Freshness performance according to IEC 63169 in relation to consumer requirements in fresh produce storage

Astrid Klingshirn, Eva Häußler und Lilla Brugger

Abstract

Humidity controlled vegetable drawers have become a standard equipment in refrigerators. With the release of IEC 63169:2020 the analysis of the humidity retention within storage zones based on a food simulant system has been enabled, which allows for the assessment of the fresh keeping performance of storage zones. The comparison of the freshness retention of vegetables in storage areas with minimum to maximum weight loss rates according to the normative measurement parameter shows a good correlation. As vegetables are mainly stored w/o packaging, the weight loss rate must be considered in addition to temperature, to assess the usability of storage zones in refrigerators.

Keywords: refrigerator, vegetable, freshness performance, fresh weight loss, quality analysis, humidity-controlled compartment, EN IEC 63169:2020

Abgleich der Frischhalte-Performance von Haushaltskühlgeräten gemäß IEC 63169 mit Verbraucheranforderungen an die Lagerung pflanzlicher Frischwaren

Kurzfassung

In Kühlgeräten haben sich feuchtigkeitsregulierte Gemüsefächer als Standardausstattung etabliert. Die IEC 63169:2020 ermöglicht die Analyse der Feuchterückhaltung von Lagerbereichen auf der Grundlage eines Lebensmittelsimulanzsystems, wodurch Ableitungen zur Frischhalte-performance möglich sind. Der Abgleich des Frischeerhalts von Gemüsen in Lagerbereichen mit minimalen bis maximalen Entfeuchtungsraten auf Basis der normativen Messgröße zeigt eine gute Korrelation. Da Gemüse überwiegend offen eingelagert wird, muss neben der Temperatur zwingend auch die Entfeuchtungsrate zur Bewertung der Gebrauchstauglichkeit von Lagerbereichen in Kühlgeräten mit herangezogen werden.

Schlagworte: Kühlgerät, Gemüse, Frischeperformance, Frischmasseverlust, Qualitätsanalyse, feuchtegeregelte Zone, EN IEC 63169:2020

Freshness performance according to IEC 63160 in relation to consumer requirements in fresh produce storage

Astrid Klingshirn, Eva Häußler und Lilla Brugger

Introduction

The average per capita food loss in Germany is 75 kg (2021 data), of which 30 % is avoidable. Inadequate storage at all stages of the food chain, including households, is one of the key contributing factors, especially when it comes to fruit and vegetable losses. Fresh produce losses amount to 34 %, representing the largest food loss share, with an avoidable waste intensity of 13% (De Laurentis et al. 2018, Deutsche Welthungerhilfe 2022, Kemna R & van Holsteijn F 2017). Chilled storage, along with proper further storage parameters, including storage atmosphere and handling parameters, are essential. This also includes hygiene aspects, as well as sensitive product handling, to avoid mechanical damage. Long term storage of highly perishable horticultural products mostly requires low temperatures (0 to 4 °C), in combination with a high relative humidity (> 95 %). Just by controlling these parameters, along with air circulation around the product, the driving forces in deterioration, namely microbial decay, respiration activity and transpiration losses, can be properly controlled. Provided that the storage conditions are optimal, a storage time gain of up to 26 % can be realized for broccoli and even up to 49 % for lettuce in comparison (El-Ramady et al. 2014, Kemna & Holsteijn 2017).

Transpiration loss as key deterioration parameter of fruit and vegetables in chilled storage

The consumer demand for high quality fruit and vegetables has increased sharply throughout recent years. If fruit and vegetables show external defects or do not conform to trade class requirements, they are discarded and do not even reach supermarkets. Thus, consumers have elevated expectations in fruit and vegetable quality, starting from the selection process and continuing to quality retention in storage. This is further pushed by the increasing importance of plant-based nutrition styles, along with the desire for a more sustainable lifestyle (Nutrition Hub 2021, Industrieverband Agrar e. V. 2013).

As fruit and vegetables are highly perishable products, with their metabolism being active post-harvest, quality changes and spoilage are inevitable. This includes obvious deterioration effects such as changes in texture, colour, odour, and taste. The storage factors temperature, humidity, air movement and atmosphere composition influence deterioration in storage (Herppich et al. 2010, Klingshirn et al. 2019).

The temperature of the postharvest environment has the greatest impact on the shelf life of stored goods, as low temperature depresses the metabolic activity of the product itself, biochemical deterioration processes and the activity of micro-organisms (Herppich et al. 2010). Not only temperature, but also humidity has a significant effect on postharvest shelf life. Plants that are separated from the parent plant cannot replenish water lost by transpiration and respiration, as the two basic water loss mechanisms in storage (Bartz & Brecht 2003).

The difference in water vapor pressure between the product surface and its environment is the driving force for water loss of the product. The (water) vapor pressure deficit (VPD) is defined as the difference in water activity of the product and the water activity of the atmosphere surrounding it. With a given product-specific transpiration coefficient and the VPD, the expected water loss can be estimated. One can assume that the vapor pressure on the product surface equals the saturation vapor pressure on its surface, as fresh goods normally have a high-water content. Considering the above assumptions, the water loss - or more detailed - the transpiration rate of said goods is proportionally related to the VPD:

$$transpiration\,rate = transpiration\,coefficient\ \cdot VPD$$

Transpiration is understood as the transport of moisture through the skin of a fruit or a vegetable product, the evaporation of the moisture from the commodity surface and the transition of the moisture to the environment by convection mechanism. At temperatures below 4 °C transpiration losses are the dominating factor in fresh weight loss (FWL), amounting to ~90 % of the total loss. The remaining 10 % of weight loss are caused by respiration. Transpiration coefficients can vary widely within the same crop or even within one single cultivar. The reasons for these different rates are pre-harvest factors as well as post-harvest handling parameters like mechanical damages, microbial contamination, or cool-down technology and rate (Bartz & Brecht 2003).

For many fruits and vegetables even a minor water loss of 3-10 % causes a major quality loss, becoming predominantly obvious by a loss of crispness and discoloration (El-Ramady et al. 2014, Kays & Paull 2004).

Performance analysis of humidity control systems in refrigerators

Refrigerator manufacturers come up to the growing demand of consumers in providing improved storage conditions for fruits and vegetables. Vegetable compartments on the market come along with a high variety of humidity control systems. Within chill compartments, with storage temperatures close to 0 °C, separate storage zones for vegetables and fruit, including humidity control functions, have become a market standard.

With growing numbers of dynamic cooled refrigerators, in which - depending on the cooling circuit layout - humidity levels can be as low as 30 % rH, additional humidity control options for fruits and vegetables, which are typically stored without packaging, are decisive (WRAP 2008). Several previous studies have already investigated the effect of humidity-controlled vegetable drawers in refrigerators with different cooling circuit designs and storage zone layouts, showing a substantial shelf-life extension in optimum humidity and temperature conditions, which represents a considerable advantage for consumers (Klingshirn et al. 2019).

For consumers it is crucial to be able to already assess the performance parameters of a refrigerator storage system upon purchasing, which can hardly be managed just by visual inspection or manufacturer marketing claims. With the release of IEC 63169:2020 an analysis method has been established, that allows for analysis of the freshness performance of humidity-controlled storage zones: The measurement of transpiration losses of fresh produce in storage is enabled, based on a food simulant system. The simulant, consisting of a water filled test tray with 18 test sheets, simulates the transpiration loss of leafy vegetables.

The analysed weight loss rate [g / 24 h] of the test tray provides the water loss and thus the transpiration loss of the stored goods, giving further information on the tested refrigerator test zones and its humidity retention functionality. The higher the weight loss rate, the more water a product losses, resulting in a shorter storage time. The repeatability and reproducibility of the analysis approach of EN IEC 63169:2020 and the correlation to leafy vegetables has been proven. Spinach, as a leafy vegetable, has been used for the simulations, due to its high transpiration rate, representing a highly perishable vegetable (Klingshirn et al. 2020, Wucher et al. 2021).

A further differentiation of weight loss rates of other vegetables is required in order to be able to evaluate the performance range of available technologies. The measured weight loss rate values have not yet been translated into evaluation parameters that can be used by consumers.

The present study examines the quality evolution and maximum shelf life of different vegetables and a mixed vegetable load in vegetable drawers, covering a broad spectrum of weight loss rates according to IEC 63169:2020, ranging from 0.5 g / 24 h to 16 g / 24 h. The main focus is on comparing the weight loss rate categories of the different test zones with the quality loss of the stored products within the very same test zones. Based on this, an evaluation of the consumer benefit of the storage systems can be derived, with regard to quality retention and storage time.

In order to consider typical consumer behavior and expectations to a sufficient extent, a consumer survey on the storage behavior of fruit and vegetables is carried out in advance, focusing on storage duration, storage quantities, packaging status and the range of variation of stored commodities.

Material and Methodology

Consumer survey on fruit and vegetable storage in refrigerators

The online survey is conducted for a 15-day period in August 2021, using SoSci Survey. The survey is conducted without further quota specifications and distributed within Germany, using the Albstadt-Sigmaringen University mailing list, as well as professional networks with relevant specialist groups (XING, Deutsche Gesellschaft für Hauswirtschaft e. V.) and social media platforms (Facebook, LinkedIn), with a total of 291 participants. The overall 13 query clusters are divided into four sections: Fruit and vegetable purchasing behavior, filling level of the vegetable drawer, packaging status in storage and stored fruit and vegetable varieties. In addition, the participants are asked to upload a photo of their actual vegetable drawer load (return rate: 26 %), to further specify and compare load, storage variety and packaging status. The evaluation of the consumer survey consists of two parts: Data from the online survey (n = 291) and data derived from the uploaded photos (n = 75). The descriptive analysis of the transmitted data is done using Excel Professional Plus 2016.

Weight loss and vegetable quality evolution analysis

In a pre-analysis eight vegetable drawers, covering the range of 0.5 to 16 g / 24 h according to IEC 63169:2020, are identified. These test zones are supposed to be representative for the range of typical refrigerator test zones, covering static and dynamic cooled cooling technologies. The basic weight loss rates are determined in a triple approach, using one test tray per test zone with 18 test sheets and a filling of 600 g ± 50 g of pre-cooled distilled water. The reference value of 0.5 g / 24 h is implemented by storing the test tray in a hermetically sealed plastic box, the maximum value of 16 g / 24 h is realized by openly storing the test tray in a refrigerator compartment, simulating the worst-case approach. Higher rates of up to 50 g / 24 h have been reported, yet based on pre-tests, the impact of weight loss rates of > 20 g / 24 h have not shown differentiable effects in produce quality loss compared to 16 g / 24h.

All refrigerators being evaluated have a manufacturing date from 2017 onwards. The temperature control of the appliances is adapted to assure a temperature of 4 °C (± 1.6 K) within the test zones. The following table provides the key information on the analysed test zones, including the cooling technology layout, storage climate parameters and weight loss rates according to IEC 63169:2020.

Table 1: Specification of analyzed test zones and corresponding mean values (MV) und standard deviations (SD) of storage temperature (T) and relative humidity (rH)

Weight loss according to IEC 63169 [g / 24 h]	Cooling technology layout	Type of test zone	Test zone volume [L]	T (MV) [°C]	T (SD) [°C]	rH (MV) [%]	rH (SD) [%]
0.5	Dynamic cooled	Airtight box	10.6	4.0	0.3	100	1.4
1	Dynamic cooled	Vegetable drawer	20.9	4.1	0.7	97	5.2
3	Static cooled	Vegetable drawer	35.2	4.2	0.5	93	3.3
4	Static cooled	Vegetable drawer	37.0	5.2	0.4	89	6.6
7	Dynamic cooled (Full No Frost)	Vegetable drawer	37.0	3.8	0.5	84	7.5
11	Static cooled	Refrigerator compartment	260.0	4.0	0.7	82	13.1
13	Static cooled	Vegetable drawer	37.0	5.6	0.4	86	7.6
16	Static cooled	Refrigerator compartment	187.0	5.4	0.4	87	9.4

In each test zones 3 types of vegetables, covering different transpiration rates, are stored as a single variety load, based on the test approach of IEC 63169:2020. For each vegetable four measurement runs are performed, with two sets of the same vegetables from different raw material batches being stored in parallel.

Next to that, a mixed load is analysed to evaluate the impact of an increased test zone load and the quality evolution of further vegetable varieties, as typically found in consumer reality: 4 types of vegetables are stored in parallel in a double approach. In mixed load storage a volume adaption is implemented by proportionally decreasing the load (Table 2).

All vegetables are bought in local retail and stored packaged at 4 °C prior to further sorting (to ensure the same output quality) and distribution to the test zones. All vegetables (except broccoli) are stored in open plastic trays to prevent product damage whilst handling. The storage time is adapted to the typical consumer storage periods and typical shelf-life values in chilled storage.

Table 2: Specification of stored vegetables, storage time and test zone loads (SL: single load, ML: mixed load)

Vegetable commodity	Storage time [days]	Load in test zone	Plastic tray dimension
Spinach leaves	7	SL: 50 g	5 x 12 x 17 cm
Carrots (without green)	14 / 9	SL: 450 g (~ 4 carrots) ML: 180 g – 450 g (2 - 4 carrots, depending on test zone volume)	6 x 13 x 22 cm
Lamb´s lettuce	7 / 9	SL: 50 g ML: 20 g – 50 g (depending on test zone volume)	5 x 12 x 17 cm
Broccoli	9	ML: 425 g – 1500 g (1 - 3 broccoli, depending on test zone volume)	without tray
Romaine lettuce	9	ML: 100 g – 350 g (1-3 lettuce hearts, depending on test zone volume)	6 x 13 x 22 cm

The analysis parameters are FWL (in g and %) and sensory quality, from which quality loss and maximum storage time are derived. The analyses are conducted in two- to four-day intervals, depending on the quality evolution dynamics of each vegetable variety. The change in sample weight in relation to the initial weight is determined as the percentage FWL, using an analytical balance (L 2200 S Sartorius, Readability: 0.01 g). The sensory analysis of the stored vegetables follows DIN 10952 (evaluation test with scale), based on a 6-point scale, also allowing 0.5 evaluation steps. A value of 1 is representing a superior quality and a value of 6 is describing an insufficient quality with completely changed characteristics.

Two trained panellists perform all analyses. The sensory evaluation covers colour, texture, and odour analyses, which are summed up to a total quality index, with different weight factors for the sensory attributes, depending on the vegetable variety (Table 3). Odour is neglected for carrots and romaine lettuce, as it is below the threshold level within the analysis period. The quality index of 3.6 corresponds to the consumption limit and is equivalent to the end of the shelf life (SL) of the product. The definition of a reference value based on quantitative descriptive tests follows basic shelf-life evaluation procedures of the food industry (Kilcast 2000). If the limit value of 3.6 is not reached within the analysis period, the maximum storage time is determined by regression analysis, thus estimated a maximum.

Table 3: Sensory index calculation by vegetable commodity

Vegetable commodity	Sensory quality index
Spinach	(Colour x 3 + Odour x 2 + Texture x 5) / 10
Carrots	(Colour x 2 + Texture x 3) / 5
Lamb's lettuce	(Colour x 3 + Odour x 2 + Texture x 5) / 10
Broccoli	(Colour x 3 + Odour x 2 + Texture x 5) / 10
Romaine lettuce	(Colour x 2 + Texture x 3) / 5

On each monitoring day a photo of the stored vegetable commodities is taken. The temperature and relative humidity in each test zone are monitored throughout the whole storage period, using mobile USB temperature and rH-data loggers (Omega engineering, OM-EL-USB-2L-LCD).

Results and discussion

Consumer survey on fruit and vegetable storage in refrigerators

To take sufficient account of typical consumer storage behaviour in the evaluation of the performance of storage systems, fruit, and vegetable consumption and storage patterns retrieved by the online survey and the photo analysis, are summed up as a starting point. All respondents indicate to buy fresh fruits and vegetables at least 2-3 times a week, which agrees with the shopping frequency data for fresh produce in Germany (HDE 2021). The storage period of fresh produce varies between 1 up to more than 14 days: 75 % state to consume the products within one week or less. This confirms, as also shown by Cox & Downing (2007) or Chardon & Swart (2016), that a good retention of the quality must be provided in storage for approximately 7 to 10 days for highly perishable produce.

In the survey 18 % state that food spoilage does not occur upon storage; the most common reasons for fruit and vegetable losses in storage are microbial decay (24 %), changes in colour (19 %) or texture (17 %), as found in other studies (Danone 2021).

The following figures sum-up the online survey and photo analysis results of the vegetable drawers filling level (A), the variety of stored fruits and vegetables (B) and the fruit and vegetable packaging status in storage (C).

Regarding the **filling level** (Figure 1 A) the data from the analysed photos and the online survey do not show any differences: In about 60 % of the vegetable drawers the load level is > 75 %. In 16 % of the drawers also further goods like preserved foods and beverages are stored (~18 %).

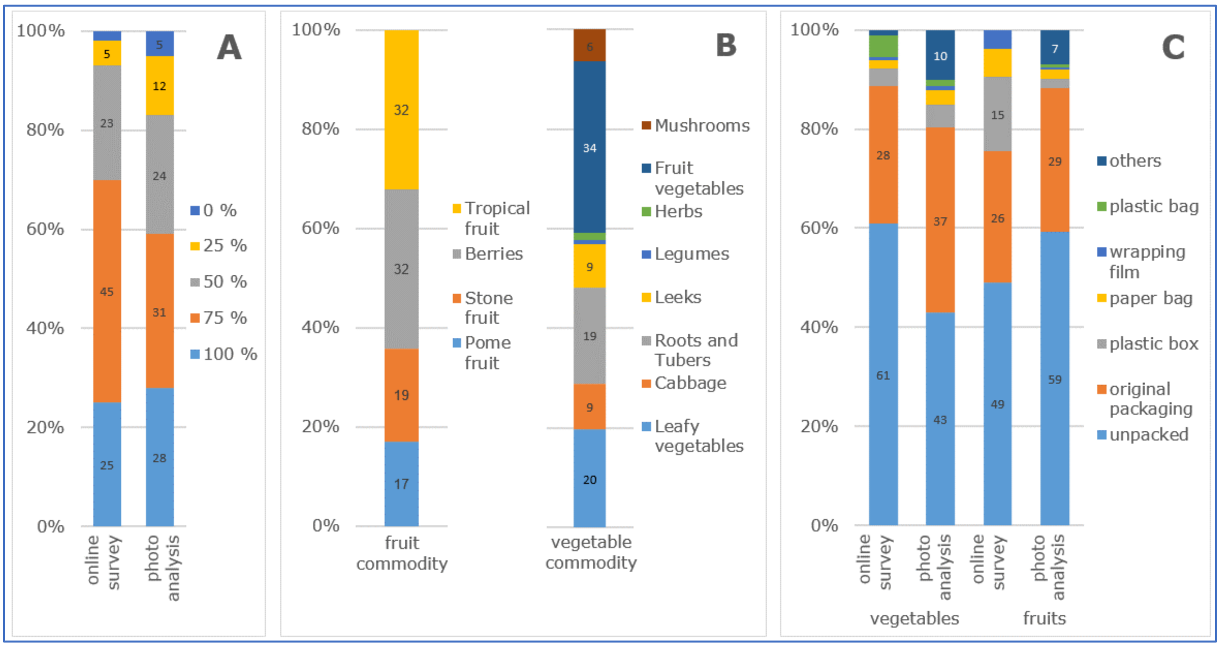


Figure 1: Vegetable drawer filling level (A), fruit and vegetable variety (B) and fruit and vegetable packaging status (C)

The **variety of commodities** (Figure 1 B) ranges from 1 to up to 10, with 3.3 different varieties in average. Fruit vegetables (34 %), leafy vegetables (20 %) and roots and tubers (19 %) are the most common. About half of the observed vegetable drawers contain fruits (Figure 1 B). About one third (32 %) are tropical fruits (e.g., bananas and mangos), which should not be stored in the refrigerator, as they are temperature sensitive. The high share of storage of cold-sensitive products may be related to the higher ambient temperatures during the survey period. Berries, which belong to highly perishable fruits, are also found in one third (32 %) of the drawers. Stone fruit and pome fruit are stored in equal proportions (~18 %).

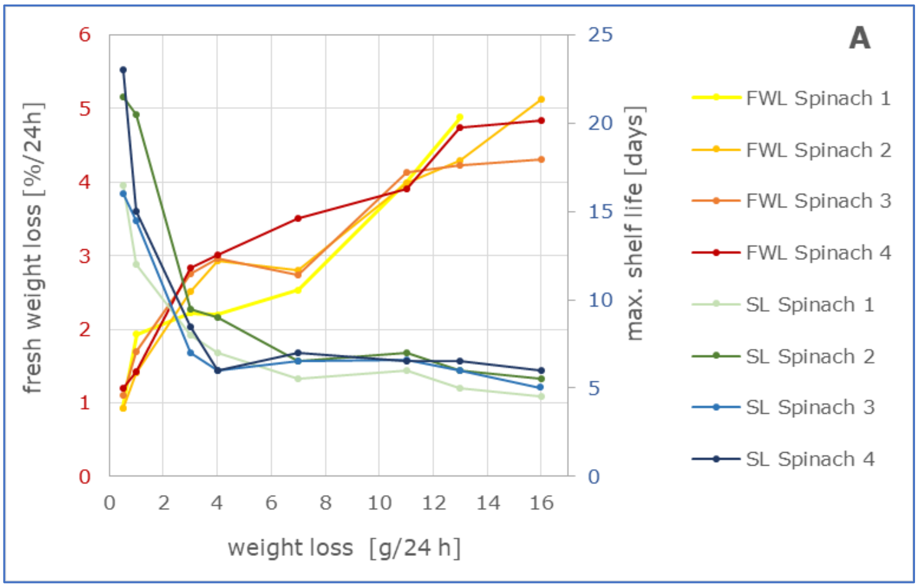
Regarding the **packaging status** respondents indicate to mostly store vegetables (60 %) and fruits (50 %) without packaging. The photo analysis shows slightly different shares (43 % / 60 %, Figure 1 C). Approximately 30 % of stored goods are in their original packaging; re-packaging is thus subordinate in importance. The photo analysis further reveals a highly diverse packaging behavior starting from a completely packed storage to a completely unpackaged storage (Figure 2, pictures from left to right).

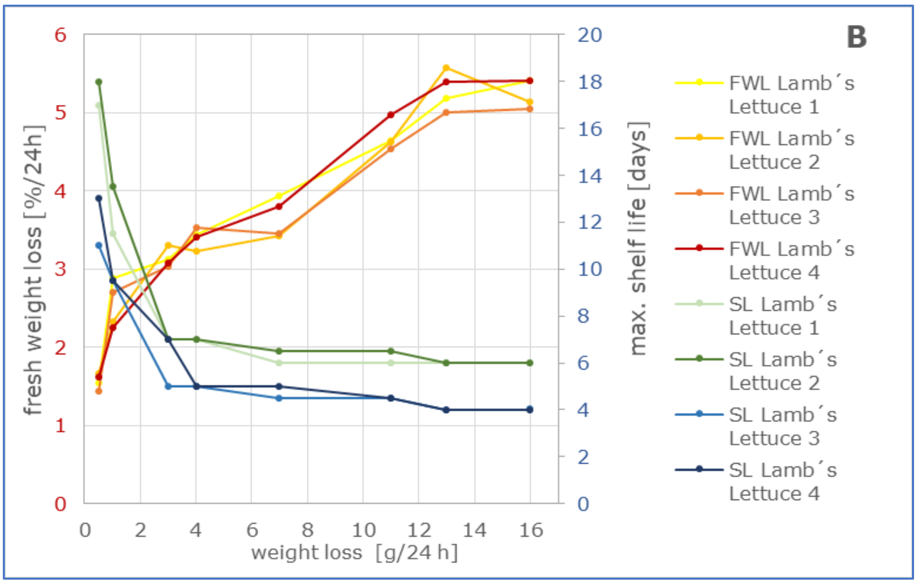
Figure 2: Diversity of food packaging status in vegetable drawers (data from online-survey)

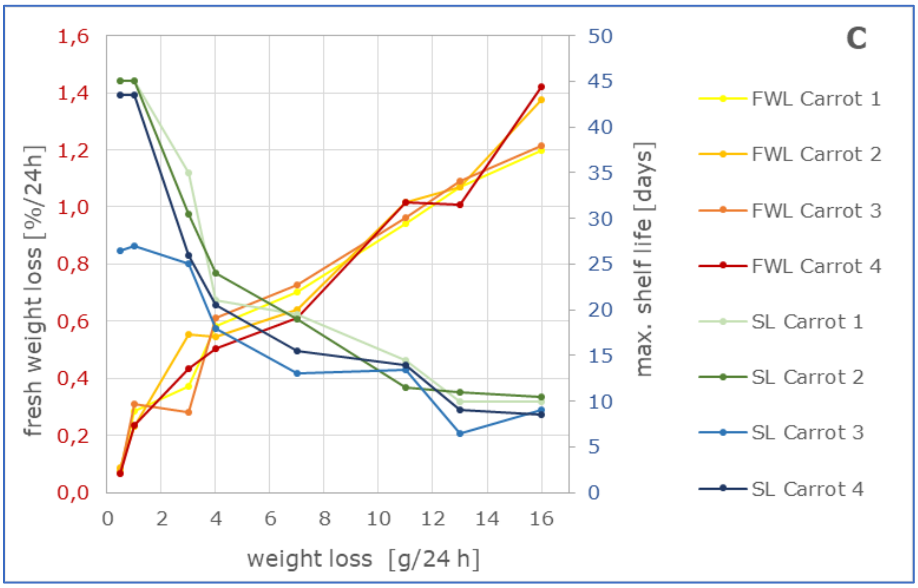
The photo analysis also reveals further storage aspects that must be considered in overall freshness retention: Products are frequently stored in several layers, enhancing mechanical damage and thus decay. In ~40 % of the drawers cut products are stored, of which 79 % are stored without an additional packaging, further enhancing weight loss (Figure 2).

Weight loss and vegetable quality evolution analysis

The following figures illustrate the FWL [%] and the maximum storage time [days] by test zone weight loss (cf. Table 1) according to IEC 63169:2020. Table 4 outlines the corresponding maximum shelf-life values by weight loss rate. For all test runs and settings the FWL increases with increasing test zone FWL-rates, strongly supporting the underlying principle of IEC 63169:2020. Raw material variations are shown in all vegetables, underlining the necessity of a food simulant, as currently applied.







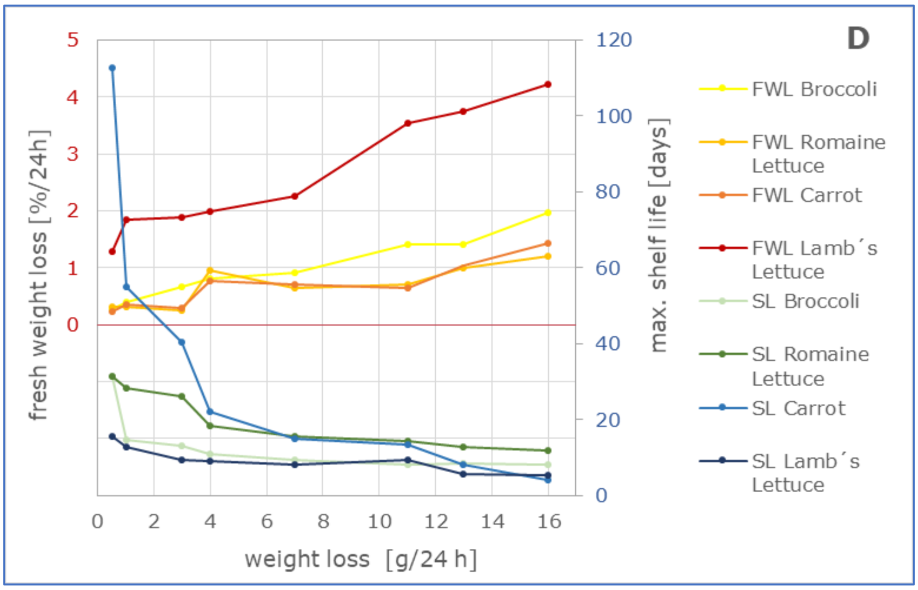


Figure 3 (A-D): FWL and maximum SL in spinach (A), lamb´s lettuce (B), carrots (C) and mixed load (D) by weight loss rate

For **spinach** (Figure 3 A) the FWL follows a linear increase (weight loss rate / day ~0.57 %), showing a flattening from 13 g / 24 h onwards indicating that the maximum weight loss level has been reached. The SL shows a linear decrease from 0.5 to 4 g / 24 h. From test zone weight loss rates of > 4 g / 24 h onwards, the differences in maximum storage time are negligible.

In **lamb´s lettuce** (Figure 3 B) the second leafy vegetable commodity being analysed, the very same pattern is shown in FWL with weight loss rates / 24 h of 0.67 % and a flattening from 13 g / 24 h onwards. The SL follows a linear decrease to a rate of 3 g / 24 h, the SL differences > 3 g / 24 h onwards are neglectable. An obvious difference in SL in storage varieties 1 and 2 is clearly visible, caused by the different raw material batches used. However, these differences do not become obvious in FWL.

Figure 4 clearly shows that for high sensitive leafy vegetables just storage systems with weight loss rates < 3 g / 24 h will come up to typical maximum storage times of up to 7 days, as FWL induces strong texture loss and colour change. No differences are found between the vegetables stored in zones with a weight loss rate > 3 g / 24 h.

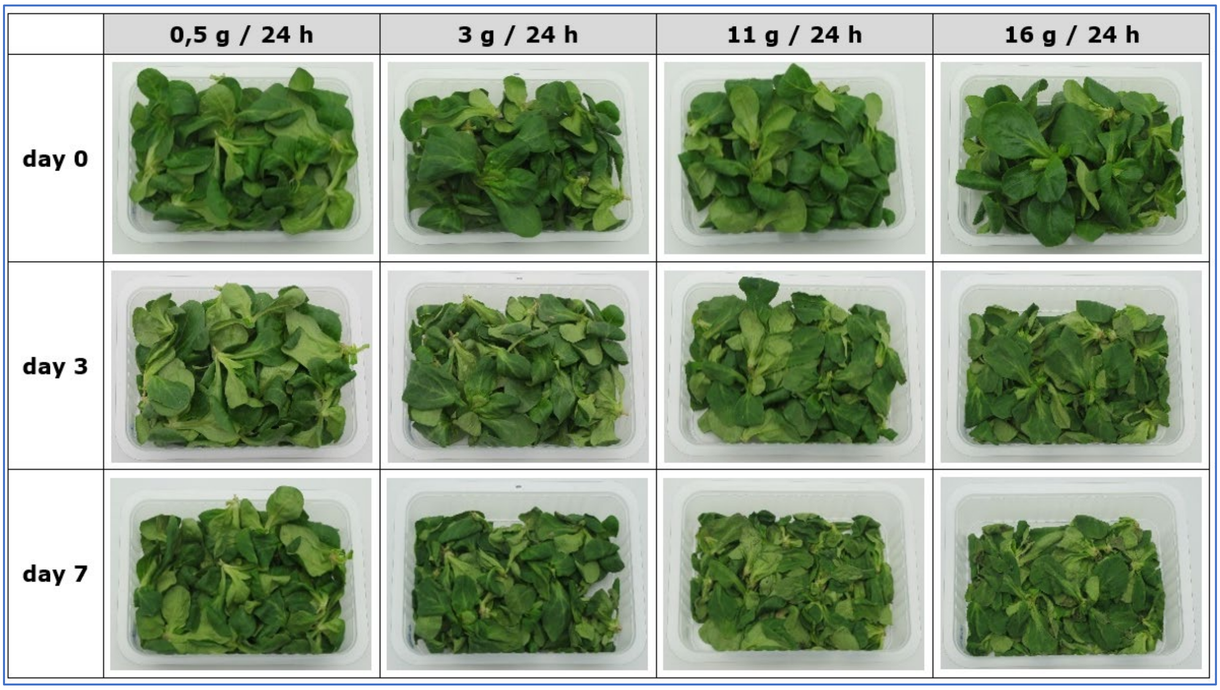


Figure 4: Quality evolution of lamb´s lettuce at storage day 0, 3 and 7, stored in test zones with weight loss rates of 0.5, 3, 11 and 16 g / 24 h

In carrots, the change of the FWL and the maximum storage time shows a stronger characteristic with increasing weight loss values. The FWL of **carrots** (Figure 3 C) shows a linear increase with weight loss rates of 0.1 % / 24 h. In between a flattened increase (0.07 % / 24 h) is shown up to 11 g / 24 h. The SL follows a linear decrease to a rate of 4 g / 24 h, the SL differences > 11 g / 24 h onwards are neglectable. In general, carrots have the longest SL of all stored vegetables with about 45 days in the test zone 0.5 g / 24 h. The variances can be explained by the different organic structures of the used vegetables. The high surface to mass ration in spinach and lamb´s lettuce leads to a fast weight loss and therefore to a fast loss of quality resulting in a shorter SL. The retrieved data indicate that this process significantly accelerates above a specific fresh weight value of approx. 4 g / 24 h. In comparison to this, carrots have a much smaller surface to mass ratio.

The **mixed load** evolution is shown in Figure 3 D with an adjusted primary y-axis for a better distinction of the results. The FWL and SL of **lamb´s lettuce** in mixed load is comparable to the single load values with 0.5 % FWL / 24 h. The SL of **carrots** in mixed load is twice as high as the SL of the single load carrots, due to the different raw material batches used.

For **broccoli,** the FWLs follows a linear increase to a rate of 7 g / 24 h to 11 g / 24 h, showing a flattening from 11 g / 24 h onwards. The SL decreases to rate of 1 g / 24 h onwards the shelf-life differences are neglectable, as they only decrease slightly. The FWL of **romaine lettuce** increases to a rate of 3 g / 24 h, further on the FWL hardly increases.

The SL increases with decreasing test zone weight loss rates, allowing for a clear differentiation of test zone freshness performance. Taking into consideration typical consumer behavior, best performing test zones showing weight loss rates ≤ 3 g / 24 h, especially address consumers who demand for extended storage times and consumers who typically have perishable leafy vegetables in stock. The SL in such storage zones can be increased by a factor of up to 4 for carrots, by a factor of 3 for broccoli, lamb´s lettuce and spinach up to 3 and by a factor of 2 for romaine lettuce (Table 4).

Table 4: Maximum storage time of all stored vegetables, including a comparison of single and mixed load data (practical SL is highlighted, data obtained by regression analysis is preceded by "~ / >")

	Maximum storage time [days]						
Weight loss acc. to EN IEC 63169 [g / 24 h]	**Spinach (SL)**	**Lamb's lettuce (SL)**	**Carrots (SL)**	**Broccoli (ML)**	**Lamb's lettuce (ML)**	**Carrots (ML)**	**Romaine lettuce (ML)**
0,5	~19,5	~15	>40	>25	~15.5	>50	>30
1	~15,5	~11	>40	15	~13	~50	>28
3	8.5	6,5	~35.5	~13.0	9,5	~40	~26
4	7	6	~26	11.0	9	~22	~18.5
7	6.5	5.5	~19.5	9	8	~15	~15.5
11	6	5.5	~16.5	8	9.5	13.5	~14.5
13	5.5	5	~13	8,5	5.5	8	~13
16	5	5	~12	8	5.5	4	~12

For most consumers, typically storing fresh produce up to 7 days, as well as consumers, predominately storing products with lower transpiration rates, storage systems up to 11 g / 24 h will sufficiently prevent product loss.

When storing predominantly leafy vegetables, a packaged product storage is recommended in storage systems > 4 g / 24 h. For an average load pattern with less sensitive products this applies from > 11 g / 24 h. Manufacturers must implement corresponding instructions in order to compensate for the lack of knowledge in proper product storage on the part of the user.

The variance of the results found (e.g., deviations between two charges) can be explained by the variation of the raw material quality. It should be noted that pre- or post-harvest damages of the products are not always clearly visible. For example, the raw material quality of the broccoli used for this study turned out to be not satisfying.

Conclusion

Refrigerators providing optimum freshness performance prevent premature product loss and compensate for incorrect product handling by the consumer.

Next to storage temperature, humidity retention is an important factor to retain food quality of perishable fresh produce in a refrigerator. The results of this study show, that at storage temperatures of ~4°C, humidity-controlled storage zones in refrigerators offer the possibility to improve the storage quality retention of vegetables, extending the SL of commodities by a factor of 2 or greater, providing a valuable contribution to the prevention of food loss. As consumers frequently just have limited skills in handling food properly, efficient humidity retention systems could compensate limited knowledge and thus further decrease food loss.

The investigated test method offers the possibility to distinguish different design concepts regarding the humidity retention capability, mainly for leafy vegetables. By this, the end consumer may be provided with a certain orientation, but since there are further parameters, which can impact the SL, such as the temperature in the storage zone and condensation, the judgement of a refrigerator storage system by the weight loss value provided by IEC 63169 as a kind of threshold value will not be sufficient. Therefore, further deep investigations are necessary before assessment criteria could be used as a kind of incentive system.

References

Bartz J & Brecht J (2003): Postharvest Physiology and pathology of vegetables. New York: Marcel Dekker.

Bognar A, Bohling H, Fort H (1990): Nutrient Retention in Chilled Foods. In: Gormley T: Chilled Foods. The state of the art (305-336). London: Elsevier Applied Science.

Chardon J, Swart A (2016): Food consumption and handling survey for quantitative microbiological consumerphase risk assessments. Journal of Food Protection (79).

Cox J, Downing P (2007): Food Behaviour Consumer Research: Quantitative Phase. https://wrap.org.uk/sites/default/files/2020-12/Food-behaviour-consumer-research-quantitative-phase.pdf (zuletzt abgerufen am 23.02.2022).

Danone (2021): Food Waste. Die große Verbraucher*innen-Studie für Deutschland, Österreich und die Schweiz. https://www.danone.de/content/dam/danone-corp/danone-dach/danone-weltweit/danone-und-too-good-to-go-food-waste-studie-chartbericht.pdf (zuletzt abgerufen am 24.02.2022).

De Laurentiis V, Corrado S, Sala S (2018): Quantifying household waste of fresh fruit and vegetables in the EU. In: Waste Management(77): 238-251.

Deutsche Welthungerhilfe (2022): Lebensmittelverschwendung. Ursachen & Fakten. https://www.welthungerhilfe.de/lebensmittelverschwendung/ (zuletzt abgerufen am: 19.02.2022).

DIN ICE 63169:2020: Electrical household and similar cooling and freezing appliances – food preservation.

DIN 10952:1991: Sensory testing methods; evaluation test with scale, testing method.

El-Ramady H, Domoskos-Szabolcsy E, Abdalla N, Taha H, Fári M (2014): Postharvest Management of Fruits and Vegetables Storage. Sustainable Agriculture Reviews (107). Springer International Publishing AG Switzerland.

HDE (2021): Handelsreport Frische Lebensmittel. https://einzelhandel.de/component/attachments/download/10592 (zuletzt abgerufen am: 28.02.2022).

Herppich W, Geyer M, Herold B, Schlüter O, Linke M (2010): Obst und Gemüse nach der Ernte. aid infodienst Ernährung, Landwirtschaft, Verbraucherschutz e. V.

Industrieverband Agrar e. V. (2013): Verbraucher kaufen lieber perfekte Lebensmittel. https://www.iva.de/iva-magazin/umwelt-verbraucher/verbraucher-kaufen-lieber-perfekte-lebensmittel (zuletzt abgerufen am: 08.02.2022).

Kays S & Paull R (2004): Postharvest biology. Athen: Exon Press: 435 ff.

Kemna R & van Holsteijn F (2017): Preparatory review study on Commission Regulation (EC) No. 643/2009 and Commission Delegated Regulation (EU) No. 1060/2010: Complementary research on optimal food storage conditions in refrigeration appliances. European Union.

Kilcast D (2000): Sensory evaluation methods for shelf-life assessment. In: Kilcast D, Subramaniam P (Ed.): The stability and shelf life of foods. Boca Raton: CRC Press: 79–105.

Klingshirn A, Brugger L, Gienger M, Dietz LM (2019): Performancebewertung von feuchtegeregelten Gemüseschalen in Kühlgeräten. Hauswirtschaft und Wissenschaft 67 (2019), ISSN 2626-0913. https://haushalt-wissenschaft.de doi: 10.23782/HUW_14_2019.

Klingshirn A et al. (2020): Test design for condensate analysis in refrigerator vegetable drawers. Hauswirtschaft und Wissenschaft 68 (2020), ISSN online 2626-0913. https://haushalt-wissenschaft.de doi: 10.23782/HUW_18_2019.

Nutrition Hub (2021): Trendreport Ernährung 2021: pflanzlich, smart und klimafreundlich. https://www.nutrition-hub.de/post/nutrition-trend-report-die-10-wichtigsten-ern%C3%A4hrungstrends-2021 (zuletzt abgerufen am: 10.02.2022).

Waste and Resources Action Programme (2008): Helping consumers reduce fruit and vegetable waste. https://wrap.org.uk/sites/default/files/2020-10/WRAP-RTL044-001%20Final%20report.pdf (zuletzt abgerufen: 14.02.2022).

Wucher H, Klingshirn A, Brugger L, Stamminger R, Kölzer BS, Engstler A & Gindele T (2021): Evaluation of humidity retention in refrigerator storage systems by application of a food simulant. International Journal of Refrigeration-revue Internationale Du Froid.

ORIGINAL (DOUBLE PEER REVIEW) EINGEREICHT: 01.04.2022 ANGENOMMEN: 20.05.2022

Autorinnen

Prof. Dr. Astrid Klingshirn (Korrespondenzautorin), Dipl.-Ing. Lilla Brugger, Eva Häußler MSc, Fakultät Life Sciences, Hochschule Albstadt-Sigmaringen, Anton-Günther-Str. 51, 72488 Sigmaringen

Kontakt: klingshirn@hs-albsig.de

Interessenkonflikt

Die Autorinnen erklären, dass kein Interessenkonflikt vorliegt.

Zitation

Klingshirn A, Brugger L & Häußler E (2022): Freshness performance according to IEC 63169 in relation to consumer requirements in fresh produce storage. Hauswirtschaft und Wissenschaft (70) 2022, ISSN online 2626-0913. https://haushalt-wissenschaft.de doi: 10.23782/HUW_09_2022