Effects of packaging material on fruit shelf-life:

How improve product quality and reduce food waste.

Executive Summary

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Introduction

The adhesion and persistence of microorganisms to the surfaces in contact with foods contribute to spread pathogens and spoilage microorganisms to foods, influencing their shelf-life and food safety (Barnes, et al. 1999; Bae et al. 2012). Although very few literature data are available on the survival of microorganisms on packaging materials (including corrugated and plastic packages), several studies have shown that various foodborne pathogens including *Escherichia coli* and *Listeria monocytogenes* can survive for hours or even days on utensils and equipment surfaces (Kusumaningrum et al. 2003; Wilks et al. 2005; Wilks et al. 2006; Martinon et al. 2012), thus fresh produces have been incriminated in several outbreaks caused by *E. coli* O157:H7, *Salmonella* spp. and *L. monocytogenes* (Allegre et al. 2010; Scallan et al. 2011: Oliveira et al. 2012: Siroli et al. 2014). In fact, pathogens eventually introduced during the production chain may remain until the product consumption due to the lacking of treatments able to inactivate the microbial cells. In addition, the interruption of cold chain during distribution, sale and home storage determine rapid deterioration of this kind of products due to the growth of spoilage microorganisms present on fruit and vegetable due to the environment and surface (including packaging materials) cross contamination. To increase the limited shelf-life of fresh produce the tendency is to pack unripe fruit and vegetable negatively affecting their sensory features. Consequently, controlling the permanence of microorganisms to surfaces, including packaging materials is fundamental in reaching food safety standards, reducing food waste, improving the overall quality (i.e. texture, flavor, aroma) and shelf-life of fresh produce. The literature data demonstrated that packaging materials can be contaminated by a lot of spoilage and pathogenic microorganisms (Suominene et al. 1997). The wide variability is mainly due to the differences in chemical-physic features of packaging materials but also in logistic. Spore-forming bacteria (belonging to the genera *Bacillus, Geobacillus, Alicyclobacillus* e *Clostridium*) and moulds (belonging mainly to the species *Aspergillus niger, A. cinnamomeus* and *Cladosporium herbarum*) are the microoganisms most present on packaging. On the other hand, they are widespread microorganisms, resistant to adverse environmental conditions and endowed with high spoilage potential (Binderup et al. 2002; Turtoi and Nicolau 2007).

Past studies

The need to better understand these mechanisms, to examine the real situation and thus improve the conditions of packaging to facilitate the marketing of fruit and vegetables have stimulated the 3-year collaboration between Consorzio Bestack and Bologna University. In particular during the first year, we have evaluated and compared the microbiological load (in terms of spoilage and pathogenic species) of the packaging used for commercialization of fresh fruit and vegetables: corrugated cardboard *versus* reusable plastic containers RPCs; both packaging materials and packaged fruits over storage were analyzed to evaluate the cell loads of masophylic aerobic bacteria, total and fecal coliforms, aerobic and anaerobic spore forming bacteria, yeast and moulds. Also the presence of the main pathogenic species associated to fresh produce was evaluated. Although **the data collected showed the lowest microbial cell loads for corrugated than RPC**, the role of the packaging in fruit contamination was not analyzed in depth. For this, during the send year we have studied the effect of packaging throughout a challenge test where the packaging materials (corrugated and RPCs) were deliberately inoculated with a defined cell load of *E. coli* (indicator of fecal contamination).

The data collected indicated that the probability of transfer of the strain of *E.coli* employed from packaging to fruits was significantly higher for RPC respect to corrugated.

So in this perspective, in order to evaluate the shelf-life of fresh fruit, in relation to the packaging used, a new Challenge tests were performed inoculating the packaging with the same amount of bacterial of two spoilage microorganisms, packaging the product inside and then measuring transfer rate and concentration of the bacteria

Material and methods

Saccharomyces cerevisiae and *Pseudomonas* spp., were inoculated at cell loads of 10^3 CFU/cm^2 and 10^4 CFU/cm^2, respectively, in corrugated and RPC. The contaminated packaging materials were filled with peaches taking into consideration as independent variables the number of fruit damages, storage temperature and time of commercialization. The fruits stored in the contaminated packaging were analyzed at the time taken into consideration in the experimental plan and in the following days (48 and 72 hours later) in order to evaluate their shelf-life in relation to packaging materials. For each packaging and condition, 20 fruits were analyzed. The sampling was performed washing the peach in 50 ml of ringer solution (0.9% NaCl) in order to define the cell loads of *Pseudomonas* spp *and Saccharomyces cerevisiae* transferred from packaging to fruits. The data collected at the time of commercialization were modeled using Statistica for Windows (Statsoft, Tulsa, OK) in order to obtain the best fit-equations describing the effects of independent variables on spoilage microorganism cell loads. The data collected at the time of commercialization and in the further 48 and 72 hours, on the bases of the *Pseudomonas* spp cell loads, permitted to estimate also the peach shelf life (in days) calculated as time necessary for the spoilage bacterium to reach 10^7 ufc/ fruit defined as the maximum level of bacterial load which does not allow sales and consumption.

Results

The challenge test performed with *S. cerevisiae* and *Pseudomonas* spp. showed that the microbial cell transfer was significantly higher when the products were packed in RPC than in corrugated packaging. **The reduced transfer of microbial cells to fruits resulted in a shelf-life increases of 1-3 days for the samples packed in**

Load levels of Saccharomyces cerevisiae (log cfu / fruit) detected in the fruits analyzed at the time of marketing the plan in relation to the experimental variables considered

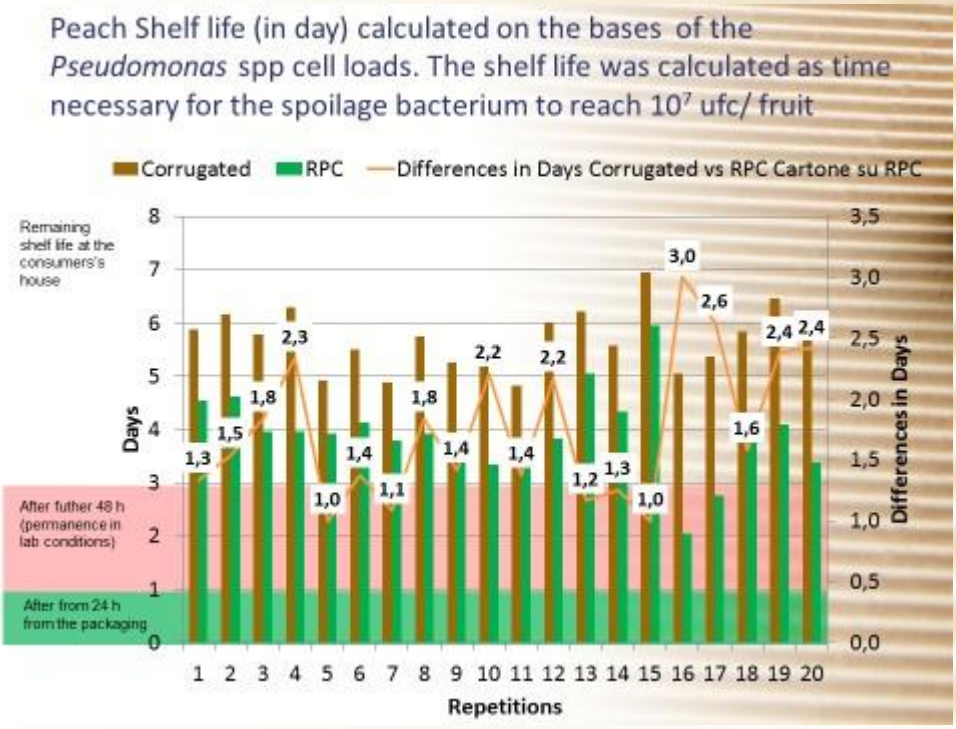
Run	Load detected in the products in the RPC (Log CFU / fruit)	Load detected in the products in CORRUGATED (Log CFU / fruit)	Temperature (°C)	Time of Sale (ore)	Number of damage
1	4.2	2.8	9	29	1
2	4.5	3.0	9	58	1
3	4.3	3.0	9	29	3
4	4.6	3.1	9	58	3
5	5.2	2.9	19	29	1
6	5.3	3.0	19	58	1
7	5.3	3.2	19	29	3
8	5.8	3.3	19	58	3
9	4.7	3.4	14	43.5	2
10	4.6	3.2	14	43.5	2
11	4.3	3.3	14	14.5	2
12	5.4	3.5	14	72.5	2
13	4.4	3.4	14	43.5	0
14	4.7	3.6	14	43.5	4
15	4.4	2.8	4	43.5	2
16	5.6	4.0	24	43.5	2
17	5.0	3.3	14	43.5	2
18	5.9	3.1	19	58	0
19	4.7	3.0	9	58	0
20	4.5	2.9	9	29	0

15.842 cells > 631 cells

794.328 cells > 1.259 cells

corrugated compared to RPCs. Also, the independent variables (fruit damages, storage temperature and time of commercialization) were able to affect the shelf-life of the products but in a lesser extent.

Figure 1. Peach shelf-life (in day) calculated on the bases of the *Pseudomonas* spp cell loads. The shelf life was calculated as time necessary for the spoilage bacterium to reach 10^7 ufc/ fruit



Conclusions

In general, the three years of collaboration between Bestack and University of Bologna provided important information on the microbiological quality of corrugated and RPC packages. In general, important information on the role of packages on microbial contamination of fruits and experimental proofs on some strengths (if storage and logistic are appropriate) of corrugated cardboard packages were obtained. Since the "quality-accuracy" of logistic (and sanitization for plastic materials) chain significantly affects the contamination level before fruit packaging and the latter affects the fruit shelf-life, it would be important to manage the package supply chain (and the sanitization system for plastic) in order to maintain the surface contamination level of mesophylic aerobic bacteria lower than 10^2 CFU/cm^2.

Moreover, the results of the research have pointed out that **the use of corrugated packaging for fruit commercialization represents an advantage in terms of minor microbial transfer, of increase of fruit shelf-life and of reductyion of food waste both in the supply chain and in the consumer's home**. Also, this last effect corresponds to an increase of consumer satisfaction and consequently to a major process sustainability.

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