

Report of the Scientific Committee of the Spanish Agency for Food Safety and Nutrition (AESAN) on fruits and vegetables that have a risk of spoilage when presented for sale to consumers in bulk

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Working group

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Abstract

In recent years, Spanish legislation has promoted the implementation of a circular economy to minimise the negative effects of waste generation and management.

Thus, Royal Decree 1055/2022 of 27 December on packaging and packaging waste establishes measures aimed at the prevention of waste, the promotion of bulk food sales, the increase of reusable packaging and the promotion of recycling and marking of products. In particular, paragraph 4 of Article 7 states that food retailers shall take the necessary measures to present fresh fruit and vegetables marketed whole in bulk. This obligation shall not apply to fruit and vegetables packed in lots of 1.5 kg or more, fruit and vegetables packed under a protected or registered variety or bearing an indication of differentiated quality or organic farming, as well as fruit and vegetables that present

a risk of spoilage or depletion when sold in bulk.

A report has been requested from the Scientific Committee to determine which fruits and vegetables are most at risk of spoilage when presented in bulk for sale to the consumer and the possible food safety risks arising from this.

The report identifies mechanical damage, water loss and microbial contamination as the main causes of spoilage in vegetables and mushrooms marketed in bulk.

In terms of food safety, increased mechanical damage and risk of cross-contamination by viruses and pathogenic bacteria, which may proliferate during the shelf life of the product, are expected in bulk marketed vegetable and mushroom products. Such contamination may have a greater impact on vegetable products that are consumed raw and unpeeled.

Although an advanced stage of maturity leads to a higher susceptibility to mechanical damage, and consequently to microbial spoilage, it is difficult to objectify a risk maturity level to be applied across the board to all vegetables, especially fruits.

Cleaning, conditioning and cutting of external parts of vegetables marketed in bulk can lead to an increased likelihood of microbial contamination, as well as increased water loss, so it is recommended to reduce or limit these actions.

A non-exhaustive list of the most commonly consumed fruits, vegetables, tubers or mushrooms that may present a risk of spoilage or depletion when sold in bulk is proposed, based on the risk of mechanical damage, water loss and microbial spoilage by pathogenic or spoilage microorganisms, without prejudice that other plant products of less common use at present may, at a later stage, be included in this list. It is concluded that no tubers present a significant risk when sold in bulk.

In order to minimise the occurrence of defects in bulk vegetable products it is recommended that good hygienic practices are followed in primary production, storage and distribution of the products and to minimise the post-harvest period. In the retail trade it is also recommended to observe good hygiene practices, to prevent mechanical damage and microbial contamination, and to encourage customers to follow them.

In order to reduce the amount of packaging waste, it is recommended that, where possible, the materials necessary to present products in bunches, without the need for additional packaging material, be prioritised.

It is recommended that reusable and/or recyclable materials be used in packaging.

Key words

Fruits, vegetables, tubers, mushrooms, spoilage, plastic, packaging, bulk.

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1. Introduction

In line with the need to minimise the adverse effects of waste generation and management on human health and the environment, Law 7/2022, of 8 April, on waste and contaminated soils for a circular economy was published in 2022 (BOE, 2022a). Article 18 (4) provides as follows: *“In order to promote the prevention of single-use packaging, at the latest by 1 January 2023, food retailers with an area equal to or greater than 400 square metres shall allocate at least 20 % of their sales area to the supply of products presented without primary packaging, including the sale in bulk or by means of reusable packaging”*. Consequently, this Law promotes, among other possibilities, the bulk sale of foodstuff in general.

On the other hand, Royal Decree 1055/2022, of 27 December, on packaging and packaging waste, prepared by the Ministry for the Ecological Transition and the Demographic Challenge, carries out a comprehensive review of Spanish regulations in this matter in line with the objectives of the European Union that will allow progress in the implementation of the circular economy and achieve the new packaging recycling objectives for 2025 and 2030 (BOE, 2022b).

The main novelties of this royal decree include measures aimed at the waste prevention, bulk food sales promotion, reusable packaging increase and recycling and marking of products promotion.

In particular, Article 7 (4) states that *“food retailers shall take the necessary measures to present in bulk those fresh fruit and vegetables marketed whole. This obligation shall not apply to fruit and vegetables packed in lots of 1.5 kg or more, or those packed under a protected or registered variety or bearing an indication of differentiated quality or organic farming, as well as those presenting a risk of deterioration or loss when sold in bulk, which shall be determined by order of the Ministry of Agriculture, Fisheries and Food, in coordination with the Ministry for the Ecological Transition and the Demographic Challenge and the Spanish Agency for Food Security and Nutrition, within six months of the entry into force of this Royal Decree”*.

Once the aforementioned list is published, businesses will have 6 months to adapt the sale of fruits and vegetables that do not fall into these cases.

A report has been requested from the Scientific Committee to determine which fruits and vegetables are more prone to deterioration when presented in bulk for sale to the consumer and the possible food safety risks arising from this.

On the other hand, it has been requested the assessment of the potential risk of further deterioration due to the degree of maturity or the removal of certain parts to present them “clean” (such as, for example, celery and clean leek or carrot without leaves) indicating, also, any other necessary considerations.

2. Title: fruits, vegetables, tubers and mushrooms

- **Fruits.** The generic name “Fruits” refers to the infructescence, the seed or the fleshy parts of floral organs that have reached an adequate degree of maturity and are suitable for human consumption (BOE, 1978). This report will include the fresh fleshy fruits included in the first section of chapter XXII of the Spanish Food Code (BOE, 1967). Fresh fruits will be presented for

consumption whole, healthy and clean, free of any abnormal external moisture or any strange smell or taste. They should have a normal appearance and development, according to the variety, season and production area (BOE, 1967).

- **Vegetables.** The generic name “Vegetables” refers to any herbaceous horticultural plant that can be used as raw or cooked food (BOE, 1978). There is a specific group of ‘Vegetables’ in which the edible part is constituted by its green organs (leaves, stems or inflorescences). The name ‘Fresh legumes’ refers to the unripe fruits and seeds of leguminous vegetables. Based on the part of the plant to which they belong, vegetables can be distinguished as: fruits, cabbage bulbs, leaves and tender stems, inflorescences, green legumes, fruiting vegetables, roots and young stems, being all included in the first chapter XXI section of the Spanish Food Code (BOE, 1967).
- **Tubers.** The generic name ‘Tubers’ refers to parts of underground stems or roots of some plants, healthy, mature, clean of soil and other impurities and that, in their natural state, or properly preserved, are suitable for human consumption (BOE, 1978). They include potatoes, sweet potatoes, and tiger nuts (chapter XIX of the Spanish Food Code (BOE, 1967)).
- **Mushrooms.** ‘Mushrooms’ are fruiting bodies belonging to certain species of higher fungi, both cultivated and wild, intended to be supplied to the consumer as food (BOE, 2009).

3. Causes of deterioration of fruits, vegetables, tubers and mushrooms

Fresh fruits and vegetables are highly perishable products that can easily deteriorate during handling along the supply chain from the producer to the final retailer. Fruits and vegetables contain between 65 and 95 % water and, being living parts of plants, have a continuous post-harvest metabolic activity. This post-harvest metabolic activity makes them change their characteristics depending on the handling, storage and treatment of the product, all of which has a decisive impact on the useful life of the product. The deterioration of fresh products often results in rapid decomposition and thus loss of the product for human consumption, especially in the ripening and senescence phases of the vegetable (James and Zikankuba, 2017).

The deterioration of fresh products may result from biological factors, including microbiological, physiological, biochemical and physical factors acting on the products (Table 1). These factors can be caused by improper handling of products during harvest, transport and storage, ineffective quality control and adverse storage, transport and distribution conditions. In addition, time and temperature are key determinants of deterioration (United Nations, 2007).

Table 1. Main causes of deterioration in vegetables	
Deterioration factor	Determination of causes
Biological and physiological	
Pests (insects, rodents, birds)	Improper agricultural/handling practices
Rottenness and disease	Attacks by microorganisms
Respiration rate	High temperatures
Ethylene Production	High temperatures and storage combined with climacteric products
Growth and development of microorganisms	Extended post-harvest periods and high temperatures
Maturation and senescence	Extended post-harvest periods and high temperatures
Perspiration and water loss	Extended post-harvest periods and high temperatures
Chemical and biochemical	
Softening and loss of texture	Extended post-harvest periods and high temperatures
Enzymatic oxidation	Extended post-harvest periods, high temperatures and high oxygen concentration and availability
Photooxidation	Exposure to light
Physical	
Bruises, impacts, wounds, crushing, etc.	Handling
Dehydration and loss of firmness	Extended post-harvest periods and low relative humidity

With reference to the table above, packaging may allow to minimise some of the deterioration factors such as, for example, microbial growth, perspiration and water loss or softening and loss of texture in some of the stages of the production, transport and marketing chain of fruits and vegetables and other fresh products.

4. Quality parameters of fruits, vegetables, tubers and mushrooms

The quality level of fruits, vegetables, tubers and mushrooms determines acceptance by the end consumer. Some of the parameters on which the sector relies to determine the level of quality are: appearance, size, shape, integrity, brightness, consistency, defects, colour texture, aroma, flavour and nutritional value (Barrett et al., 2010). Post-harvest stages, including retailing, can lead to **loss of quality**, which largely depends on the nature of the product and handling and storage conditions. A general description of the main causes of post-harvest losses for different fruit and vegetable groups is presented in Table 2.

Table 2. Description of the alteration in different groups of vegetables	
Group	Main causes of post-harvest losses and poor quality
Tubers, roots and bulbs Potatoes, sweet potatoes, carrots, beets, onions, garlic	Mechanical damage Sprouting Decrease in water content Damage due to cold
Cabbages, leaves and stems Cabbages, lettuce, chard, spinach	Mechanical damage Decrease in water content Relatively high respiration rates Pigment degradation
Inflorescences and flower cabbages Artichokes, cauliflower, broccoli	Mechanical damage Decrease in water content Pigment degradation Flower abscission
Immature fruits, fruiting vegetables and green legumes Cucumbers, pumpkins, eggplants, sweet peppers, green beans	Mechanical damage Decrease in water content Harvest overripe Cold damage
Fruits Tomatoes, melons, bananas, mangoes, apples, grapes, cherries, peaches, apricots	Mechanical damage Decrease in water content Harvest overripe Cold damage

Modified from: University of Maryland (2002).

Consequently, a gradual loss of quality occurs during the entire post-harvest, which will also influence the probability of deterioration of fruits and vegetables once in the retail trade. *A priori*, retailing, the last stage of the post-harvest period, can impact basically the appearance, integrity and consistency, and may lead to defects, due, among other factors, to water loss, microbiota presence in the vegetable, lack of protection, inadequate temperature and relative humidity, and manipulation. In turn, all this can trigger microbial and enzymatic deterioration.

5. Impact of maturity status and previous operations

Ripe fruit may be more susceptible to mechanical damage due to loss of firmness. Therefore, firmness is a useful criterion to classify fruits at different maturity levels and to separate overripe and damaged fruits from those of good quality (Wang et al., 2006). For example, in fresh apples, the harvest time affects the subsequent mechanical damage due to changes in turgidity and firmness that mainly dominate the maturation process (García et al., 1995). In addition, physiological and compositional changes occur during ripening, such as sugar production from reserve polysaccharides, which **make fresh fruits and vegetables a suitable substrate for microbial growth** (Osorio and Fernie, 2013). The probability of microbial contamination in plant products depends on several factors such as surface morphological characteristics, presence of exudates, state of maturity and post-harvest handling practices (Kumar et al., 2016). Microbiological infection and deterioration of fruits and vegetables can be initiated, by Gram-positive, Gram-negative bacteria and fungi at any stage, between physiological to commercial maturity, and even more so in overripe fruits. While

parasites are a major concern for food safety, they have not been identified as compromising the sensory qualities of products and are not usually implicated in the deterioration of whole products (Barth et al., 2009).

During the post-harvest period, the vegetables undergo several transformations and **operations before** their sale that aim to remove deteriorated external parts that are not visually attractive to the consumer, or that can lead to the alteration of the product, reducing its useful life. Such operations mainly comprise cleaning, cutting or separation of the external parts of the plant (FAO/WHO, 2008). Despite the increased mechanization of these processes, **cross-contamination events may occur** through food handlers, especially if the operations are performed manually or not following correct hygiene practices (Gil et al., 2015). In fact, the appearance of cuts and slits in certain parts of the product increases the exposed surface with the consequent **risk of microbial contamination** (Alegbeleye et al., 2022).

Certain groups of microorganisms, especially fungi, can penetrate through plant tissues forming aporesoriums that favour the subsequent penetration of pathogenic microorganisms through a combination of mechanical pressure and tissue destruction by extracellular enzymes (Barth et al., 2009). The rupture of the cuticle favours contamination by certain foodborne pathogens, as shown by some studies (Benner, 2014). Therefore, outbreaks of food toxoinfection associated with external contamination of plants by direct contact of manipulators and/or consumers with the product have been reported (James, 2006). In laboratory-level studies using plants with damaged tissues, *Salmonella* spp. populations and pathogenic strains of *Escherichia coli* have been reported to reach population sizes up to 10 times greater than colonisation through intact tissue (Aruscavage et al., 2008). The release of nutrients through tissue degradation makes them available and act as a substrate for microbial growth (Goudeau et al., 2013). Some fruits with high wax content on the outside, are less likely to be contaminated, since they tend to have smoother surfaces where the microorganisms adhered to them can be removed more easily by washing and disinfection procedures (Palma-Salgado et al., 2020). The breakdown of these hydrophobic tissues increases the hydrophilicity of the microenvironment and develops greater bacterial adhesion (Brandl, 2008). In addition, increased **water loss occurs** accelerating the enzymatic reactions that give rise to plant senescence (Escalona et al., 2010) (Muslaomanovic et al., 2021).

Therefore, since the operations of cleaning, processing and cutting of external parts of vegetables marketed in bulk can lead to an increase in the likelihood of microbial contamination and, thus of the risk to the consumer, **it is recommended to reduce or limit these operations** except where this is essential (e.g. presence of exudates, oxidation of tissues, loss of turgidity of the external part, etc.). In addition, it must be considered that unpackaged products may be subject to a **greater loss of integrity**, as well as a reduction in their size due to water losses if processing operations have been carried out.

Finally, in order to minimise the occurrence of defects in bulk vegetable products it is also recommended that good hygienic practices are followed in primary production, storage and distribution of the products in accordance with the recommendations of the United States Food and Drug Administration (FDA, 1998) or *Codex Alimentarius* (CAC, 2003).

6. Objectives of packaging of fruits, vegetables, tubers and mushrooms

Royal Decree 1055/2022 of 27 December on packaging and packaging waste, in its Chapter 1, Article 2, defines "Packaging" as any product manufactured with materials of any nature and used to contain, protect, handle, distribute and present goods, from raw materials to finished articles, at any stage of the manufacturing, distribution and consumption chain (BOE, 2022b). In addition, primary and secondary packaging are defined as:

- Sale packaging or primary packaging. Any packaging designed to constitute a sales unit to the final consumer or end user at the point of sale, whether covering the product in whole or only partially, but in such a way that the content cannot be modified without opening or modifying said packaging.
- Grouped packaging or secondary packaging. Any container designed to constitute at the point of sale a grouping of a certain number of sales units, whether it is to be sold as such to the user or final consumer, or if it is used solely as a means of replenishing the shelves at said point and can be separated from the product without affecting its characteristics.

Many studies in the literature recognise that the packaging of fruits and vegetables is an effective technology to prolong the shelf life of these products, which are usually perishable (Oliveira et al., 2015). **The packaging of fruits and vegetables made available to the consumer aims to protect the product from mechanical damage and adverse environmental conditions during its handling and distribution**, its main functions being (Thompson and Mitchell, 2007):

- Provide physical protection against mechanical damage: open wounds (cuts or punctures) or bruises due to impacts, compression, vibration or abrasion.
- Provide protection against water loss. Many fruit and vegetable products suffer deterioration such as wilting, wrinkling or drying due to water loss during handling and marketing. This water loss is due to water vapour pressure difference between the product which is normally close to saturation (100 %) and the surrounding environment which is drier. The package offers a partial barrier against the movement of water vapour.
- Provide safety to the product as it prevents contamination and contact with the hands of manipulators and consumers.
- Facilitate special treatments, such as, for example, grapes packed with pads containing sodium metabisulfite, or asparagus, which must be packed vertically and with a wet pad that reduces their dehydration.
- Allow labelling and facilitate traceability.

7. Food safety in bulk fruits and vegetables

The exposure of unpackaged products at point of sale, and their handling increases the risk of contamination by foodborne pathogens. Such contamination may pose an increased risk if the fruits or vegetables have suffered previous mechanical damage, since the growth potential of pathogenic bacteria during the useful life of the product is higher. No studies address contamination and microbial growth specifically during bulk sales. However, the situation can be expected to be ana-

logous to any other waiting time at room temperature, aggravated by the manipulation by potential consumers. In this regard, microorganisms on the plant surface can penetrate through wounds or bruises producing hydrolytic enzymes that cause cell necrosis and maceration of plant tissues (Abbot and Boraston, 2008). The greater exposure surface and the release of water create a hydrophilic microenvironment that favours the adherence of microorganisms and their survival throughout storage. For example, previous studies have shown that *Salmonella* and pathogenic strains of *Escherichia coli* reached population sizes 10 times higher than those presented in intact tissues (Aruscavage et al., 2008) (Brandl, 2008) in which surface hydrophobicity facilitates the elimination of microorganisms by the application of decontamination treatments. Hydrophobicity also causes the modification of the distribution of microorganisms on the surface of tissues (Marik et al., 2020).

In the case of *Listeria monocytogenes*, its growth under storage conditions may be favoured by an increase in temperature and relative humidity, as well as a lower population density of the microbiota present in the product. For example, Aytac and Gorris (1994) observed that the behaviour of *L. monocytogenes* was different in legume shoots since the pathogen proliferated to a greater extent in those samples with a lower density of native microbiota. On the other hand, temperature and relative humidity during storage influence the growth of *L. monocytogenes*. In this sense, Huang et al. (2020) demonstrated that storage at temperatures above 20 °C exponentially increased *L. monocytogenes* population in various types of plant-based foods. Other factors associated with surface structure and nutrient availability were studied by Flessa et al. (2005), demonstrating that *L. monocytogenes* did not proliferate in those samples that remained intact compared to those with a higher surface humidity.

At the consumer level, it should be noted that contamination by pathogens can be minimised in cooked or peeled products, but can persist in those simply washed or even consumed without washing.

8. Fruits, vegetables, tubers or mushrooms at risk of spoilage or spoilage when sold in bulk

Royal Decree 3423/2000 defines the “Product sold in bulk” as that product that has not been previously packaged and is weighed in the presence of the consumer (BOE, 2000).

The purpose of this report is to determine in which cases, provided that the quantity of product made available to the consumer is less than 1.5 kg, some of these functions cannot be ignored. As stated above, those that have a greater importance are **the protection against mechanical damage, the minimisation of water loss and the avoidance of microbial contamination**. Bulk sales can lead to a greater possibility of contamination, due to handling, along with the possible loss of integrity and consistency, and the presence of wounds, which can trigger microbial and enzymatic deterioration, in the retail trade itself or at the consumer’s home (Gil et al., 2015). Mechanical damage results in the rupture of cell walls and membranes leading to the release of oxidative enzymes, bringing the substrates contained in the vacuoles into contact with the polyphenolic compounds and giving rise to enzymatic browning (Mitsuhashi-Gonzalez et al., 2010). The injuries produced as a result of mechanical damage accelerate physiological processes such as respiration, evapotrans-

piration through the injured skin causing the loss of firmness, and other biological processes such as microbial deterioration.

Table 3 contains a non-exhaustive list of the fruits, vegetables, tubers or mushrooms that, based on the probability of mechanical damage, water loss and the presence of altering or pathogenic microorganisms, may need the protection conferred by the packaging. Since there is no scientific literature that addresses the specific problem of the bulk sale of fruits and vegetables, the prioritisation has been carried out based on the qualitative categorization of the different risks by the members of the working group as “Very high”, “High” or “Medium”. In order to be able to offer a prioritised list (see first column), a numerical value has been assigned to the categories (Very high= 3, High= 2, Medium= 1), with which the averages of the numerical values granted by the different members of the working group determine the order of priority. For the estimation of the overall risk, equal weight has been assigned to the three types of risks considered.

Table 3. Risk of mechanical damage, water loss and microbial contamination

Fruits, vegetables, tubers or mushrooms		Risk of mechanical damage	Risk of water loss	Risk of microbial contamination	Global risk
1	RED FRUITS (blueberries, raspberries, strawberries, blackberries, currants)	Very high	Very high	Very high	Very high
2	SPROUTS	High	Very high	Very high	Very high
3	EDIBLE FLOWERS	High	Very high	High	High
4	AROMATIC HERBS (peppermint, mint, coriander, chives, parsley, basil, dill, cherries, fresh oregano)	High	Very high	High	High
5	POME FRUITS (grapes, lychees, physalis)	Very high	High	High	High
6	LEAFY VEGETABLES (lettuce, endive, buds, escarole, arugula, lamb's lettuce, chicory, kale, pak choi)	High	Very high	High	High
7	MUSHROOMS	Very high	High	Medium	High
8	LEAFY VEGETABLES (chard and spinach)	High	Very high	Medium	High
9	STONE FRUITS (cherries and apricots)	Very high	Medium	Medium	High
10	INFRUCTESCENCES (figs and fresh brews)	Very high	Medium	Medium	High
11	INFLORESCENCES (Brussels sprouts, broccoli, cauliflower)	High	High	Medium	High
12	STONE FRUITS (plums, dates)	High	Medium	Medium	Medium
13	STEM AND ROOT VEGETABLES (celery, radishes)	Medium	High	Medium	Medium
14	FRUIT VEGETABLES (cherry tomatoes and mini varieties)	High	Medium	Medium	Medium
15	POME FRUITS (loquats, persimmons)	High	Medium	Medium	Medium
16	STEM AND ROOT VEGETABLES (carrots, scallions, tender garlic, asparagus)	Medium	Medium	Medium	Medium
17	FRUIT VEGETABLES (chilli peppers)	Medium	Medium	Medium	Medium
18	LEAFY VEGETABLES (cabbage)	Medium	Medium	Medium	Medium

Conclusions of the Scientific Committee

This report identifies mechanical damage, water loss and microbial contamination as the main causes of deterioration in vegetables and mushrooms marketed in bulk.

In terms of food safety, increased mechanical damage and risk of cross-contamination by viruses and pathogenic bacteria, which may proliferate during the shelf life of the product, are expected in bulk marketed vegetable and mushroom products. Such contamination may have a greater impact on vegetable products that are consumed raw and unpeeled.

Although an advanced stage of maturity leads to a higher susceptibility to mechanical damage, and consequently to microbial deterioration, it is difficult to objectify a risk maturity level to be applied across the board to all vegetables, especially fruits.

Cleaning, conditioning and cutting of external parts of vegetables marketed in bulk can lead to an increased likelihood of microbial contamination, as well as increased water loss, so reducing or limiting these actions is recommended.

A non-exhaustive list (Table 3) of the most commonly consumed fruits, vegetables, tubers or mushrooms that may present a risk of deterioration or loss when sold in bulk is proposed, based on the risk of mechanical damage, water loss and microbial deterioration by pathogenic microorganisms, without prejudice that other plant products of less common use at present may, at a later stage, be included in this list. It is concluded that no tubers present a significant risk when sold in bulk.

In order to minimise the occurrence of defects in bulk vegetable products it is recommended that good hygienic practices are followed in primary production, storage and distribution of the products and to minimise the post-harvest period. In the retail trade it is also recommended to observe good hygiene practices, to prevent mechanical damage and microbial contamination, and to encourage customers to follow them.

In order to reduce the amount of packaging waste, where possible (spring onions, spring garlic, chard, spinach, carrots, etc.), priority should be given to presentation in bunches by using appropriate materials (ribbons, rubber bands, etc.) that do not require additional packaging.

It is recommended that reusable and/or recyclable materials be used in packaging.

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