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Effect of temperature in domestic refrigerators on fresh-cut Iceberg salad quality and waste

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ABSTRACT

The evolution of different quality parameters (firmness, weight loss, colour changes, microbial counts, consumer rejection) of packed fresh-cut Iceberg salad was assessed at 4, 8 and 12 °C to simulate domestic refrigerators running at different conditions. The increase in storage temperature did not affect salad firmness and weight loss but increased colour changes, microbial growth and consumer rejection. A survey among Italian consumers was also carried out and demonstrated that fresh-cut salad was mainly consumed within the first 5 days after purchasing. Consumer rejection data were combined with data relevant to the distribution of salad consumption over the days following product purchase, to estimate salad wasting risk. When salad was stored at 4 and 8 °C, estimated wasted packages within the expiration date (7 days) were < 1%. By contrast, 13% of the packages was estimated to be wasted within 7 days of storage at 12 °C. Quantification of wasting risk is a necessary information to identify efficient and sustainable interventions to tackle food waste.

1. Introduction

Fresh-cut salad is nowadays regularly consumed in most developed countries. In addition, its market continues to grow at a sustained pace in countries undergoing the industrialisation process (Soliva-Fortuny and Martin-Belloso, 2003). The reason for this global success lies not only in freshness and nutritional value of the product but also in its convenience (Rocha and Morais, 2007).

Minimal processing is known to make fresh-cut salad particularly prone to biochemical reactions and microbiological spoilage, leading to changes in colour and appearance that compromise product acceptability (Martin-Diana, Rico, Barry-Ryan, Frias, Mulcahy & Henehan, 2005; Gonzales-Aguilar, Ayala-Zavala, De La Rosa, & Ivarez-Parrilla, 2010). To delay quality depletion and guarantee product shelf life, the control of temperature is crucial. The cold chain is compulsorily maintained during production, distribution and retail (DM No 3746/2014; EC No 1234/2007; EU No 1169/2011). In addition, the product should be stored under refrigerated conditions (below 5 °C) during domestic storage until use. However, literature data indicate that recommended temperature for refrigerated foods is barely maintained at household level (Marklinder & Eriksson, 2015). A survey carried out in France indicated that the average temperature in the refrigerators was 6.6 °C with a minimum value of 0.9 °C and a maximum value of 11.4 °C (Laguerre, Derens, & Palagos, 2002). Bakalis, Giannakourou, & Taoukis (2003) not only found large temperature differences among the compartments of 110 refrigerators but also observed that 8% of them were running at 10–12 °C. In addition, Kennedy et al. (2005) reported that 59 out of 100 domestic refrigerators tested in their study had an average temperature higher than 5 °C and 6 of them were kept above 10 °C. According to Limbo, Torri, Sinelli, Franzetti, and Casiraghi (2010), 19 thermal histories recorded in Italy highlighted that in 75% of the cases the temperature of food stored in domestic refrigerators was higher than 8 °C. According to James, Evans, & James (2008), domestic storage of chilled foods appears to be the weakest link in the entire chill-chain.

Based on these considerations, domestic storage temperatures higher than recommended, being responsible for a fastest quality decay of fresh-cut salad, could also be associated to a higher wasting risk. It has been estimated that lowering home refrigerated temperature from 7 to 4 °C could annually save 32,000 t of leafy salad waste in UK (Brown, Hipps, Easteal, Parry, & Evans, 2014). However, this estimate was based on the general assumption of waste savings proportionality with shelf life extension at different storage temperature, since specific data were not available. This is quite surprising, considering that consumers are the largest contributors to global food discard and that food wasted at domestic level ranges between 15 and 30% with fruit and vegetables accounting for one third of the entire waste (Williams, Wikstrom, Otterbring, Lofgren, & Beretta, 2012; Gunders, 2012; Lebersorger & Schneider, 2011; Kantor, Lipton, Manchester, and

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Oliveira, 1997). Despite these evidences, to our knowledge, the effect of domestic storage temperature on food waste has never been directly quantified. As indicated by Brown et al. (2014), truly comparative data about the potential effect of domestic storage temperature on waste saving would require product quality and consumption behaviour be carefully monitored during storage at different temperatures.

In the light of these considerations, the present research was addressed to compare the effect of different storage temperatures in domestic refrigerators on fresh-cut salad quality and waste generation. To this aim, Iceberg salad was chosen as a typical example of fresh-cut salad due to its susceptibility to storage temperature and wide diffusion at global level (Casati and Baldi 2012). Commercial Iceberg salad pouches were stored at 4, 8 and 12 °C. At increasing time during storage, salad was analysed for quality indices (firmness, weight loss, colour, microbial counts) and consumer rejection by survival analysis. A survey about habits of salad consumption of Italian consumers was also carried out to obtain data relevant to the frequency of salad consumption during its storage in domestic refrigerators. Waste of salad during domestic storage at different temperatures was then estimated by multiplying consumer rejection and consumption data. Differences in salad quality and waste were discussed as a function of storage temperature.

2. Materials and methods

2.1. Sample preparation

Rectangular packages of transparent bi-axially oriented polypropylene pouches (BOPP, 0.035 mm) measuring 30 × 25 cm and containing 200 g Iceberg salad (*Lactuca sativa* var. *Capitata* L.), sealed under modified atmosphere (8% CO_2, 8% O_2, 84% N_2), were provided by a local producer on the production day between February and May 2015. Salad variety and package size were chosen since the most commonly available on the Italian market. The expiration date was set by the producer after 7 days from the production. Salad packages were stored in dark conditions at 4 ± 1 °C, 8 ± 1 °C or 12 ± 1 °C (fifteen packages for each storage temperature). At increasing time during storage samples were removed from the refrigerator and submitted to the analyses. In particular, analyses were carried out on samples stored for: 4, 7, 10 and 14 days at 4 °C; 2, 3, 5, 6, 7, 8, 9, 10 and 13 days at 8 °C; 1, 2, 5 and 7 days at 12 °C.

2.2. Salad characterization

2.2.1. Weight loss

Weight loss was determined by weighting the content of the package before and after the storage period. Weight loss was expressed as g kg^{-1}.

2.2.2. Firmness

Salad firmness was examined using a ten-blade Kramer shear cell, attached to Instron 4301 (Instron Ltd., High Wycombe, UK). Ten grams of salad were placed into the Kramer cell and compressed 50 mm at a 2.5 mm s^{-1} speed. Maximum force was recorded by using the software Automated Materials Testing System (Version 5, Series IX, Instron Ltd.). Force-distance curves were recorded and firmness was taken as the maximum force required to compress salad (kN). For each sample, eight measures were performed at each storage time.

2.2.3. Microbiological analyses

Ten grams of fresh-cut salad was 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 and 0.1 or 1.0 mL were spread on agar plates for aerobic microorganisms or mixed with agar base for anaerobic microorganisms, respectively. The media and conditions were the following: Plate Count Agar (Oxoid, Italy) was used for enumeration of aerobic mesophilic bacteria and incubation was carried out at 30 °C for 48 h; Pseudomonas Agar Base supplemented with Pseudomonas Cetrimide Fusidine Cephaloridine Supplement (Oxoid, Italy) was used for *Pseudomonas* spp., which were determined after aerobic incubation at 30 °C for 48 h. The salad extract was gently mixed with violet red bile glucose (Oxoid, Italy) and incubated at 37 °C for 24 h to enumerate enteric bacteria. Pour plating in ColiID (BioMérieux, France) with a covering layer of the same medium incubated at 37 °C for 24 h was used for enumeration of total and faecal coliforms.

2.2.4. Picture acquisition and image analyses

Images of fresh-cut salad were acquired by using an image acquisition cabinet (Immagini and Computer, Bareggio, Italy) equipped with a digital camera (EOS 550D, Canon, Milano, Italy). The digital camera was placed on an adjustable stand positioned 60 cm above a black cardboard base where the sample was placed. Light was provided by four 100 W frosted photographic floodlights, 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 5184 × 3456 pixels, 72 × 72 dpi.

Image analyses were performed using Image-Pro Plus (ver. 6.3, media Cybernetics, Inc., Bethesda, Md., U.S.A.). Attention was focused on quantification of the percentage of brown and green pixels in the images. RGB (Red Green Blue) values corresponding to the brown areas of fresh-cut salad 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). Browning and greenness indices were calculated as the percentage ratios between the sum of brown or green pixels and the sum of all pixels of the pictures.

2.3. Consumer data collection

Nine hundred-fifty consumers of fresh-cut salad were selected by asking students and workers from the University of Udine (Italy) if they generally consume fresh-cut salad. Only subjects providing a positive answer 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 salad rejection

At increasing time during storage, salad packages were shown to consumers in a portable refrigerated cabinet. The latter guaranteed 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 salad package and answer to the following question: “If this salad was in your refrigerator, would you consume it, or would you throw it away?”. For each storage time, one salad package was visually assessed by 50 consumers. Each consumer required about 1 min for acceptability evaluation. Completing the evaluation by all the 50 consumers required approximately 2 h. Analyses were performed on samples stored for increasing time until 100% rejection was approached. Reaching this percentage required 6, 9 and 4 times of analysis for salad stored at 4, 8 and 12 °C, respectively.

2.3.2. Fresh-cut salad consumption

After salad rejection evaluation, consumers were led in another room and asked to provide information about fresh-cut salad consumption habits by filling a questionnaire (Fig. 1). Six hundred-fifty consumers were involved in this survey. In particular, consumers were