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Study of Shelf life on
carrots packed in paper
bags and plastic trays
in comparison
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Aim of the study:

comparing the shelf life of carrots stored in two different packages for 14 days at 6 °C and 20 °C

**Paper bag with
transparent window
(24 bags)**



**Plastic tray with
plastic film
(24 trays)**



Data collection has been performed in six sampling:

- T0** 22/02/2021
packaging
- T2** 24/02/2021
- T4** 26/02/2021
- T7** 01/03/2021
- T9** 03/03/2021
- T11** 05/03/2021
- T14** 08/03/2021

Materials and methods

Carrots has been packed on february 22nd (T0) and the samples have been delivered to the laboratory on february 23rd .

At T2, samples have been divided and stored as below:

- 12 plastic trays and 12 paper bags have been stored at temperaure of 6°C
- 12 plastic trays and 12 paper bags have been stored at room temperature (20°C) and exposed at artificial light during the morning.

Data collection has been performed every 2/3 days for 15 days (six sampling) starting from T2 through the opening of one pack for each type of packaging (T2, T4, T7, T9, T11) and the remaining packs at T14.

Colour analysis with Minolta colorimeter (CIE L*a*b*) have been performed at T2, T7 and T14.

Sensory analysis on raw carrots have been performed at T2, T10 and T14.



Data collection

Sampling days

T2 24/02/2021

T4 26/02/2021

T7 01/03/2021

T9 03/03/2021

T11 05/03/2021

T14 08/03/2021

Quality parameters:

- ✓ Package integrity
- ✓ Freshness (scoring scale from 10=fresh to 0=not fresh)
- ✓ Condensation rate
- ✓ Cortex browning rate
- ✓ Cortex brightening
- ✓ Crown greening
- ✓ Root flexibility
- ✓ Rots and molds rate
- ✓ New leaves and sprouts rate
- ✓ New lateral roots rate
- ✓ Cortex shriveling rate

Carrots (cv Maestro)

Carrots in different packages are of the same cultivar and from the same batch.



Carrots are morphologically different: some have a rounded tip, while others have a pointed and longer tip. In the latter, tip was not always intact but it was broken or damaged.

Dimensions of the roots are not homogeneous in each package: carrots in paper bags are more uniform, all of them have medium size; carrots packed in plastic trays are very variable in size (from small to large).

Paper bag at T2
(24/02/2021)



Plastic tray at T2
(24/02/2021)



Quality at T2; 24th February

Paper bags

Average of 9,7 roots/pack
(ranging from 9 carrots to 10)



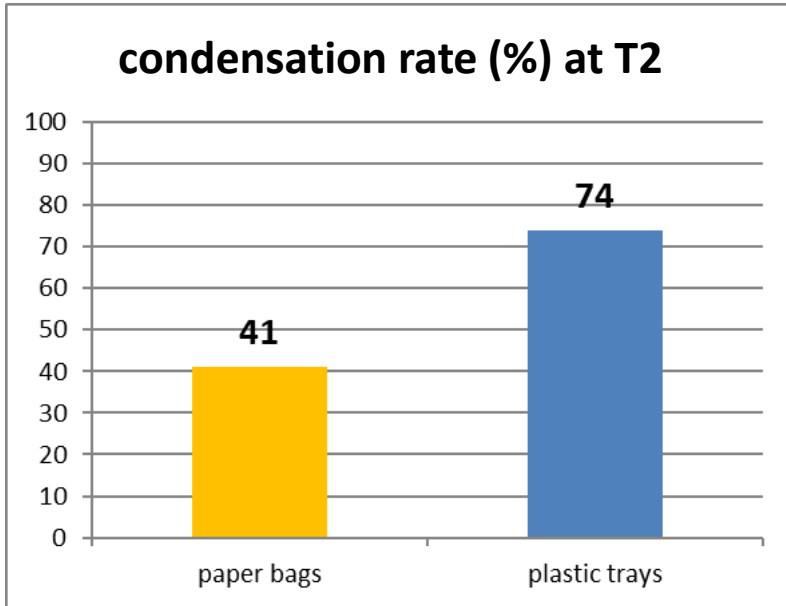
Plastic trays

Average of 11,4 roots/pack
(ranging from 10 carrots to 15)

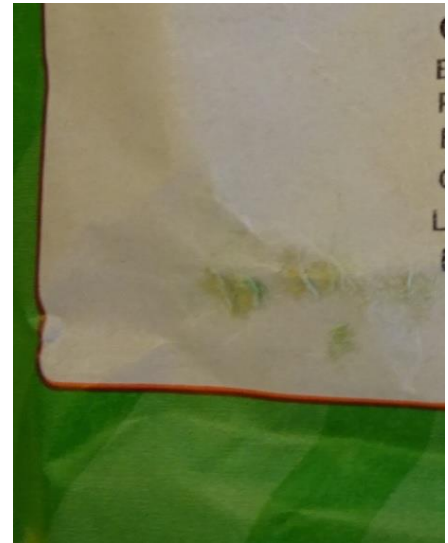


The paper bag is more attractive in terms of colors and aesthetic appearance, it arouses curiosity and encourages purchase due to the better sustainability. Moisture is perceived during the handling and stains due to the condensation can be seen on the back of the bag. The plastic tray allows to better appreciate the product but it has many cracks in the film and a larger amount of condensation than paper package.

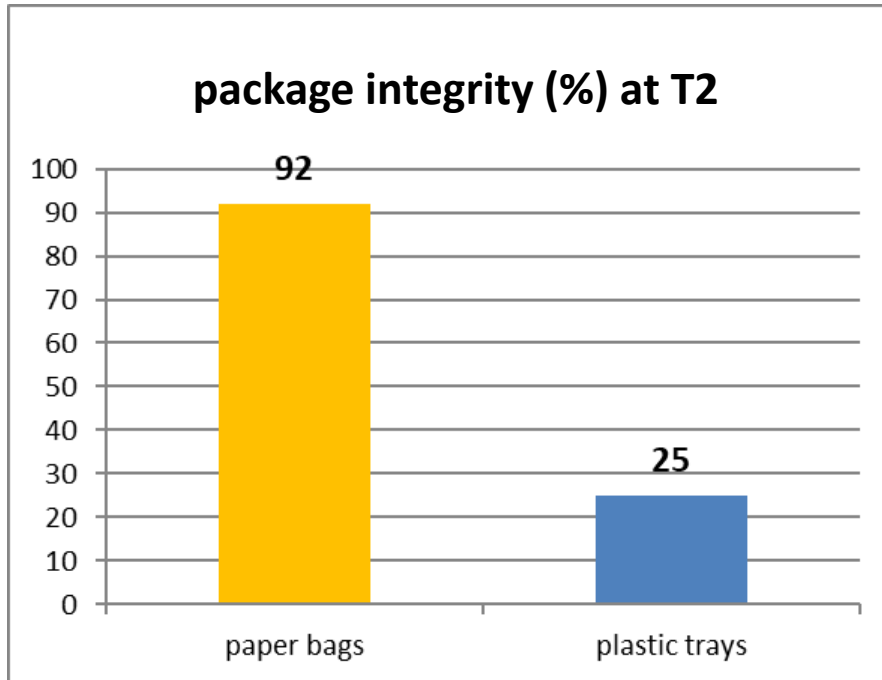
Condensation rate at T2



Plastic trays show an incidence of condensation of 74% on the bottom and sides of the packages. The paper bags show an incidence of condensation of 41%, packages are wet to the handling and small spots due to humidity can be seen on the back.



Package integrity at T2



92% of the paper bags are intact, except for one, that has a crack of about 3 cm in the seal. The plastic trays show numerous cracks of the film specially on the edge of the tray and only 25% of them are intact.

Results of shelf-life at 6°C

6°C: quality at T2

Paper bag at T2
(24/02/2021)



Fresh appearance, very low condensation, bag slightly wet on the back. 13% of carrots show browning.



Plastic tray at T2
(24/02/2021)

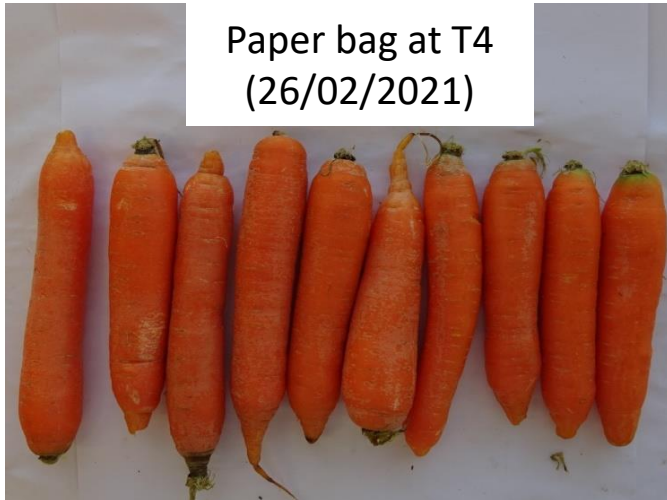


Fresh appearance, generous condensation. 20% of carrot show browning.



6°C: quality at T4

Paper bag at T4
(26/02/2021)



Fresh appearance, slight condensation, bag slightly wet on the back.
10% of carrots show some mold on the crown.

Plastic tray at T4
(26/02/2021)



85% of carrots have translucent tips and visible initial rot growing. 4 carrots have rot along the root. There is a large amount of condensation.



6°C: quality at T7

Paper bag at T7
(01/03/2021)



Very slight browning of the tips on 44% of the roots. No condensation. 20% of carrots have mild mold on the crown.



Plastic tray at T7
(01/03/2021)



Presence of condensation in the packages. 98% of tap-roots shows rot on the tip, and 64% has it also along the root.



6°C: quality at T9

Paper bag at T9
(03/03/2021)



The tips are spoiled and brown in 40% carrots. 30% of carrots are brown even along the root. 30% have mild mold on the crown.



Plastic tray at T9
(03/03/2021)



100% of carrot show browning and rot on the tips and along the root. Rots are grown also on the cut leaves left on the crown.



6°C: quality at T11



Packages are wet but without condensation, 44% of roots have blackened tips and 44% has mold at the crown.



100% of carrots show browning and rot on the tips and along the root.



6°C: quality at T14

Paper bag at T14
(08/03/2021)



Plastic tray at T14
(08/03/2021)



49% of roots have blackened tips; 45% has mold at the crown.



100% of the roots show extensive rot, 37% of them have also mold.

Plastic tray at T14
(08/03/2021)



Paper bag at T14
(08/03/2021)



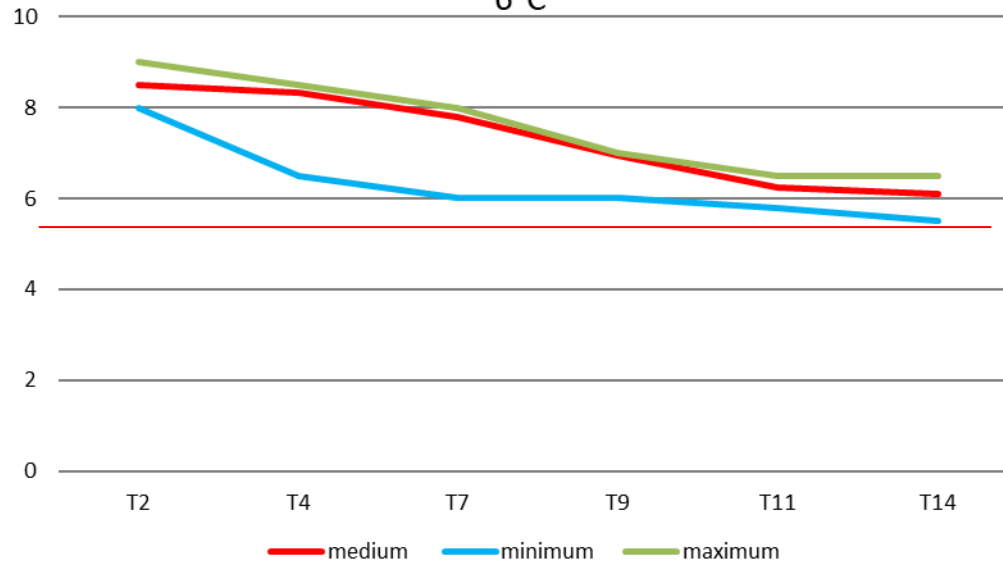
Storage at 6°C: freshness

Freshness of carrots stored in paper bags is more than good at T2 and it continues to be more than adequate during the entire storage.

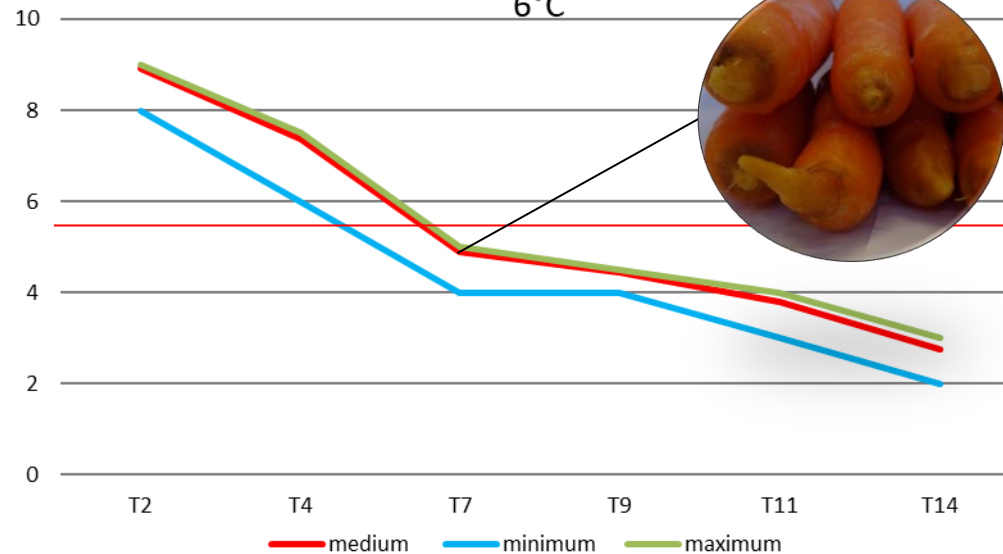
At T7 browning on the tips, molds on the crown, lighter areas in the cortex and softening of the finer roots are observed, but they do not make the product not acceptable.

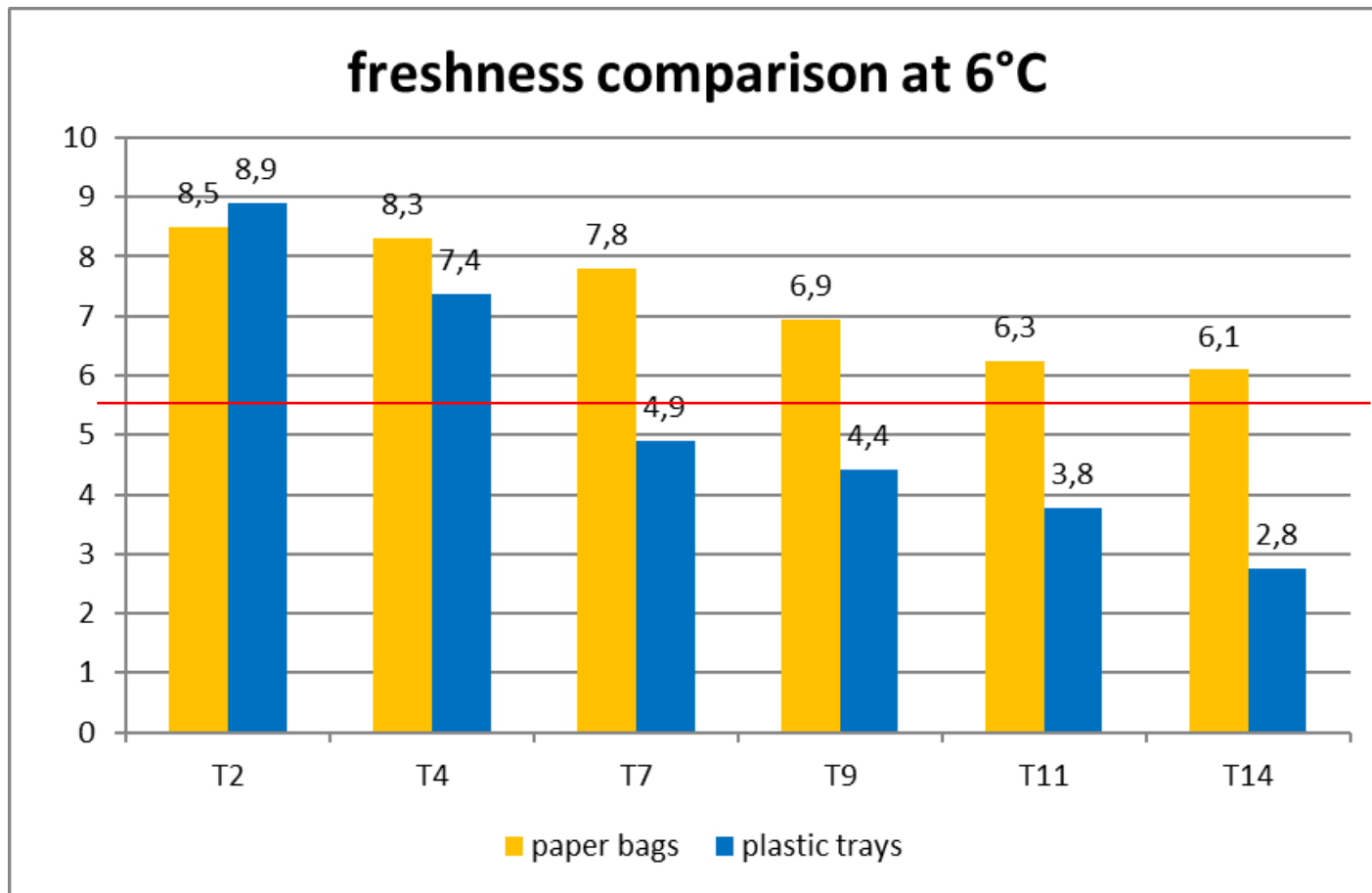
Freshness of carrots in the plastic tray is similar to that of samples in paper bags at T2 and it is adequate until T4. Starting from T7, browning and rot make the product not acceptable. Rots grow over time in all roots and development of molds has been detected at T14.

freshness evaluation carrots in paper bags stored at 6°C



freshness evaluation carrots in plastic trays stored at 6°C

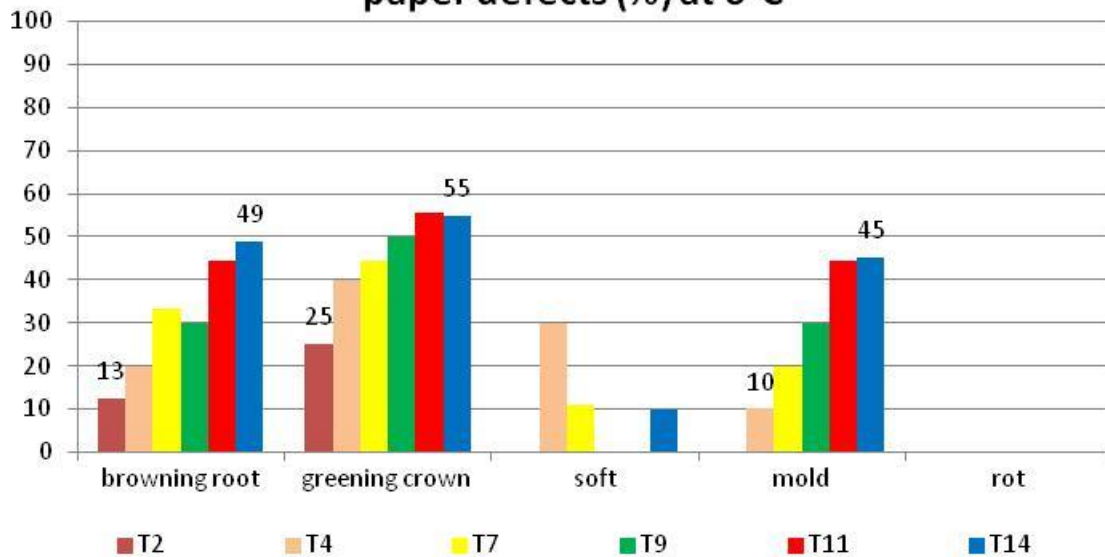




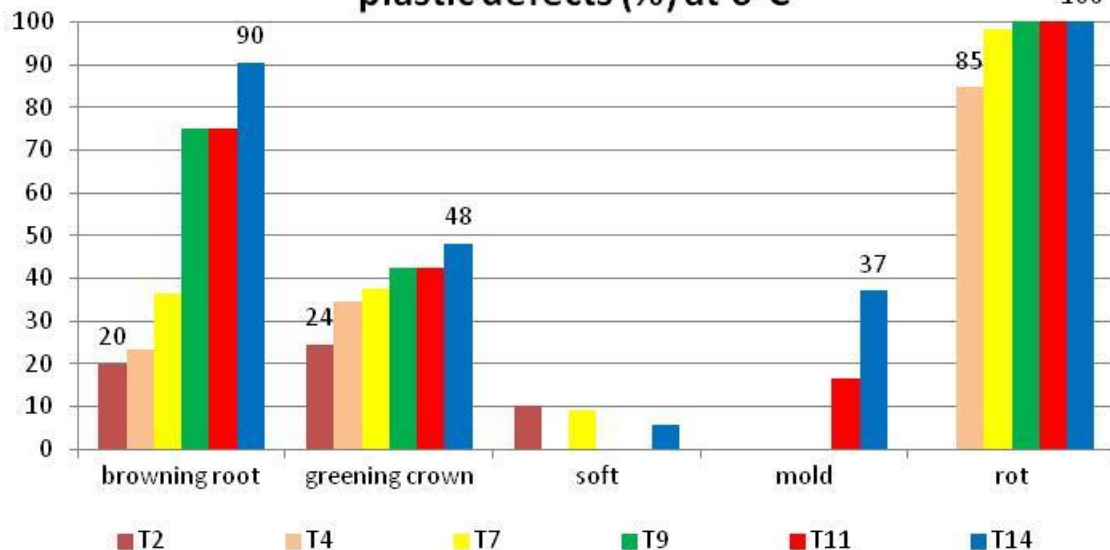
NOTE: red line corresponds to the value 5,5 (insufficiency)

Freshness of carrots in the plastic trays starts to decrease quickly at T4. Differences between samples are noticeably accentuated at T7. At T7, samples in the plastic trays are below the level of acceptability due to the presence of rot on roots tips. The freshness in paper bags is over the limit of acceptability level during the entire storage period.

paper defects (%) at 6°C



plastic defects (%) at 6°C



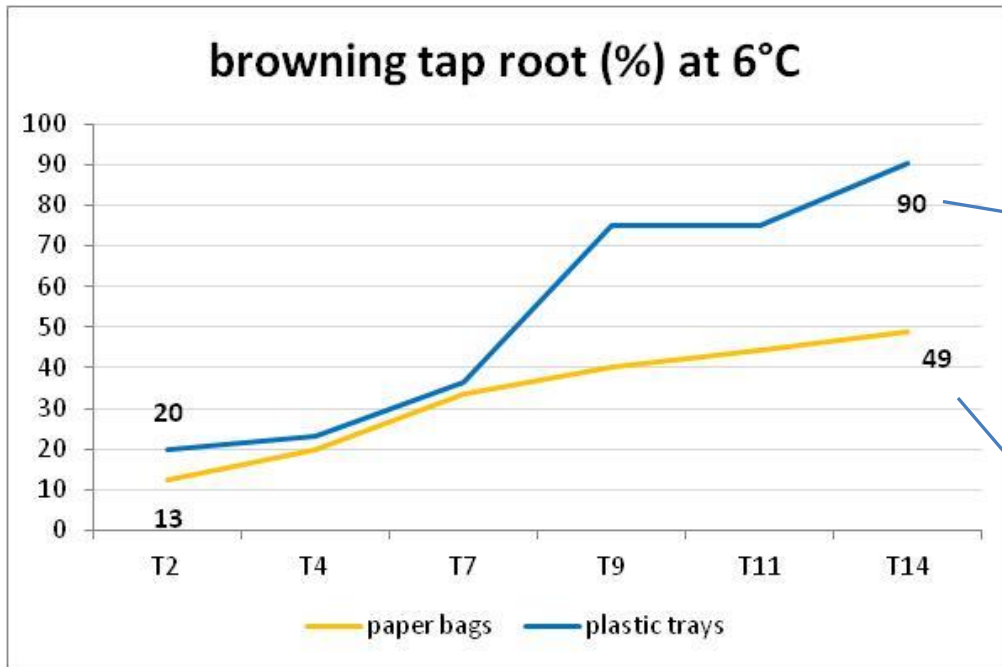
PAPER BAG

- Browning starts on the tips at T2 and it increases reaching 49% of carrots at T14. It mainly affected the tips.
- Greening has been observed on the crown of 25% of carrots at T2 and it increases affecting 55% of roots at T14.
- Molds growth is localized on the crown of carrots throughout the entire storage. It affects 10% of carrots at T2 and it increases reaching 45% of carrots at T14.
- Softening of the roots is sporadic and affects only the thinner ones.

PLASTIC TRAY

- From T4, there is a high incidence of rot (85%) affecting both the tips and the rest of the roots.
- 20% of the roots shows browning at T2, which grows rapidly due to the onset of brown rot.
- At T11, molds appear in areas with rots, 37% of the roots show molds at T14.

- Greening has been observed on the crown of 24 % carrots at T2, 48% of carrots show greening at T14.
- Softening of the roots is sporadic and affects only the thinner ones.

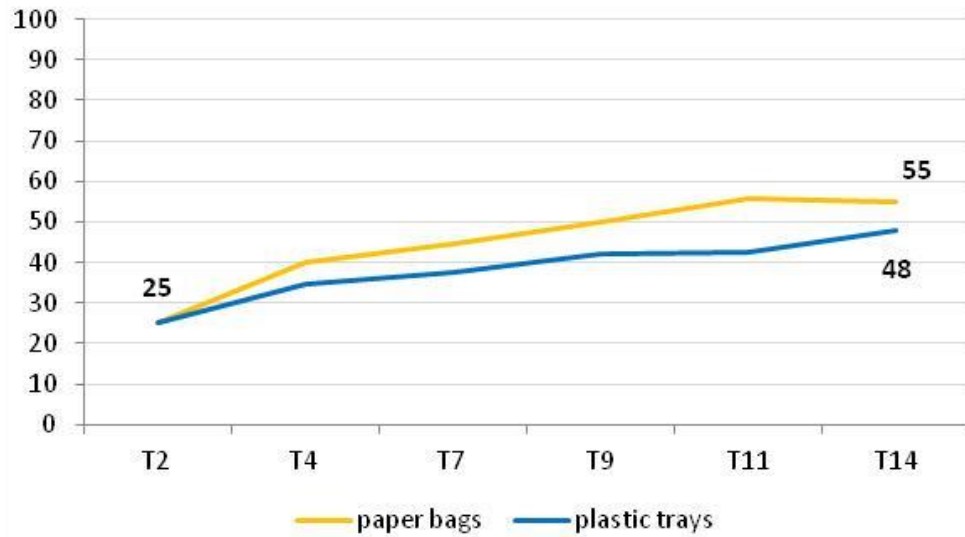


At T2, a slight browning affects few roots in both types of package.

In the plastic tray there is a sudden increase from T7 due to the browning of the areas with rots. 90% of the roots show browning at T14.

In the paper bag the increase is smaller and browning affects 49% of the roots at T14, mostly on the tips.

crown greening (%) at 6°C



Greening of the crown is similar in both packages at T2 and it increases showing the same trend over time. In the last storage day, the incidence of roots with green crown is 48% for plastic trays and 55% for paper bags.



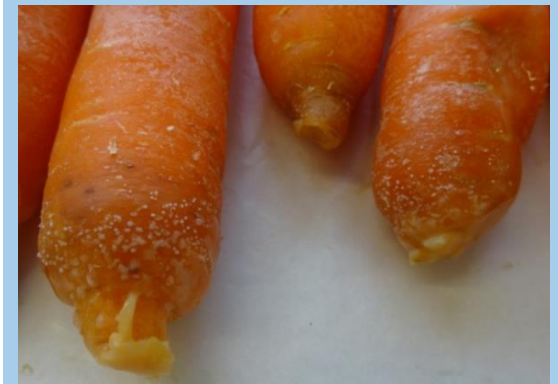
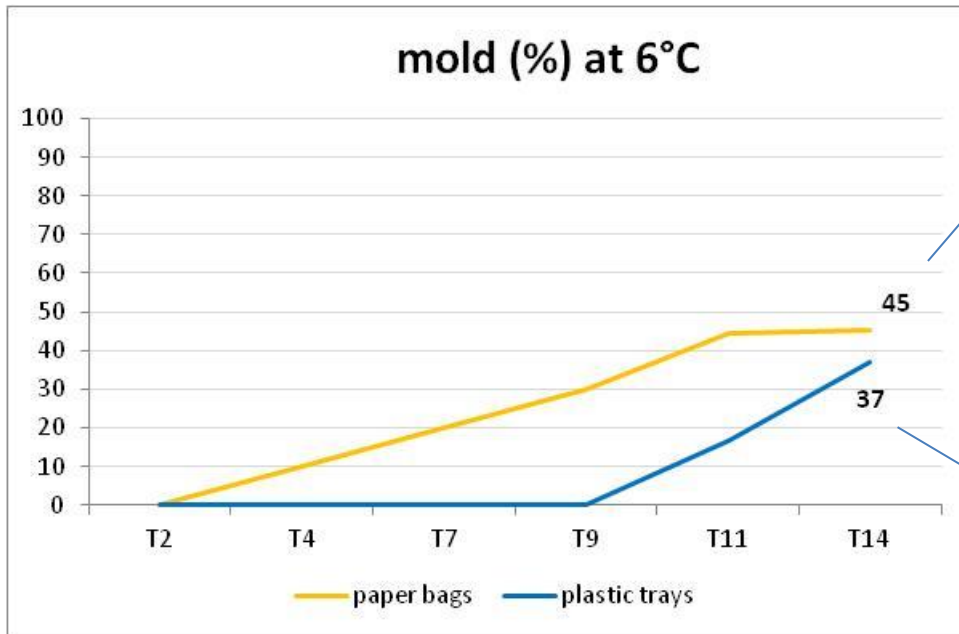
Paper bag at T14

(08/03/2021)



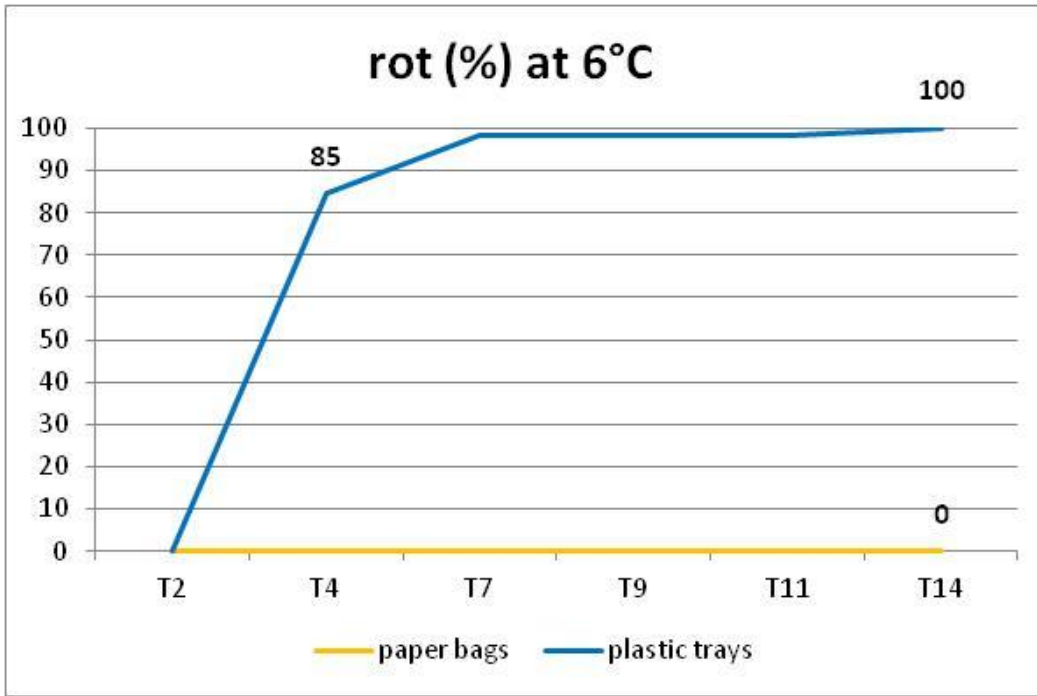
Plastic tray at T14

(08/03/2021)



Molds growth is different:

- Paper bags show an increase in **molds in the roots crown**. Molds affect 45% of the roots at T14.
- Plastic trays** do not show molds growth until T9, when they appear in **the areas with rots (mostly on the tips and crowns)**. 37% of roots show molds at T14.



85% of plastic tray carrots show rots on the tips and along the roots already at T4. At T7 100% of roots are affected by rots.

This phenomenon is caused by the high condensation in plastic package.

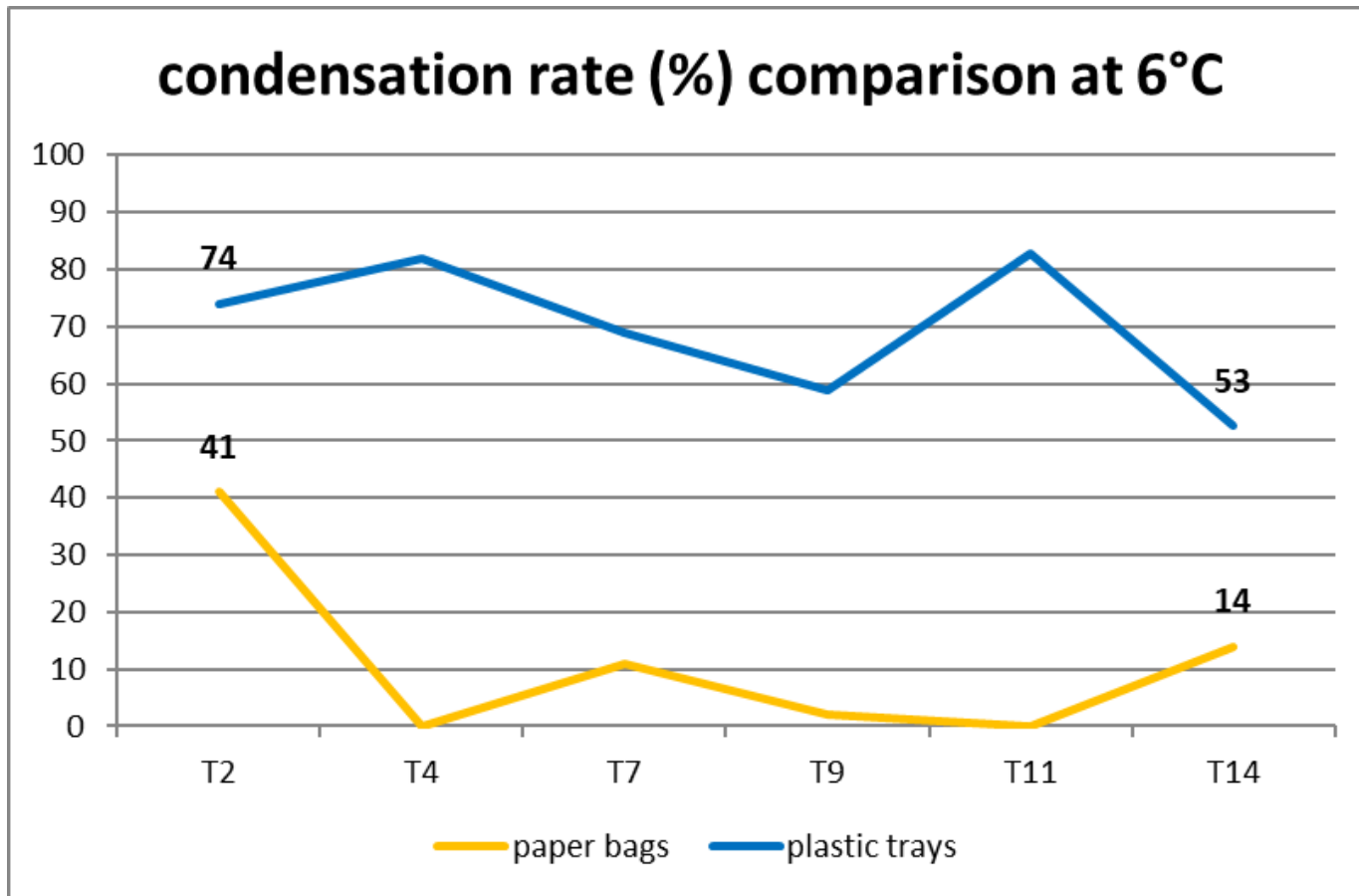
There is no rotting in the paper bag samples during the entire storage.

T4

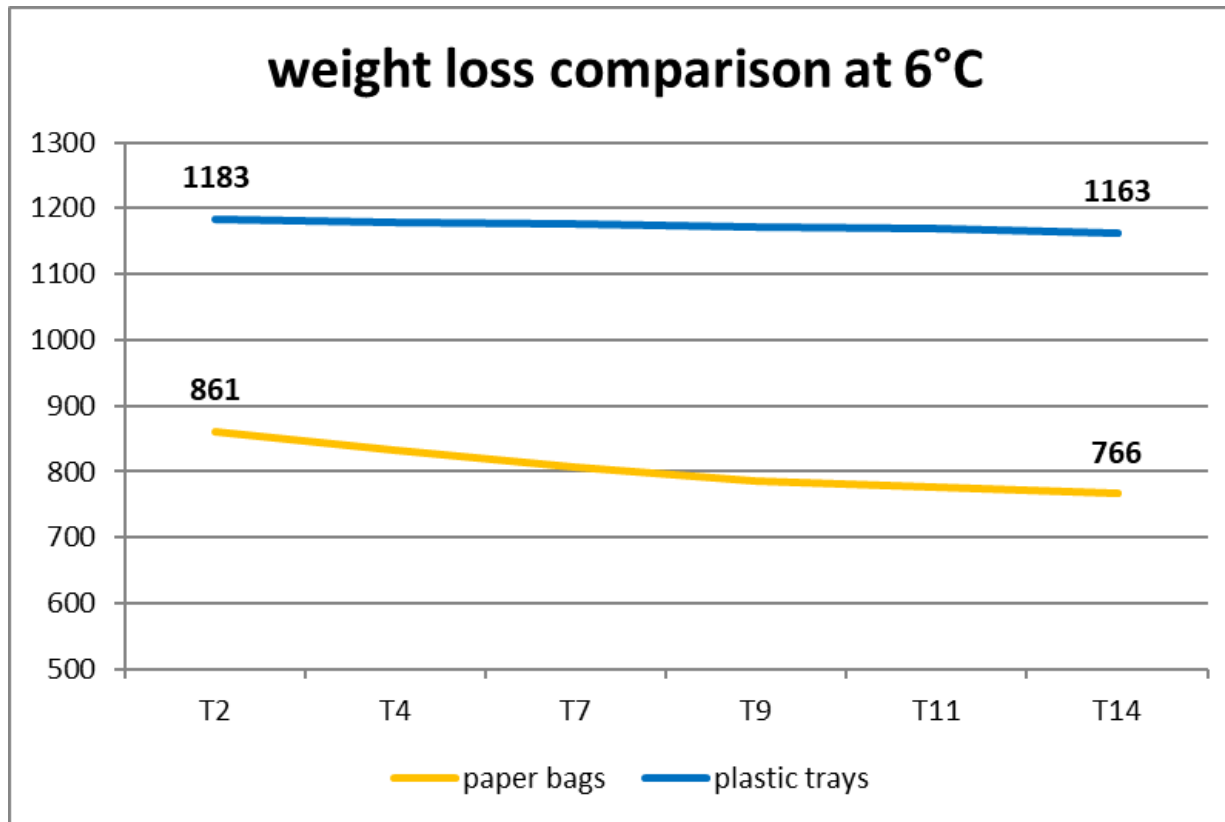


T14





At T2, condensation is higher in the plastic tray (incidence of 74%) than in paper bags (incidence of 41%) and it stays high throughout storage until the last day (53% at T14). In paper bags the incidence of condensation decreases during the storage and reaches value of 14% at T14.

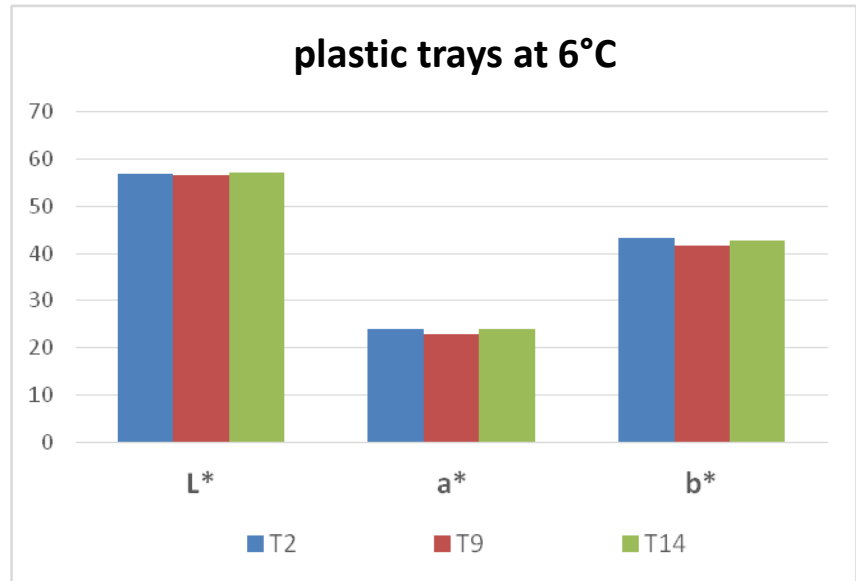
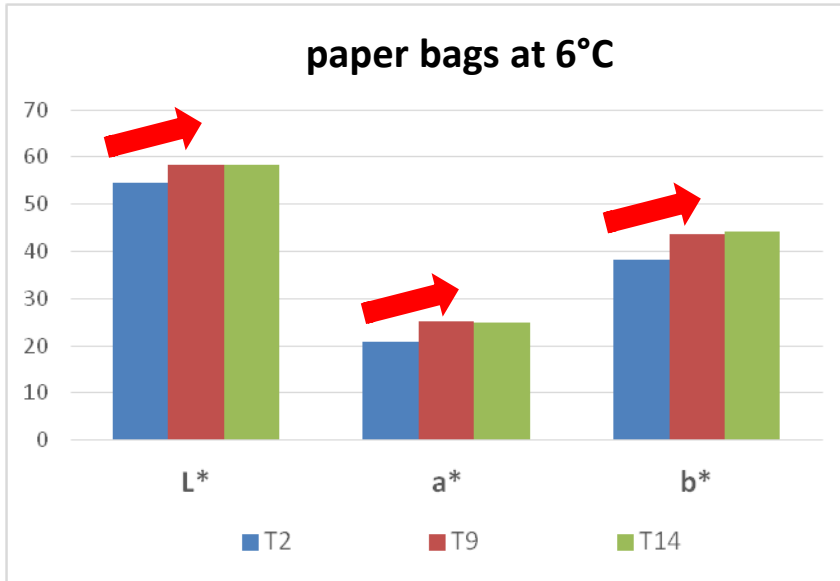


Weight loss plastic trays: 1,7%

Weight loss paper bags: 11,0%

At 6 °C, the weight loss of plastic trays is lower than the paper bags one. The plastic film creates a barrier for moisture generated by breathing of the product visible as droplets of condensation (major cause of the development of rot). Despite of this, the weight loss observed in paper bags does not affect the qualitative and sensory characteristics of the product.

Evaluation of peel colour indices during storage (CIE L*a*b*)



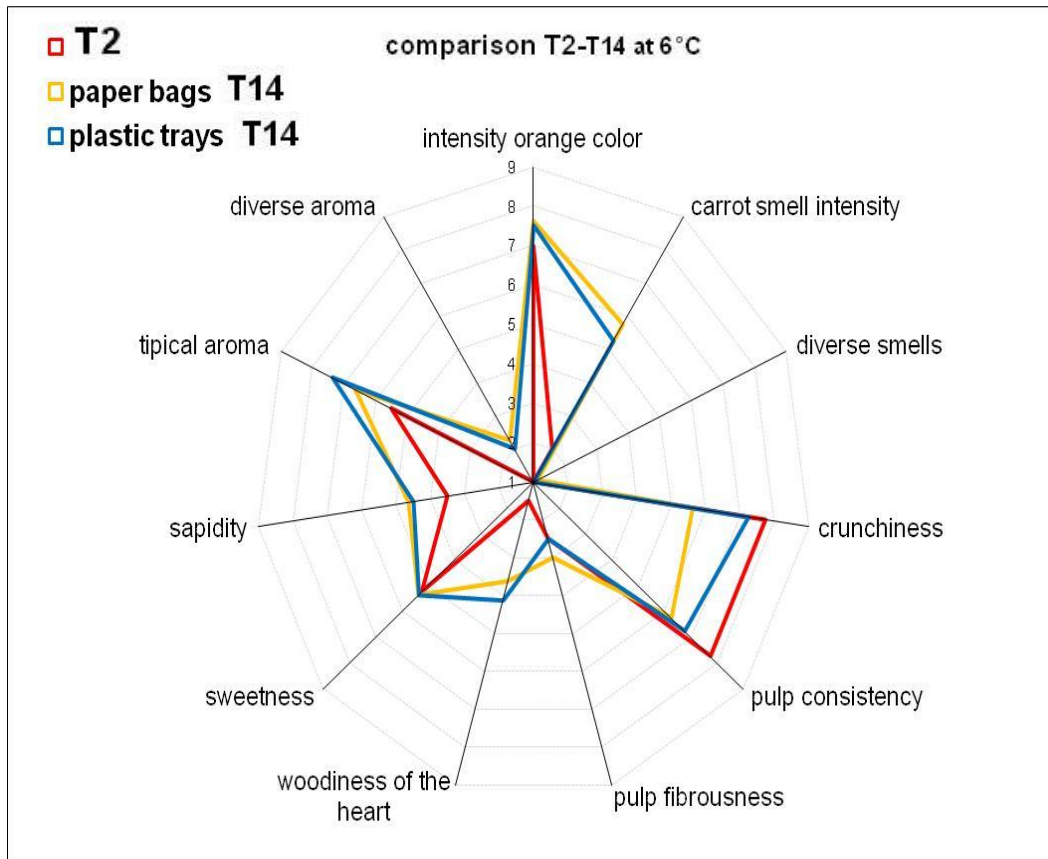
Color indices show an increase from T2 to T7 in paper stored samples:

- **L*** increases towards the white region (more bright) over time.
- **a*** index increases (more red color) over time.
- **b*** index increases (more yellow color) over time.

No significant differences can be described in samples stored in plastic trays.

6°C: sensory profile

The analysis has been carried out on raw carrots after peeling and cutting of the crown.



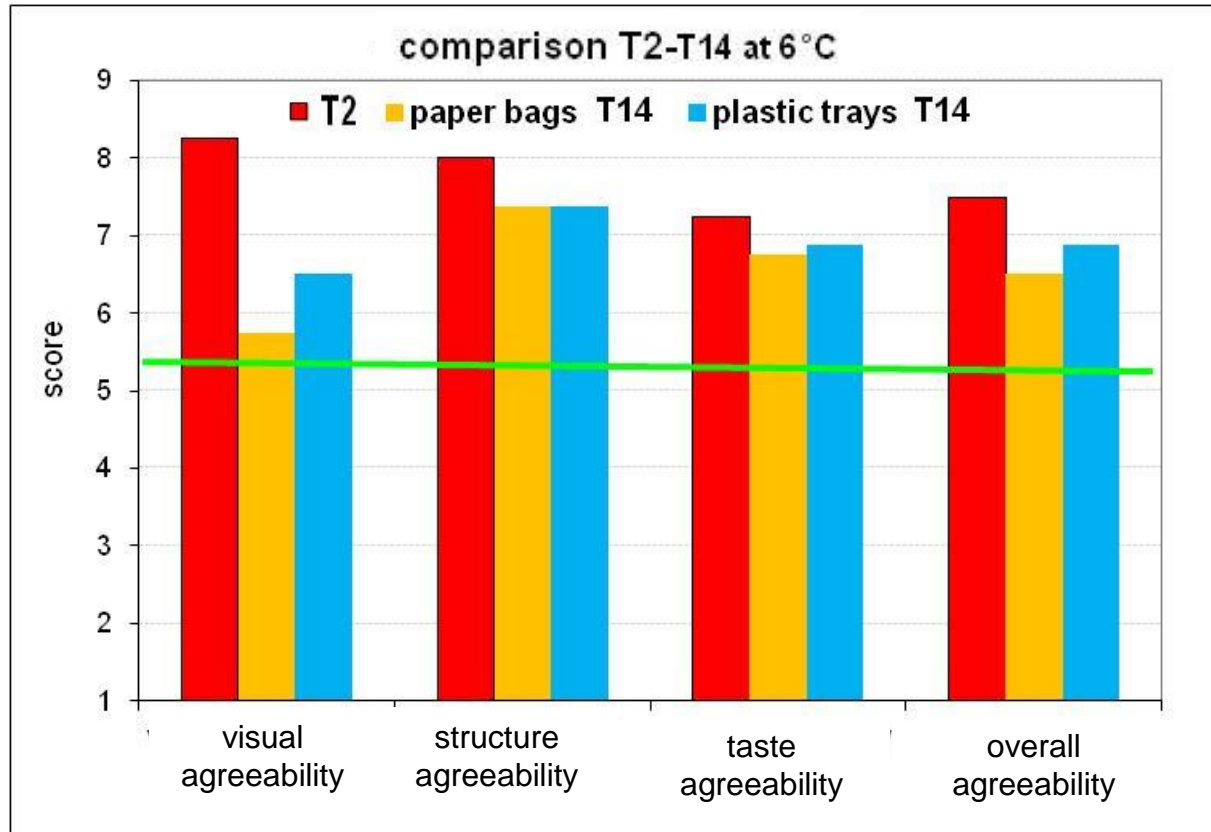
Sensory profiles were similar for both packages at T2.

At T14, 100% of carrots stored in paper and 35% of the plastic carrots were edible.

Paper bags: there is an increase of the typical smell intensity at T14. Structure is slightly more tender and less crunchy than those at the T2, but still very good. The typical aroma increases from T2 to T14, no off-flavors have been perceived.

Plastic trays: the typical smell is much less intense than the one in paper bag. The texture is less hard and less crunchy than those at T2, pulp is softer than samples stored in paper. Sweetness does not change during storage, while **bitterness increases**. Flavor intensity is very similar to paper stored samples; **lost of typical aroma** occurs and **stale and metallic fragrances** have been perceived.

6°C: agreeability judgement



At T2, both samples have been equally appreciated. Acceptability scores decrease in all aspects at T14, especially structure agreeability in samples stored in plastic trays. The overall agreeability is still good in carrots stored in paper bag and adequate in carrot stored in plastic trays.

Results of shelf-life at 20°C

20°C: quality at T2

Paper bag at T2
(24/02/2021)



Plastic tray at T2
(24/02/2021)



Fresh appearance, the bag is wet to the touch on the back. 10% of the carrots show browning of the root.

All trays have high condensation. Carrots have firm and bright orange tips.



20°C: quality at T4

Paper bag at T4
(26/02/2021)



There is a small condensation. 40% of carrots show browning root and soft tips, beginning of cortex discoloration.

Plastic tray at T4
(26/02/2021)



All trays have abundant condensation. **66% of the roots have rots on tips and crowns. Smell is bad.**



20°C: quality at T7

Paper bag at T7
(01/03/2021)



Plastic tray at T7
(01/03/2021)



100% of roots have rots and molds



Carrots appear dehydrated. 40% of roots have a flexible structure. 7 carrots have withered tips. 70% has molds on the crown. 40% shows brown areas, especially on the tips.

20°C: quality at T9

Paper bag at T9
(03/03/2021)



Carrots packed in paper bags are dehydrated, all of them have brown areas. 70% has molds. 50% has a flexible structure. 20% of the roots have rots.



100% of the roots have rots and molds



20°C: quality at T11

It was not possible to analyze samples packed in plastic trays because they were too compromised.

Paper bag at T11
(05/03/2021)



Carrots packed in paper bags are dehydrated, all of them have brown areas, especially on the tips, but also on the tap-root. 70% has molds on the crown and 50% has a flexible structure. 20% of roots show rots.

20°C: quality at T14



Carrots stored in paper bags are dehydrated and the cortex is discolored. All of them have many brown areas; 75% of roots have molds on the crown and flexible structure. 25% of roots are rotten.

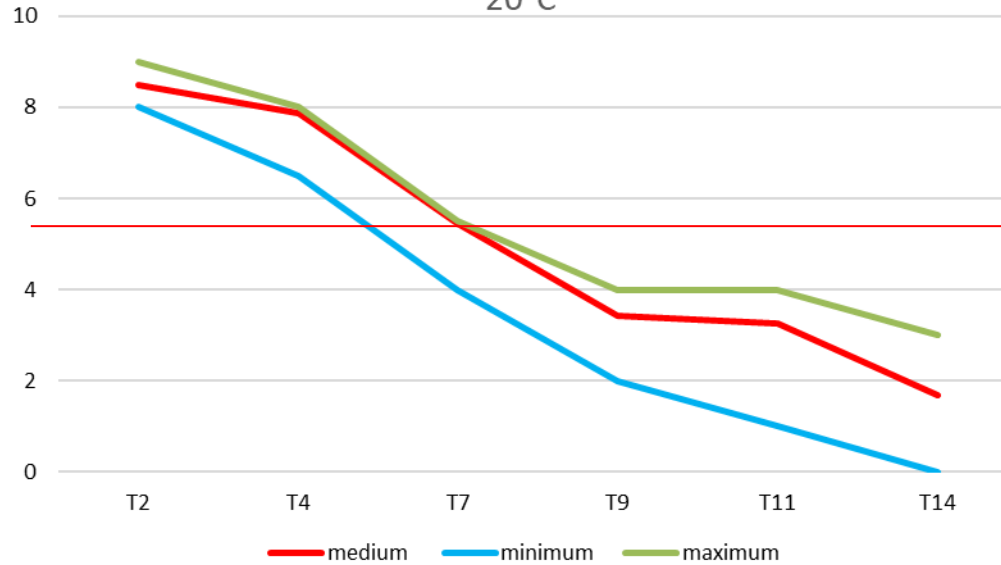


Storage at 20°C: freshness

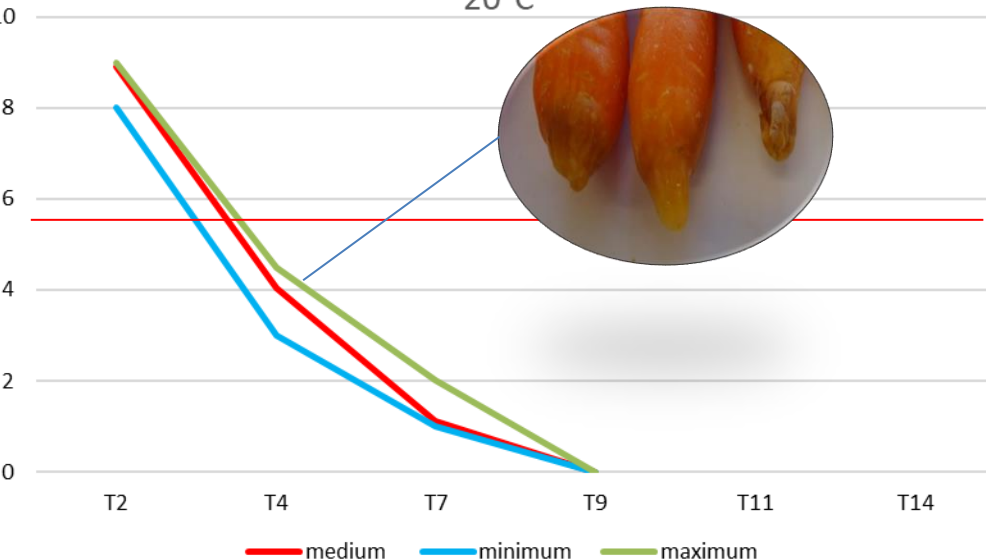
Freshness of carrots stored in paper bags is good until T4. At T7, the score is just almost acceptable due to dehydration (causing the roots to be too flexible), brown areas and molds at the crown.

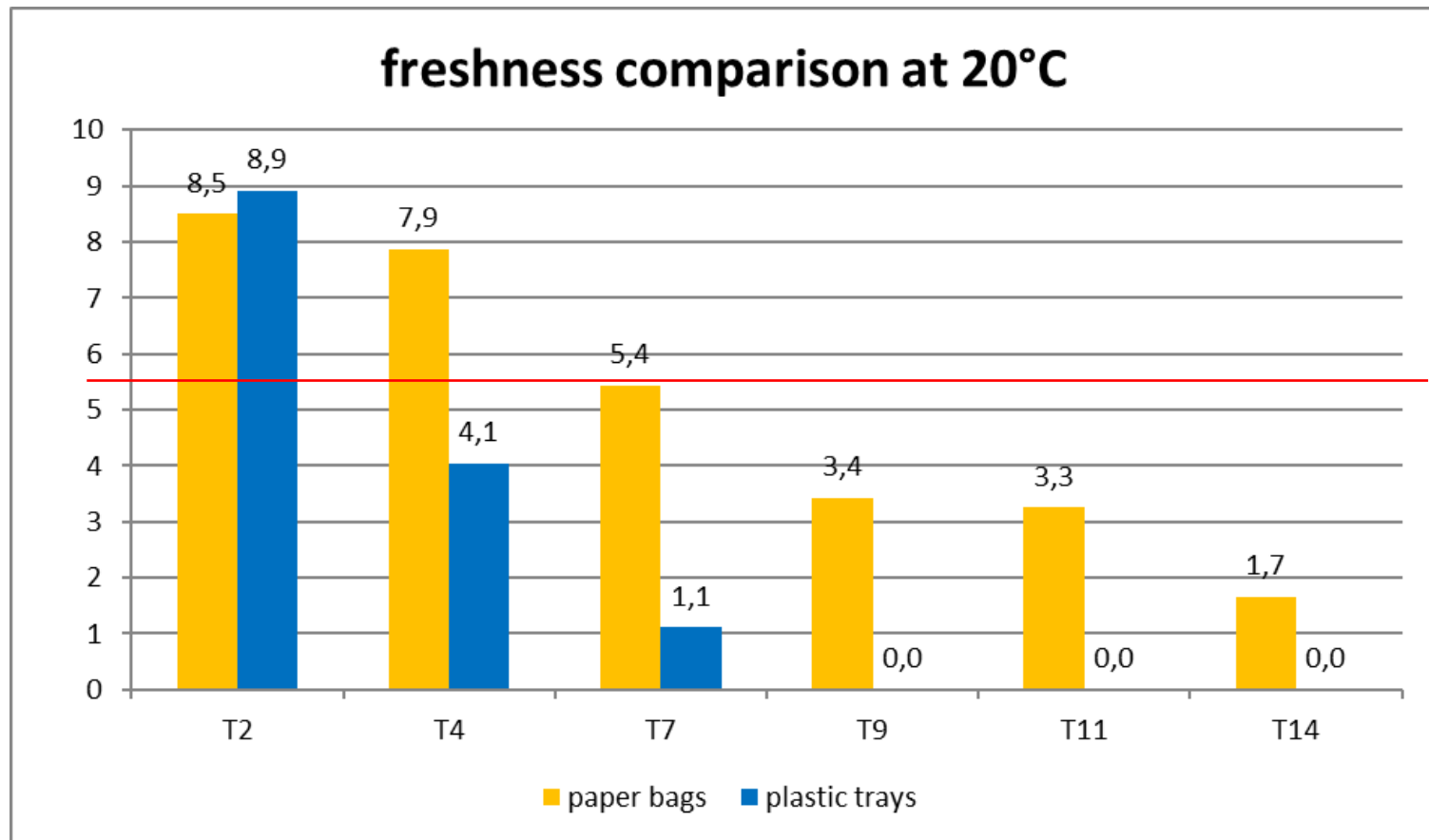
Freshness of samples in plastic trays is already seriously compromised at T4 due to the high incidence of rots and the development of bad smell.

freshness evaluation carrots in paper bags stored at 20°C



freshness evaluation carrots in plastic bags stored at 20°C





NOTE: red line corresponds to the value 5,5 (insufficiency)

Freshness decreases over time. At T4, freshness of the plastic tray stored carrots is not acceptable (high incidence of rots and bad smell). Freshness of the paper stored carrots is still acceptable until T4 and it decreases under the limit of acceptability level at T7 (dehydration, flexible roots, molds on the crown and brown areas).

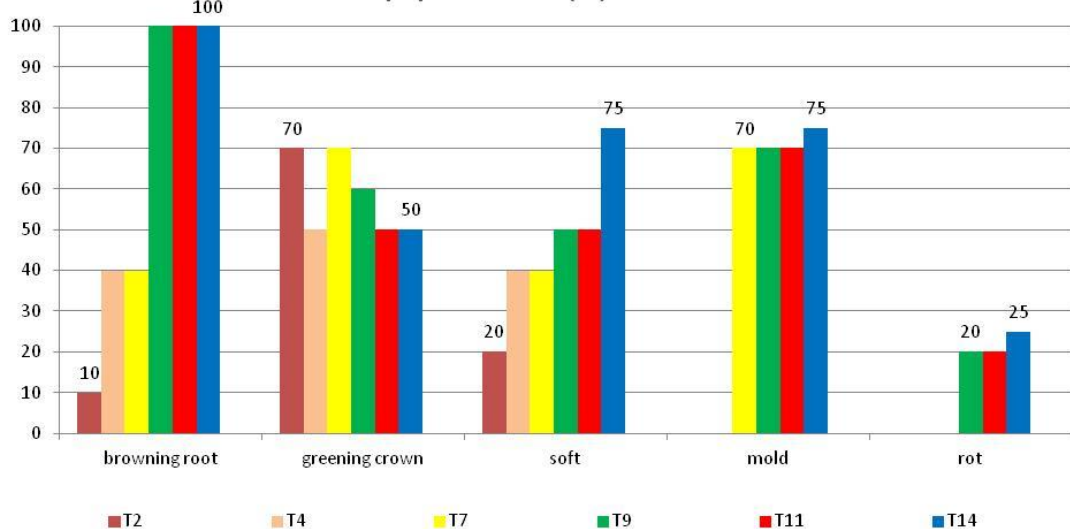
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- At T2, 20% of roots show brown areas and 100% of carrots are brown at T9.
- Greening affects 50-70% of roots for the entire storage.
- Number of flexible roots increases over time: from 20% at T2 to 75% at T14.**
- At T7, 70% of roots show molds on the crown. Molds grow also along the roots and 75% of carrots has molds at T14.
- Rots appear at T9 and affect 25% of roots at T14.

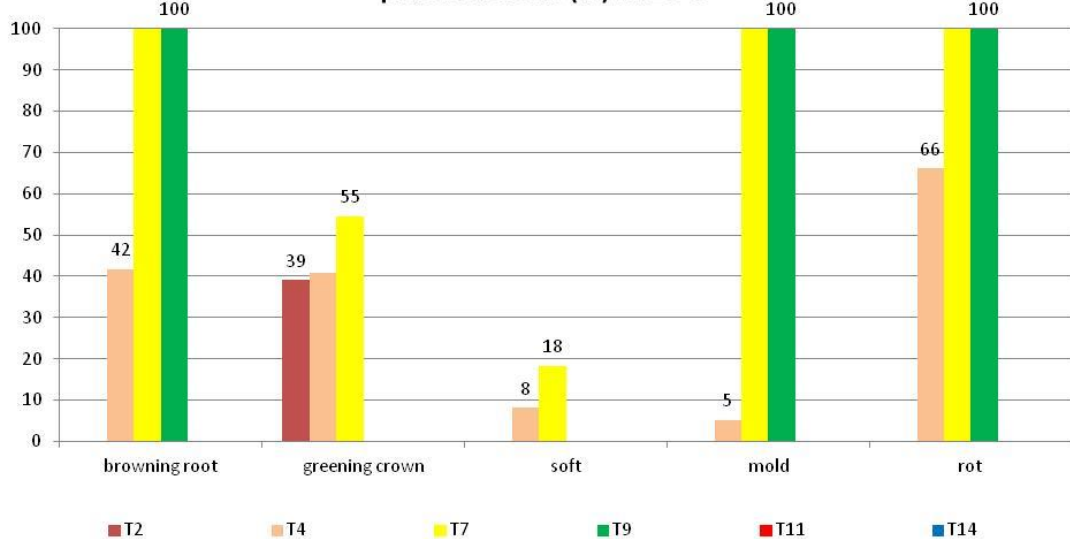
PLASTIC TRAYS

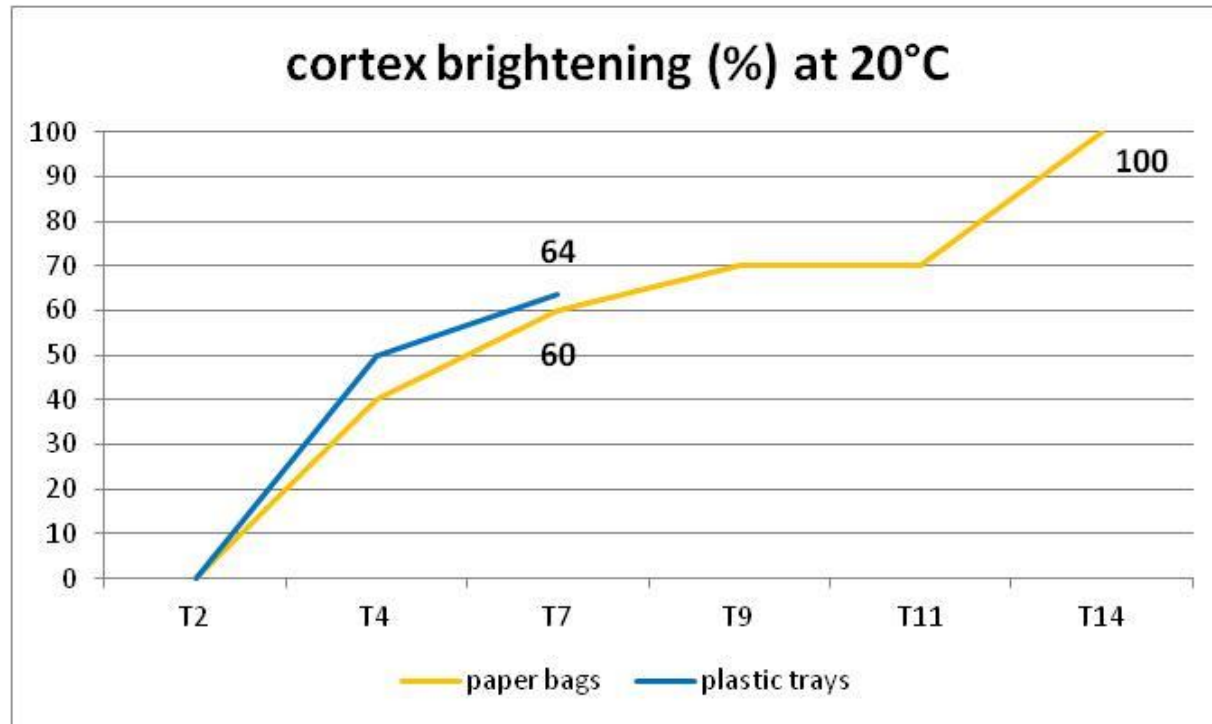
- Starting from T4, there is a high incidence of rots (66% of carrots) on the tips and along the root.**
- At T4, 42% of roots have brown areas due to rots.
- Softening of roots is sporadic and it affects only the thinnest.
- At T4, **molds** appear on the rot infected areas and **100% of roots has molds at T14.**
- At T2, green zones affects 39% of roots and 55% at T7.

paper defects (%) at 20°C



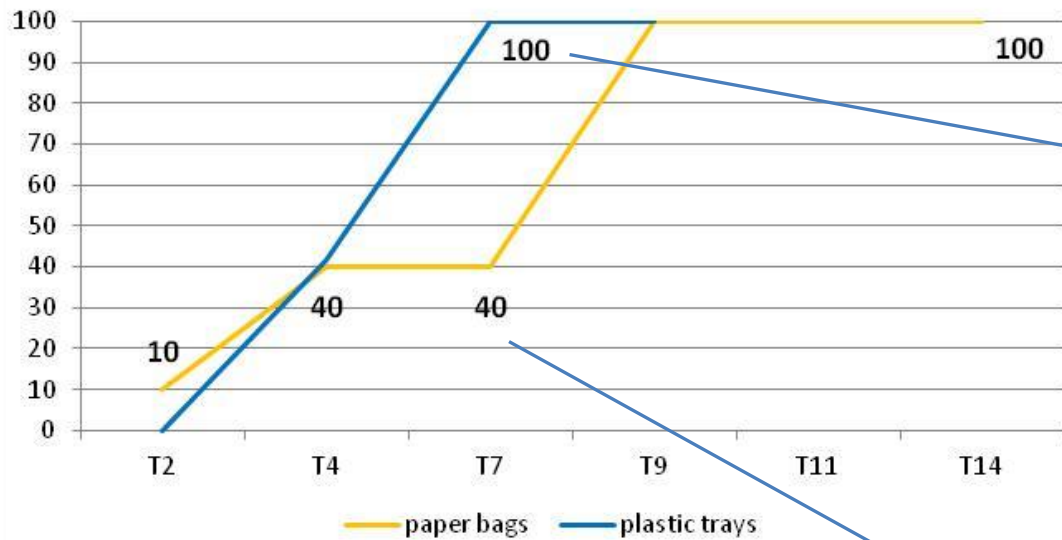
plastic defects (%) at 20°C





Cortex brightening (presence of a slight whitish layer) is visible at T4 in both packages, it increases showing the same trend for both samples until T7. 70% of roots stored in paper bags show cortex brightening at T11. At T14, this value increases to 100%.

browning tap-root (%) at 20°C

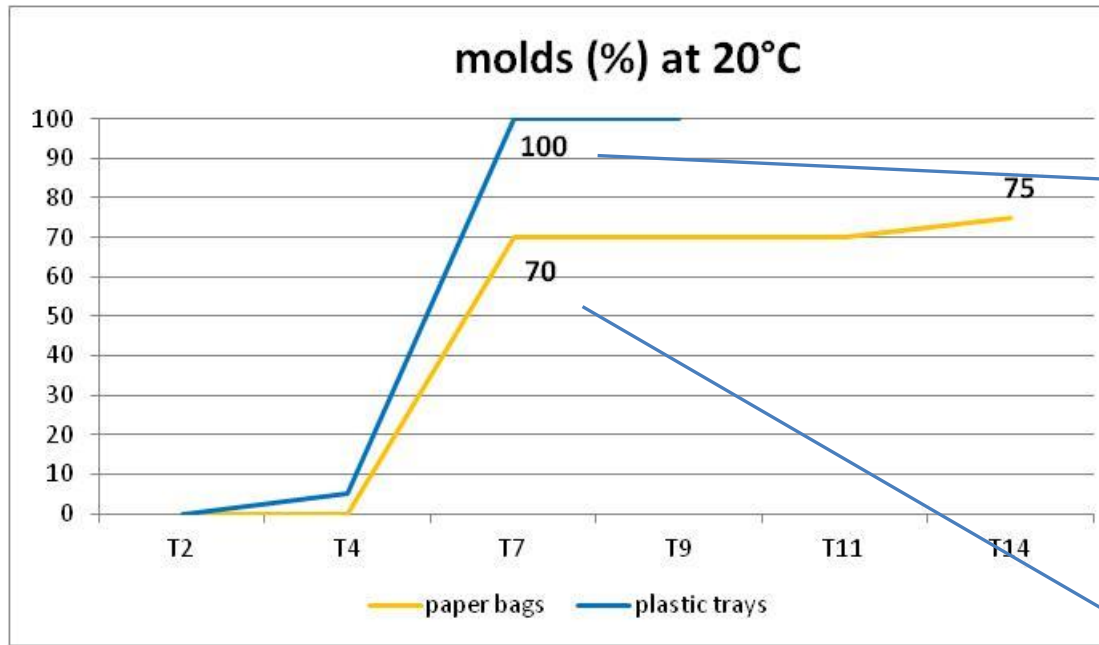


At T2, there are brown zones on 10% of roots in paper bag, while 40% of roots with browning are present in both packages at T4.

At T7, browning is on 40% of the carrots in paper bags, while all the roots stored in plastic trays present brown zones with rots.

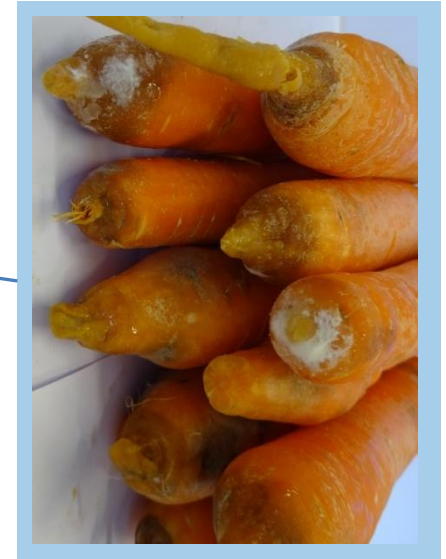
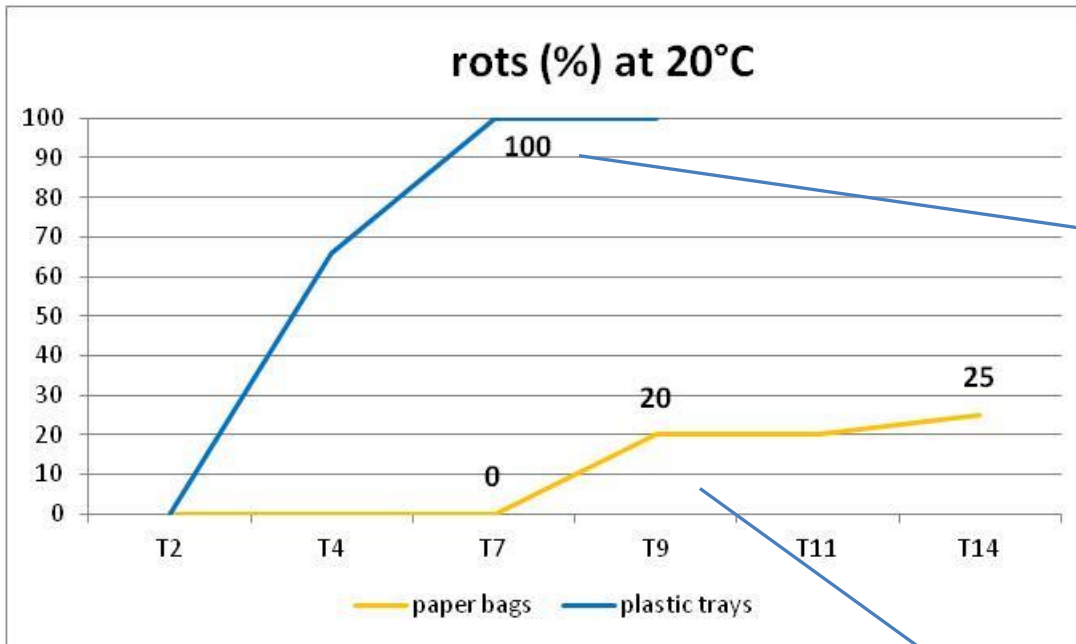
At T9, in paper bags brownings (mainly localized on the tips) cover 100% of the roots.





Molds growth is different:

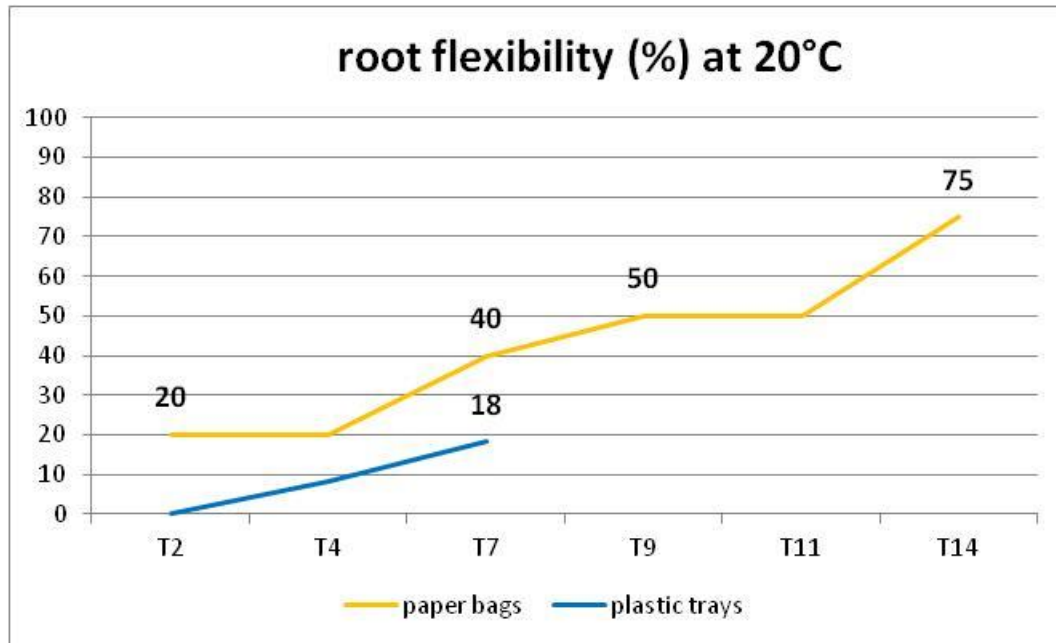
- In paper bags molds appear only **around the crown** at T7. Then, at T14, they extend to the rest of the root in 75% of the carrots;
- **plastic trays** favor the development of molds. Number of roots affected by molds increases over time arriving at **100% at T14**.



From T4, rots on the tips and along the roots appear into the plastic trays and they cover all roots at T7.

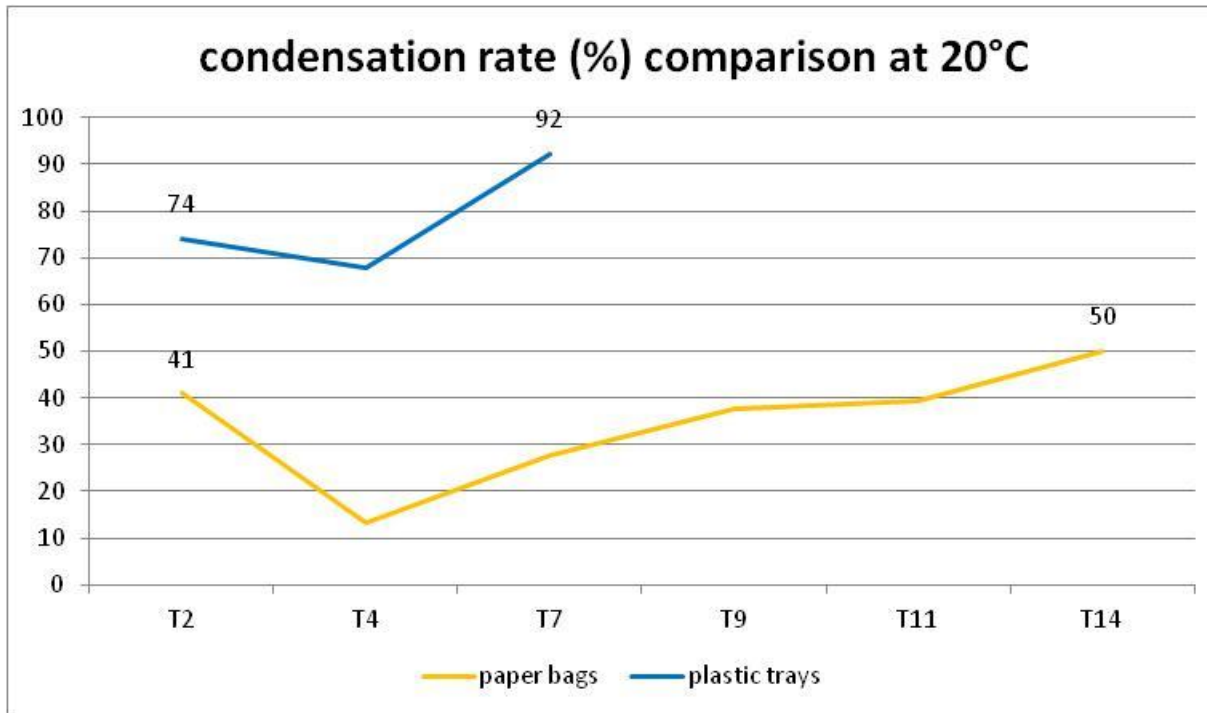
This phenomenon is caused by the high level of condensation in plastic packaging.

In paper bags, the development is lower because of less condensation: the first rots were observed at T9 on about 20% of the roots, increasing to 25% at T14.

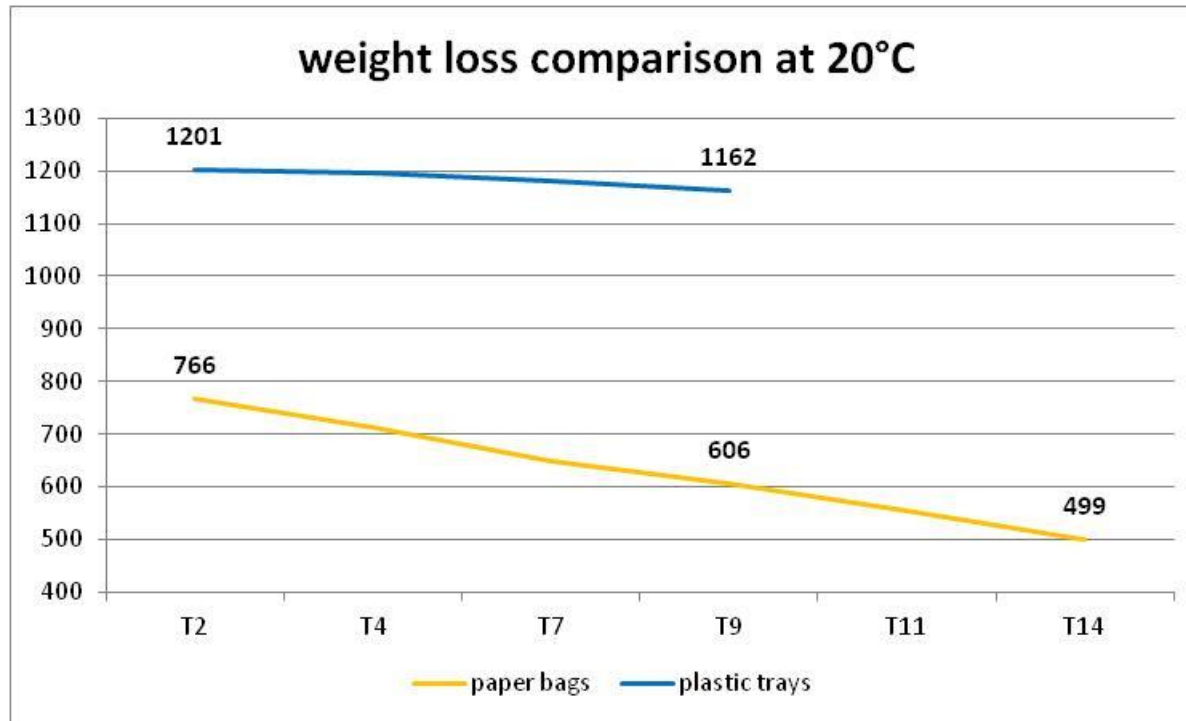


The roots softening process is lower in plastic trays (presence of moisture) than in paper bags where it is already present at T2 and develops on 50% of the carrots at T11 and on 75% at T14 (very dry environment).





At T0, condensation is highest in plastic trays (74%) and it affects about 92% at T9. Condensation in plastic package is about 41% at T2. Initially, it decreases but then increases again throughout storage, up to the 50% at T14.



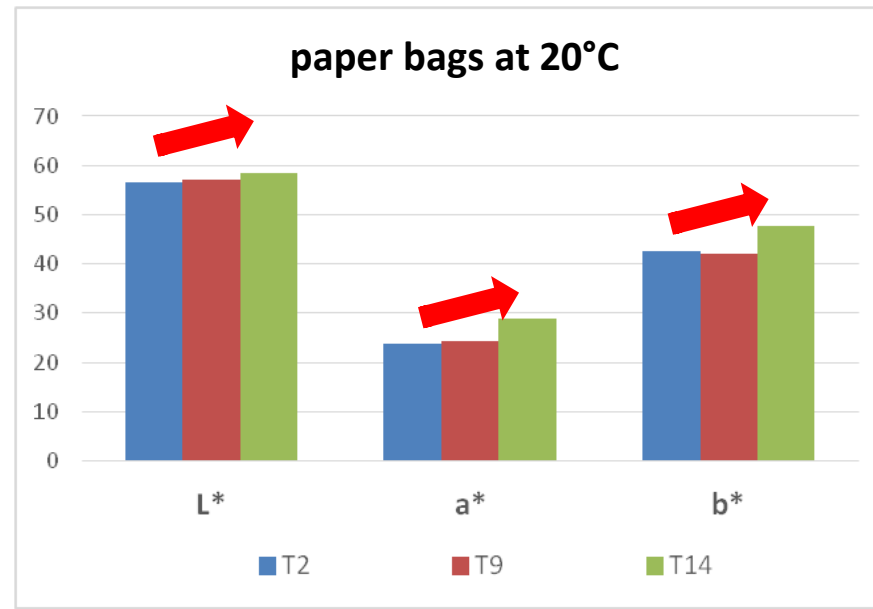
Weigh loss plastic trays at T9: 3,25%

Weight loss paper bags at T9: 20,8%

At T9, the last storage day for plastic samples, the weight loss of carrots stored in paper bags was six times the value in plastic.

The same phenomenon, that occurred at a temperature of 6°C, is amplified during storage at 20°C.

Variation of the peel colour indices ($L^*a^*b^*$) during storage



In paper package, the color indices increase:

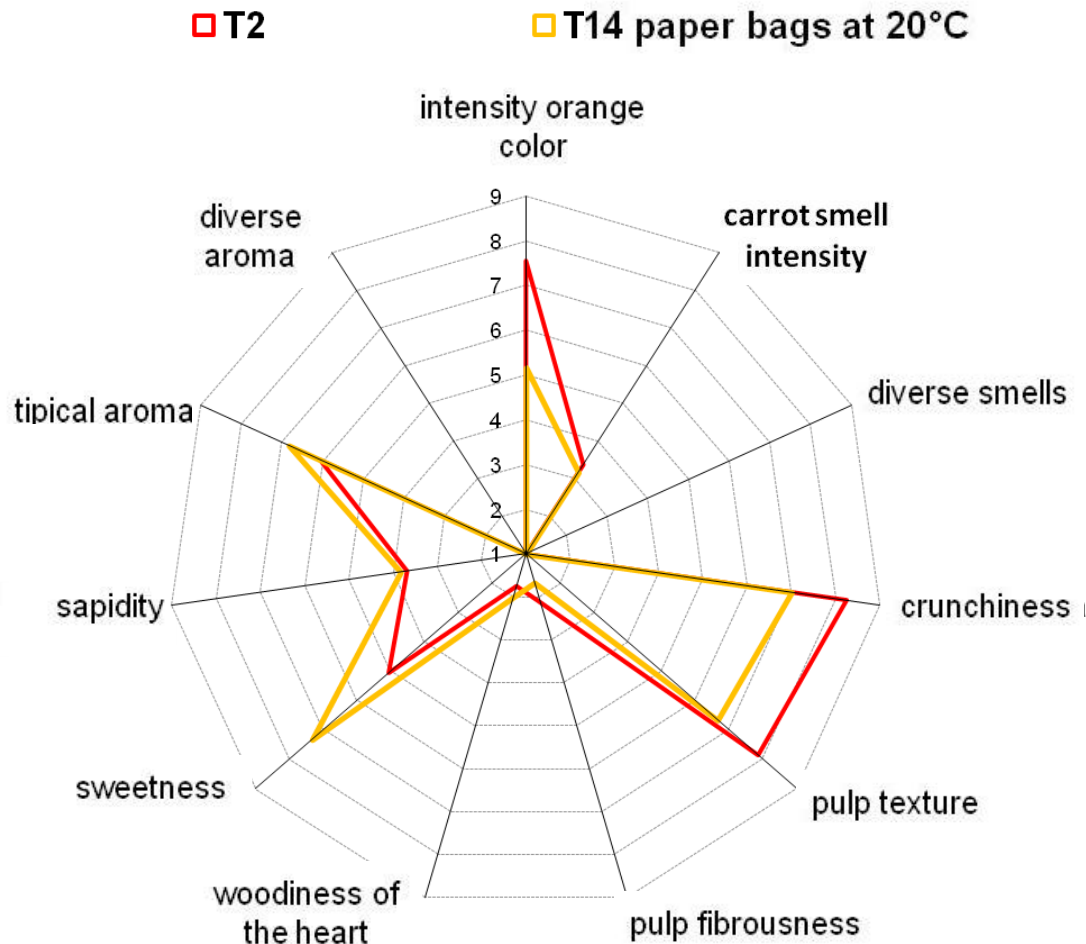
L^* increases in the white region (more lightness).

The a^* and b^* indices increase especially at the end of storage (T14). They show higher red and yellow colour.

In the plastic package, color analysis could not be continued because samples were already compromised at T9.

20°C: sensory profile

The analysis has been performed on the raw product, after peeling and cutting of the crown.



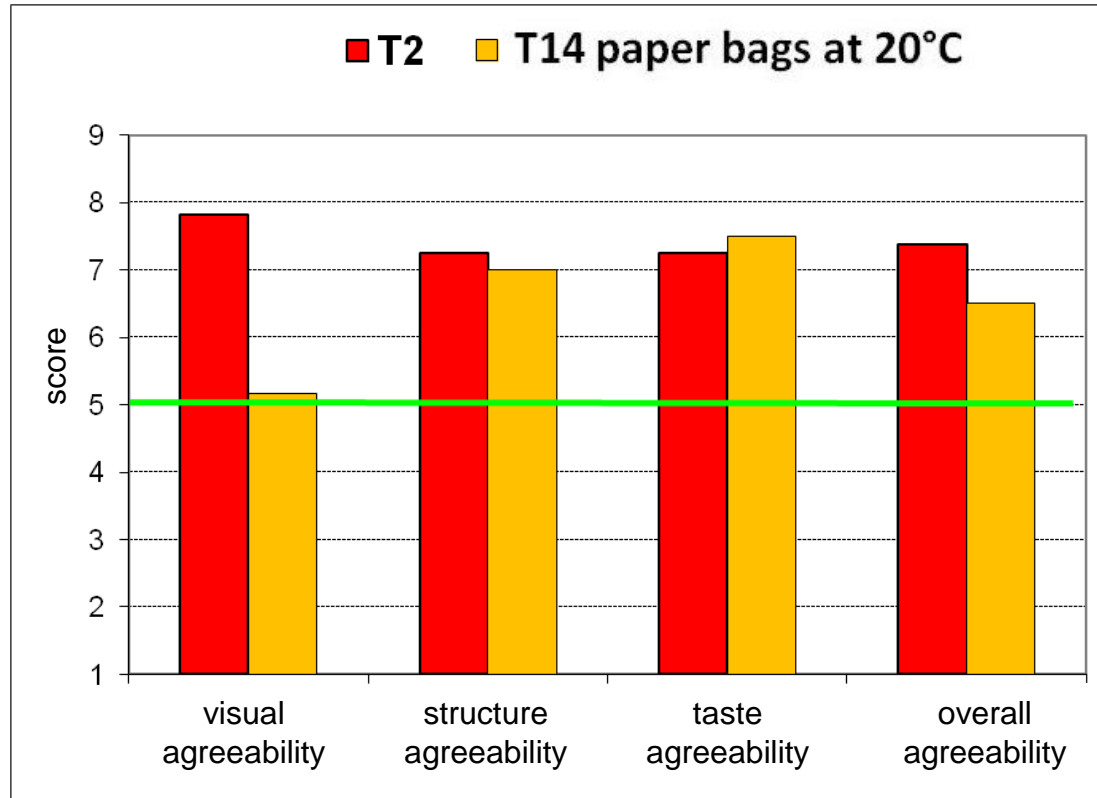
At T2, sensory profile of samples from the two packages are equal.

At T14, about 60% of the roots in paper are edible. The carrots stored in plastic could not be tasted, because they were not edible already at T7.

At T12, the color intensity decreases due to dehydration, the texture is softer, but still hard.

Flavour is noticeably sweeter and a bit more aromatic than T2, with an intense typical aroma and no off-flavours development.

20°C: agreeability judgements



Starting from T2, there is a high decrease in visual agreeability (still acceptable) because of the presence of brown zones on the peel. On the contrary, there is an increase of the taste agreeability because of the higher sweetness, given by a higher concentration of sugars due to the loss of water in the product. This phenomenon does not modify the acceptability of the structure, which remains at a good level.

Conclusions

At the storage temperature of 6°C there is a lot of condensation in the plastic trays, which promotes rots and molds growth and makes the product not acceptable from T7. **Paper packaging ensures a better storage of the roots and allows to preserve freshness which is still acceptable in the last storage day.** The roots have much less molds and browning, whose development remains limited to root crowns and tips, and there is not development of rots.

At 20°C, the aging process is faster than storage at 6°C for both packages. In plastic trays, there is a lot of condensation which increases rots and molds and makes the product not acceptable from T4. In contrast, the paper bag promotes dehydration on the carrots and browning on the tips. The roots become dehydrated and lose their turgidity becoming flexible with a dry, rubbery structure over time. **Carrots storage in paper bags at room temperature should be avoided for long periods of time, as 14 days. The paper package can be used for a maximum of 7 storage days.**