Shelf life model				
Mathematical equation used for shelf life determination	**Mathematical equation used for transfer through food packaging system**	**Consumers acceptability**	**Products studied**	**References**
$\frac{dq}{q^n} = -\sum (k_i \Delta t_i)_{T_i}$ $k = k_0 e^{\frac{E_a}{RT}}$ q: quality; n: reaction order of the phenomenon controlling the deterioration of the food; k_i: rate constant; Δt_i: time interval; T_i: interval temperature; k_0 : constant ; E_a : activation energy ; R: gas constant; T: temperature.	None	No	Variety peaches "elegant lady"	Aiello et aL 2012
$t_s = t_{lag} + \frac{1}{\mu_{max}} \ln(\frac{N_c}{N_0})$ $\sqrt{\frac{1}{t_{lag}}} = b_{lag}.(T - T_{lag,min})$ $\sqrt{\frac{1}{\mu_{max}}} = b_{\mu}.(T - T_{\mu,min})$ $\log N = logN_0 + \frac{\mu_{max}}{\ln(10)}.A - \frac{1}{\ln(10)}.\ln(1 + \frac{e^{\mu_{max}A} - 1}{10^{(\log N_{max} - logN_0)}})$ $A = t + \frac{1}{\mu_{max}}.ln\frac{e^{-\mu_{max}t} + \frac{1}{e^{t_{lag}\mu_{max}} - 1}}{1 + \frac{1}{e^{t_{lag}\mu_{max}} - 1}}$ t_s: shelf life (days); t_{lag}: lag time (days); μ_{max}: maximum specific growth (days^{-1}); N_c microbial count (CFU/g); N_0: initial microbial count (CFU/g); N_{max}: maximal microbial count (CFU/g); T: temperature (°C); b_{lag} and b_{μ}: slope parameters; $T_{lag,min}$ and $T_{\mu,min}$: minimal temperature (°C).	None	No	Ready to eat product: combination of braised green peppers and dry anchovies	Lee et al 2008
$y(t) = y_0 + \mu_{max}A(t) - \frac{1}{m}\ln(1 + \frac{e^{m\mu_{max}A(t)} - 1}{e^{m(y_{max} - y_0)}})$ $A(t) = t + \frac{1}{\mu_{max}}\ln(e^{-\mu_{max}t} + e^{h_0} + e^{-\mu_{max}t - h_0})$ $\ln(\mu_{max}) = \ln(\mu_{ref}) - \frac{E_A}{R} \times (\frac{1}{T} - \frac{1}{T_{ref}})$	None	No	Minced pork meat	Koutsoumanis et al 2008

y and y_0: logarithm of the microbial cell concentration and initial microbial cell concentration (log CFU/g) at time t (h); μ_{max}: maximum specific growth rate (h^{-1}); m: curvature parameter; A: delayed time variable (h); h_0: constant parameter; T: temperature (K); μ_{ref}: specific growth rate (h^{-1}) at reference temperature T_{ref} (K); E_A: activation energy ($kJ.mol^{-1}$); R: gas law constant ($kJ.mol^{-1}.K^{-1}$)				
$$y(t) = y_0 e^{-e^{\frac{\mu_{max}}{y_0}(\delta - t)+1}}$$ $$\delta = b_0 + b_1 a_w + b_2 CO_2 + b_{12} a_w CO_2 + b_{11} {a_w}^2 + b_{22} {CO_2}^2$$ y and y_0: microbial cell concentration at time t and intial time; μ_{max}: maximum specific growth rate; δ: lag phase, that was dependent of pH and CO_2 concentration; b_0, b_1, b_2, b_{12}, b_{11}, b_{22} : coefficient term.	None	No	Bakery product	Guynot et al 2003
$$SL = \beta_0 + \beta_1 \times pH + \beta_2 \times SSC + \beta_3 \times (S.Eval) + \beta_4 \times (\Delta E) + \beta_5 \times (no\ treatment) + \beta_6 \times (Ca - citric\ acid) + \beta_7 \times (ascorbic + citric\ acid) + \beta_8 \times (USND + Ca - ascorbate) + \beta_9 \times (USND + ascorbic + citric\ acid) + \beta_{10} \times (Golden\ Delicious) + \beta_{11} \times (Cripps\ Pink) + error$$ SL: Shelf life; β_0 to β_{11} being fitting parameters (dimensionless); SSC: Soluble Solids and ΔE : color measurement $$SL_{MAX} = \alpha_0 + \alpha_1 \times \log(Ebac) + error$$ SL_{MAX}: Shelf life according to bacterial development (days); α_0 and α_1: estimated parameters; $Ebac$: enumeration of bacteria growth ($CFU.g^{-1}$)	None	No	Apple Golden Delicious and Cripps Pink	Putnik et al 2017
$$\log(CFU) = K + A \times e^{-e^{(\mu_{max} \times 2.7182 \times \frac{LDP - t}{A}) + 1}}$$ $$\frac{1}{LDP} = Z e^{\frac{-E_{LDP}}{RT}}$$ $$\mu = A' e^{\frac{-E_\mu}{RT}}$$ K: initial level of bacterial count (log $CFU.g^{-1}$); A: increase of the population (log ($CFU.g^{-1}$)); μ_{max}:	None	No	Minced beef meat	Limbo et al 2010

maximal growth rate (Δlog(CFU.g^{-1}).day^{-1}); LDP: lag phase duration (days); t: the storage time (days); Z and A': pre-exponential factor (days^{-1} and log(CFU.g^{-1}).days^{-1}); T temperature (K); E_{LDP}: activation energy (kJ.mol^{-1}); R: gas law constant (J.K^{-1}.mol^{-1}); $t_s = \frac{d^2CO_2}{dt^2} = \frac{d^2PC1}{dt^2} = \frac{d^2Hue}{dt^2} = t_0e^{-bT}$ for narrow temperature range t_s and t_0: estimated stability time (days) at temperature T and temperature 0°C; b: slope of regression line; $PC1$: component analysis; Hue: hue index measured through color L (lightness), a (redness) and b (yellowness).				
$$P(R_t) = 1 - e^{-e^{\frac{\ln(t)-\mu}{\sigma}}}$$ $$P(C_t) = \frac{(t+n-1)!}{(n-1)!\,t!}(1-p)^n p^t$$ $P(R_t)$: probability of the food to be rejected by consumers at time t, which was used to estimate shelf life; μ *and* σ*:* intercept and scale parameters; $P(C_t)$: probability of the food to be consumed by consumers at time t*;* n and p: size and probe parameters.	None	Question asked to consumers: "If this salad was in your refrigerator, would you consume it, or would you throw it away?" The limit of acceptability represents the time at which 25% of consumers rejected the product.	Fresh-cut Iceberg salad	Manzocco et al 2017
$$X = X_0e^{k_Tt}$$ $$k_T = k_{ref}e^{-\frac{E_A}{R}(\frac{1}{T}-\frac{1}{T_{ref}})}$$ X : sensory quality parameter; X_0: initial sensory parameter; t: time (days); reaction rate constant (days^{-1}) that is dependent of temperature T (K); k_{ref}: reaction rate constant (days^{-1}) at reference temperature T_{ref} (K); E_A: activation energy (kcal.mol^{-1}); R: gas law constant (kcal.mol^{-1}.K^{-1})	None	Question asked to consumers: "Would normally buy and consume the samples?". The rejection function $S(t)$ is defined as the probability of a consumer rejecting a product before time *t.* $S(t) = S_{sev}(\frac{\mu_{T_{ref}} - \frac{E_A}{R}(\frac{1}{T} - \frac{1}{T_{ref}})}{\sigma})$ S_{sev}: survival function of the smallest extreme value distribution; T: temperature (K); $\mu_{T_{ref}}$: parameter at reference temperature T_{ref} (K); E_A: activation energy (kcal.mol^{-1}); R: gas law constant (kcal.mol^{-1}.K^{-1}). The limit of acceptability tested was 25% and 50%.	Butterhead lettuce	Lareo et al 2009

$F(t) = e^{-(\frac{t}{\alpha})^{\beta}}$ F: firmness (Nmm); t: time (days); α and β: scale and shape constant parameters of distribution (dimensionless)	None	Question asked to consumers: "Imagine you are in a supermarket to buy raspberries, would you buy this tray?" The limit of acceptability represents the time at which 50% of consumers rejected the product.	Raspberries	Adobeti et al 2015
Microbial growth: $\frac{dx(t)}{dt} = a(t) \times \frac{1-x(t)}{X_{max}} \times x(t)$ $a(t) = \frac{q(t)}{1+q(t)}$ $q(t) = q_0 \times e^{\mu_{max} t}$ $\lambda = \frac{\ln(1+\frac{1}{q_0})}{\mu_{max}}$ $\mu_{max} = \mu_{opt} \times Y(T) \times Y(pH)$ $Y(T) = CM_1(T)$ and $Y(pH) = CM_1(pH)$ $CM_n(x) = \frac{(x - x_{max}) \times (x - x_{min})^n}{(x_{opt} - x_{min})^{n-1}} \times (x_{opt} - x_{min})(x - x_{opt})(x_{opt} - x_{max})((n-1)x_{opt} + x_{min} - nx)$ x: number of cells (CFU.g^{-1}); X_{max}: maximum population density (CFU.g^{-1}); μ_{max}: maximum growth rate (h^{-1}); λ: lag period; $q(t)$ and q_0: physiological state of the cell at time t (h) and initial time. Ascorbic acid degradation: $C = C_{\infty}(1 - e^{kt})$ C and C_{∞}: concentration of ascorbic acid at time t and equilibrium; k: kinetic constant.	None	Amount of money the consumers was willing to pay for their preferred alternative compared to the standard alternative was used to set limits for acceptable and unacceptable costs for deli salads.	Deli salads	Skjerdal et al 2017
$SL = \beta_0 + \beta_1 \times L + \beta_2 \times a + \beta_3 \times b + \beta_4 \times SL + \beta_5 \times R_{O_2} + \beta_6 \times R_{CO_2} + \beta_7 \times R_{CO_2} + \beta_8 \times (Golden\ Delicious) + \beta_9 \times (Cripps\ Pink) + \beta_{10} \times (no\ treatment) + \beta_{11} \times (ascorbic + citric\ acid) + \beta_{12} \times (Ca - ascorbate) + \beta_{13} \times (USND + Ca - ascorbate) + \beta_{14} \times (USND + ascorbic + citric\ acid) + error$	$R_{O_2} = \frac{\frac{kP_{O_2}}{x} \times A \times \frac{(y_{O_2}^{out} - y_{O_2}^{in})}{100} - \frac{V_f}{100} \times \frac{dy_{O_2}}{dt}}{M}$ $R_{CO_2} = \frac{\frac{V_f}{100} \times \frac{dy_{CO_2}}{dt} - \frac{kP_{CO_2}}{x} \times A \times \frac{(y_{CO_2}^{out} - y_{CO_2}^{in})}{100}}{M}$ Where $V_f = V_{total} - \frac{M}{M_{\rho}}$ And $A = lenght \times width$ R: respiration rate (cm^3.kg^{-1}.day^{-1}.atm^{-1}); $\frac{kP}{x}$=P: permeance (cm^3.m^{-2}.day^{-1}.atm^{-1}); A: packaging surface area (m^2); M:	No	Apple Golden Delicious and Cripps Pink	Putnik et al 2017

β_0 to β_{14} being fitting parameters (dimensionless); ΔE: color measurement (dimensionless); L, a and b: CIE LAP parameters; SL: Shelf Life; R_{O2}: Respiration rate represented in O_2 consumption ($cm^3.kg^{-1}.day^{-1}.atm^{-1}$); R_{CO2}: Respiration rate represented in CO_2 production ($cm^3.kg^{-1}.day^{-1}.atm^{-1}$)	apple cultivar packaged mass (kg); x: film thickness (cm); y: volumetric concentration (% v/v O_2 and CO_2); M_ρ: fresh-cut apple density; V_{total}: total volume inside the packaging (cm^3); V_f: free volume inside the packaging.			
Weight loss : $\frac{dW_l}{dt} = t_r + M_c r_{CO_2} W_s$ $t_r = m_w A_c = VPD \times K_t \times A_c = (a_w - RH)p_s \times \frac{1}{\frac{1}{K_s} + \frac{1}{K_a}} \times A_c$ W_l: weight loss; t_r: amount of water vapor transpired from the surface of fruit ($kg.m^{-2}.h^{-1}$); M_c: carbon loss due to respiration r_{CO_2}; m_w: water vapor flux ($kg.h^{-1}$); A_c: surface area of the commodity (m^2); VPD: vapor pressure deficit (Pa); K_t: transpiration coefficient ($kg.m^{-2}.s^{-1}.Pa^{-1}$); a_w: water activity of fresh produce; RH: relative humidity inside package (%); p_s: saturated vapor pressure (Pa); K_s: Skin mass transfer coefficient ($kg.m^{-2}.s^{-1}.Pa^{-1}$); K_a: air-film mass transfer coefficient ($kg.m.^{-2}.s^{-1}.Pa^{-1}$). Spoilage : $\frac{dN}{dt} = Rel_{MR} \times k_s \times N \times (\frac{N_{max} - N}{N_{max}})$ $Rel_{MR} = \frac{r_{CO_{2(f)}}([O_2], [CO_2], [H_2O], T_s)}{r_{CO_2}(21\%O_2, 0.03\%CO_2, T_s)}$ N: spoilage at time t; N_{max} : maximum spoilage; k_s: spoilage rate; Rel_{MR}: metabolic rate; r_{CO_2}: respiration rate	$\frac{d[O_2]_i}{dt} = 100 \times \frac{P_{O_2} A_p P_{atm}}{L_f} \left(\frac{[O_2]_0}{100} - \frac{[O_2]_i}{100} - W_p r_{O_2} \right) \times \frac{1}{V_f}$ $\frac{d[CO_2]_i}{dt} = 100 \times \frac{P_{CO_2} A_p P_{atm}}{L_f} \left(\frac{[CO_2]_0}{100} - \frac{[CO_2]_i}{100} - W_p r_{CO_2} \right) \times \frac{1}{V_f}$ $r_{O_2} = \frac{Vm_{O_2}.[O_2]}{Km_{O_2}.\left(1 + \frac{[CO_2]}{Kmc_{CO_2}}\right) + [O_2].\left(1 + \frac{[CO_2]}{Kmu_{CO_2}}\right)}$ $r_{CO_2} = RQ_{ox}.r_{O_2} + \frac{Vm_{CO_2(f)}}{\left(1 + \frac{[O_2]}{Km_{CO_2(f)}} + \frac{[CO_2]}{Kmc_{CO_2(f)}}\right).Kmc_{CO_2(f)} + 1}$ $\frac{dm_{pr}}{dt} = P_{H_2O} A_p (\frac{P_i - P_0}{L_f}) \left(\frac{0.018 P_{atm}}{RT_s} \right)$ $P = P_{ref} + \frac{\pi R_h^2 \times D_{i,air}}{L_f + R_h} \times N_h$ $[CO_2]_i$ and $[CO_2]_i$: concentration of oxygen and dioxygen gases (%) in the package at time t (s); $[O_2]_0$ and $[CO_2]_0$: concentration of oxygen and dioxygen gases outside (%); P and P_{ref}: film permeability and reference permeability of film ($mL.m^{-1}.h^{-1}.atm^{-1}$); A_p: total surface area of package (m^2); P_{atm}: atmospheric pressure (Pa); L_f: thickness of packaging film (m); W_p: weight of product (kg); V_f: free volume in headspace (mL); $r_{O_2}$and r_{CO_2}: oxygen consumption rate and dioxygen production rate ($mol.kg^{-1}.s^{-1}$); Vm: maximum evolution rate ($mol.kg^{-1}.h^{-1}$); Km: Michaelis-Menten constant (%); Kmc: Michealis-Menten constant for non-competitive inhibition (% or kPa); Kmu: Michealis-Menten constant for non-competitive inhibition (% or kPa); RQ: respiratory quotient; P_i and P_o: partial pressure vapor inside and outside package (Pa); T_s: temperature of produce surface (K); R_h: radius of perforation (m); $D_{i,air}$: diffusion coefficient in air ($m^2.s^{-1}$); N_h: number of perforations.	No	Strawberries	Joshi et al 2019
$\frac{dN}{dt} = \mu_{max} N_t (1 - \frac{N_t}{N_{max}})$ for $t > lag$ and $\frac{dN}{dt} = 0$ for $t \leq lag$ $\mu_{max} = \mu_{opt} \gamma_T \gamma_{pH} \gamma_{a_w} \gamma_{O_2} \gamma_{CO_2} \varepsilon$	$V_{HS} \frac{dC_{j,HS}}{dt} + C_{j,HS} \frac{dV_{HS}}{dt} = \varphi_{j,L} + \varphi_{j,I} + S_{j,F}$	No	Processed cheese,	Chaix et al 2015 And

$\gamma_T = \frac{(T-T_{max})(T-T_{min})^2}{(T_{opt}-T_{min})[(T-T_{opt})-\frac{(T_{opt}-T_{max})(T_{opt}+T_{min}-2T)}{(T_{opt}-T_{min})}]}$ $\gamma_{pH} = \frac{(pH-pH_{max})(pH-pH_{min})}{(pH-pH_{min})(pH-pH_{max})-(pH-pH_{opt})^2}$ $\gamma_{a_w} = \frac{(a_w-1)(a_w-a_{w_{min}})}{(a_w-a_{w_{min}})(a_w-1)-(a_w-a_{w_{opt}})^2}$ $\gamma_{CO_2}(x,t) = 1-\frac{C_{CO_2,F}(x,t)}{C_{CO_2,max}}$ $\gamma_{O_2}(x,t) = 1-\frac{C_{O_2,F}(x,T)-C_{O_2,min}}{C_{O_2,max}(T)-C_{O_2,min}}$ $\varepsilon = \sum_W \frac{\phi_W}{2\Pi \mathrm{v} \neq \mathrm{w}(1-\phi_W)}$ And $\phi_W = (\frac{W_{opt}-W}{W_{opt}-W_{min}})^3$ for W= {*T*,*pH*,a_w} ≤ W_{opt} N_t: microorganism population (CFU.g^{-1}) at time t and position *x* within the food sample; N_{max}: maximal population (CFU.g^{-1}); μ_{max}: maximal growth rate (s^{-1}); lag: lag time duration (h) for the microorganism of interest; μ_{opt}: optimal growth rate (s^{-1}); γ_w with *w*= {*T*,*pH*,a_w,O_2,CO_2}: adimensional weighting parameters representing respectively the influences of environmental factors such as temperature, pH, water activity, dissolved O_2 and CO_2 concentrations over microorganism growth rate; ε: parameter representing the interactions between the different environmental parameters; W, W_{min}, W_{max} and W_{opt}: current, minimal, maximal and optimal values for microbial growth of the environmental factor of concern; C_F, C_{max} and C_{min}: concentration of dissolved gases into the food, maximal and minimal concentration of withstanding by microorganisms (kg.m^{-3}); ϕ_W: interaction term.	$\varphi_{j,L} = M_j Pe_j(\frac{A_L}{e_L})(p_{j,\infty}-p_{j,HS})$ $\varphi_{j,I} = k(\frac{M_j A_I}{RT})(p_{j,HS,I}-p_{j,HS})$ $p_{j,HS,I} = \frac{C_{j,F,x=0}}{M_j k_{H,j}}$ $\frac{\partial C_{j,F}}{\partial t} = D_j \frac{\partial^2 C_{j,F}}{\partial x^2}$ and $D_j \frac{\partial C_{j,F}}{\partial x} = \frac{\varphi_{j,I}}{A_I}$ for x=0, ∀ t $S_{j,F} = \left(\frac{r_{O_2\,max} \cdot p_{O_2,HS}}{K_m + p_{O_2,HS}}\right) N_t . m$ $k_j = k_{0,j} e^{-\frac{E_{a,k,j}}{R}\times(\frac{1}{T}-\frac{1}{T_{ref,k,j}})}$ V_{HS}: volume of headspace (m^3); $C_{j,HS}$ mass concentration of gases species, namely O_2, CO_2 and N_2 in headspace (kg.m^{-3}) at time t (s); $\varphi_{j,L}$ and $\varphi_{j,I}$: mass flow through the lid film L from the surrounding atmosphere to the headspace and at the interface I between the food sample and headspace (kg.s^{-1}); $S_{j,F}$: net production rate due to microbial respiration/fermentation; M: molar mass (kg.mol^{-1}); Pe: Permeability through the lid film (mol.m^{-1}.s^{-1}.Pa^{-1}); A: surface area (m^2); e: thickness (m); $p_{j,\infty}$, $p_{j,HS}$ and $p_{j,HS,I}$: partial pressure of gases in the surrounding atmosphere, in the headspace and at the immediate vicinity of the food surface (Pa); k: external mass transfer coefficient at the interface between the food sample and the headspace (m.s^{-1}); R: ideal gas constant (J.mol^{-1}.K^{-1}); T: temperature of the food/packaging system; $C_{j,F,x=0}$: mass concentration at the food surface (kg.m^{-3}); $r_{O_2\,max}$: maximum respiration rate (kg.s^{-1}.CFU^{-1}); K_m: Michaelis-Menten constant (Pa); N_t: microorganism concentration (CFU.g^{-1}); m: mass of food (g); $k_{H,j}$: solubility coefficient of gases (mol.Pa^{-1}.m^{-3}); D_j: apparent diffusivity in food (m^2.s^{-1}); k_j: temperature dependent parameters as permeability, apparent diffusivity and solubility; $k_{0,j}$: value of parameter at reference temperature T_{ref} (K); E_a: activation energy (J.mol^{-1}).		poultry and salmon	Guillard et al 2016
$logN(t) = \log(N_{min} + \frac{N_{max}-N_{min}}{1+e^{-\mu_{max}(t-t_i)}})$ $\ln(\mu_{max}) = \ln(\mu_{ref} - d_{CO_2}\times CO_2) + \frac{E_A}{R}(\frac{1}{T_{ref}}-\frac{1}{T})$ $Shelf\ life = \frac{(\log(NMD)-\log(N(0))\times\ln(10)}{\mu_{max}\times 24}$	$-(\frac{\partial n}{\partial t})_p - (\frac{\partial n}{\partial t})_F = \frac{P}{R}(\frac{1}{T_H}\frac{\partial V_H}{\partial t} + V_H\frac{\partial \frac{1}{T_H}}{\partial t})$ $(\frac{\partial n}{\partial t})_F = M_F(\frac{\partial c}{\partial t})$	No	Fresh scallops	Simpson et al 2007

N, N_{min} and N_{max}: bacterial concentration at time t (h); minimal and maximal bacterial concentration (CFU.g-1); μ_{max}: specific growth rate (h^{-1}); μ_{ref}: maximum specific growth rate (h^{-1}) at reference Temperature T_{ref} (K); T: temperature (K); d_{CO_2}: constant (h^{-1}); CO_2: gas concentration; E_A: activation energy (J.mol^{-1}); R: ideal gas constant (Pa.m^{-3}.kmol^{-1}.K^{-1}); NMD: bacterial concentration for reaching minimum spoilage.	$$(\frac{\partial c}{\partial t}) = D(\frac{\partial^2 c}{\partial x^2})$$ $$(\frac{\partial n}{\partial t})_p = (\frac{PA}{e})_p P(y_H - y_a)$$ $$k = k_0 e^{-\frac{E_a}{RT}}$$ n: number of moles per gas (kmol); t: time (s); P: permeability (kmol.m^{-1}.s^{-1}.Pa^{-1}); R: ideal gas constant (Pa.m-3.kmol.K); T_H: temperature in headspace (K); V_H: volume of headspace (m^3); M_F: food mass (kg); c: gas concentration in food (kmol.kg^{-1}); D: diffusion coefficient (m^2.s^{-1}); x: distance in the x axis (m); A: area (m^2); e: thickness (m); y_H and y_a: molar volumetric fraction in headspace and air (kmol.kmol^{-1}); k: parameters that depend of temperature as permeability, solubility and diffusivity; k_0: constant; E_A: activation energy (J.mol^{-1}); R: ideal gas constant (Pa.m^{-3}.kmol^{-1}.K^{-1}).			
$$T_m = \frac{2.303}{\mu}(log_{10}\frac{N_s}{N_0})$$ T_m: shelf life (day); N_0: initial bacterial concentration (CFU.g^{-1}); N_s: maximum allowable bacterial concentration (CFU.g^{-1}); μ: bacterial growth (day^{-1}).	$$V\frac{\partial c'}{\delta t} = -Ac \times \sqrt{\frac{D}{\pi t}}$$ $$\frac{\partial c}{\partial t} = D\frac{\partial^2 c}{\partial z^2}$$ $$\frac{\partial v'}{\partial t} = p_0 S \Delta p_0 + k_c - p_c S \Delta p_c$$ V: package volume (cm^3); c and c': CO_2 concentration in the sauce and in the gas phase (mol.cm^{-3}); A: interfacial area (cm^2); D: CO_2 effective diffusivity (cm^2.s^{-1}); z: CO_2 flux coordinate (cm); v': CO_2 volume in the gas phase (cm^3); p_0 and p_c: O_2 and CO_2 permeability (cm^3.m^{-2}.day^{-1}.atm^{-1}); S: package superficial area (m^2); Δp_0 and Δp_c O_2 and CO_2 partial pressure difference (atm).	No	Pesto sauce	Fabiano et al 2000
$$t_{SL} = D^{-1}(D_{acc})$$ $$\frac{dD}{dt} = k_D D \frac{D_{max} - D}{D_{max}} \delta_{CO_2}$$ $$\delta_{CO_2} = 1 - \frac{x_{CO_2}(t)}{x_{CO_{2}max}}$$ t_{SL}: Shelf life (days); D: percentage of surface deterioration (%) at time t (s); D_{acc}: maximal acceptable deterioration at t_{acc} (%); D_{max}: maximum percentage of deterioration (%); k_D: deterioration rate constant (s^{-1}); δ_{CO_2}: inhibiting effect of carbon dioxide on the deterioration rate	$$\frac{dn}{dt} = \varphi + R + S$$ $$\frac{dn_{O_2}}{dt} = \frac{P_{O_2}A}{e}(p_{O_2}^{out} - p_{O_2}^{in}) - \frac{R_{O_{2}max} p_{O_2}^{in}}{Km_{O_2} + p_{O_2}^{in}} m - \beta_{O_2} D$$ $$\frac{dn_{CO_2}}{dt} = \frac{P_{CO_2}A}{e}(p_{CO_2}^{out} - p_{CO_2}^{in}) - \frac{R_{CO_{2}max} p_{CO_2}^{in}}{Km_{CO_2} + p_{CO_2}^{in}} m - \beta_{CO_2} D$$ $$k(T) = k_{ref} e^{-\frac{E_{A,k}}{R}(\frac{1}{T} - \frac{1}{T_{ref,k}})}$$ n: quantity of gases species (mol); t: time (s); φ: mass flow of gases through the packaging film between the surrounding atmosphere and the headspace (mol.s^{-1}); R: the net production or consumption of gases due to	Question asked to consumers : "Just by looking at the strawberries in the tray, are you willing to buy the product or not?" The limit of acceptability represents the time t_{acc} in days at which more than 50% of the panel rejected the product i.e. answered 'No' to the asked question.	Strawberries	Matar et al 2018

(dimensionless); x_{CO_2}: quantity of carbon dioxide in the headspace (%); $x_{CO_2 max}$: maximal quantity (%).	respiration (mol.s^{-1}); S: the net production or consumption of gases due to metabolic deviation (mol.s^{-1}); P: permeability of the film for gas (mol.m^{-1}.Pa^{-1}.s^{-1}); A: surface area of the film (m^2); e: thickness of the film (m); p^{out}: atmospheric partial pressure of gas (Pa); p^{in}: partial pressure of gas in the headspace (Pa); R_{max}: maximum respiration rate per kg of food (mol.kg^{-1}.s^{-1}); Km: constant of Michaelis Menten (Pa); m: the weight of the food product (kg); β_{O_2} and β_{CO_2}: rate of oxygen consumption and carbon dioxide production due to the deterioration (mol.s^{-1}.%$^{-1}$); D: percentage of surface deterioration (%); k: temperature T (K) dependent parameter as P and R_{max}; k_{ref}: value of parameter k at reference temperature T_{ref} (K); E_A: activation energy (J.mol^{-1}); R: gas law constant (J.mol^{-1}.K^{-1}).			

Link from shelf life to food loss and waste

Mathematical equation used to link shelf life and FLW	Integration of consumers behavior	Shelf life set up	Product studied	Reference
$$y = b_0 + \frac{b_1}{x}$$ y: returned goods ratio, considered in the article as food waste; x: shelf life; b_0 and b_1: constant.	None	Shelf life is considered as the time of product before reaching the expired shelf life date.	826 different products from an Italian food company	Spada et al 2018
$$FLP_1 = e^{-k_a SL}$$ $$FLP_2 = \frac{1}{1-e^{-1}} \times e^{-e^{\frac{1}{-k_b SL}} - e^{-1}}$$ $$FLP_3 = k_c SL$$ FLP: food loss probability; SL: shelf life; k_a, k_b and k_c: kinetic constant.	None	Experimental : Microbiological and sensory quality assessment.	Ripened cheese	Conte el al 2015
$$Q'_t = (w-t)^x + \sum_{t-1}^{1} Q_t + (Q_c^w \frac{1}{w})(SL - w)$$ Q'_t: cumulative quantity of product sold; Q_t: amount of product sold; SL: shelf life; w: time remaining before reaching shelf life at deliver step; Q_c^w: quantity of food delivered by the producer.	None	Experimental : Chemical-physical, microbiological and sensory quality assessment.	Cheesecake	Gutierez et al 2017
$$P(W_t) = P(C_t) \times P(R_t)$$ $$P(W_t) = \frac{(t+n-1)!}{(n-1)!\,t!}(1-p)^n p^t \times (1 - e^{-e^{\frac{\ln(t)-\mu}{\sigma}}})$$ $P(W_t)$: total amount of wasted food; $P(R_t)$: probability of the food to be rejected by consumers at time *t; μ and σ:* intercept and scale parameters; $P(C_t)$: probability of the	None	Model (see part I of table)	Fresh-cut Iceberg salad	Manzocco et al 2017

food to be consumed by consumers at time t; n and p: size and probe parameters.				
$f_c = \sum_{i=1}^{n}(\frac{\Delta t_i}{SL_i})_{T_I}$ $f_t = 1 - f_c$ f_c and f_t: fraction of consumed and residual shelf life; Δt_i: time interval; SL_i: shelf life interval; T_I: temperature in the interval. Fractions above the 100% consumed shelf life are considered as food losses and wastes.	None	Model (see part I of table)	Variety peaches “elegant lady”	Aiello et aL 2012
$l_s^p = a\int_{t_i}^{t_j} D_s^p(t)dt + b$ $L_{tot}^p = \sum_{s=1}^{s=s_{tot}} l_s^p\, w$ l_s^p: percentage of losses (%) of the scenario s using the packaging p; D_s^p: deterioration curve; t_i and t_i: time at which the post-harvest stage begins and ends respectively (s); a and b: estimated parameters; w: likelihood consumer behaviors; L_{tot}^p: cumulative percentage of loss within the sum of all scenarios.	$w = P_T P_d P_p$ w: likelihood consumer behaviors; P_T: probability to storage temperature at home : ambient or refrigerated storage; P_d: probability to storage duration at home, before consumption : one day or more; P_p: probability related to packaging state: kept or removed packaging at home.	Model (see part I of table)	Strawberries	Matar 2018

Link from food loss and waste to environmental impact

Mathematical equation used to link food loss and waste and environmental impact	Food loss and waste estimation	Shelf life estimation	Product studied	References
$e = B(1 - L)$ $E^i = B(F^i + P^i + W_P^i) + W^i BL$ e: eaten food; B: purchased food (kg, L etc); L: fraction of food losses (L=0=no losses; L=1=all purchased food is lost); E^i: overall energy use or environmental impact (MJ, carbon dioxide equivalent etc); F^i: energy use or environmental impact to produce and distribute one unit of purchased food to consumer; P^i: energy use or environmental impact to produce the packaging for one unit of purchased food to consumer; W_P^i: waste handling of packaging; W^i: waste handling of the food losses at consumer phase.	Hypothetic	None No realistic scenario	Ketchup, bread, milk, cheese, beef, minced meat, rice and yoghourt	Williams et al 2011; Wikström et al 2010; Wikström et al 2014; Wikström et al 2016
$E(x)^{product} = \frac{E(0)^{product} + xE^{food\ treatment}}{1 - x}$ $E(x)^{product}$ and $E(0)^{product}$: life cycle environmental impact of a food product per unit of food consumption	$x \equiv \frac{l}{\rho_{edible} M_{total}}$ $l = (N\rho_{edible}M - r_M d_{consume})\frac{F}{r_M d_{consume}}$	None No realistic scenario	Ham products	Yokokawa et al 2018

when the value of food loss rate is x and 0 respectively; $E^{food\ treatment}$: environmental impact derived from waste treatment for the same amount of food waste as a unit of consumption.	x: food loss rate; l: food losses (kg); ρ_{edible}: proportion of edible parts in the food; M_{total}: total amount of food provided; N number of products per purchase (constant); M: amount of food per package; r_M:average rate of consumption per day (kg.day^{-1}) ; $d_{consume}$: number of days of food consumption ; F: Functional unit based on the amount of food consumption.			
$WEI_i = PEI + PEFI \times FLP_i$ WEI_i: eco-indicator; PEI and $PEFI$:environmental impact of the package and packaged food; FLP_i: food loss probability.	Model (see part II of table)	Yes, experimental (texture, weight loss, microbiological, sensory (Costa el al 2016)): Realistic scenario	Ripened cheese	Conte el al 2015
LCA was made using SimaPro with the ReCiPe method.	Model (see part II of table)	Yes, experimental: Realistic scenario	Cheesecake	Gutierez et al 2017
LCA standardization method (ISO, 2006)	Modelling based on Discrete Event Simulation (DES) technique (Quested, 2013)	Yes, experimental (microbiological) (Muriel-Galet et al (2012)): Realistic scenario	Fresh milk	Manfredi et al (2015)
$NGWP_k = (\Delta GWP_{nano,k} - GWP_{food,k} \times r_{k,j})_{jk}$ $NGWP$: Net Global Warming Potential; $\Delta GWP_{nano,k}$: additional GWP for nanomaterials incorporated to package food type *k*; $GWP_{food,k}$: reduced GWP due to avoided food waste; $r_{k,j}$: average percentage of food waste avoided by nano-packaging per 1 kg of packaged food.	$r_{i,k,j} = \frac{w_{i,k}(p'_{i,k} - p_{i,k})}{1 - p_{i,k,j}}$ $r_{i,k,j}$: percentage of food waste avoided by nano-packaging per kg of packaged food *k* with a *j*-day shelf life extension; w: percentage of food wasted with the use of packaging without nanomaterials; $p\ and\ p'$: likelihood of complete food consumption within the original shelf life and for one day more.	Yes, experimental (color, microbiological, physical) (Gokkurt et al (2012); Huang et al (2017); Emamifar et al (2010); Lloret et al (2016)): Realistic scenario	Apricot, tomato paste, fresh orange juice and cooked ham	Zhang et al (2019)
LCA was made using SimaPro with Eco invent 3.4.	Model (see part II of table)	Model (see part I of table) Realistic scenario	Strawberries	Matar et al 2018

Supplementary table: Model used in literature for shelf life estimation in MAP and its link to FLW reduction and environmental impact