g): 13.78 - 36.05 Ph: 6.4 - 5.25	RAM (log ufc/g): 1.7 - 3.6 Lactic bacteria (log ufc/g): 0.95 - 2.92	5-point descriptive scale (5 = "very good"; 4 y 3 = "good"; 2 y 1 = " bad"). Appearance: 4.3 a 3.2 taste: 4.3 a 3.4 smell: 4.1 a 3.2 Texture: 4.0 a 3.1	Treated in brine in 4% sodium chloride (NaCl) solution for 2 h. vacuum packed in plastic bags Stored at 4 °C for 30 days	(Alcicek, 2014)
		Not reported	Moisture content: 6.89% - 2.26% Peroxide value (POV): 20 - 35 m_{eq}/kg lipid p-Anisidine value (AnV): 20 - 38 Thiobarbituric acid TBARS (mgMDA/kg_l): 2.5 - 13 Total oxidation value TOTOX: 40 - 80 Acidity value AV (mgNaOH/g): 12.5-27.5 Phospholipid class analysis PL (%): 20.06 - 20.10 Changes in phospholipid class compositions (mol %): 43.46 - 42.03 Fatty acid analysis FAA: 2.30 - 7.55 Polyunsaturated fatty acids PUFA (50.62% - 56.35% of total fatty acids)	Not reported	Not reported	Dried clams, were obtained from a local market in Dalian, Liaoning, China *Mactra chinensis Philippi* (MP) Stored at 50 °C for 20 days	(Xie et al., 2018)
Mussel		Loss of weight (%): 0 - 1.4 Elasticity (mm): 7.8 - 3.7 Chicness (mJ): 5.9 - 1.5	pH: 6.8 - 7.24 TVBN (mg/100 g): 8.5 - 14 myofibrillar protein (mg/g): 57 - 22 Ca, ATPase activity (U/mg): 0.19 - 0.11 Total hydrogen sulfide content (mmol/g):	RAM (log ufc/g): 3.15 - 2.38 Staphylococcus (log ufc/g): 2.76 - 1.90 2.76 - 1.85 E. Coli (log ufc/g): 2.76 - 1.85	Not reported	Frozen half shell mussel (*Mytilus edulis*). (polystyrene trays) Stored at -18 °C for 90 days	(Gao, Jiang, Lv, Benjakul, & Zhang, 2021)
Shrimp		Shear stress (N): 23 - 17 Exuded loss (%): 2.9 - 5.0 CIELab L*: 64.96 - 58.27 a*: 7.86 - 5.54 b*: 5.58 - 3.73	TVBN mg/100g): 4.5 - 23 PV (meq 0_2/kg): 1 - 8.2 TBA (mg MDA/kg): 0.3 - 2.7 pH: 6.63 - 7.62 polyunsaturated fatty acids (PUFA, g/100 g): 28.98 - 22.43	RAM (log ufc/g): 2.0 - 6.8 Psychrophilic bacteria (log ufc/g): 1.9 - 6.3 Pseudomonas (log ufc/g):1.5 - 6.2 Enterobacteria (log ufc/g): 1.1 - 6.0 Lactic acid bacteria LAB (log ufc/g): 1.4 - 5.5	Not reported	Harpioschylid mantis shrimp Cooked and peeled, in polystyrene trays and multilayer bag with LLDPE and polyamide. Stored at 4 °C for 15 days.	(Temdee, Singh, Zhang, & Benjakul, 2022)

		linoleic acid (g/100 g): 1.31 - 0.71 linolenic acid (g/100 g): 0.19 - 0.18				
Oysters	Muscle shear force (g): 528.9 - 246.0 CIELab L*: 72.19 - 70.51 a*: -0.52 - 0.82 b*: 9.43 - 11.17	pH: 6.55 - 6.0 TVBN (mg/100 g): 4.37 - 27.77	RAM (log ufc/g): 5.66 - 5.75 Staphylococcus (log ufc/g): 2.76 - 1.90 4.09 - 3.23 E. Coli (log ufc/g): 2.74 - 2.40	Not reported	Fresh oyster meat, 6.0 ± 0.5 cm in length, Cooled in ice water in polystyrene containers, soaked in 0.1% potassium sorbate Stored at 4 °C for 7 days	(Tantratian & Kaephen, 2020)
Octopus	Not reported	TVBN (mg/100g): 3.50 a 16.0 TMA-N (mg/10g): 2.7 a 3.8	psicotroficas (log ufc/g): 6.4 - 3.9 Staphylococcus (log ufc/g): 4.7 -o 2.8 Enterobacteria (log ufc/g): 4.7 - 2.8 Pseudomonas (log ufc/g): 3.2 - 1.8 Vibrio (log ufc/g): 4.5 - 2.0	QIM inverted scale sensory test (0 point is the best quality and any higher score is worse quality.) Smell: 0.91 - 3.17 Texture: 0.91 - 3.67 Color: 1.27 - 6.33	Red octopus (octopus maya) with an average weight of 896 g Stored at 4 °C for 18 hours to 100 hours	(Gullian- Klanian et al., 2016)
Atlantic horse mackerel (Trachurus trachurus)	Water content (%) 79 -77 Mass loss (%) 0.05 - 2.8 Protein Viscosity (Pa*s) 1.4-1.3 CIELab L* 34 - 35 a* 2.5 - 2.2 b* 3.5 - 5.5 Hardness (N) 4.8 - 7.8	TVB-N (mg TVB-N/100 g mackerel) 15.3 - 135 pH 6.8 - 8.2 TBARS (mg MDA/kg of mackerel) 2.0 - 7.0	Total viable bacteria (log UFC/g) 5.8 -10 Total aerobic mesophiles (log UFC/g) 6.0 - 9.8 Pseudomonas spp. (log UFC/g) 4.4 - 10 H_2S-producing microorganisms (log UFC/g) 8.0 - 9.0 Enterobacteriaceae (log UFC/g) 3.0 -6.0 Lactic acid bacteria (log UFC/g) 3.0-7.0	Not reported	Atlantic horse mackerel fillets They were randomly divided into 5 lots. Stored at 4 °C for 13 days	(Zarandona et al., 2021)

Table 4
Values for shelf life indicators in dairy products

Product	Physical	Chemical	Microbiological (log CFU/mL)	Sensory (1-7)	Experimental conditions	References
Fermented milk	Viscosity (50 s^{-1}, mPa s): 7.3 ± 1.7 Serum separation (mL/50 mL): 3 - 20 mL	Acidity (% lactic acid): 0.46% - 0.45% pH. 4.05 - 4.00	RAM: 0.2 - 4.2 Lactobacillus: 7.6 - 7 Streptococcus: 8.4 - 8.2 Yeast/molds: 0.3 to 4.8	Consistency: 5 - 3 General acceptance: 3 - 2.8	Ultrasound treatment 25% 10 minutes stored at 4 °C for 60 days	(Kilic-Akyilmaz et al., 2023)
Raw milk	Not reported	Acidity (°Th): 12 - 44 Protein (mg/mL): 32 - 12.5	APC (aerobic plate count): 2.7 to 10.5 RAM: 2.5 - 8.5 Enterobacteria: 2.3 to 7.8 Psychrophiles: 2.4 - 7.8 Staphylococcus: 1.2 - 5	Smell (scale 0 - 20): 19.4 - 3.4 Color and brightness: 19.6 - 7.2	Stored at 4 °C for 12 days	(Li et al., 2023)
Pasteurized milk	Not reported	Acidity (°Th): 35.5 - 21 Protein (mg/mL): 32.5 - 20	APC (aerobic plate count): 1.8 - 10 RAM: 0.8 - 3.6 Enterobacteria: 0.1 - 3.6 Pseudomonas: 0.5 - 9 Yeasts Psychrophiles: 1 - 6.8	Smell (scale 0 - 20): 20 - 4.2 Color and brightness: 20 - 6	Stored at 4 °C for 11 to 37 days.	
Milk formula		Vitamin C (mg/100 g): 17.2 - 15.7 Vitamin A (µg/100 g): 152 - 132 Vitamin E (mg/100 g): 5.3 - 4.4			Infant milk formula Stored at 25 °C for 6 months	(Jiang et al., 2021)

		Lipid hydroperoxides (µmol/kg): 17 - 30 Propionaldehyde (µmol/kg): 19.5 - 25.7 Hexanal (µmol/kg): 0.93 - 0.95 ∑ PUFA: polyunsaturated fatty acids (mg/100g): 183.3 - 182.7 ∑ AGPI n-3: polyunsaturated fatty acids n-3 (mg/100 g): 37.4 - 36.3				
		Vitamin C (mg/100 g): 17.2 - 11.3 Vitamin A (µg/100 g): 152 - 144 Vitamin E (mg/100 g): 5.3 - 4.4 Lipid hydroperoxides (µmol/kg)): 17 - 32 Propionaldehyde (µmol/kg) 19.5 - 35.8 Hexanal (µmol/kg): 0.93 - 14.3 ∑ PUFA: polyunsaturated fatty acids (mg/100 g): 183.3 - 179.2 ∑ AGPI n-3: polyunsaturated fatty acids n-3 (mg/100 g): 37.4 - 35.6			Stored at 40 °C for 6 months.	
Cottage cheese	Not reported	Not reported	Lactobacillus (log ufc/g): 0.1 - 2.7 Coliforms (log ufc/g): 0.1 - 2.7 RAM (log ufc/g): 0.4 - 5.7 Cocci (log ufc/g): 0.01 - 1.3	Not reported	Stored at 8 °C for 48h	(Chaturvedi, Basu, Singha, & Das, 2023)
Melted cheese	Hardness (g): 720 - 200 Adhesion (gs): -0.18 to -0.12 Cohesiveness: 0.66 - 0.6 Elasticity (mm): 6.2 - 2.9	Moisture (%) 48,5 - 47 Ash (%): 4.35 - 4.21 pH: 5.17 - 5.13 Acidity (%): 0.16 - 0.25 Lipids (%): 27.6 - 29.5 Proteins (%): 16.2 - 16.5	Not reported	Appearance (Scale 2 to 5): 4 - 3.6 Adhesiveness (Scale 2 - 5): 3.8 - 3.6 Gumminess (scale 2 - 5): 4 - 4 Chicness (scale 2 - 5): 4 - 4.5 General acceptance (scale 2 - 5): 3.8 - 3.8	Block-type melted cheese fortified with date seeds. Stored at 5°C for 5 months	(Alqahtani, Alnemr, Alqattan, Aleid, & Habib, 2023)
Fresh cheese	Loss of weight (%): 1.8 - 12 Dry extract (%): 32.5 - 36.8 CIELab: L*: 95.46 - 94.20; a*: -1.87 - 1.81; b*: 9.21 - 9.41 Hardness (N): 13 - 32. Chicness (J): 0.08 - 0.185	radical scavenging (DPPH, %): 3 - 4 pH: 6.82 - 6.35 acidity (%): 0.195 - 0.420 TBA mg MDA/kg): 0.005 - 0.035	Listeria monocytogenes (log ufc/g): 3.6 - 7.8 RAM (log ufc/g): 4.1 - 8.6	hedonic scale from 1 to 5 Smell: 48 - 3.3 Color y appearance: 4.5 - 3.5 Texture: 4.6 - 2.8 Gusto: 4.7 - 3.10 General acceptance: 4.5 - 3.7	Stored at 4 °C for 15 days	(Aminian-Dehkordi, Ghaderi-Ghahfarokhi, Saei-Dehkordi, & Fazlara, 2023)
Sour cream butter	Not reported	Acidity index (mg KOH/g butter): 0.12 a 0.40 Peroxide value (meq/kg butter): 4.43 a 15.25 Oxidative stability (Rancimat at 110 °C): 18 h/min	Not reported	Not reported	stored at 4 °C for 60 days	(Alipour, Marhamatizadeh, & Mohammadi, 2023)
Fresh butter	Moisture (%): 14.23 - 14.05 Non-greasy solids (%): 1.57 - 1.66 Fat (%): 82.87 - 84.37	Fatty acid (g/100 g fat) C18: 11.50 - 12.27 C18:2 4.90 - 4.63 Peroxide value (meq/kg butter): 0.30 - 0.28 Oleic acid base (%): 0.14 - 0.19 Iodine (I2 g/100g): 29.56 - 28.52 Saponification (mg KOH/g): 234.55 - 233.47	RAM (log ufc/g): 2.28 - 2.46) Staphylococcus (log ufc/g): 0.95 - 2.43 E. coli (log ufc/g): 2.47 - 1.58 Psychrophiles (ufc/g): 2.31 - 2.46	Not reported	Wrapped in low density polyethylene (LDPE) Ag film. 10 g packets Stored at 4 °C for 30 days.	(Pouyamanesh, Ahari, Anvar, & Karim, 2022)
Yoghurt	Tuluq Not reported	pH 4.26 - 4.13 Titratable acidity (lactic acid g/100 g): 0.95 - 1.7 Total solids (g/100 g): 17.23 - 35.67 Protein content (g/100 g): 5 - 11 Fat content (g/100g): 6 - 17 Syneresis (g/100 g free serum): 33.2 - 18.6	Not reported	9-point hedonic scale Surface brightness 8.71 -7.86 Surface smoothness: 8.28 - 8.14 Firmness: 8.01 - 9.95 Mouthfeel: 9.14 - 9.00	Concentrated Yogurt Sheep or goat skin bags Stored at 4 °C for 60 days.	(Alirezalu et al., 2019)

			Lipolysis content: (meq/100g oil): 0.39 - 0.40 Nitrogen fractions TN (g/100 g): 0.74 - 1.80 NS/TN (%): 14.11 - 15.38 NPN/TN (%): 10.83 - 12.26		Similar to a foreign animal/flavor: 15.42 - 18.85 Acidic or sour taste: 8.28 - 9.28 Rancid taste: 8.28 - 9.57 Yeast/mold taste: 8.14 - 9.28 General flavour: 7.34 - 8.14 General acceptance: 41.48 - 43.09		
	Torba	Not reported	pH 4.09 - 4.56 Titratable acidity (lactic acid g/100g): 1.08 - 1.6 Total solids (g/100g) 16.98 - 37.47 Protein content (g/100 g) 6 - 12 Fat content (g/100 g) 7 - 18 Syneresis (g/100 g free serum) 33.2 - 18.1 Lipolysis content (meq/100g oil): 0.40 - 0.45 Nitrogen fractions TN (g/100 g) 0.91 - 1.96 NS/TN (%): 10.41 - 14.19 NPN/TN (%): 8.09 - 12.66	Not reported	9-point hedonic scale Surface brightness 8.00 -7.14 Surface smoothness: 8.00 - 7.14 Firmness: 8.01 - 10.00 Mouthfeel: 8.86 - 8.71 Similar to a foreign animal/flavor: 16.85 - 18.57 Acidic or sour taste: 7.43 - 7.67 Rancid taste: 7.00 - 9.28 Yeast/mold taste: 7.00 -9.43 General flavour: 7.14 - 7.14 General acceptance: 40.01 - 40.13	Samples in cloth bag Stored at 4 °C for 60 days	
Dessert		CIELab: L* 46.88 - 40.54; a* 40.80 - 4.31; b* 5.44 - 3.76 Hardness (N): 34.35 - 55.64 Adhesiveness (N/s): 0.24 - 0.19 Elasticity (mm): 0.17 - 0.17 Gumminess (N/mm): 4.42 - 5.06 Chewiness (N/mm): 1.02 - 1.49 Cohesion: 0.13 - 0.08 W_a 0.63 - 0.62	Moisture (%): 25 - 24 Acidity (%) 0.23 - 0.35 Total sugars (%): 65 - 60 Free fatty acid (%): 0.1 - 0.35 Ascorbic acid (mg/100g): 2.5 - 1.8 Antioxidant activity (%DPPH RSA) 70 - 75 Total phenol content (mg GAE/100g) 800 - 500	Total plate count (ufc/g) 1.5×10 - 1.1×10 Yeast and mold count (ufc/g) 0 - 7.0 × 10 Coliforms (ufc/g) <10^1 - <10^1	Color 8.48 - 6.97 Texture 8.24 - 6.97 flavour 8.40 - 6.04 Acceptability 8.40 - 6.66	The desserts were wrapped in butter paper (thickness 40 µm; water vapor transmission rate 14 cm 3 /m^2 /24 h. oxygen transmission rate 12.5 cm^3/m^2/24 h) and were packaged in polypropylene trays. Stored at 25 ± 2 °C for 21 days.	(Singh et al., 2022)
		CIELab: L* 46.88 - 43.90; a* 4.80 - 4.62; b* 5.44 - 3.66 Hardness (N): 34.35 - 66.26 Adhesiveness (N/s): 0.24 - 0.15 Elasticity (mm): 0.17 - 0.07 Gumminess (N/mm): 4.42 - 5.70 Chewiness (N/mm): 1.02 - 1.73 Cohesion: 013 - 0.02 W_a: 0.63 - 0.61	Moisture (%): 25 - 21 Acidity: 0.23 - 0.36 Total sugars (%): 65 - 55 Free fatty acid (%) 0.1 - 0.2 Ascorbic acid (mg/100g) 2.6 - 1.8 Antioxidant activity (%DPPH RSA) 50 - 70 Total phenol content (mg GAE/100g) 800 - 500	Re Total plate count (ufc/g): 1.5×10 - 1.2×10 Total plate count (ufc/g): 0 - 6.0×10 Coliforms (ufc/g): < 10^1 - <10^1	Color 8.48 - 7.10 Texture 8.24 - 6.43 flavour 8.40 - 6.50 Acceptability 8.40 - 6.68	Stored at (4 ± 2 °C) for 28 days	

Table 5
Values for shelf life indicators in meat products

Product	Physical	Chemical	Microbiological	Sensory	Experimental conditions	References
Pork	CIELab: L* 68.84 - 50.16; a* 4.40 - 13.50; b* 3.25 - 7.26 Water retention %: 0 - 12.04 Hardness [N] 10.25 - 15.66 Cohesion 0.03 - 0.02 Elasticity [mm]: 0.35 - 0.25 Gumminess [N]: 0.37 - 0.36	pH 5.59 - 7.3 TVB-N (mg/100 g) %: 1.15 - 30.49	Total viable bacteria count TVC (log CFU/g): 3.50 - 8.0 Enterobacteriaceae: 2.40 - 5.50 Pseudomonas spp.: 3.90 - 8.0 Count of psychrotrophic bacteria: 3.10 - 8.0	Chewiness [N*mm] 0.11 - 0.08 Color 5.00 - 1.00 Smell 5.00 - 1.00	Fresh pork steaks (60 - 80 g) 15 boxes Stored at 4 °C for 15 days.	(Montone et al., 2023)

Pork chop	Not reported	VBN: 6.68 -15.00; pH: 6.45 - 6.12 TBA: 0.88 - 4.18	TAC: 2.87 - 7.75	Sensory evaluation: 9.00 - 7.44	Ground Beef Pork Chop Stored at -18 °C* for 204 days	(Park et al., 2018)
Beef	CIELab L* 64.74 - 99.22 a* 47.70 to -3.50 b*-50.39 to -8.19	pH: 5.52 - 6.38 VBN (mg%): 5.83 - 50.73 TBA (mg MDA/kg): 0,71 – 2.46 Methylamine 60 - 72 h (µg/g) 3.27 - 4.21 Dimethylamine 48 - 72 h (µg/g) 0.25 - 11.19 TMA trimethylamine 0-72 h (µg/g) 0.44 - 38.82	RAM TBC (log UFC/g): 3.81 - 8.74	Not reported	Stored at 20 °C for 72 hours	(Lee & Shin, 2019)
Fresh pork loin	Loss of weight: 10.08% Cut: 21,39 - 31,11 N L* 57.4 ± 0.23 - 57.63 a* 0.9 ± 0.02 - 0.92 b* 5.0 ± 0.02 - 5.02	pH 5.87 - 6.8 TVC 3.07 - 9.02 log CFU g^{-1} TVB-N 40.7 - 240.5 mg kg^{-1} TBA 0.07 - 0.84 mg MDA kg^{-1} Thiol groups 0.067 - 0.031 mmol g^{-1}	Not reported	Average liker scale (Color, smell, Acceptance): 5 – 1	Stored at 4 °C for 14 days	(Hu et al., 2022)
Lamb meat	CIELab L* 48.52 - 46.19 a* 7.08- 2.33 b* 5.66 - 3.76 Water retention (WHC) %: 4.50 - 3.9	pH 6.27 - 6.40	Bacterial load (log CFU/g) 6.26 - 8.05 Total Coliforms (log CFU/g) 4.5 - 6.0	9-point hedonic scale (average) Appearance: 6.33 Texture: 5.27 Juiciness 4.87 General acceptance 5.93	Stored at 4 °C for 3 days.	(Hajar-Azhari et al., 2023)
Buffalo meat	Hardness (N) 67.0 - 46.59 CIELab L* 36.4 - 33.8 a* 12.0 - 8.7 b* 6.0 - 3.5	pH 5.96 - 6.43 Moisture % 7.29 - 67.23	Total viable count (TVC) log UFC/g: 3.21 - 10.30 Psychrotrophic count (PTC): 2.19 - 9.17 *Escherichia coli* count: 1.39 - 4.43 Coliform count: 2.84 - 7.0 *Staphylococcus aureus* count: 1.50 - 4.98 Fungal count (molds and yeasts): 1.15 - 4.15	Hedonic scale of 1 - 9 points Texture 8.9 - 3.0 Smell 8.9 - 3.0 Appearance 8.9 - 2.9 Color 8.9 - 2.9 Acceptance 8.9 - 5.0	It was cut into 2 x 2 x 2 cm^3 Packed in plastic bags Stored at 4 °C for 9 days	(Samani, Jooyandeh, & Behbahani, 2023)
Chicken Nuggets	Water holding capacity (WHC) % 93.28 - 86.94	TBA (mg MDA/kg): 0.24 - 2.39 Protein oxidation (DNBH) (nmol carbonyl content/mg protein): 0.60 - 6.44 pH 6.64 - 4.39	Total bacterial count (log ufc/g): 1.477 - 5.25 Coliform count (log ufc/g): 1.30 - 3.5 Total yeast and mold count (log ufc/g) 0 - 2.39	Average Aspect 8.60 Flavour 8.20 Color 8.60 General acceptance 8.30	Negative control samples (NC) Chicken nugget shape (3.8 cm diameter, 1.3 cm thick with an average weight of 17.5 g). Chicken nuggets were placed on plates and wrapped with polyethylene film, stored 4 °C for 24 days	(El-Sohaimy, Abd El-Wahab, Oleneva, & Toshev, 2022)
Beef patties	Not reported	Not reported	Total viable counts (TVC) log CFU/g: 5.0 - 9.50 *Staphylococcus aureus* count (log CFU/g): 2.5-4.5 Mold and yeast counts (log CFU/g): 2.3 - 5.36	Average Color 5.0; Flavour 5.0; Texture 5.0 General acceptance 15.0	100 g hamburger patty containing 60% beef. Packed separately in zippered plastic bags. Stored at 4 °C for 12 days	(Homayounpouret al., 2021)
Pork sausages	Hardness (gf): 2700.0 - 4837.7 Elasticity (mm): 6.67 - 6.50 Gumminess (kg mm^{-1}): 224.4 - 47.7 Chewiness (kg mm^{-1}): 135.7 - 317.8 Cohesion: 7.90 - 10.01 CIELab: L* 70.37 - 68.94; a* 9.98 - 9.00; b* 7.24 - 7.73	pH 6.37 - 6.35 Expressive moisture (EM) % 15.61 - 11.28 Raw protein (%): 16.81 - 19.71 Raw fat (%): 15.63 - 17.83 Moisture (%): 66.27 - 59.98 TBA (mg MAD/kg): 0.080 - 0.47	Total bacterial counts (TBC) (Log CFU/g) 3.00 - 3.54 Enterobacteriaceae count (EBC) (Log CFU/g) 3.00 - 3.50	Not reported	Samples (1.3 cm long and wide) Vacuum packed Stored at 10 °C for 35 days.	(Qiu & Chin, 2022)
Pork salami	Hardness (N): 7736 - 8709 Elasticity (mm): 0.29 - 0.30 Chewiness (N mm): 4636-4636 a_w: 0.889 - 0.890 CIELab L* 39.77 - 44.44; a* 17.98 - 18.42 b* 11.52 - 12.17	pH 4.71 - 5.01 Moisture (%): 40.37 - 38.70 Protein (%): 28.40 - 28.60 Lipid (%): 23.48 - 23.62 TBA: Malaldehyde concentration (mg MDA/kg) 0.090 - 0.167 Nitrite (ppm): 3.23 - 0.87 Nitrate (ppm) 25.68 - 29.22	Not reported	Attribute evaluation (average) Sour flavour 6.64 Acidic aroma 6.19 Rancid flavour 0.55 Rancid aroma 0.36	Packs of 100 g of product Salami slices Stored from 22 - 25 °C for 120 days.	(Demarco, Romio, Alfaro, & Tonial, 2022)

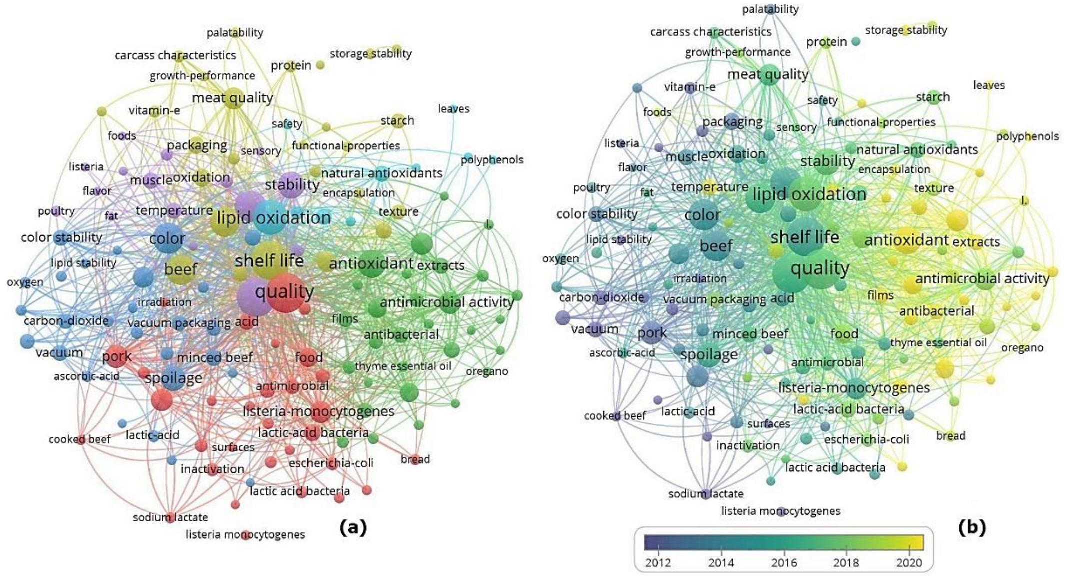

Figure 3. Shows the analysis of keyword co-occurrence. (a) visualization of networks and clusters; (b) visualization of overlapping over time. The search criteria was performed in the web of science database, by title, year and the keyword used was: shelf life; the food areas searched were (grains or cereal or flours or legumes, fruits and vegetables, fish and seafood, dairy or milk, meat or beef or burger or poultry); period from 2000 to 2024 and using VosViewer (https://www.vosviewer.com/).

This alteration can occur not only as a consequence of auto-oxidation phenomena (oxidative rancidity), but also as a result of the action of microbial lipases (hydrolytic rancidity) (Xia et al., 2023). The concern about lipid oxidation is related to the fact that derivatives of this reaction are implicated in the development of cancer, disruption of cell membranes, and the development of cancer (Wright et al., 2017), enzyme disruption and in-activation of protein damage. Lipid oxidation is a series of chemical and biochemical reactions that cause changes in the type and concentration of molecular species present in the food, such as malondialdehyde (Bassey et al., 2022).

12. Current and future challenges

The future challenges in the food industry range from producing more food with fewer resources to feed a rapidly growing world population to developing environmentally sustainable solutions in response to climate change or producing new varieties of foods with nutritional properties that support human health, to informing consumers of the impact of the environmental conditions to which different foods are subjected on their shelf life. Promote the development of procedures to inform consumers of the exact shelf life of foods during prolonged storage. Incorporate new technologies in shelf-life extension to ensure future food supply. Developing new packaging that is environmentally friendly and also extends the shelf life of food. The substitution of animal products for new sources of protein (algae, insects, among others) that are more sustainable. On the other hand, using graphical representations it is feasible to detect information gaps or areas that require further exploration on this topic: The volume of the nodes, combined with the central and peripheral location of these, makes it possible to observe the connections between one concept and others. Figure 3 shows the co-occurrence of the keywords of the analyzed articles, corresponding to life cycle studies and their monitoring indicators. Five clusters are identified in Figure 3(a):

Red cluster: studies concerning shelf life determination with microbial indicators for fermented pro-ducts in general.

Light blue cluster: studies concerning shelf life determination using different processing technologies.

Green cluster: studies concerning shelf life determination of edible films and coatings and their properties.

Yellow cluster: studies concerning shelf life determination of meat products in general.

Purple cluster: studies concerning shelf life determination in poultry in general.

Figure 3(b) identifies the topics, from the oldest to the most recent. Currently, it can be observed that in food shelf-life studies, indicators of bioactive compounds and edible films are being considered. The less recent articles are associated with the shelf life of foods with microbial indicators. It is suggested to carry out shelf life studies in food, focusing on aspects such as bioactive compounds, edible films and nanocomposites, among others.

13. Conclusions

Currently, consumers are more concerned about their health and the environment in which they live, which is why they prefer to consume functional foods that are made with ecological and environmentally friendly packaging since these types of packaging better preserve proteins and antioxidants in the food. The shelf life of food normally depends on the packaging used for distribution in the market; the longer conservation of the product depends on this to protect it from external factors, such as environmental changes, temperature, light, physical changes, chemical, microbiological sensory evaluation, etc.; which may present internal changes and changes in its composition, quality and the shelf life of the product when exposed to unfavorable conditions. Some indicators used to determine the shelf life of foods are pH, humidity, water activity, color, thiobarbituric acid, and microbiological activity, among others.

Acknowledgments

The authors would like to thank the FITOGEN program of the Universidad de Los Lagos for their support in carrying out this work.

Conflicts of Interest

No conflicts of interest

Author contributions

T. Espinoza-Tellez: conceptualization, research, writing the initial draft and revision. R. Quevedo-León: research, writing the initial draft, review and supervision. Oscar Diaz-Carrasco: research, revision of the manuscript.

ORCID

T. Espinoza-Tellez https://orcid.org/0000-0003-1491-1051
R. Quevedo-León https://orcid.org/0000-0001-8132-838X
O. Diaz-Carrasco https://orcid.org/0000-0002-0937-9825

References

Ahari, H., & Naeimabadi, M. (2021). Employing Nanoemulsions in Food Packaging: Shelf Life Enhancement. *Food Engineering Reviews*, *13*(4), 858-883. https://doi.org/10.1007/s12393-021-09282-z

Alcicek, Z. (2014). Effects of different liquid smoke flavor levels on the shelf life of venus clam (*Chamelea gallina*, l 1758) meat. *Journal of Food Processing and Preservation*, *38*(3), 964-970. https://doi.org/10.1111/jfpp.12052

Alipour, A., Marhamatizadeh, M. H., & Mohammadi, M. (2023). Studying the shelf life of butter containing fucoidan, by evaluating sensory and chemical properties. *Food Science & Nutrition*. https://doi.org/10.1002/fsn3.3277

Alirezalu, K., Inacio, R. S., Hesari, J., Remize, F., Nemati, Z., Saraiva, J. A., . . . Lorenzo, J. M. (2019). Nutritional, chemical, syneresis, sensory properties, and shelf life of Iranian traditional yoghurts during storage. *LWT - Food Science and Technology, 114*. https://doi.org/10.1016/j.lwt.2019.108417

Alqahtani, N. K., Alnemr, T. M., Alqattan, A. M., Aleid, S. M., & Habib, H. M. (2023). Physicochemical and Sensory Properties and Shelf Life of Block-Type Processed Cheeses Fortified with Date Seeds (*Phoenix dactylifera* L.) as a Functional Food. *Foods*, *12*(3). https://doi.org/10.3390/foods12030679

Aminian-Dehkordi, A., Ghaderi-Ghahfarokhi, M., Saei-Dehkordi, S., & Fazlara, A. (2023). Layer-by-Layer Coating Approach Based on Sodium Alginate, Sage Seed Gum, and Savory Oil: Shelf-Life Extension of Fresh Cheese. *Food and Bioprocess Technology*. https://doi.org/10.1007/s11947-022-02990-2

An, H. J., Zhai, C., Zhang, F., Ma, Q. Y., Sun, J. F., Tang, Y. W., & Wang, W. X. (2023). Quantitative analysis of Chinese steamed bread staling using NIR, MIR, and Raman spectral data fusion. *Food Chemistry, 405*. https://doi.org/10.1016/j.foodchem.2022.134821

Anand, S., Pang, E., Livanos, G., & Mantri, N. (2018). Characterization of Physico-Chemical Properties and Antioxidant Capacities of Bioactive Honey Produced from Australian Grown "*Agastache rugosa*" and its Correlation with Colour and Poly-Phenol Content. *Molecules*, *23*(1). https://doi.org/10.3390/molecules23010108

Andrade, M. A., Rodrigues, P. V., Barros, C., Cruz, V., Machado, A. V., Barbosa, C. H., . . . Silva, A. S. (2023). Extending High Fatty Foods Shelf-Life Protecting from Lipid Oxidation and Microbiological Contamination: An Approach Using Active Packaging with Pomegranate Extract. *Coatings*, *13*(1). https://doi.org/10.3390/coatings13010093

Bassey, A. P., Chen, Y. F., Boateng, E. F., Zhang, Y. Y., Diao, X. Y., Nasiru, M. M., . . . Zhou, G. H. (2022). Evaluation of physicochemical, microbiological, and sensory profiles of vacuum-packed cooked low-salt pork belly under refrigeration and room-temperature storage. *LWT-Food Science and Technology, 167*. https://doi.org/10.1016/j.lwt.2022.113847

Bonciu, E., Rosculete, C. A., Olaru, A. L., & Rosculete, E. (2022). Changes in the quality of food during storage and the main determining factors. *Scientific Papers-Series a-Agronomy, 65*(2), 335-340.

Bottegal, D. N., Lobón, S., Latorre, M. A., Bertolin, J. R., & Alvarez-Rodríguez, J. (2023). Colour Stability, Fatty Acid Profile, and Lipid Oxidation in Meat Stored in Modified Atmosphere Packaging from Light Lambs Fed with Concentrate with Carob Pulp "*Ceratonia siliqua* L.". *Antioxidants*, *12*(8). https://doi.org/10.3390/antiox12081482

Bressan, F., & Toledo, G. L. (2020). The influence of expiration date on purchase and consumption decisions of food products. *Estudios Gerenciales*, *36*(157), 439-453. https://doi.org/10.18046/j.estger.2020.157.3909

Burdon, J., Billing, D., & Pidakala, P. (2017). Avoiding Chilling Damage in 'Hass' Avocado Fruit by Controlled Atmosphere Storage at Higher Temperature. *Hortscience*, *52*(8), 1107-1110. https://doi.org/10.21273/hortsci12070-17

Carrillo, I., & Abigail, M. (2014). Vida útil de los alimentos / Lifetime food. *CIBA Revista Iberoamericana de las Ciencias Biológicas y Agropecuarias*, *2*(3).

Chang, Y. H., Chang, C. M., & Chuang, P. T. (2023). Shelf-Life Assessment of Bread Partially Substituted with Soy Protein Isolate. *Applied Sciences-Basel, 13*(6). https://doi.org/10.3390/app13063960

Chaturvedi, K., Basu, S., Singha, S., & Das, K. (2023). Predictive microbial growth modelling for an effective shelf-life extension strategy of Chhana (Indian cottage cheese*). Food Control*, *149*. https://doi.org/10.1016/j.foodcont.2023.109697

Clodoveo, M., Muraglia, M., Fino, V., Curci, F., Fracchiolla, G., & Corbo, F. (2021). Overview on Innovative Packaging Methods Aimed to Increase the Shelf-Life of Cook-Chill Foods. *Foods, 10*(9). https://doi.org/10.3390/foods10092086

Cui, F. C., Zheng, S. W., Wang, D. F., Ren, L. K., Meng, Y. Q., Ma, R., . . . Li, J. R. (2024). Development of machine learning-based shelf-life prediction models for multiple marine fish species and construction of a real-time prediction platform. *Food Chemistry, 450*. https://doi.org/10.1016/j.foodchem.2024.139230

de Rezende, L. P., Barbosa, J., & Teixeira, P. (2022). Analysis of Alternative Shelf Life-Extending Protocols and Their Effect on the Preservation of Seafood Products. *Foods*, *11*(8). https://doi.org/10.3390/foods11081100

Deepa, C., & Hebbar, H. U. (2017). Effect of micronization of maize grains on shelf-life of flour. *Journal of Food Processing and Preservation*, *41*(5). https://doi.org/10.1111/jfpp.13195

Demarco, F., Romio, A. P., Alfaro, A. D., & Tonial, I. B. (2022). Effects of Natural Antioxidants on the Lipid Oxidation, Physicochemical and Sensory Characteristics, and Shelf Life of Sliced Salami. *Food and Bioprocess Technology*, *15*(10), 2282-2293. https://doi.org/10.1007/s11947-022-02877-2

Ding, C., Khir, R., Pan, Z. L., Zhao, L. M., Tu, K., El-Mashad, H., & McHugh, T. H. (2015). Improvement in Shelf Life of Rough and Brown Rice Using Infrared Radiation Heating. *Food and Bioprocess Technology*, *8*(5), 1149-1159. https://doi.org/10.1007/s11947-015-1480-5

Dulta, K., Koşarsoy Ağçeli, G., Thakur, A., Singh, S., Chauhan, P., & Chauhan, P. K. (2022). Development of Alginate-Chitosan Based Coating Enriched with ZnO Nanoparticles for Increasing the Shelf Life of Orange Fruits (*Citrus sinensis* L.). *Journal of Polymers and the Environment.* https://doi.org/10.1007/s10924-022-02411-7

Dusková, M., Dorotíková, K., Macharácková, B., Jezek, F., Kameník, J., & Sedo, O. (2024). The shelf life of cooked sausages with reduced salt content. *Acta Veterinaria BRNO*, *93*(1), 115-121. https://doi.org/10.2754/avb202493010115

El-Sohaimy, S. A., Abd El-Wahab, M. G., Oleneva, Z. A., & Toshev, A. D. (2022). Physicochemical, Organoleptic Evaluation and Shelf Life Extension of Quinoa Flour-Coated Chicken Nuggets. *Journal of Food Quality*, *2022*. https://doi.org/10.1155/2022/9312179

Fadiji, T., Rashvand, M., Daramola, M. O., & Iwarere, S. A. (2023). A Review on Antimicrobial Packaging for Extending the Shelf *Life of Food*. *Processes*, *11*(2). https://doi.org/10.3390/pr11020590

Faradilla, R. H. F., Lee, G., Arns, J. Y., Roberts, J., Martens, P., Stenzel, M. H., & Arcot, J. (2017). Characteristics of a free-standing film from banana pseudostem nanocellulose generated from TEMPO-mediated oxidation. *Carbohydrate Polymers*, *174*, 1156-1163. https://doi.org/10.1016/j.carbpol.2017.07.025

Farahanian, Z., Zamindar, N., Goksen, G., Tucker, N., Paidari, S., & Khosravi, E. (2023). Effects of Nano-Bentonite Polypropylene Nanocomposite Films and Modified Atmosphere Packaging on the Shelf Life of Fresh-Cut Iceberg Lettuce. *Coatings*, *13*(2). https://doi.org/10.3390/coatings13020349

Fennema, O., & Tannenbaum, R. (2008). Química de los alimentos (Vol. 3). Acribia

Ferreira, S. M., Matos, L. C., & Santos, L. (2024). Harnessing the potential of chestnut shell extract to enhance fresh cheese: a sustainable approach for nutritional enrichment and shelf-life extension. *Journal of Food Measurement and Characterization*, *18*(2), 1559-1573. https://doi.org/10.1007/s11694-023-02260-5

Fischer, I. H., Tozze, H. J., de Arruda, M. C., & Massola, N. S. (2011). Postharvest of 'Fuerte' and 'Hass' avocados: physical and chemical characteristics, damages and control of diseases. *Semina-Ciencias Agrarias*, *32*(1), 209-220. https://doi.org/10.5433/1679-0359.2011v32n1p209

Forsido, S. F., Welelaw, E., Belachew, T., & Hensel, O. (2021). Effects of storage temperature and packaging material on physico-chemical, microbial and sensory properties and shelf life of extruded composite baby food flour. *Heliyon*, *7*(4). https://doi.org/10.1016/j.heliyon.2021.e06821

Franklin, L. M., Chapman, D. M., King, E. S., Mau, M., Huang, G. W., & Mitchell, A. E. (2017). Chemical and Sensory Characterization of Oxidative Changes in Roasted Almonds Undergoing Accelerated Shelf Life. *Journal of Agricultural and Food Chemistry*, *65*(12), 2549-2563. https://doi.org/10.1021/acs.jafc.6b05357

Freitas, M. A., & Costa, J. C. (2006). Shelf life determination using sensory evaluation scores: A general Weibull modeling approach. *Computers & Industrial Engineering*, *51*(4), 652-670. https://doi.org/10.1016/j.cie.2006.04.005

Gao, Y. P., Jiang, H. L., Lv, D., Benjakul, S., & Zhang, B. (2021). Shelf-Life of Half-Shell Mussel (*Mytilus edulis*) as Affected by Pullulan, Acidic Electrolyzed Water, and Stable Chlorine Dioxide Combined Ice-Glazing during Frozen Storage. *Foods*, *10*(8). https://doi.org/10.3390/foods10081896

Ghoshal, G., Bungar, S. P., Rachtanapun, P., & Phimolsiripol, Y. (2023). Advanced biomaterial-based active packaging for food shelf-life extension. *International Journal of Food Science and Technology*, *58*(2), 851-853. https://doi.org/10.1111/ijfs.16191

González H, M. I., Mesa G, C. A., & Quinteros C, O. A. (2014). Estimación de la vida útil de almacenamiento de carne de res y de cerdo con diferente contenido graso. *Vitae*, *21*, 201-210.

Gullian-Klanian, M., Jose Sanchez-Solis, M., Terrats-Preciat, M., Delgadillo-Diaz, M., & Aranda, J. (2016). Quality indicators and shelf life of red octopus (*Octopus maya*) in chilling storage. *Food Science and Technology*, *36*(2), 304-312. https://doi.org/10.1590/1678-457X.0077

Guo, Q., Cai, J. H., Ren, C. W., Li, Y. T., Farooq, M. A., & Xu, B. (2022). A new strategy for the shelf life extension of fresh noodles by accurately targeting specific microbial species. *Food Control*, *138*. https://doi.org/10.1016/j.foodcont.2022.109037

Gwirtz, J. A., & Garcia-Casal, M. N. (2014). Processing maize flour and corn meal food products. *Annals of the New York Academy of Sciences*, *1312*(1), 66-75. https://doi.org/10.1111/nyas.12299

Gyawali, R., Feng, X., Chen, Y. P., Lorenzo, J. M., & Ibrahim, S. A. (2022). A review of factors influencing the quality and sensory evaluation techniques applied to Greek yogurt. *Journal of Dairy Research*, *89*(2), 213-219. https://doi.org/10.1017/s0022029922000346

Hajar-Azhari, S., Daud, N., Muhialdin, B. J., Joghee, N., Kadum, H., & Hussin, A. S. M. (2023). Lacto-fermented garlic sauce improved the quality and extended the shelf life of lamb meat under the chilled condition. *International Journal of Food Microbiology*, *395*. https://doi.org/10.1016/j.ijfoodmicro.2023.110190

Halloub, A., Raji, M., Essabir, H., Chakchak, H., Boussen, R., Bensalah, M. O., . . . Qaiss, A. (2022). Intelligent food packaging film containing lignin and cellulose nanocrystals for shelf life extension of food. *Carbohydrate Polymers*, *296*. https://doi.org/10.1016/j.carbpol.2022.119972

Homayounpour, P., Sani, M. A., & Shariatifar, N. (2021). Application of nano-encapsulated Allium sativum L. essential oil to increase the shelf life of hamburger at refrigerated temperature with analysis of microbial and physical properties. *Journal of Food Processing and Preservation*, *45*(11). https://doi.org/10.1111/jfpp.15907

Hosseini, M. S., Zahedi, S. M., Abadia, J., & Karimi, M. (2018). Effects of postharvest treatments with chitosan and putrescine to maintain quality and extend shelf-life of two banana cultivars. *Food Science & Nutrition*, *6*(5), 1328-1337. https://doi.org/10.1002/fsn3.662

Hu, H. X., Yong, H. M., Zong, S., Jin, C. H., & Liu, J. (2022). Effect of chitosan/starch aldehyde-catechin conjugate composite coating on the quality and shelf life of fresh pork loins. *Journal of the Science of Food and Agriculture.* https://doi.org/10.1002/jsfa.11877

Inestroza-Lizardo, C., Mattiuz, B. H., da Silva, J. P., Galati, V. C., & Voigt, V. (2018). Hyperbaric pressure at room temperature increases post-harvest preservation of the tomato cultivar 'Debora'. *Scientia Horticulturae*, *228*, 103-112. https://doi.org/10.1016/j.scienta.2017.10.013

Jiang, Y. J., Yang, X. Y., Jin, H. N., Feng, X. H., Tian, F., Song, Y., . . . Zhang, W. (2021). Shelf-life prediction and chemical characteristics analysis of milk formula during storage. *LWT*, *144*. https://doi.org/10.1016/j.lwt.2021.111268

Kahlon, T. S., Avena-Bustillos, R. J., Kahlon, A. K., & Brichta, J. L. (2021). Consumer sensory evaluation and quality of Sorghum-Peanut Meal-Okra snacks. *Heliyon*, *7*(5). https://doi.org/10.1016/j.heliyon.2021.e06874

Kato, H. C. A., Joele, M., Sousa, C. L., Ribeiro, S. C. A., & Lourenco, L. F. H. (2017). Evaluation of the Shelf Life of Tambaqui Fillet Processed by the Sous Vide Method. *Journal of Aquatic Food Product Technology*, *26*(10), 1144-1156. https://doi.org/10.1080/10498850.2014.986593

Kaur, P., Kaur, K., Devgan, K., Kumar, M., Sandhu, K., & Kaur, A. (2022). Potential of low-dose aqueous ozone treatment and packaging to extend quality and shelf-life of green pea pods under cold storage. *Journal of Food Processing and Preservation*, *46*(10). https://doi.org/10.1111/jfpp.16165

Kebeya, N., Nduko, J. M., & Muliro, P. S. (2021). Evaluation of Consumer Sensory Acceptability and Shelf Life of Orange-fleshed Sweet Potato-enriched Mozzarella Cheese. *Current Nutrition & Food Science*, *17*(7), 764-772. https://doi.org/10.2174/1573401317999210422093112

Kilic-Akyilmaz, M., Kurt, C., Uzunoglu, T. P., Turkmen, F., Gunes, G., & Erem, E. (2023). Comparison of high intensity ultrasound and heat treatment for extending shelf life of a fermented milk beverage. *International Dairy Journal*, *141*. https://doi.org/10.1016/j.idairyj.2023.105617

Kosegarten, C. E., Ramirez-Corona, N., Lopez-Malo, A., & Mani-Lopez, E. (2022). Wheat-based fried snacks shelf-life prediction using kinetic, probabilistic, and time-to-fail models. *Journal of Food Processing and Preservation*. https://doi.org/10.1111/jfpp.16548

Ktenioudaki, A., Esquerre, C. A., Nunes, C. M. D., & O'Donnell, C. P. (2022). A decision support tool for shelf-life determination of strawberries using hyperspectral imaging technology. *Biosystems Engineering*, *221*, 105-117. https://doi.org/10.1016/j.biosystemseng.2022.06.013

Lauteri, C., Ferri, G., & Pennisi, L. (2023). A Quality Index Method-based evaluation of sensory quality of red mullet (*Mullus barbatus*) and its shelf-life determination. *Italian Journal of Food Safety*, *12*(1). https://doi.org/10.4081/ijfs.2023.10927

Lee, D. S., & Robertson, G. L. (2022). Shelf-life estimation of packaged dried foods as affected by choice of moisture sorption isotherm models. *Journal of Food Processing and Preservation*, *46*(3). https://doi.org/10.1111/jfpp.16335

Lee, E. J., & Shin, H. S. (2019). Development of a freshness indicator for monitoring the quality of beef during storage. *Food Science and Biotechnology*, *28*(6), 1899-1906. https://doi.org/10.1007/s10068-019-00633-5

Li, Y. J., Weng, P. F., Wu, Z. F., & Liu, Y. A. (2023). Extending the Shelf Life of Raw Milk and Pasteurized Milk with Plantaricin FB-2. *Foods*, *12*(3). https://doi.org/10.3390/foods12030608

Li, Y. L., Zhong, K., Wang, X., Wang, H. Y., Zhang, Y. J., Shi, B. L., . . Wang, S. S. (2023). Sensory Evaluation and Model Prediction of Vacuum-Packed Fresh Corn during Long-Term Storage. *Foods*, *12*(3). https://doi.org/10.3390/foods12030478

Liplap, P., Charlebois, D., Charles, M. T., Toivonen, P., Vigneault, C., & Raghavan, G. S. V. (2013). Tomato shelf-life extension at room temperature by hyperbaric pressure treatment. *Postharvest Biology and Technology*, *86*, 45-52. https://doi.org/10.1016/j.postharvbio.2013.06.006

Liu, Y., Zhu, Y. L., Yang, Y., Hu, S. W., & Jiang, W. (2022). Quality improvement of shrimp (*Litopenaeus vannamei*) during refrigerated storage by application of Maillard peptides/water-soluble chitosan coating. *Food Science & Nutrition*. https://doi.org/10.1002/fsn3.2894

Liu, Y. N., Wang, R., Wang, D. B., Sun, Z. L., Liu, F., Zhang, D. Q., & Wang, D. Y. (2022). Development of a food packaging antibacterial hydrogel based on gelatin, chitosan, and 3-phenyllactic acid for the shelf-life extension of chilled chicken. *Food Hydrocolloids*, *127*. https://doi.org/10.1016/j.foodhyd.2022.107546

Lomate, G. B., Dandi, B., & Mishra, S. (2021). Development of antimicrobial LDPE/Cu nanocomposite food packaging film for extended shelf life of peda (vol 16, pg 211, 2018). Food packaging and shelf life, 29.

Mangaraj, S., Thakur, R. R., & Nishad, P. (2023). Design of a modified atmosphere packaging for apple using concept of mathematical modeling for phytochemicals stability and shelf-life enhancement. *Journal of Food Process Engineering*, *46*(4). https://doi.org/10.1111/jfpe.14285

Manthou, E., Tarlak, F., Lianou, A., Ozdemir, M., Zervakis, G. I., Panagou, E. Z., & Nychas, G. J. E. (2019). Prediction of indigenous Pseudomonas spp. growth on oyster mushrooms (*Pleurotus ostreatus*) as a function of storage temperature. *LWT*, *111*, 506-512. https://doi.org/10.1016/j.lwt.2019.05.062

Mayookha, V. P., Pandiselvam, R., Kothakota, A., Ishwarya, S. P., Khanashyam, A. C., Kutlu, N., . . . El-Maksoud, A. A. A. (2023). Ozone and cold plasma: Emerging oxidation technologies for inactivation of enzymes in fruits, vegetables, and fruit juices. *Food Control*, *144*. https://doi.org/10.1016/j.foodcont.2022.109399

Montone, A. M. I., Malvano, F., Taiano, R., Capparelli, R., Capuano, F., & Albanese, D. (2023). Alginate Coating Charged by Hydroxyapatite Complexes with Lactoferrin and Quercetin Enhances the Pork Meat Shelf Life. *Foods*, *12*(3). https://doi.org/10.3390/foods12030553

Moradi, D., Ramezan, Y., Eskandari, S., Mirsaeedghazi, H., & Dakheli, M. J. (2023). Plasma-treated LDPE film incorporated with onion and potato peel extract-A food packaging for shelf life extension on chicken thigh. *Food packaging and shelf life*, *35*. https://doi.org/10.1016/j.fpsl.2022.101012

Moura-Alves, M., Machado, C., Silva, J. A., & Saraiva, C. (2022). Shelf-life determination of an egg-based cake, relating sensory attributes microbiological characteristics and physico-chemical properties. *International Journal of Food Science and Technology*, *57*(10), 6580-6590. https://doi.org/10.1111/ijfs.16001

Nguyen, M. P. (2020). Impact of Alginate Coating on Shelf life and Quality of Carrot (*Daucus carota* L.) during Storage. *Bioscience Research*, *17*(1), 366-370.

Ogura, N., Nakagawa, H., & Takehana, H. (1975). Effect of high temperature short term storage of mature green tomato fruits on changes of their chemical composition after ripening at room-temperature - studies on storage temperature of tomato fruits. *Journal of the Agricultural Chemical Society of Japan*, *49*(4), 189-196. https://doi.org/10.1271/nogeikagaku1924.49.189

Ouahioune, L. A., Wrona, M., Nerín, C., & Djenane, D. (2022). Novel active biopackaging incorporated with macerate of carob (*Ceratonia siliqua* L.) to extend shelf-life of stored Atlantic salmon fillets (*Salmo salar* L.). *LWT*, *156*. https://doi.org/10.1016/j.lwt.2021.113015

Palanisamy, S., Selvaraju, G. D., Selvakesavan, R. K., Venkatachalam, S., Bharathi, D., & Lee, J. T. (2024). Unlocking sustainable solutions: Nanocellulose innovations for enhancing the shelf life of fruits and vegetables - A comprehensive review. *International journal of biological macromolecules*, *261*. https://doi.org/10.1016/j.ijbiomac.2024.129592

Pal, S., & Bhattacharjee, P. (2018). Polypropylene-based packaging materials for shelf-life enhancement of yellow corn (Zea mays) kernels: Effects on lutein, aflatoxin content, sensory, and nutritional profiles. *Journal of Food Processing and Preservation*, *42*(6). https://doi.org/10.1111/jfpp.13618

Pande, H., Kapse, S., Krishnan, V., Kausley, S., Satyavathi, C. T., & Rai, B. (2024). Prediction of Shelf Life of Pearl Millet Flour Based on Rancidity and Nutritional Indicators Using a Long Short-Term Memory Network Model. *ACS Food Science &*

Technology, *4*(3), 786-795. https://doi.org/10.1021/acsfoodscitech.4c00005

Park, J. M., Lee, S. H., Koh, J. H., & Kim, J. M. (2018). Determination of Shelf Life Model of Pork Cutlet and Pork Lard during Accelerated Storage Conditions. *Korean Journal for Food Science of Animal Resources*, *38*(4), 664-678. https://doi.org/10.5851/kosfa.2018.e3

Patrignani, M., Battaiotto, L. L., & Conforti, P. A. (2022). Development of a good quality honey biscuit filling: Optimization, sensory properties and shelf life analysis. *International Journal of Gastronomy and Food Science*, *28*. https://doi.org/10.1016/j.ijgfs.2022.100508

Pedros-Garrido, S., Clemente, I., Calanche, J. B., Condon-Abanto, S., Beltran, J. A., Lyng, J. G., . . . Whyte, P. (2020). Antimicrobial activity of natural compounds against listeria spp. and their effects on sensory attributes in salmon (*Salmo salar*) and cod (*Gadus morhua*). *Food Control*, *107*. https://doi.org/10.1016/j.foodcont.2019.106768

Pedros-Garrido, S., Condon-Abanto, S., Clemente, I., Beltran, J. A., Lyng, J. G., Bolton, D., . . . Whyte, P. (2018). Efficacy of ultraviolet light (UV-C) and pulsed light (PL) for the microbiological decontamination of raw salmon (*Salmo solar*) and food contact surface materials. *Innovative Food Science & Emerging Technologies*, *50*, 124-131. https://doi.org/10.1016/j.ifset.2018.10.001

Petric, T., Kiferle, C., Perata, P., & Gonzali, S. (2018). Optimizing shelf life conditions for anthocyanin-rich tomatoes. *PLoS One*, *13*(10). https://doi.org/10.1371/journal.pone.0205650

Pilavtepe-Celik, M., & Buzrul, S. (2021). Shelf-life Estimation of Mullet (Mugil cephalus) Fillets by Mathematical Models Based on Some Biochemical Parameters and Sensory Evaluation. *Kafkas Universitesi Veteriner Fakultesi Dergisi*, *27*(5), 625-631. https://doi.org/10.9775/kvfd.2021.25998

Pivovarov, O., Kovalova, O., Koshulko, V., & Aleksandrova, A. (2021). Study of use of antiseptic ice of plasma-chemically activated aqueous solutions for the storage of food raw materials. *Journal of Food Science and Technology-Ukraine*, *15*(4), 95-105. https://doi.org/10.15673/fst.v15i4.2260

Pouyamanesh, M., Ahari, H., Anvar, A. A., & Karim, G. (2022). Packaging based on Ag-Low Density Polyethylene for shelf-life extension of pasteurized and traditional butters at refrigerated temperature. *Food Science and Technology*, *42*. https://doi.org/10.1590/fst.67020

Qi, T. T., Ji, J., Zhang, X. L., Liu, L., Xu, X. H., Ma, K. L., & Gao, Y. T. (2022). Research progress of cold chain transport technology for storage fruits and vegetables. *Journal of Energy Storage*, *56*. https://doi.org/10.1016/j.est.2022.105958

Qiu, Z. Z., & Chin, K. B. (2022). Evaluation of physicochemical properties and shelf life of regular-fat model sausages by wrapping with sodium alginate active film containing different levels and drying method of lotus rhizome root powder. *Journal of Food Processing and Preservation*, *46*(11). https://doi.org/10.1111/jfpp.16996

Romanazzi, G., & Moumni, M. (2022). Chitosan and other edible coatings to extend shelf life, manage postharvest decay, and reduce loss and waste of fresh fruits and vegetables. *Current Opinion in Biotechnology*, *78*. https://doi.org/10.1016/j.copbio.2022.102834

Salinas-Hernandez, R. M., Gonzalez-Aguilar, G. A., & Tiznado-Hernandez, M. E. (2015). Utilization of physicochemical variables developed from changes in sensory attributes and consumer acceptability to predict the shelf life of fresh-cut mango fruit. *Journal of Food Science and Technology-Mysore*, *52*(1), 63-77. https://doi.org/10.1007/s13197-013-0992-0

Samani, E. S., Jooyandeh, H., & Behbahani, B. A. (2023). The impact of Zedo gum based edible coating containing Zataria multiflora Boiss essential oil on the quality enhancement and shelf life improvement of fresh buffalo meat. *Journal of Food Measurement and Characterization*. https://doi.org/10.1007/s11694-023-01811-0

Sanchez-Rivera, M. M., & Bello-Perez, L. A. (2008). Effect of temperature in the oxidation reaction of banana starch (*Musa paradisiaca* l.). activation energy determination. *Revista Mexicana de Ingeniería Química*, *7*(3), 275-281.

Santos, A. C., de Oliveira, R. F., Henry, F. D., Maia, J. D., Moulin, M. M., Della Lucia, S. M., . . . Rampe, M. C. C. (2020). Physicochemical composition, lipid oxidation, and microbiological quality of ram mortadella supplemented with *Smallanthus sonchifolius* meal. *Food Science & Nutrition*, *8*(11), 5953-5961. https://doi.org/10.1002/fsn3.1880

Sarika, K., Jayathilakan, K., Lekshmi, R. G. K., Priya, E. R., Greeshma, S. S., & Rajkumar, A. (2019). Omega-3 enriched Granola bar: Formulation and Evaluation under different Storage Conditions. *Fishery Technology*, *56*(2), 130-139.

Sierra, N. M., Londono, A., Gomez, J. M., Herrera, A. O., & Castellanos, D. A. (2019). Evaluation and modeling of changes in shelf life, firmness and color of 'Hass' avocado depending on storage temperature. *Food Science and Technology International*, *25*(5), 370-384. https://doi.org/10.1177/1082013219826825

Sikora, M., & Swieca, M. (2018). Effect of ascorbic acid postharvest treatment on enzymatic browning, phenolics and antioxidant capacity of stored mung bean sprouts. *Food Chemistry*, *239*, 1160-1166. https://doi.org/10.1016/j.foodchem.2017.07.067

Singh, R. (2000). Scientific Principles of Shelf-Life Evaluation in MAN, CMD; JONES, AA 2000. Shelf-life Evaluation of Foods. In: Springer.

Singh, V., Aggarwal, P., Kaur, S., & Kaur, N. (2022). Intermediate moisture date (Phoenix dactylifera L.) based dessert with natural sugars: Phytonutritional profile, characterization, sensory quality, and shelf-life studies. *Journal of Food Processing and Preservation*, *46*(12). https://doi.org/10.1111/jfpp.17237

Sistková, I., & Cizková, H. (2024). Methods for Determining and Predicting Shelf Life of Food Products. *Chemicke Listy*, *118*(4), 211-219. https://doi.org/10.54779/chl20240211

Sylchuk, T., Tsyrulnikova, V., Zuiko, V., & Riznyk, A. (2021). Sorption properties of bread based on oatmeal. *Ukrainian Food Journal*, *10*(2), 361-374. https://doi.org/10.24263/2304-974x-2021-10-2-12

Tantratian, S., & Kaephen, K. (2020). Shelf-life of shucked oyster in epigallocatechin-3-gallate with slightly acidic electrolyzed water washing under refrigeration temperature. *LWT*, *118*. https://doi.org/10.1016/j.lwt.2019.108733

Tarlak, F. (2020). Development and validation of one-step modelling approach for prediction of mushroom spoilage. *Journal of Food and Nutrition Research*, *59*(4), 281-289.

Tavakoli, S., Regenstein, J. M., Daneshvar, E., Bhatnagar, A., Luo, Y. K., & Hong, H. (2022). Recent advances in the application of microalgae and its derivatives for preservation, quality improvement, and shelf-life extension of seafood. *Critical Reviews in Food Science and Nutrition*. https://doi.org/10.1080/10408398.2021.1895065

Temdee, W., Singh, A., Zhang, B., & Benjakul, S. (2022). Effect of vacuum packaging on shelf-life extension of cooked and peeled harpiosquillid mantis shrimp (*Harpiosquilla raphidea*) during refrigerated storage. *International Journal of Food Science and Technology*, *57*(7), 4451-4462. https://doi.org/10.1111/ijfs.15778

Van der Vossen-Wijmenga, W. P., Zwietering, M. H., Boer, E. P. J., Velema, E., & den Besten, H. M. W. (2022). Perception of food-related risks: Difference between consumers and experts and changes over time. *Food Control*, *141*. https://doi.org/10.1016/j.foodcont.2022.109142

Wang, L. X., & Teplitski, M. (2023). Microbiological food safety considerations in shelf-life extension of fresh fruits and vegetables. *Current Opinion in Biotechnology, 80. https://doi.org/10.1016/j.copbio.2023.102895*

Wickramaarachchi, L. A., Rajawardana, D. U., Gunasekara, M., Herath, H. M. T., & Jayasinghe, M. A. (2024). Development and evaluation of physico-chemical, sensorial, and shelf- life of grain-milk beverages. *Journal Of Cereal Science*, *116*. https://doi.org/10.1016/j.jcs.2024.103875

Wright, H. J., Hou, J., Xu, B. Z., Cortez, M., Potma, E. O., Tromberg, B. J., & Razorenova, O. V. (2017). CDCP1 drives triple-negative breast cancer metastasis through reduction of lipid-droplet abundance and stimulation of fatty acid oxidation. *Proceedings of the National Academy of Sciences of the United States of America*, *114*(32), E6556-E6565. https://doi.org/10.1073/pnas.1703791114

Xia, J. Y., Jiang, N., Zhang, B., Sun, R. X., Zhu, Y. Z., Xu, W. C., . . . Ma, Y. H. (2023). Bacterial Changes in Boiled Crayfish between Different Storage Periods and Characterizations of the Specific Spoilage Bacteria. *Foods*, *12*(16). https://doi.org/10.3390/foods12163006

Xie, H. K., Zhou, D. Y., Hu, X. P., Liu, Z. Y., Song, L., & Zhu, B. (2018). Changes in Lipid Profiles of Dried Clams (*Mactra chinensis* Philippi and *Ruditapes philippinarum*) during Accelerated Storage and Prediction of Shelf Life. *Journal of Agricultural and Food Chemistry*, *66*(29), 7764-7774. https://doi.org/10.1021/acs.jafc.8b03047

Yang, S. Y., Su, X. G., Prasad, K. N., Yang, B., Cheng, G. P., Chen, Y. L., . . . Jiang, Y. M. (2008). Oxidation and peroxidation of postharvest banana fruit during softening. *Pakistan Journal of Botany*, *40*(5), 2023-2029.

Yang, X. Y., Xu, B. C., Lei, H. M., Luo, X., Zhu, L. X., Zhang, Y. M., . . . Liang, R. R. (2022). Effects of grape seed extract on meat color and premature browning of meat patties in high-oxygen packaging. *Journal of Integrative Agriculture*, *21*(8), 2445-2455. https://doi.org/10.1016/s2095-3119(21)63854-6

Yin, C., Wang, J., Qian, J., Xiong, K., & Zhang, M. (2022). Quality changes of rainbow trout stored under different packaging conditions and mathematical modeling for predicting the shelf life. *Food packaging and shelf life*, *32*, 100824. https://doi.org/10.1016/j.fpsl.2022.100824

Yuceer, M., & Caner, C. (2022). Investigate the enzyme-texturized egg albumen on the functionality, sensorial and textural characteristics of cooked meringue cookies during storage. *Journal of Food Measurement and Characterization*, *16*(4), 2961-2968. https://doi.org/10.1007/s11694-022-01397-z

Zambon, A., Gonzalez-Alonso, V., Lomolino, G., Zulli, R., Rajkovic, A., & Spilimbergo, S. (2023). Increasing the Safety and Storage of Pre-Packed Fresh-Cut Fruits and Vegetables by Supercritical CO2 Process. *Foods*, *12*(1). https://doi.org/10.3390/foods12010021

Zarandona, I., López-Caballero, M. E., Montero, M. P., Guerrero, P., de la Caba, K., & Gómez-Guillén, M. C. (2021). Horse mackerel (*Trachurus trachurus*) fillets biopreservation by using gallic acid and chitosan coatings. *Food Control*, *120*, 107511. https://doi.org/10.1016/j.foodcont.2020.107511

Zielinska, D., Bilska, B., Marciniak-Lukasiak, K., Lepecka, A., Trzaskowska, M., Neffe-Skocinska, K., . . . Kolozyn-Krajewska, D. (2020). Consumer Understanding of the Date of Minimum Durability of Food in Association with Quality Evaluation of Food Products After Expiration. International Journal of Environmental Research and Public Health, 17(5). https://doi.org/10.3390/ijerph17051632