Elsevier Editorial System(tm) for Food Research International

Manuscript Draft

Manuscript Number: FOODRES-D-18-02560R1

Title: Effect of expiry date communication on acceptability and waste of fresh-cut lettuce during storage at different temperatures

Article Type: Research Articles

Keywords: expiry date; temperature abuse; fresh-cut salad; consumer rejection; wasting risk

Corresponding Author: Professor Lara Manzocco, Ph.D.

Corresponding Author's Institution: Dipartimento di Scienze AgroAlimentari, Ambientali e Animali

First Author: Marilisa Alongi

Order of Authors: Marilisa Alongi; Sandro Sillani; Corrado Lagazio; Lara Manzocco, Ph.D.

Abstract: The effect of expiry date communication on acceptability and wasting risk of fresh-cut lettuce was investigated. Fresh-cut lettuce was packed in plastic pouches reporting or not the expiry date on the label and stored at recommended (8 °C) or abuse temperature (12 °C) for increasing time up to 21 days. Lettuce was assessed during storage for colour, total viable count, consumer rejection and wasting risk. Independently on storage temperature, the presence of the expiry date caused an increase of wasting risk. When lettuce was stored at 8 °C, about 4% packages were estimated to be wasted within the expiry date (7 days). Even a lower amount of waste was estimated when expiry date was not reported. Within 7 days of storage at 12 °C, 12% of the packages without expiry date was estimated to be wasted. This percentage increased to 27% when the expiry date was printed on the lettuce label. Results emphasise the dramatic effect of the presence of the expiry date on the consumer decision to waste food.

Effect of expiry date communication on acceptability and waste of fresh-cut salad during storage at different temperatures

The present paper originates from a previous paper, recently published on Food Research International (Effect of temperature in domestic refrigerators on fresh-cut Iceberg salad quality and waste by Manzocco, Alongi, Lagazio, Sillani and Nicoli, FRI, 102, 129-135, 2017), demonstrating that the increase in temperature during refrigerated domestic storage increased the risk of food wasting. This result was obtained by using a survey methodology based on the combination of consumer rejection data and data relevant to the distribution of salad consumption over the days following product purchase. One of the experts reviewing this paper suggested that "*consumers can take into account the expiration date of the product printed on the package as factor influencing the decision of acceptance/reject*". Based on this interesting suggestion, we have carried out the research activity described in the present paper. The study case of fresh-cut salad packed in plastic pouches reporting or not the expiry date on the label and stored at recommended (8 °C) or abuse temperature (12 °C) was considered. Results show that expiry date communicated on the product label might significantly affect product quality perception and thus food wasting.

Ms. Ref. No.: FOODRES-D-18-02560 Title: Effect of expiry date communication on acceptability and waste of fresh-cut salad during storage at different temperatures
Food Research International

Dear Editor,
All referees' suggestions were carefully evaluated and addressed. Detailed answers to each comment are reported below. Changes made to the paper are indicated in red in the manuscript.
Best regards,
Lara Manzocco

Reviewer #1:

1. Highlights: Please specify the third and fourth sentences in detail; those are too general.
The sentences were detailed as required by the reviewer.

2. Lines 94-95: If any, please provide more information about lighting condition (e.g., illumination level).
Details about the lighting conditions were added in the text (lines 91-92).

3. Lines 101-104: Please provide the reference relevant to the sentences.
Reference was added in the text (lines 96-97 and 316-317).

4. Lines 108-109: This sentence is confusing. I am wondering if a total of 700 consumers participated in the test. If not, did some of the 700 consumers take part in the test? Please clarify this.
Seven hundred consumers were selected and participated in the test. The text was clarified accordingly (lines 106-107).

5. Lines 121-122: Why did the authors select those dates? If there was a justification, please describe it.
Dates were chosen based on the results obtained from a previous study (Manzocco, L., Alongi, M., Lagazio, C., Sillani, S., Nicoli, M. C. (2017). Effect of temperature in domestic refrigerators on fresh-cut Iceberg salad quality and waste Food Research International, 102, 129–135). The reference was added in the text (line 120).

6. Lines 123-127: These sentences are not clear. It seems that each participant did not evaluate all test-samples. If so, I am wondering how the authors did control plausible group-variations (e.g., by variations in demographics, dietary habits, etc.) in terms of sample evaluation, when conducting this study and analyzing the data.
In order to evaluate the consumer rejection, the procedure developed by Hough (2010) was followed. There are two storage designs to perform survival analysis (Hough, G. 2010. Sensory Shelf Life Estimation of Food Products. Boca Raton: CRC press, Taylor & Francis Group, pages 73-78):

1) *basic design: samples from a same production batch are stored for increasing time. This implies they are tested on different days by a high number of different subjects (more than 250 consumers).*
2) *reverse storage design: samples from different production batches are stored for different times and analyzed on the same day by a limited number of subjects (50 consumers).*

Given the intrinsic variability of the salad, we decided to select the basic design, which allows using the same production batch by increasing the number of consumers involved in the study.

I am also wondering if the participants were allowed to smell and/or touch the test samples during their evaluation because those sensory cues are important in determining consumer rejection of the samples. If all sensory cues are allowed to use, the results might be different from the current findings.
We definitely agree with the reviewer that allowing the consumers to smell/touch the product could provide different results. The latter could be also affected by other factors, such as having paid for the product or testing it in different social environment or at different times in the day. Further research is certainly needed to improve wasting risk prediction by collecting data relevant to product acceptability in different conditions. Given this complexity, it is however noticeable that significant differences in wasting risk were already observed following the visual assessment solely.

7. Line 132: Please clarify what the "scale" parameter indicates.
8. Line 150: Please clarify what the "probe" parameter indicates.
Scale, probe as well as intercept and size are the experimental parameters of the models (Equations 1 and 2). This was clarified in the text (lines 131 and 151).

9. Lines 133-162: If those four equations were already published in journals, please indicate the references.
References were added in the text as suggested by the Reviewer (lines 132, 148 and 158).

10. Lines 177-178: If the references are not relevant to the sentence, please delete them.
The text was modified accordingly (line 180).

11. Lines 249-252: With interesting results from this study, the authors need to describe how their findings can be applied to food industries as well as to general consumers. I am just curious about whether the authors are positive or not on the effect of expiry date on the consumer decision to waste food. I did not fully catch the major message of the authors based on this study.
Both discussion and conclusion sections were implemented (lines 252-255 and 263-267).

12. Captions for Figures: Please provide more information about each figure.
Captions were further detailed.

Reviewer #2:

1) L12: "increase of product waste". It is not clear in the abstract whether you actually measured the amount wasted or the "wasting risk". Clear up this confusion.
The methodology applied allowed estimating the wasting risk. The abstract was clarified.

2) L23: I do not agree that consumers are responsible for this food waste. It is mainly due to retail practices, packaging, carbon-footprint, etc. Consumers are basically the victims of the system.
We agree with the reviewer that most domestic food waste is due to causes which are not under consumer control (e.g. conservative "use by" date setting, unappropriated retail conditions). The text was modified yet reporting that, according to the literature, between 15 and 30% of food is wasted at domestic level (line 21).

3) L69: "Iceberg salad…", was it only lettuce? If so, change "salad" for "lettuce" throughout, starting with the title.
Changes were made.

4) L123-126: you had 50 consumers per storage time; considering both storage temperatures, you had a total of 14 storage times; thus your 700 total consumers? If this is so, you should make it clearer. Did each consumer evaluate with and without expiry date? If so, was the order of presentation balanced or randomized in any way?
The text was modified to clarify these points (line 121).

5) L145-146: indicate why you chose a negative binomial.
The reason was clarified and supported by further literature (lines 146-147 and 283-285).

6) L165: It is not clear what the three measurements that were averaged are referring to.
The text was clarified (line 166).

7) Figure 2: in line 127 you stated the study lasted until 100% rejection. This is not what we see in Figure 2 (a). Explain.
Estimating the rejection probability by survival analysis requires approaching the 100% rejection (Hough, 2010). Such a percentage was obtained after more than 20 days for lettuce stored at 8 °C. However, since consumption of lettuce would occur within 10 days (Fig. 3), the authors only showed the timespan of interest for the present research. The material and methods relevant to fresh-cut lettuce rejection were implemented to explain this aspect (lines 124-126).

8) Figure 2: If expiry date was 7 days, it is difficult to understand such low rejection at storage times greater than 7 days when the expiry date was published. Especially at 8° C storage. I would certainly not eat lettuce over its expiry date, for fear of some sort of microbial poisoning, even if the lettuce looked ok.
Being food technologists, the authors agree with the referee. However, it is noteworthy that many consumers are not aware of food safety issues and thus do not pay attention to printed expiry dates or, when they care about them, often do not behave accordingly. This is probably one of the interesting results of the paper and is discussed in lines 200-212.

9) L230-231: doesn´t this contradict Figure 2, in the sense that with no expiry date there was less rejection?
This consideration refers to the consumption probability (Figure 3), which accounts for the probability that a consumer decides to pick up a product package to consume it. On the contrary, the rejection probability (Figure 2) refers to the probability that a consumer that already decided to consume the product, finds it unacceptable for consumption. According to the literature (Manzocco et al., 2017), these events can be considered independent. Figure 2 and Figure 3 thus provide different information, not in contradiction.

Highlights

Domestic waste of fresh-cut salad was estimated by the wasting risk methodology

Independently on storage temperature, expiry date communication increased salad waste

At 8 °C expiry date communication increased salad waste from 1 to 4%

At 12 °C salad waste increased from 12 to 27% when the expiry date was communicated

Effect of expiry date communication on acceptability and waste of fresh-cut lettuce during storage at different temperatures

Abstract

The effect of expiry date communication on acceptability and wasting risk of fresh-cut lettuce was investigated. Fresh-cut lettuce was packed in plastic pouches reporting or not the expiry date on the label and stored at recommended (8 °C) or abuse temperature (12 °C) for increasing time up to 21 days. Lettuce was assessed during storage for colour, total viable count, consumer rejection and wasting risk. Independently on storage temperature, the presence of the expiry date caused an increase of wasting risk. When lettuce was stored at 8 °C, about 4% packages were estimated to be wasted within the expiry date (7 days). Even a lower amount of waste was estimated when expiry date was not reported. Within 7 days of storage at 12 °C, 12% of the packages without expiry date was estimated to be wasted. This percentage increased to 27% when the expiry date was printed on the lettuce label. Results emphasise the dramatic effect of the presence of the expiry date on the consumer decision to waste food.

Keywords

Expiry date; temperature abuse; fresh-cut lettuce; consumer rejection; wasting risk

1. Introduction

Consumers are known to be important contributors to global food waste. Between 15 and 30% of the food is actually wasted by consumers with fruit and vegetables accounting for one third of the entire waste (Williams, Wikstrom, Otterbring, Lofgren, & Beretta, 2012, Gunders, 2012; Lebersorger & Schneider 2011; Scott Kantor, Lipton, Manchester, & Oliveira, 1997). The decision to consume or reject food is the result of the joint processing of a number of different information in the human brain (Manzocco, 2009). In fact, intrinsic food quality attributes, such as appearance, colour and taste, originate a sensory acceptability response. The latter is then combined with affective, cognitive and behavioural reactions to extrinsic food attributes, generating the final consumption decision (Zeithaml, 1988; Grunert, Hartvig-Larsen, Madsen, & Baadsgaard, 1996). Expiry date is a typical food extrinsic attribute concurring to this decision (Dinnella, Torri, Caporale, & Monteleone, 2014; Vidal, Ares, & Gimenez, 2013). It has the specific objective of communicating the consumer that the product could not have the expected level of quality ("Best before" date) or safety ("Use by" date) if consumed after the specified date. It is generally agreed that communication to consumer about food expiry date might significantly affect consumer perception of food quality, influencing consumption decision and wasting behaviour at domestic level (Priefer, Jörissen, & Bräutigam, 2016). Despite the number of campaigns aiming at increasing the aware reading of expiry dates, information about their effect on food waste at domestic level is still limited.

Consumer food waste at domestic level is mainly estimated by applying loss factors to the amount of food available for human consumption or analysing waste composition (Scott Kantor *et al.*, 1997; Ojeda-Benítez, Armijo-de Vega, & Marquez-Montenegro, 2008). These methodologies only provide indication about the overall food waste and are not suitable to study the effect of a specific factor, such as expiry date communication, on food waste. The latter may be directly measured at domestic level by asking consumers to keep a kitchen diary of their wasteful behaviour (Williams *et al.*, 2012). However, having the latter an intrinsic moral and ethical implication, consumers may

minimize consciously or unconsciously their wasting tendency, leading to not representative data (Beretta, Stoessel, Baier, & Hellweg, 2013; Lebersorger & Schneider, 2011; Scott Kantor *et al.*, 1997). For instance, about 20% of Italian consumers declare a highly virtuous behaviour that does not fit with actual food waste data (Waste Watcher, 2013).

More recently, a methodology has been proposed to quantify food waste without letting consumer know to be involved in a waste study (Manzocco, Alongi, Lagazio, Sillani, & Nicoli, 2017). This method is based on the combination of consumer rejection data with data relevant to the distribution of product consumption over the days following product purchase. This approach resulted efficacious in estimating the effect of storage temperature on fresh-cut lettuce waste at domestic level. It is likely that it might be further exploited to study the effect of factors other than storage temperature, including expiry date printed on the product label.

The present research was thus addressed to investigate if, and at what extent, expiry date communication might modify consumer acceptability and waste of fresh-cut lettuce during domestic storage. In addition, to show the combined effect of expiry date and storage conditions on domestic waste, fresh-cut lettuce packages, reporting or not the expiry date on the label, were stored at 8 or 12 °C to simulate domestic or abuse storage conditions. Lettuce was assessed for colour, total viable count, consumer rejection and wasting risk.

2. Materials and methods

2.1. Sample preparation

Iceberg lettuce (*Lactuca sativa* var. *Capitata* L.) packages were provided by a local producer on the production day between February and May 2015. Two hundred grams lettuce were sealed under modified atmosphere (8% CO_2, 8% O_2, 84% N_2) in rectangular pouches (30 x 25 cm) of transparent bi-axially oriented polypropylene (BOPP, 0.035 mm). Lettuce variety and package size were chosen

as they are the most commonly available on the Italian market. One aliquot of 20 lettuce packages reported no information about expiry date on the label. A second aliquot of 20 lettuce packages reported an expiry date corresponding to 7 days after productions. An expiry date of 7 days was selected since corresponding to the shelf life attributed by the producer to the lettuce considered in the present research. Each aliquot of lettuce packages was further divided in two aliquots that were stored in dark conditions at 8 ± 1 or 12 ± 1 °C, respectively. At increasing time during storage, samples were removed from the refrigerated cells and submitted to analyses.

2.2. Lettuce characterization

2.2.1. Microbiological analyses

For the enumeration of aerobic mesophilic bacteria, 10 grams of fresh-cut lettuce were aseptically removed from the package, placed in a Stomacher bag with 90 mL of maximum recovery diluent (Oxoid, Italy) and homogenised for 1 min at normal speed and temperature in a Stomacher (International PBI, Milan, Italy). Serial dilutions (1:10) were made in sterile maximum recovery diluent, 0.1 mL were spread on Plate Count Agar (Oxoid, Italy) and incubation was carried out at 30 °C for 48 h.

2.2.2. Picture acquisition and image analyses

Fresh-cut lettuce images were acquired by using a digital camera (EOS 550D, Canon, Milano, Italy), placed on an adjustable stand positioned 60 cm above a black cardboard base where the sample was placed. Light was provided by four frosted photographic floodlights (23 W, 65.2 lm/W, Philips, Amsterdam, Netherlands) in a position allowing minimum shadow and glare. Other camera settings were: shutter time 1/250 s, F-Number F/2,8 and focal length 60 mm. Images were saved in jpeg format resulting in pictures of 5,184 x 3,456 pixels, 72 x 72 dpi.

Image analyses were performed using Image-Pro Plus (ver. 6.3, media Cybernetics, Inc., Bethesda, Md., U.S.A.). Brown and green pixels in the images were quantified based on the procedure applied by Manzocco, Rumignani, & Lagazio (2012). In particular, RGB (Red Green Blue) values corresponding to the brown areas of fresh-cut lettuce were R (77-111), G (47-85), B (15-35), while those corresponding to the green ones were R (50-130), G (80-140), B (10-70). The ratio between the brown and the green pixels in the image was computed. This ratio, defined as browning index, was taken as indicator of increase in enzymatic browning at cut edges and concomitant loss in typical green colour of fresh lettuce.

2.3. Consumer data collection

Consumers of fresh-cut lettuce were selected by asking students and workers from the University of Udine (Italy) if they generally consume fresh-cut lettuce. Seven hundred subjects provided a positive answer and thus participated to the study. They were between the ages of 18 and 63 years with average age of 25 ± 8 years, and approximately balanced between males (47%) and females (53%). Participants were not told to be involved in a study relevant to domestic food waste but were informed that acquired data would have been used for research purposes and asked to sign an informed consent.

2.3.1. Fresh-cut lettuce rejection

At increasing time during storage, lettuce packages were shown to consumers in a portable refrigerated cabinet, guaranteeing temperature maintenance of the sample during the assessment without allowing consumers to visualise the temperature display, which was covered by a piece of cardboard. Each consumer was asked to look at a lettuce package and answer to the following question: “If this lettuce was in your refrigerator, would you consume it, or would you throw it away?”. In particular, analyses were carried out on samples stored for: 1, 3, 6, 7, 8, 10, 14, 16 and 21 days at 8 °C; 1, 2, 5, 7 and 8 days at 12 °C. Dates were chosen based on the results obtained

from a previous study (Manzocco *et al*., 2017). A total of 14 analysis times were required and for each of them, one lettuce package was visually assessed by 50 consumers based on a random order. Each consumer required about 1 min for acceptability evaluation. The researchers in charge of the test never drove consumer attention to the label printed on the lettuce package. Completing the evaluation by all the 50 consumers required approximately 2 hours. Analyses were performed on samples stored for increasing time until 100% rejection was approached while results were shown with reference to the time span of 10 days.

The probability that the consumer rejects fresh-cut lettuce at a given time during refrigerated domestic storage due to unacceptable characteristics was estimated by elaborating rejection data via survival analysis (Hough, 2010). The Weibull function (1) was used to describe the evolution of the probability of lettuce rejection $P(R_t)$ during storage. P(R_t) is thus the probability of the food to be rejected by consumers at time t (1), where μ and σ are the intercept and the scale experimental parameters, respectively (Hough, 2010).

$$P(R_t) = 1 - e^{-e^{\left(\frac{\ln(t)-\mu}{\sigma}\right)}} \qquad (1)$$

The likelihood function was used to estimate the unknown parameters and the rejection probability percentage was computed by multiplying $P(R_t)$ by 100.

2.3.2. Fresh-cut lettuce consumption

After lettuce rejection evaluation, consumers provided information about fresh-cut lettuce consumption habits. In particular, they were asked to indicate the number of the lettuce packages usually purchased during a shopping and the number of purchased packages they usually consume each day during domestic refrigerated storage up to 10 days. Data relevant to fresh-cut lettuce consumption habits were elaborated to estimate the probability that the consumer decides to consume fresh-cut lettuce at a given time during its refrigerated domestic storage, as reported by Manzocco *et al*. (2017). Briefly, consumption data were normalized based on the total number of

purchased packages and the average consumption on each day after purchase was calculated. The Negative Binomial model (2), which results particularly effective for the analysis of discrete data (Byers, Allore, Gill, & Peduzzi, 2003) was fitted to the average consumption distribution, to describe the consumption probability of fresh-cut lettuce during storage time (Manzocco *et al.*, 2017):

$$P(C_t) = \left(\frac{(t+n-1)!}{(n-1)!t!}\right)(1-p)^n p^t \qquad (2)$$

were $P(C_t)$ is the probability that the consumer decides to consume the food at time t, and n and p are the size and the probe experimental parameters, respectively. Minimum chi-square method was used to fit model-based probabilities to observed frequencies and the consumption probability percentage was computed by multiplying $P(C_t)$ by 100.

2.3.3. Fresh-cut lettuce wasting risk

Domestic fresh-cut lettuce wasting risk was estimated based on a probabilistic approach (Manzocco *et al.*, 2017). The probability of the food to become a waste $P(W_t)$ (3) at the storage time t was expressed in mathematical terms as the product of $P(C_t)$ (2) and $P(R_t)$ (1) (Manzocco *et al.*, 2017):

$$P(W_t) = P(C_t) \cdot P(R_t) \qquad (3)$$

Substituting equations 1 and 2 in equation 3, the wasting risk model results as follows:

$$P(W_t) = \left[\left(\frac{(t+n-1)!}{(n-1)!t!}\right)(1-p)^n p^t\right] \cdot \left[1 - e^{-e\left(\frac{\ln(t)-\mu}{\sigma}\right)}\right] \qquad (4)$$

The total amount of wasted food until time t, expressed as a percentage, was calculated by summing up $P(W_t)$ values over the desired time interval.

2.4. Computational details

Browning index and total mesophilic bacteria data are averages of three measurements at least and are reported as means ± SD (standard deviation). Analyses of variance (ANOVA) was performed

with significance level set to $P < 0.05$. The Tukey procedure was used to test differences between means. All the computations were carried out using R, ver 3.2.3 (R Core Team, 2015).

3. Results and Discussion

3.1. Quality of fresh-cut lettuce during storage

Fresh-cut lettuce was stored at 8 and 12 °C to simulate domestic storage under recommended or abuse conditions, respectively (Marklinder & Eriksson, 2015). As expected, lettuce presented visually detectable changes during storage, the most prominent of which were green colour bleaching and browning development at cut edges. The samples were thus analysed for colour changes by image analysis. In addition, the increase in total mesophilic bacteria was assessed since it is an indicator of quality decay for this kind of product (Paillart *et al*., 2017) (Fig. 1). Upon 7 day-storage at 8 °C, a slight increase in the browning index was observed (Fig. 1a) in agreement with previous data (Ferrante, Incrocci, Maggini, Serra, & Tognoni, 2004; Agüero, Yommi, Camelo, & Roura, 2007). The microbial count of lettuce was initially in the expected magnitude range for this product, i.e. 4 log CFU g^{-1}, and progressively increased during storage. Several European countries established a maximum limit of 7 log CFU g^{-1} for total viable count in minimally processed fruits and vegetables (King, Magnuson, Török, & Goodman, 1991; Baur, Klaiber, Hammes, & Carle, 2004; Conte, Conversa, Scrocco, Brescia, Laverse, & Elia, 2008; Francis, Thomas, & O´Beirne, 1999). This limit was reached after 7 days of storage at 8 °C, which corresponded to the expiry date chosen by the producer for the lettuce considered in the present research.

When lettuce was stored at 12 °C a faster increase in browning index was observed (Fig. 1b). The visual appearance of the product was also significantly impaired due to the development of intense wilting and formation of exudates in the packages. Concomitantly, a fast increase in total

mesophilic bacteria was detected so that the 7 log CFU g^{-1} limit was exceeded after 5 days of storage, and thus two days earlier than the expiry date established by the producer (7 days).

3.2. Effect of expiry date communication on the rejection of fresh-cut lettuce stored at different temperatures

Lettuce stored at 8 or 12 °C, reporting or not the expiry date on the label, was evaluated by consumers to assess the effect of expiry date communication on consumer rejection (Fig. 2). Data were fitted according to the Weibull model and experimental parameters μ and σ are reported in Table 1.

In agreement with the literature (Rico, Martín-Diana, Barat, Barry-Ryan, 2007), the rejection of fresh-cut lettuce progressively increased during storage (Fig. 2), due to product quality decay (Fig. 1). Independently on storage temperature, the presence of the expiry date caused an increase of product rejection. In the absence of an expiry date, consumers expressed a rejection judgement mainly based on their visual experience of the product. It can be hypothesised that the expiry date represented an additional information that, in combination with the product sensory perception, induced consumer to assume a more conservative behaviour. Despite several authors have demonstrated that consumers are scarcely aware of the meaning of information reported on the label (Harcar & Karakaya, 2004; Whitworth, 2001), other authors claimed that expiry date is the most important feature considered by consumers to evaluate food at domestic level (Ragaert, Verbeke, Devlieghere, Debevere, 2004; Dinnella *et al.*, 2014). This contradictory information could be related to the fact that even if consumers pay attention to the expiry date reported on the label, they do not always behave accordingly (Fig. 2).

3.3. Effect of expiry date communication on the consumption distribution of fresh-cut lettuce

To understand whether the expiry date affects consumer intention to consume the product during the days after purchase, the methodology reported in the literature by Manzocco *et al*. (2017) was used. In particular, consumers were asked to describe the purchasing and consumption habits of fresh-cut lettuce presenting or not the expiry date. The Negative Binomial model (Equation 2) was fitted to consumption probability data and estimates of the experimental parameters *n* and *p* are reported in Table 2. Data were expressed as consumption probability (Fig. 3).

Fig. 3 shows the probability that the consumers decide to consume fresh-cut lettuce at a given time during its refrigerated domestic storage. It can be noticed that the consumption probability of fresh-cut lettuce decreased during time and most lettuce was intended to be consumed within few storage days, independently from the labelled expiry date. When the expiry date was present on the package, the higher consumption probability (24%) was observed after one day from purchase, and 99% consumption was expected to occur within 7 days of storage. Based on these data, it can be inferred that consumers trusted labelled information and distributed product consumption within the storage time indicated by the expiry date (Ragaert *et al.*, 2004; Theotokis, Pramatari, & Tsiros, 2012). In the absence of expiry date, the maximum consumption probability (32%) was observed on the purchase day, and nearly 60% lettuce was expected to be consumed during the first 2 days after purchase. In the same time-span, only 45% of the lettuce with expiry date was intended to be consumed. According to these data, when no expiry date was provided, consumers consumed most of the lettuce in a shorter time, being their decision mainly guided by awareness of product susceptibility to quality decay.

3.4. Effect of expiry date communication on waste of fresh-cut lettuce stored at different temperatures

The estimation of the waste probability of fresh-cut lettuce during domestic storage was obtained by applying Equation 3 to the consumption and rejection functions of fresh-cut lettuce (Fig.s 2-3)

(Manzocco *et al*., 2017). Fig. 4 compares the effect of the presence of expiry date on the cumulative probability that the product stored at 8 or 12 °C is wasted by consumers since unsuitable for the meal.

The percentage of purchased packages that was expected to be wasted by consumers progressively increased during storage and accounted for considerable differences, depending on labelled information and storage temperature (Fig. 4). When lettuce was stored at the recommended temperature (8 °C) and presented the expiry date, only a negligible number of packages (4%) was expected to be wasted within the expiry date set by the producer (7 days). Even a lower amount of waste was estimated when expiry date was not reported on lettuce package stored at 8°C. Storage under temperature abuse (12 °C) led to a significant increase in the wasting risk of fresh-cut lettuce. Within the shelf life expected by the producer (i.e. 7 days), 12% of packages with no expiry date was estimated to be wasted. The presence of the expiry date more than doubled this percentage, emphasising the critical effect of expiry date on lettuce waste at domestic level. Results pointed out the dramatic effect of the combination of presence of the expiry date and inadequate storage temperature on the consumer decision to waste food. Thus, raising stakeholders' awareness towards proper food storage practices is essential to guarantee the efficacy of any intervention aimed at reducing food waste (e.g. technological processes to extend food shelf life, choice of the expiry date to be printed on the product label).

4. Conclusions

Results reported in this paper demonstrate that consumer decision to waste fresh food at domestic level is affected by the interaction between two different quality aspects: (i) the product quality, which is sensory perceived by consumers and (ii) the product quality expected by consumers based on expiry date. A rational management of labelled information is required to avoid waste generation by driving consumer attention not only to expiry and "best before" dates, but also to recommended

storage conditions (e.g. temperature). In addition, it is noteworthy that the company choice of the expiry date is mainly quality driven, thus implying the existence of a certain time span between product shelf life and its safe life. The latter is actually related to the eventual occurrence of safety risks. Further research is required to understand if increasing the shelf life, while guaranteeing food safety, could represent a possible answer to the urgent need of decreasing food waste.

Acknowledgements

This research was supported by Ministero dell'Istruzione, dell'Università e della Ricerca (Prot. 957/ric 28/12/2012) "Long Life, High Sustainability". Project 2012ZN3KJL.

The Authors thank Dr. Kristyna Kupcova for contributing to analyses.

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Captions for Fig.s

Fig. 1. Total mesophilic bacteria and browning index of lettuce stored at (a) 8 °C and (b) 12 °C.

Fig. 2. Rejection probability during storage at 8 (a) or 12 (b) °C of fresh-cut lettuce reporting or not a 7-days expiry date on the label. Symbols: data. Line: Weibull function estimate.

Fig. 3. Consumption probability of fresh-cut lettuce reporting or not a 7-days expiry date on the label.

Fig. 4. Cumulative wasting risk during storage at 8 or 12 °C of fresh-cut lettuce reporting or not a 7-days expiry date on the label.

Figure 1

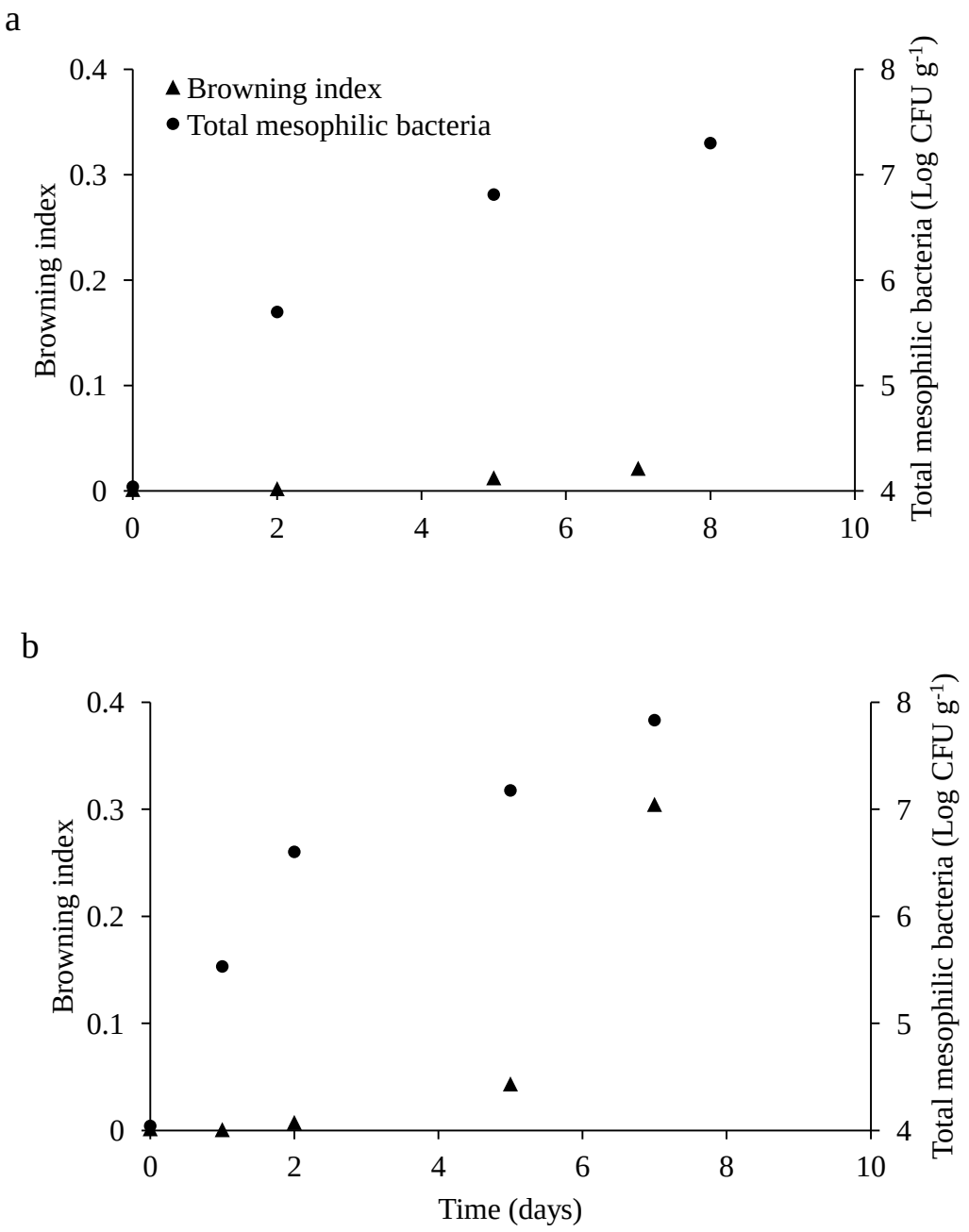

Fig. 1.

Figure 2

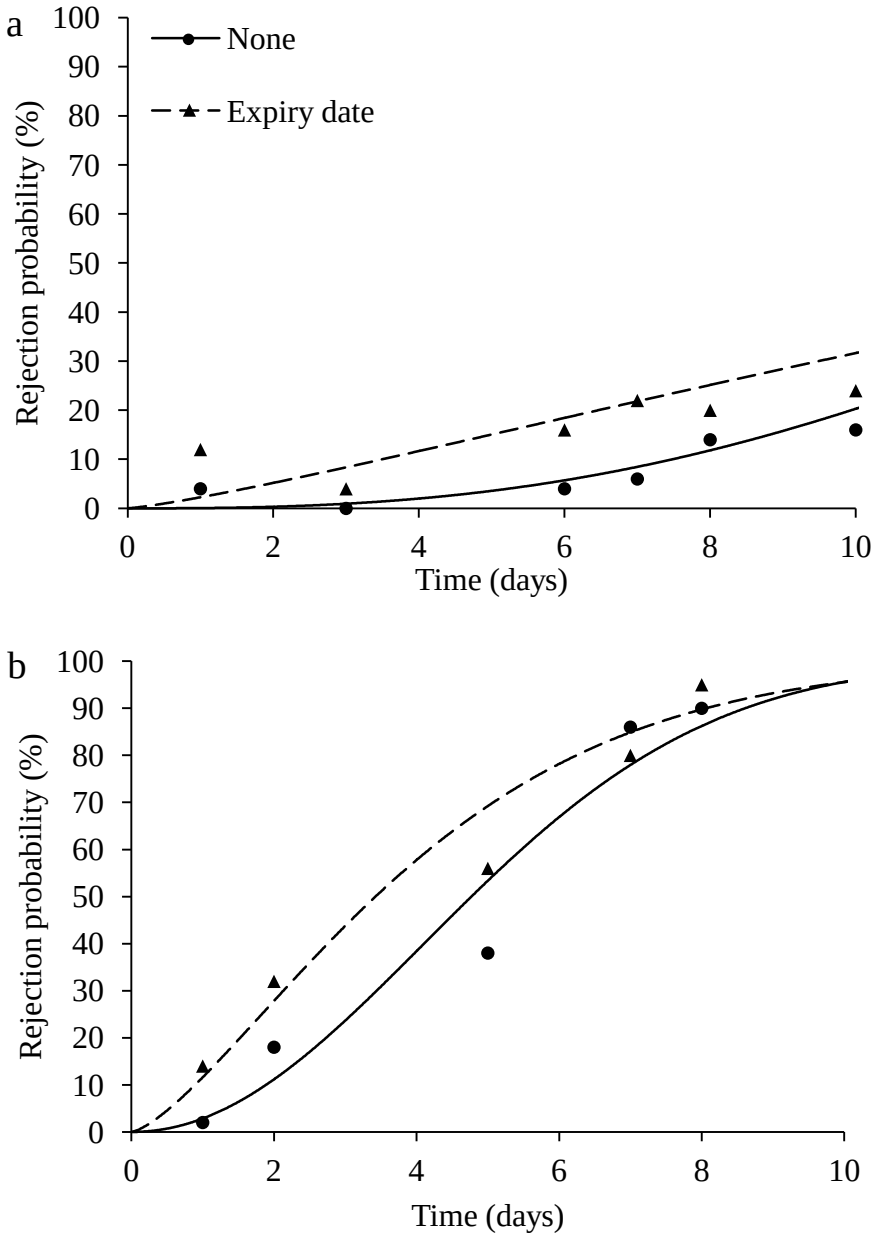

Fig. 2.

Figure 3

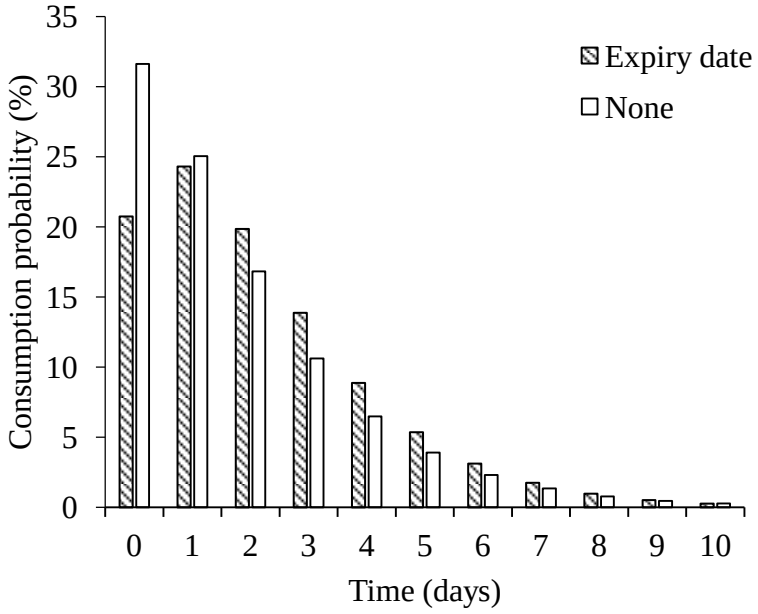

Fig. 3.

Figure 4

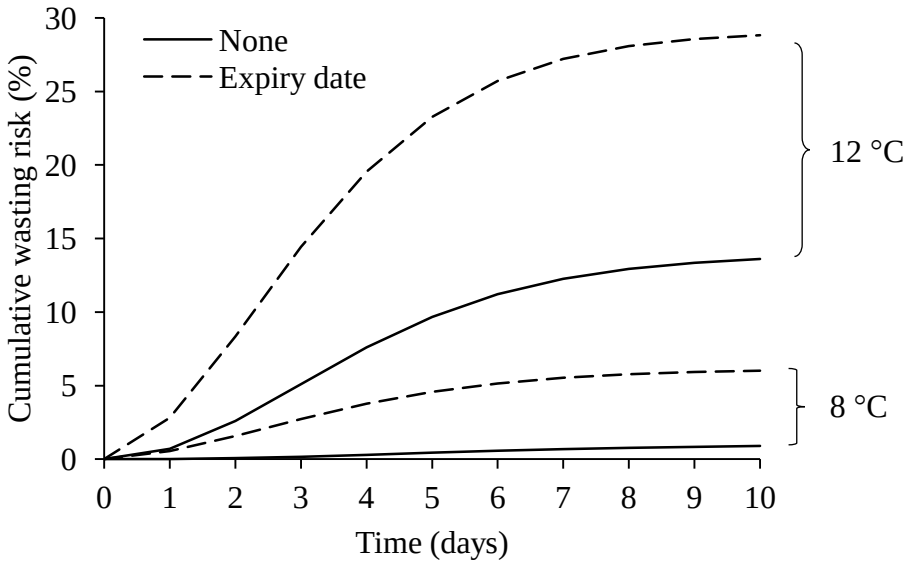

Fig. 4.

Table 1

Weibull model parameters (μ and σ) of consumption probability during storage at 8 or 12 °C of fresh-cut salad reporting or not expiry date on the label.

Storage temperature (°C)	Information	μ (SE)	σ (SE)
8	Expiry date	3.09 (0.24)	0.82 (0.20)
	None	2.86 (0.09)	0.38 (0.07)
12	Expiry date	1.49 (0.14)	0.71 (0.15)
	None	1.74 (0.12)	0.49 (0.12)

Table 2

Negative Binomial model parameters (*n* and *p*) of consumption probability of fresh-cut salad with 7 days' shelf life or without shelf life indication.

Information	*n* (SE)	*p* (SE)
Expiry date	2.53 (0.20)	0.54 (0.05)
None	1.44 (0.12)	0.45 (0.02)

*Graphical Abstract