Nordic Council
of Ministers

PLASTIC PACKAGING FOR FRESH FRUITS AND VEGETABLES

An overview of function, spoilage and food safety

CONTENTS

This publication is also available online in a web-accessible version at:
https://pub.norden.org/temanord2026-516

PREFACE

This report was commissioned by the Nordic Platform for Reduced Food Loss and Waste and produced by the Swedish Food Agency. The Nordic Platform for Reduced Food Loss and Waste and its activities are financed by and operate under the Nordic Council of Ministers for fisheries, aquaculture, agriculture, food, and forestry.

In light of ongoing regulatory developments within the European Union regarding the ambitions to reduce the use of plastic packaging material for fruits and vegetables, there is a need for information to inform early discussions and coordination efforts in the Nordics.

The purpose of this report is to examine how shelf life and food safety may be affected by the absence or presence of plastic (or other) packaging for fruits and vegetables under typical retail conditions.

The primary target audience comprises authorities, policymakers and stakeholders involved in food waste prevention, packaging policy and sustainable food systems, particularly within the Nordic context.

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March 2026

SUMMARY

This report was commissioned by the Nordic Platform for Reduced Food Loss and Waste and produced to inform Nordic dialogue on plastic packaging for fresh fruit and vegetables in light of the EU Packaging and Packaging Waste Regulation (PPWR 2025/40). From 2030, plastic packaging for fresh fruit and vegetables below 1.5 kg will be banned, with exemptions where necessary. While the European Food Safety Authority (EFSA) is conducting a comprehensive scientific assessment and further Commission guidance is expected, this report provides an overview to support coordination pending EFSA's conclusions.

The report addresses five specific questions:

1. **What is the purpose of having packaging on fruit and vegetables?**
   Packaging fulfils four principal functions: protection of physical integrity, protection against quality deterioration, ease of use, and communication. It facilitates logistics, portioning, traceability, consumer information and reduces mechanical damage during transport and handling. By influencing moisture and gas exchange, packaging can reduce water loss and slow physiological processes leading to senescence. Modern packaging technologies – e.g. modified atmosphere packaging and edible coatings – were not analysed in depth in this report.
2. **What can happen if fruit and vegetables are not packaged?**
   Without packaging, certain products are more exposed to bruising, cuts, dehydration, light and ethylene from nearby produce. Mechanical damage accelerates deterioration and may favour microbial spoilage or growth of pathogens. Produce with high surface-to-volume ratios, thin epidermal layers and limited protective cuticle are particularly susceptible to wilting. Products with thicker skins or lower surface-to-volume ratios may tolerate bulk presentation with limited impact on quality.
3. **Are there products for which packaging is particularly important or necessary?**
   The need for packaging is product specific. Soft fruits, stone fruits at advanced maturity, leafy greens, fresh herbs and mushrooms are especially vulnerable to injury and dehydration and are more likely to benefit from protective primary packaging. Climacteric fruits continue to ripen after harvest and produce ethylene, while certain vegetables are sensitive to ethylene exposure. Packaging, temperature control or physical separation may help manage ethylene emission from climacteric produce and protect ethylene sensitive produce.

4. **What is the effect of consumer produce bags for loose items?**
   Limited direct evidence was identified. Thin consumer produce bags primarily serve practical purposes such as weighing and transport. They are not designed to provide significant mechanical protection, and any protective effect is likely indirect through reduced handling.
5. **Are there microbiological risks associated with not having packaging?**
   Most contamination occurs earlier in the production chain. Conventional non-modified packaging does not eliminate intrinsic microbiological risks, and pathogen growth rates are not necessarily lower in packaged products. High humidity within packaging may even favour microbial growth. However, packaging may have indirect food safety benefits by reducing mechanical damage and handling.

SAMMANFATTNING PÅ SVENSKA

Plastförpackningar för frukt och grönsaker – funktion, förskämning och livsmedelssäkerhet

Denna rapport har tagits fram för att ge underlag till den nordiska dialogen om användning av plastförpackningar för färsk frukt och grönsaker. Detta görs mot bakgrund av EU:s nya förordning om förpackningar och förpackningsavfall, PPWR (2025/40). Från 2030 förbjuds plastförpackningar för färsk frukt och grönt under 1,5 kg, med möjlighet till undantag där behov av förpackningar kan motiveras. I väntan på att Europeiska myndigheten för livsmedelssäkerhet (Efsa) tar fram ett mer omfattande vetenskapligt underlag ger denna rapport en översikt för att stödja samordning.

Rapporten besvarar fem specifika frågor:

1. **Vad är syftet med att ha förpackning på frukt och grönsaker?**
   Förpackningar fyller fyra huvudsakliga funktioner: skydd av fysisk integritet, skydd mot kvalitetsförsämring, användarvänlighet samt kommunikation. De underlättar logistik, fördelning i lämpliga kvantiteter, spårbarhet, konsumentinformation samt minskar mekaniska skador under transport och hantering. Genom att påverka fukt- och gasutbyte kan förpackningar minska vattenförlust och bromsa fysiologiska processer som leder till degradering och förskämning. Moderna förpackningstekniker såsom förpackning i modifierad atmosfär och så kallade "edible coatings" analyserades inte ingående i denna rapport.
2. **Vad kan hända om frukt och grönsaker inte är förpackade?**
   Utan förpackning är vissa produkter mer utsatta för stötar, skärskador, uttorkning, ljus och eten från närliggande produkter. Mekaniska skador påskyndar nedbrytning och kan gynna mikrobiell förskämning eller tillväxt av patogener. Produkter med stor yta i förhållande till volym, tunn epidermis och begränsat skyddande vaxlager är särskilt känsliga för uttorkning. Produkter med tjockare skal eller liten yta i förhållande till volym kan ofta säljas i lösvikt med begränsad kvalitetsförlust.
3. **Finns det produkter där förpackning är särskilt viktig eller nödvändig?**
   Behovet av förpackning är produktspecifikt. Exempelvis är mjuka bär, stenfrukter i sent mognadsstadium, bladgrönsaker, färska örter och svamp särskilt känsliga för skador och uttorkning och har därför större nytta av skyddande primärförpackning. Klimakteriska frukter som äpplen, bananer

och tomater producerar växthormonet eten och fortsätter att mogna efter skörd. Vissa frukter och grönsaker är känsliga för eten eftersom det påskyndar mognad och åldrande. Förpackning, temperaturkontroll eller fysisk separation kan bidra till att hantera dessa processer.

4. **Vilken effekt har frukt- och grönsakspåsar påsar för lösviktsvaror?**
   Tunna frukt- och grönsakspåsar har främst en praktisk funktion, exempelvis för vägning och transport. De är inte utformade för att ge betydande mekaniskt skydd, och eventuell skyddande effekt är sannolikt indirekt genom minskad hantering.
5. **Finns det mikrobiologiska risker med att inte ha förpackning?**
   De flesta mikrobiologiska föroreningar sker tidigare i produktionskedjan. Konventionella, icke modifierade förpackningar reducerar inte sådana mikrobiologiska faror, och tillväxt av sjukdomsframkallande mikroorganismer är inte nödvändigtvis lägre i förpackade produkter. Hög luftfuktighet i förpackningar kan till och med gynna mikrobiell tillväxt. Förpackningar kan dock minska mikrobiologiska risker indirekt genom att minska mekaniska skador och hantering.

Obs. Publikationen har i sin helhet tagits fram på engelska. Endast titel och sammanfattning har översatts till svenska.

BACKGROUND

Food waste reduction is a key priority in Sweden, across the Nordic region and within the European Union. Food production is the sector with the greatest overall impact on global ecosystems, and reducing food waste is therefore recognised as an essential measure to limit environmental pressures while improving the efficiency and sustainability of food systems.

The European Union's new Regulation on Packaging and Packaging Waste (PPWR, Regulation (EU) 2025/40) introduces a ban on plastic packaging for fresh fruits and vegetables sold in quantities below 1.5 kg, to be implemented from 2030. The regulation allows for exemptions where packaging is demonstrably necessary, including to prevent water loss or loss of turgidity, microbiological hazards, physical damage or oxidation, or where packaging is required to avoid the mixing of organic and non-organic products.

A comprehensive assessment of the available evidence is being carried out by the European Food Safety Authority (EFSA 2025), and in February 2027, the European Commission is expected to publish a non-exhaustive list of fruit and vegetable products that may be exempted on such grounds.

This report is intended as a preparatory overview, supporting early knowledge-building, dialogue and coordination at national and Nordic level. The report should be understood as a targeted overview of selected scientific sources, rather than a comprehensive or systematic literature review on the need for (plastic) packaging of fruits and vegetables.

Specific questions to be answered

1. **What is the purpose of having packaging on fruits and vegetables?**
2. **What can happen to fruits and vegetables if they are not packed in plastic or other packaging?**
3. **Are there any fruits and vegetable products for which plastic packaging or other packaging is extra important or necessary?**
4. **What is the effect of produce bags used by consumers when purchasing fruits and vegetables that are sold loose?**
5. **Are there any microbiological risks of not having packaging on fruits and vegetables?**

DATA AND METHODOLOGY

Data sources

Similar commissions have been undertaken in other European Union Member States, including Spain (AESAN, 2023) and Belgium (OVAM, 2024), and these have provided valuable information for the present report. Apart from that, EFSA has published opinions on microbiological hazards in food of non-animal origin including fresh and frozen fruits, vegetables and herbs identifying the most important combinations of hazards and produce (EFSA, 2013, EFSA, 2023). Additionally, a scientific literature search was conducted according to Table 1 with the intent of finding relevant literature reviews on the topic. This search was complemented by explorative searches and snowballing.

Table 1. Literature search strategy. Searches were performed on 3 December 2025 and repeated on 25 February 2026.

Database	Search terms	# results	# selected full texts
PubMed	("shrink wrap"[Title/Abstract] OR "shrink film" [Title/Abstract] OR "cling film"[Title/Abstract] OR "plastic wrap"[Title/Abstract] OR "plastic packaging" [Title/Abstract]) AND (spoilage[Title/Abstract] OR "shelf-life"[Title/Abstract]) AND (fruit*[Title/Abstract] OR vegetable*[Title/Abstract])	30	1
FSTA	TI ("shrink wrap" or "shrink film" or "cling film" or "plastic wrap" or "plastic packaging") and (spoilage or "shelf-life") and (fruit or vegetable) OR AB ("shrink wrap" or "shrink film" or "cling film" or "plastic wrap" or "plastic packaging") and (spoilage or "shelf-life") and (fruit or vegetable)	150	1
Google Scholar	vegetable fruit spoilage review "shrink wrap" OR "shrink film" OR "cling film" OR "plastic wrap" OR "plastic packaging"	5120*	2

*The first 100 results in Google Scholar were assessed.

Methods

The grouping of products was done according to EFSA (**Table A1** in the appendix) since it has further been used for the hazard prioritisation in a more recent opinion considering water used post-harvest for fresh and frozen fruits, vegetables and herbs (EFSA, 2023). Information was gathered for the products concerning key parameters/purposes for packaging, namely (i) mechanical damage (ii) prevent water loss or loss of turgidity, (iii) ethylene sensitivity and (iv) microbiological hazards and spoilage microbiota, which are compiled in **Table 2.**

The Belgian report (OVAM, 2024) was machine translated using the European Commission's eTranslation service[1]. Artificial intelligence was used to assist in summarising and editing text while writing this report. All content has been reviewed and edited by the authors.

Scope and limitations

The scope of the report is restricted to conventional primary packaging solutions used at the point of sale, plastic or other. Advanced packaging technologies such as actively modified atmosphere packaging (MAP), passive modified atmosphere packaging (PMAP), packaging systems, ethylene scavengers, and active absorbers are not analysed in depth.

This report does not provide a detailed assessment of which specific packaging types are most suitable for individual fruit and vegetable products. Some information on recommended storage conditions and packaging approaches for selected commonly consumed products is compiled in **Table A2**.

The report does not constitute a comprehensive systematic review. It should instead be regarded as an overview intended to clarify how packaging may influence key deterioration mechanisms and food safety under practical retail conditions. An extensive scientific assessment is expected to be addressed in future work by EFSA.

1. Multilingualism, translation and language-based AI services (https://translation.ec.europa.eu/)

PURPOSE OF PACKAGING FRESH FRUITS AND VEGETABLES

Packaging of fruits and vegetables can be divided into primary, secondary and tertiary packaging (AESAN, 2023, OVAM, 2024, Morya & Sharma, 2019). Primary packaging (sale packaging) constitutes the sales unit offered to the final consumer and is the primary focus of this report. Secondary packaging (grouped packaging) groups one or more primary packages, for example to facilitate handling or retail display, while tertiary packaging is mainly used for transport and logistics, typically at pallet level. For fresh fruits and vegetables, primary packaging is generally of greatest relevance for quality preservation, although secondary and tertiary packaging contribute indirectly by reducing damage during distribution (AESAN, 2023, OVAM, 2024). Food packaging fulfils four main purposes which are summarised by OVAM (2024) and are here freely translated to **protection of physical integrity**, **protection against quality deterioration**, **ease of use** and **communication**.

Protection of physical integrity

Effective protection of physical integrity is a prerequisite for transporting and distributing food within modern logistics systems. Packaging (plastic or other material) enables fruits and vegetables to be handled, stacked and transported while being protected against mechanical damage such as shocks and compression. Protection of physical integrity is to ensure that products can be moved through the supply chain without unacceptable quality loss before reaching retailers and consumers (OVAM, 2024). Another aspect of this type of protection is the use of tamper-evidence on some pre-packaged products, which allows consumers to verify that the product has not been opened prior to sale (OVAM, 2024).

Protection against quality deterioration

Another role of packaging is to reduce biological and chemical processes that may lead to quality deterioration, in retail and at the consumer. The choice of packaging material and sealing system is critical to ensure adequate protection until the product reaches the consumer (OVAM, 2024). Important aspects of the protective function include control of gas exchange and moisture conditions, which influence respiration, ethylene production, ripening, senescence and spoilage processes

(AESAN, 2023, OVAM, 2024, Hasan et al., 2024). These aspects are discussed further below. Exposure to light constitutes another protective concern for some products. Ultraviolet and short-wavelength visible light may initiate or accelerate degradation reactions, leading to discolouration and off-flavours in certain fruit and vegetable products. Some types of packaging can reduce such exposure and thereby limit light-induced quality deterioration (OVAM, 2024).

Ease of use

Many packaging solutions are introduced primarily for practical reasons. This function is for example linked to societal and consumption trends, including time constraints and demand for convenience (OVAM, 2024). Examples of applications are portioning and ease of opening and resealing (OVAM, 2024). For fruits and vegetables, ease-of-use functions also include practical aspects such as grouping multiple units into a single handling unit (e.g. 1 kg bags of produce), facilitating transport and weighing of produce sold loose (e.g. the use of produce bags), and supporting retail display (AESAN, 2023)

Communication

Communication is a central function of packaging in retail environments. Packaging enables the provision of mandatory and voluntary information, supports product identification and traceability, and allows differentiation between products, including brands or certified categories such as organic produce (AESAN, 2023, OVAM, 2024).

FACTORS DETERMINING SHELF-LIFE OF FRUITS AND VEGETABLES

The shelf life of fresh fruits and vegetables is determined by a combination of physical, physiological and microbiological factors that act throughout the supply chain, from harvest through transport and storage to retail display. These factors may be influenced – either positively or negatively – by the presence or absence of packaging.

Mechanical damage

Mechanical damage of fruits and vegetables may occur during transport, in retail display and during consumer handling (AESAN, 2023, OVAM, 2024). Typical forms of injury include abrasion, compression damage, cuts, and punctures. These injuries compromise structural integrity and may lead to cosmetic defects, physiological responses in the product itself, as well as microbiological spoilage by bacteria and fungi (AESAN, 2023).

Mechanical disruption of plant tissues breaks cellular compartmentalisation, allowing enzymes and substrates to interact, leading to enzymatic browning, as well as increasing metabolic activity, including respiration (AESAN, 2023, OVAM, 2024). Elevated respiration accelerates senescence, shortens shelf life and may also enhance ethylene production in climacteric[2] produce, thereby promoting ripening and quality loss. Mechanical injury also facilitates microbial spoilage as damaged tissues provide entry points and nutrient-rich substrates for microorganisms, including pathogenic bacteria (AESAN, 2023). Trays, clamshells and top-sealed containers are commonly used packaging formats for protecting sensitive products against mechanical injuries (OVAM, 2024, White & Lockyer, 2020).

Water vapour exchange

Water loss is another important determinant of quality and shelf life in fresh fruits and vegetables (AESAN, 2023, Morya & Sharma, 2019, OVAM, 2024). After harvest, produce continues to exchange water vapour with the surrounding environment. Fruits and vegetables that are sold loose are directly exposed to ambient air in

2. Climacteric fruits and vegetables are those that continue to ripen after harvest. They produce a natural gas called ethylene, which acts as a ripening hormone.

retail environments, where relative humidity is often lower than optimal. Water loss results in reduced turgidity, wilting and shrivelling (AESAN, 2023). This in turn may increase susceptibility to mechanical damage and microbial invasion. Products that have high surface area and delicate tissues – for example leafy vegetables, fresh herbs and berries – are especially susceptible to water loss (AESAN, 2023). Packaging can mitigate dehydration by creating a microenvironment with higher relative humidity around the product. Films and sealed trays reduce vapour diffusion and slow down transpiration (White & Lockyer, 2020). Such packaging also provides protection against mechanical damage.

Conversely, if humidity becomes too high, condensation may occur, which can negatively affect sensory quality and promote spoilage (OVAM, 2024). From a microbiological perspective, surface moisture increases the likelihood of spoilage bacteria and fungi to grow, especially in products with damaged tissues. For packaged products, materials and designs with appropriate water vapour permeability in relation to product characteristics and storage conditions should therefore be used (AESAN, 2023, OVAM, 2024).

Respiration rate

After harvest, produce continues to consume oxygen and produce carbon dioxide, using stored substrates to maintain cellular metabolism. The speed of this process influences the rate of senescence, loss of nutritional value and overall quality deterioration (Morya & Sharma, 2019, OVAM, 2024).

Respiration rates vary considerably between products. A non-exhaustive list of produce and their respiration rates is presented in OVAM (2024). Products such as broccoli, mushrooms and certain berry varieties exhibit comparatively high respiration rates, whereas others, such as apples (depending on variety) and cauliflower, show lower values. In climacteric fruits, respiration is closely correlated with ethylene production, which further regulates ripening processes (Hasan et al., 2024). Elevated metabolic activity therefore shortens potential storage life, particularly if temperature and atmospheric conditions are not optimally controlled.

Lower storage temperature may reduce the speed of respiration (Hasan et al., 2024, OVAM, 2024). Packaging may affect respiration indirectly by modifying gas exchange and the surrounding atmosphere. However, it is important that oxygen is not completely excluded from the packaging as it would lead to anaerobic conditions resulting in fermentation (OVAM, 2024). In certain types of packaging, the product's own respiration is utilised to help protect and preserve the product. In passive modified atmosphere packaging (PMAP), the internal atmosphere develops naturally through the interplay between the respiration of the fresh produce and the gas permeability of the packaging material (Berk, 2013). This approach is commonly used for fresh, respiring products such as leafy greens and cut vegetables.

Ethylene production

Fruits and vegetables can be divided into climacteric and non-climacteric species (Morya & Sharma, 2019, MSU, 2026, OVAM, 2024). Climacteric means that the products continue to ripen after harvesting due to their production of significant amounts of ethylene. This also means that ripening is accelerated when these products are exposed to external ethylene, for example by being placed next to other products that emit ethylene. There are also products that are sensitive to ethylene damage, such as yellowing in certain lettuce varieties (OVAM, 2024, Saltveit, 1999). Most vegetables are non-climacteric, whereas fruits and vegetable fruits are often climacteric. Lists of climacteric and ethylene sensitive produce were found in the report by OVAM (2024) and on the webpage of Michigan State University (2026) and were combined in Table A3 in the appendix of the present report. Packaging may protect produce from ethylene in two ways: firstly, protecting the products from ethylene from nearby fruits and vegetables; and secondly, absorbing ethylene by using packaging containing absorbents designed for climacteric products, thereby delaying ripening. Physical separation of climacteric and ethylene sensitive produce in the retail display is yet another way of protecting fruits and vegetables from the effects of ethylene. Ethylene production is temperature-dependent, and higher storage temperatures promote increased ethylene synthesis. Maintaining controlled storage temperatures can therefore also reduce ethylene production and slow ripening and deterioration (AESAN, 2023)

Light exposure

Exposure to light is another factor affecting the quality of some fresh produce (OVAM, 2024). Both ultraviolet and visible light can initiate or accelerate degradation reactions, particularly at shorter wavelengths. The intensity and duration of exposure influence processes such as discolouration in some produce (e.g. Belgian endive/chicory) and the development of off-odours and off-flavours (AESAN, 2023, OVAM, 2024). However, it should be noted that specific wavelength ranges of UV light may also enhance quality and shelf life for some produce (Sonntag et al., 2023).

FOOD SAFETY ASPECTS OF PACKAGING OF FRUITS AND VEGETABLES

Priority combinations of hazards and produce

Fruits and vegetables are not inherently contaminated by biological hazards, but these are introduced at later stages. The faecal-oral route of contamination is a key concern meaning that faecal contamination on the produce is consumed and results in illness of the consumer (JIFSAN, 2010). There are a wide range of hazards that can be transmitted faecally-orally with fruits and vegetables as vehicles, including viruses, bacteria and protozoan parasites. In the EFSA opinion "*Microbiological hazards associated with the use of water in the post-harvest handling and processing operations of fresh and frozen fruits, vegetables and herbs (ffFVHs). Part 1 (outbreak data analysis, literature review and stakeholder questionnaire)*" (EFSA, 2023), the hazard prioritization was based on reported outbreaks in the EU (2014–2020) and a literature review. The most relevant microbiological hazards identified were: (i) L. monocytogenes, Salmonella spp., and human pathogenic E. coli, which were found to contaminate a wide range of fruits and vegetables, with a high impact on morbidity (number of hospitalisations) and mortality (number of deaths). Leafy greens and sprouted seeds were the most common vehicles, but tomatoes, cucumbers, pre-cut zucchini, plums and pre-cut melon were further implicated in Salmonella outbreaks. (ii) Enteric viruses – mostly norovirus – were identified in several outbreaks with frozen berries as implicated food vehicles, causing most cases overall. Norovirus outbreaks were also associated with fresh berries and leafy greens; Further, hepatitis A virus has been implicated in outbreaks with fresh strawberries and dates (PHAS, 2026). (iii) Other hazards which caused three or more European outbreaks associated with fruits, vegetables and herbs during that seven-year period were Yersinia spp., Shigella spp., and Cryptosporidium parvum, most often with leafy greens as vehicles (EFSA, 2023).

Contamination and cross-contamination along the food chain

As stated above, fruits and vegetables are themselves not associated with human pathogens, but they are introduced to the produce from external sources. This contamination can occur during any phase of the production and handling chain. Most products can be contaminated in primary production, especially by zoonotic hazards transmitted faecal-orally, e.g., Salmonella spp., pathogenic E. coli, Cryptosporidium parvum, and Yersinia spp. (EFSA, 2023) from inadequately treated manure, soil, contaminated irrigation water, wild animals and pests, dust or workers' hands (JIFSAN, 2010). In some listeriosis outbreaks, the outbreak investigations reported that contamination occurred at the processing plant or packing house; however, bacteria could potentially have entered the processing plant from the primary produce in low (undetectable) numbers and thereafter have multiplied (EFSA, 2023). There is less information on the route of foodborne virus contamination, but enteric human viruses may contaminate fruits and vegetables all along the production chain, most often from human handling operations (EFSA, 2023), even though wastewater contaminated irrigation water was suspected in an outbreak with frozen raspberries (Mäde et al., 2013). In any case, apart from viruses – due to lack of evidence – most hazards are already supposed to have contaminated the fruit or vegetable in question before primary packaging.

Pathogen and spoilage growth potential

Bacteria that have contaminated fresh produce may be able to reproduce on the surface of the product or within the product if the tissue has been injured. The bacterial growth rate is determined by several factors such as nutrient availability, pH, water activity (available water), temperature and oxygen (Alegbeleye et al., 2022, Skandamis, 2025). Considering pathogenic bacteria, biological competition (for available nutrients and colonisation space) from present microbiota is another important factor that can limit growth of harmful hazards (Alegbeleye & Rhee, 2024). Unless the plastic packaging has a modified atmosphere or preventive substances (see for example Hasan et al., 2024) the growth rate of pathogens (and spoilage organisms) should not be significantly different in packaged compared to bulk environment since the intrinsic factors and extrinsic factors are basically the same. A (non-modified) plastic packaging can in fact make the extrinsic environment more prone to microbial (mould, yeast and bacterial) growth and mycotoxin production (Alegbeleye et al., 2022). In fact Siroli et al. (2017), measured a faster decline of added pathogens and spoilers in cardboard materials than in plastic, which was due to the entrapment of microbial cells within the fibres and the pores of the cardboard materials. Physical damage to the produce may favour growth of pathogens as well as spoilage microbiota due to the release of nutrients and the exposure of surfaces that favour adherence of microorganisms. Studies have shown that Salmonella and pathogenic strains of E. coli reached population sizes 10 times higher in wounded compared to intact tissues (AESAN, 2023). Hence, there may be an indirect benefit of packaging in relation to food safety and spoilage.

PRODUCT-SPECIFIC NEED FOR PACKAGING

The need for packaging in fresh fruits and vegetables is not uniform across product categories but depends on intrinsic product characteristics and their susceptibility to deterioration mechanisms. As discussed previously, shelf life is primarily influenced by mechanical stress, moisture balance, respiration rate and, in some cases, ethylene-related ripening processes.

Products that combine high metabolic activity, high water loss and structural fragility are generally more sensitive to quality deterioration (AESAN, 2023, OVAM, 2024). For such products, packaging – plastic or other material – may contribute to extended shelf life, particularly when combined with appropriate storage conditions, including temperature control (OVAM, 2024).

Table 2 presents categories of fruits and vegetables, examples of representative products and their relative susceptibility to mechanical damage, water and turgidity loss, ethylene sensitivity and food safety–related deterioration (including microbial spoilage). The categorisation is based on the mechanisms described in the selected sources and aims to illustrate how vulnerability varies between product groups rather than to provide an exhaustive ranking.

Produce susceptible to mechanical damage

Susceptibility to mechanical damage varies between different types of fruits and vegetables. Products that are structurally fragile or easily bruised are therefore more likely to benefit from primary packaging that limits physical stress during distribution and retail display (AESAN, 2023, OVAM, 2024). AESAN (2023) provides a non-exhaustive list of produce that are susceptible to mechanical damage. Examples are soft fruits (e.g. strawberries, raspberries, grapes) and stone fruits (e.g. cherries, peaches, plums) – the latter especially at advanced stages of maturity. Leaves (e.g. leafy greens, fresh herbs) are also sensitive as they may suffer tearing and compression damage. Mushrooms are easily bruised and discoloured by handling and may sometimes benefit from primary packaging. Many of these products are also commonly consumed raw, which increases the relevance of preventing tissue damage that may facilitate growth of microbial pathogens. The need for packaging to reduce mechanical damage does not necessarily imply that plastic material is the only option.

Produce at risk to water loss

Products that are particularly sensitive to water loss typically share structural characteristics that promote transpiration: High surface-to-volume ratio, thin epidermal layers and limited protective cuticle increase the rate at which moisture is lost to the surrounding air. Leafy vegetables such as lettuce, spinach, as well as fresh herbs, are therefore especially vulnerable to rapid loss of turgidity when exposed to retail environments with suboptimal relative humidity (AESAN, 2023). Soft fruits also exhibit sensitivity to dehydration due to delicate tissues and limited structural barriers to moisture diffusion. In contrast, products with thicker skins, waxy surfaces or lower surface-area-to-volume ratios – such as many root vegetables and certain fruits – are generally less susceptible to rapid dehydration and may tolerate bulk presentation with limited impact on quality.

Climacteric and ethylene sensitive produce

Climacteric produce are characterised by continued ripening after harvest and significant ethylene production, which accelerates maturation and senescence (OVAM, 2024). Many fruits are climacteric, whereas vegetables are often non-climacteric. Typical examples of climacteric products include apples, bananas, mangoes, tomatoes and several stone fruits.

In contrast, ethylene-susceptible products are not necessarily climacteric themselves – although there is an overlap between the groups – but respond negatively (from shelf-life point of view) to external ethylene exposure (Saltveit, 1999). Some vegetables, in particular leafy vegetables, may develop yellowing or quality defects when exposed to ethylene in mixed retail displays (OVAM, 2024, Saltveit, 1999).

Table A3 in the appendix shows selected fruits and vegetables according to ethylene sensitivity and climacteric behaviour.

Food safety and microbial spoilage

From a food hygiene perspective primary packaging is most important to prevent virus transmission in later stages of the food chain and therefore commodities associated with viral outbreaks, i.e. berries, especially strawberries and raspberries, and leafy greens are the most relevant to pack from a hygienic perspective (Table 2). Food safety aspects were rarely mentioned as the most important reason for the need of single use packaging from respondents in OVAM (2024), but by a minority in relation to grapes, berries and cherry tomatoes. In AESAN (2023) red fruits (e.g. berries) and sprouted seeds were ranked highest from a microbial contamination risk with edible flowers (flower buds), aromatic (fresh) herbs, pome fruits (grapes, lychees, physalis) and leafy vegetables in the group thereafter. As previously stated, packaging can have an indirect effect on food safety and spoilage by reducing mechanical damage that favours microbial growth and mycotoxin production (Alegbeleye et al., 2022).

Table 2. Fruits and vegetables and their relative susceptibility to key deterioration mechanisms. Information in the table is compiled and adapted from AESAN (2023), EFSA (2023), MSU (2026), OVAM (2024), and Salveit (1999). The categorisation is based on the mechanisms described in the selected sources and aims to illustrate how the relative vulnerability – using a three-graded scale (high, medium, low) – varies between product groups rather than to provide an exhaustive ranking. There can be variations within a specific category and even product, due to different varieties, for example types of apples. See Table A1 in appendix for examples of products in different food categories

General food category	Specific food categories (for examples see Appendix)	Mechanical damage	Water loss	Ethylene sensitive	Microbial contamination
Soft fruits	Strawberries	High	High	No	High[a]
	Raspberries	High	High	Yes	High[a]
	Other berries	Medium	Medium	No	Medium
Citrus fruit		Low	Low	No	Low
Apples and related fruit			Medium	Yes	Low
Stone fruit		High	Medium	No (e.g. cherries) Yes (e.g. plums)	Medium
Tropical fruit		Varies	Varies	Often (varied group)	Low
Melons		Low	Low	Yes (e.g. cantaloupes) No (watermelon)	Medium[b]

Vegetable fruits	Tomatoes	High	Medium	Yes	High[c]
	Peppers and aubergines	Medium	Medium	Yes	Medium
	Gourds and squashes (cucumber)	Medium	Medium	Yes	Medium
	Fresh pods, legumes and grain	Medium	Medium	Yes (e.g. peas in pods) No (e.g. lima beans)	Low
Leaves	Leafy greens eaten raw as salads	High	High	Yes	High[a]
	Fresh herbs	High	High	Yes	High
	Other leaves	High	High	Yes	Medium
Root and tuberous vegetables	Carrots	Low	Low	Yes	Medium
	Potatoes	Medium	Low	Yes	Low
	Other root and tuberous vegetables	Medium	High	Yes (e.g. sweet potatoes) No (e.g. radish)	Low
Bulb and stem vegetables		Medium	Medium	Yes (e.g. asparagus, celery, leek) No (e.g. green onions, onions)	Medium
Flowers and flower buds		High	High	Yes (e.g. broccoli) No (e.g. cauliflower)	Medium
Sprouted seeds		High	High	Yes	High
Fungi (mushrooms and yeasts)		High	High	No	Medium[d]

[a] Associated with viral outbreaks. [b] Outbreaks of listeriosis and salmonellosis have been associated with melons, however from cut fruits. [c] Associated with several salmonellosis outbreaks. [d] Associated with sporadic listeriosis outbreaks.

Answers to specific questions

1. What is the purpose of having packaging on fruits and vegetables?

There are four main purposes of having packaging on fruits and vegetables:

Protection of physical integrity

- Packaging protects produce against mechanical damage during transport, retail display and handling.

Protection against quality deterioration

- Packaging helps to slow the biological and chemical processes that diminish quality and accelerate product ageing. By regulating moisture and gas exchange, it influences water loss, respiration, ethylene production, ripening and senescence. In doing so, it can extend shelf life, preserve appearance and contribute to the reduction of food waste.

Ease of use

- Packaging facilitates handling, transport, portioning and retail display. It enables grouping of units into manageable sales formats, supports weighing of loose produce, and can offer convenience features such as easy opening and resealing.

Communication

- Packaging enables product identification and traceability and provides mandatory and voluntary information. It also supports differentiation between products, such as branding or separating organic certification from conventional produce.

2. What can happen to fruits and vegetables if they are not packaged in plastic or other packaging?

Many fruits and vegetables do not require packaging, but for those that are benefited by packaging, the following may happen:

Increased mechanical damage

- Greater risk of bruising, compression, abrasion and cuts during transport and handling. Damage can lead to faster deterioration and increased microbial growth.

Greater water loss

- Direct exposure to air may cause dehydration, wilting and shrivelling, particularly in leafy vegetables, fresh herbs and berries.

Faster ripening and senescence

- The absence of a protective microenvironment may result in faster respiration and greater exposure to ethylene, especially in climacteric fruits.

Increased light exposure

- May lead to discolouration and quality changes in certain products.

Food safety effects

- Tissue damage or over-ripening may favour the growth of bacteria, moulds and other fungi.

3. Are there any fruit and vegetable products for which plastic packaging or other packaging is extra important or necessary?

The need for packaging depends on product characteristics and susceptibility to deterioration. Certain fruits and vegetables are described as more likely to benefit from, or have a stronger need for, primary packaging. Table 2 and tables A2 and A3 list in more detail different produce and their properties that may motivate the use of packaging, but in general terms the following applies:

Products susceptible to mechanical damage

- Structurally fragile or easily bruised products are more likely to benefit from packaging that limits physical stress during distribution and retail display. Examples include soft fruits (e.g. strawberries, raspberries and grapes), stone fruits (e.g. cherries, peaches and plums – particularly at advanced maturity), leafy greens, fresh herbs and mushrooms.

Products susceptible to water loss

- Produce with high surface-to-volume ratio, thin epidermis and limited protective cuticle is particularly vulnerable to dehydration and loss of turgidity in retail environments. These include leafy vegetables (e.g. lettuce, spinach), fresh herbs and soft fruits. Packaging can help maintain a higher relative humidity around these products and reduce wilting and shrivelling

Products susceptible to ethylene

- Climacteric fruits continue to ripen after harvest and produce significant amounts of ethylene. Packaging of some climacteric fruits may help protect nearby ethylene sensitive produce or, in some cases, absorb ethylene to delay ripening. Ethylene-sensitive vegetables, particularly leafy vegetables, may develop quality defects such as yellowing when exposed to ethylene in mixed retail displays. Packaging, temperature control (low temperature slows down respiration and ethylene production) or physical separation of different produce can therefore be relevant for these products.

4. What is the effect of produce bags used by consumers when purchasing fruits and vegetables that are sold loose

No sources were found that directly assess the effect of produce bags. The following assessment is therefore based on general principles described in the literature. Plastic produce bags primarily serve a practical function. They facilitate weighing, handling and transport of loose produce and allow products to be grouped at the point of sale. These bags are typically thin and are not designed to provide mechanical protection. Indirect effects may occur. By grouping items, carrier bags may reduce repeated handling and thereby limit mechanical damage to some extent.

5. Are there any microbiological risks of not having packaging on fruits and vegetables?

Most microbial contaminations occur before primary packaging and conventional non-modified packaging does not eliminate intrinsic microbiological risks, and pathogen growth rates are not necessarily lower in packaged products. Reducing contamination of enteric viruses in later stages of the food chain can have an impact from a microbiological risk perspective; the highest prioritised products being soft fruits (berries), mainly raspberries and strawberries. Secondly, leafy greens, sprouted seeds, fresh herbs and (cherry) tomatoes could be considered.

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APPENDIX

Table A1. General and specific food categories of fruits, vegetables and herbs (adapted from EFSA 2013)

General food category	Specific food categories	Examples of commodities
1. Fruit (non-specified)		
Soft fruits	2. Strawberries	
	3. Raspberries	
	4. Other berries	Blackberry, blackcurrant, blueberry, cloudberry, cranberry, lingonberry, red currant, red and green grape
5. Citrus fruit		Grapefruit, lemon, lime, mandarin, orange, tangerine
6. Apples and related fruit		Apple, hawthorn, pear, quince
7. Stone fruit		Apricot, Asian plum, cherry, European plum, nectarine, peach
8. Tropical fruit		Avocado, coconut, date, dragon fruit, guava, fig, jackfruit, kiwifruit, lychee, mango, mangosteen, passion fruit, papaya, persimmon, pineapple, pomegranate, rambutan, star apple, starfruit, sugar apple, tamarind
9. Melons		Bitter melon, horned melon, muskmelon (cantaloupe, winter melon, galia), watermelon
Vegetable fruits	10. Tomatoes	Tomatoes (grape, cherry, currant, plum, beef, etc)
	11. Peppers and aubergines	Aubergine, pepper (bell, fresh, sweet, chilli, etc)
	12. Gourds and squashes	Butternut squash, button squash, courgette, cucumber, hubbard squash, kabocha, marrow, muscat, pepita squash, pumpkin
	13. Fresh pods, legumes and grain	Black-eyed pea, chickpea, common bean, fava bean, green bean, horse gram, Indian pea, kidney bean, lentil, lima bean, moth bean, mung bean, okra, pea, pigeon pea, ricebean, snap pea, snow pea, soybean, sweet corn

Leaves	14. Leafy greens eaten raw as salads	Arugula, cabbage, celery, celtuce, chard, chicory, Chinese cabbage, collard greens, cress, endive, lettuce, rocket, spinach
	15. Fresh herbs	Basil, cilantro, celery, coriander, dill, fresh tea, marjoram, mint, parsley, peppermint, rosemary, sage, thyme
	16. Other leaves	Brussel sprouts, kale, pak choy, other cabbage not eaten raw
Root and tuberous vegetables	17. Carrots	
	18. Potatoes	
	19. Other root and tuberous vegetables	Cassava, ginger, horseradish, parsnip, radish, swede, sweet potato, taro, tigernut, turnip
20. Bulb and stem vegetables		Asparagus, celeriac, celery, fennel, garlic, kohlrabi, leek, onion, shallot, spring onion
21. Flowers and flower buds		Artichoke, broccoli, cauliflower, courgette flower, squash blossom
22. Sprouted seeds		Alfalfa, broccoli, cress, chick pea, coriander, fennel, fenugreek, garlic, leek, lentil, mung bean, onion, pea, radish, shiso, sunflower, wheat
23. Fungi (mushrooms and yeasts)		

Table A2. Product-specific role and relevance of packaging for selected fruits and vegetables under typical retail conditions. Adapted and interpreted from White & Lockyer (2020).

Product	Key susceptibility	Typical packaging used	Main function(s) of packaging	Effect on quality and shelf life	Relevance of packaging	Rationale
Apples	Water loss, respiration, bruising	Sold loose or in packaging: polyethylene (PE) bags, flow wrap, cardboard trays,	Reduce water loss; protect against mechanical damage; enable handling and grouping	May reduce weight loss and slow quality deterioration	Context-dependent	Relatively robust product, but some varieties are more sensitive; benefits may be limited depending on storage conditions and supply chain
Bananas	Ethylene-driven ripening, water loss	Sold loose or in packaging: PE bags	Reduce water loss; facilitate handling and grouping	May slow visual quality deterioration	Limited	Temperature management is more important than packaging for shelf life
Broccoli	High respiration, water loss	Often in packaging: usually cling film	Reduce water loss; protect during handling	May slow wilting and quality deterioration	Often beneficial	High metabolic activity and susceptibility to dehydration
Carrots	Water loss	Sold loose or in packaging: PE tied bags	Reduce water loss; maintain turgidity; enable handling and grouping	May help maintain firmness and texture	Limited to moderate	Relatively robust but benefits from reduced water loss
Grapes	Mechanical damage, water loss	Mainly sold in packaging: PET (polyethylene terephthalate) punnets/clamshells	Protect against compression and handling; reduce water loss	May reduce physical damage and spoilage	Often beneficial	Structurally fragile and sensitive to handling; grapes may detach from stalk

Mushrooms	High respiration, water loss	Sold loose or in packaging: plastic punnet with cling film, PET clamshell or other plastic packaging	Regulate humidity and gas exchange; reduce handling	May extend shelf life if conditions are appropriate	Context-dependent	Sensitive to condensation and spoilage under high humidity; need for packaging differ between mushroom species, cf. enoki mushroom vs common mushroom
Oranges	Low susceptibility	Sold loose or in plastic net	Facilitate handling, grouping and transport	Limited effect on quality compared to when sold loose	Limited	Thick peel provides natural protection
Peppers	Water loss, respiration	Sold loose or in packaging: flow wrap PE or PE bags	Reduce water loss; protect against handling damage; enable grouping	May help maintain firmness and quality	Context-dependent	Benefits depend on storage conditions and packaging design
Potatoes	Water loss, light exposure	Sold loose or in packaging: PE bags, paper bags	Reduce water loss; protect from light; enable handling and grouping	May reduce weight loss and delay greening	Limited	Storage conditions (dark, cool) are more important than packaging
Tomatoes	Mechanical damage, ripening	Plastic or cardboard punnets, PET clamshells, flow wrap	Protect against mechanical damage; reduce handling; enable grouping	May reduce physical damage	Context-dependent	Sensitive to handling, but packaging has limited effect on ripening

Table A3. Classification of selected fruits and vegetables according to ethylene sensitivity and climacteric behaviour. Compiled and adapted mainly from OVAM (2024) and MSU (2026). It should be noted that although the classification of ethylene sensitivity and climacteric behaviour is generally consistent across different scientific sources, some variations are reported due to differences between cultivars within the same species.

N/A means information was not available in OVAM (2024) or MSU (2026) but may be available elsewhere.

Fruit or vegetable	Ethylene sensitive?	Climacteric?
Apples	Yes	Yes
Apricots	Yes	Yes
Asparagus	Yes	No
Avocados	Yes	Yes
Bananas	Yes	Yes
Beets, roots	No	N/A
Bell peppers	Yes	No
Blackberries	No	No
Blueberries (American)	No	Yes
Blueberries (European)	N/A	No
Broccoli	Yes	N/A
Brussel sprouts	Yes	N/A
Bulb onions (yellow, red, etc)	No	N/A
Butter beans/Lima beans	No	N/A
Cabbage	Yes	N/A
Carrots	Yes	N/A
Cauliflower	No	N/A

Celery	Yes	N/A
Cherries	No	No
Chili peppers	Yes	No
Chinese Pear	N/A	No
Cocoa	N/A	No
Cooking banana/Plantain	N/A	Yes
Cranberries	No	N/A
Cucumbers	Yes	No
Dragon fruit	N/A	No
Durian	N/A	Yes
Eggplant/Aubergine	Yes	No
Endive	Yes	N/A
Figs	N/A	Yes
Garlic	No	N/A
Grapefruit	No	No
Grapes	No	No
Green beans	Yes	N/A
Green onions	No	N/A
Jackfruit	N/A	Yes
Kiwi	Yes	Yes
Leeks	Yes	N/A
Lemons	No	No
Lettuce	Yes	N/A

Limes	No	No
Lychee	N/A	No
Mango	Yes	Yes
Melon (honeydew, cantaloupe, etc)	Yes	Yes
Mushrooms	No	N/A
Nectarines	Yes	Yes
Okra	Yes	N/A
Olives	N/A	No
Oranges	No	No
Papaya	N/A	Yes
Passion fruit	N/A	Yes
Peaches	Yes	Yes
Pears	Yes	Yes
Peas, in pods	Yes	N/A
Persimmon/Sharon	N/A	Yes
Pineapple	No	No
Plums	Yes	Yes
Pomegranate	N/A	No
Potatoes, early	No	N/A
Potatoes, late	Yes	N/A
Pumpkins	No	No
Quince	N/A	Yes
Radishes	No	N/A

Raspberries	Yes	No
Redcurrant	N/A	No
Spinach	Yes	N/A
Squash, summer	Yes	No
Squash, winter	No	No
Strawberries	No	No
Swedish turnip	No	N/A
Sweet potatoes	Yes	N/A
Sweetcorn	No	N/A
Tangerines	No	N/A
Tomatoes	Yes	Yes
Turnips	No	N/A
Watermelon	No	Yes

ABOUT THIS PUBLICATION

Plastic packaging for fresh fruits and vegetables

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TemaNord 2026:516

ISBN 978-92-893-8473-5 (PDF)
ISBN 978-92-893-8474-2 (ONLINE)
http://dx.doi.org/10.6027/temanord2026-516

Cover photo: Annie Spratt/Unsplash
Published: May, 2026

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This publication was funded by the Nordic Council of Ministers. However, the content does not necessarily reflect the Nordic Council of Ministers' views, opinions, attitudes or recommendations.

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