STUDY OF THE TECHNOLOGICAL QUALITY OF CITRUS SINENSIS VAR. TREATED BY GAMMA IRRADIATION COMBINED WITH REFRIGERATION DURING STORAGE

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ABSTRACT

Irradiation as an alternative quarantine treatment has been under consideration by the International Consultative Group on Food Irradiation. This study was conducted on Moroccan late oranges Citrus sinensis var. Morocco late and Citrus sinensis var. Navel lane late to investigate the effects of storage, and low dose irradiation on functional constituents, and quality. Fruit was treated with 0, 125, 250, 375 and 500 Gy of gamma irradiation in order to reduce the post-harvest losses and to increase the shelf life; there after they were stored at ambient temperature or under refrigeration. Quality parameters (juice content, pH, titratable acidity, sugar content and dry mass percentage) were evaluated immediately after the irradiation treatment and during storage. The analysis of the obtained data reveals that the irradiation did not have ominous harmful effect on the fruit quality. The modification of some physico-chemical parameters is not due to the irradiation, but can be related to other factors such as storage temperature and storage period.

I. INTRODUCTION

The citrus fruit in Morocco are considered to be today the first socioeconomic sector and is the heart of the green Morocco Plan, being classified as the most important branch of the national economy with an estimated production of 1.7 million tons/year, which is about 28 % of the total exported Moroccan merchandises. Oranges represent 53 % of the citrus fruit production according to Morocco’s foreign trade in 2009. Two varieties dominate the Moroccan oranges; the Morocco late and Navel lane late varieties. It is estimated that the exportation of these varieties will triple by 2020 (EACCE, 2009). As the sector of citrus fruits evolves in a context of strong worldwide competitive markets, it requires a quarantine treatment for the storage phase after harvest.

In Morocco a distinction between the two orange varieties is made by the following characteristics:

- The Citrus sinensis (C.sinensis) Navel oranges are characterized by a more or less pronounced excrescence (called umbilical point), and the absence of pips;
- The C.sinensis var. Morocco late oranges represent another group which clearly have an orange flesh, little or no pips, are scented, and very juicy.

Dificulties in storing the oranges are particularly considerable at the end of the summer as Moroccan producers need to store their production in order to obtain better prices. Due to the lack of cold rooms that allow a good storage after harvest, the oranges are stored in free air which causes their rot.

The irradiation of oranges by some type of radiation is one way to delay their damage. According to some studies the irradiation by electrons causes more damage than the gamma ray ionization (Chahine et al., 1999). In addition, the use of fumigation with bromide methyl has been restricted since 1995 by the Montreal Protocol. The U.S. Environmental Protection Agency (EPA) has classified methyl bromide as a Restricted Use Pesticide; which has identified irradiation as being a versatile and viable alternative for quarantine treatment in the fight against fruit flies (Patil et al., 2004). This technique is officially identified (except in the European countries) as a powerful tool to make sure that some fruits does not contain the surviving larvae of insect. Thus, many countries have adopted the irradiation method in the treatment of disinfestations so as to increase the shelf life of food; thereby conditions surrounding the application of this method in the treatment of disinfestations are determined by the choice of the most adequate amount of irradiation (Kahan et al., 1968).

The irradiation is able to treat some damage and the whole destruction caused by harmful insects (Spalding & Davis, 1985); particularly the Mediterranean’s flies which are the main enemy of the citrus fruits that decreases their quality (Lacroix et al., 2003). However, in order to make this technique efficient enough, an adequate dose of irradiation has to be used (Dennison et al., 1966), and to avoid the damages caused by such treatment, several investigations have been carried out in order to improve the conditions of the storage of citrus fruits, more precisely Citrus sinensis (oranges) (Monselise & Kahan, 1968; Nagai & Moy, 1985; Mahrouz et al., 2004).

These studies have led to the present research, combining low-dose gamma radiation and refrigeration treatment.
The quarantine treatment has been applied during the post-harvest storage of two varieties: Citrus sinensis var. Morocco late and C. sinensis var. Navel lane late. The samples were maintained at two different temperatures, 7 °C and 25 °C, after exposing them to different amounts of irradiations: 0, 125, 250, 375 and 500 Gy.

The objective of this study is to investigate the effect of ionization combined with the refrigeration effect at different degrees on the reduction of the post-harvest losses by extending the time of the conservation of the cultivated varieties, while preserving their technological and nutritive quality as much as possible. The physical and chemical characteristics were recorded during the storage period (four weeks) to determine the evolution and the effect of the ionisation on the studied samples, and to find its optimization by combining the irradiation technique with refrigeration.

II. MATERIALS AND METHODS

II.1 Collection of samples

For practical reasons, Citrus sinensis varieties produced in 2010 in the Louklos region were selected as samples. In order to constitute representative samples, the primary sampling of both varieties Citrus sinensis var. Morocco late and var. Navel lane late, was made randomly by collecting between 50 and 70 oranges from median part of the trees; while the secondary sampling was done at the laboratory.

The harvested fruits were transported immediately to the laboratory of the ionization station where they were sorted out visually (calibre, colour, absence of defect) in order to constitute five homogeneous samples of 7.5 Kg each before being treated by irradiation.

II.2 Irradiator and dosimetry

Gamma irradiation was carried out at the National Institute of Agronomic Research in the Boulkief Ionisation Station (BOIS) at Tangier, which has a Cobalt 60 source generating γ-radiation with energies of 1.17 and 1.33 MeV. The irradiator delivered a central-line absorbed dose rate of about 3.7 Gy min⁻¹ during the time of this research. Routine dosimetry during this research was done with a Harwell dosimeter (Gammachrom) and absorbance at the 530 nm wavelength was read with a (jasco V-530 UV/VIS) spectrophotometer.

II.3 Sample irradiation

Actual doses were determined by placing Harwell dosimeters (Gammachrom) within fruits of the tested batch. Four batches of the two varieties Morocco late and Navel lane late were irradiated by successive doses: 125, 250, 375 and 500 Gy. The fifth one has been kept without irradiation. After the irradiation of the various batches of the two studied varieties, the samples were dispatched at the research laboratory. Each batch has been subdivided into two, in order to keep one half at ambient temperature, and the other half under refrigeration at 7 °C.

The chemical properties were evaluated for both irradiated and non-irradiated lots immediately after treatment and during four weeks of storage.

II.4 Chemical analysis

To carry out each analysis, the whole experiment was repeated three times.

The physical characteristics (weight and percentage of juice) were recorded using a digital precision balance 10⁻⁴ g series XB120A and the fruits used for chemical and biochemical measurements were squeezed with an electric citrus press. A comparison was made between the two respective masses of fruit and juice.

The pH measurements were done directly using a pH-meter which is gauged with two buffer solutions of pH 4 and pH 7. The Index of refraction is directly related to the sugar content (Chahine, 1999) and can be easily determined by the standard methods of the AOAC (1997) using a portable refractometer (Harwell 1t 0 to 32 °Brix). The concentrations are expressed in degrees Brix at ambient temperature (approximately 20 °C).

The measurement of the amount of dry mass is based on the drainage of interstitial water. The percentage of the dry matter is given by the standard methods of the AOAC (1997).

The determination of acidity is significant for two principal reasons: on one hand, it indicates the state of the product maturity for the same variety; on the other hand the sugar and acidity ratio determines the sweetness of the fruit. Titratable acidity in terms of citric acid and ascorbic acid contents were measured using titrimetric methods (Ranganna, 1986). Total sugars are determined by AOAC (1997), giving an indication of the state of the maturity for the same variety of oranges. The sugar levels vary according to the variety and also in function of the climatology of the year. From a gustatory point of view, a minimal tenuous of sugar is necessary for the sweetness of the fruits to satisfy the consumers.

II.5 Statistical analysis

Data were analysed by using the stratigraphics software (version 4) with switch ANOVA. Two types of variance were conducted to determine effects of irradiation dose and storage time. Least significant differences (LSD) were calculated to determine the difference between the means within the groups. The chosen level of significance was P < 0.05.

III RESULTS AND DISCUSSIONS

The results of the chemical analyses carried out for each batch after one period of four weeks storage (S1, S2, S3 and S4) are presented in figures 1 to 11. The results represent the average of three to six repetitions of the analysis carried out for each parameter.
The results prove that the irradiation does not have a significant impact on the juice yield of both varieties when stored at ambient temperature (figure 1). This is confirmed by the application of ANOVA analysis, showing no significant statistical difference. Nevertheless, the ANOVA analysis confirmed that the juice yield decreases during storage.

Figure 1. The evolution of the juice yield on both varieties depending on the irradiation dose and the storage period at ambient temperature

When the oranges were stored at 7 °C after ionization, similar results were obtained. There is no meaningful statistical difference between both varieties, but a significant statistical difference between the samples was found, and the juice output is reduced during storage (figure 2).

Figure 2. The evolution of the juice yield of both varieties depending on the irradiation dose and the storage period at temperature T = 7 °C

The effects of the lack of refrigeration treatment were manifested by a slight reduction in juice production, especially for the Navel lane variety. According to the ANOVA table there is no significant statistical difference of the pH between the samples that received different irradiation doses (P value is higher or equal to 0.05), and this for the samples stored at ambient temperature (figure 3) as well as for the ones stored under refrigeration (figure 4).

Figure 3. The pH evolution of both varieties depending on the irradiation dose and the storage period at ambient temperature

Figure 4. The pH evolution of both varieties depending on the irradiation dose and the storage period at temperature T = 7 °C
The sugar contents (expressed in degrees Brix) are very important for the economic value of both Navel lane late and Morocco late oranges (figure 5). The ANOVA analysis on the total sugars for the different samples stored at ambient temperature (figure 5) was confirmed by the statistical analysis of the Brix measurements ($P = 0.0578 > 0.05$).

Figure 5. Evolution of the °Brix for both varieties depending on the irradiation dose and the storage period at ambient temperature

The Brix value for samples stored at 7 °C varies between the different samples according to the applied dose with the highest values at the 375 Gy dose for the Morocco late variety and at the 250 Gy and 500 Gy doses for the Navel lane late variety, but the application of the ANOVA table analysis proved that there is no significant effect due to storage or ionization (figure 6).

Figure 6. Evolution of the °Brix for both varieties depending on the irradiation dose and the storage period at temperature $T = 7 \, ^\circ C$

The total sugar variation follows the °Brix one and there is no big variation between values of total sugars of the samples kept under refrigeration. This is indicated by the value of $P = 0.3019$ according to the test of Cochran's one has $P = 0.3079$; so the effect of storage on sugar content is not remarkable (figure 7).

Figure 7. The evolution of total sugars for both varieties depending on the irradiation dose and the period storage at temperature $T = 7 \, ^\circ C$

It was observed that the storage have a remarkable effect on the percentage in dry matter after the application of different doses of ionization (0-0.5 kGy) for both varieties preserved at ambient temperature (figure 8).

Figure 8. The evolution of the percentage of dry matter for both varieties depending on the irradiation dose and the period storage at ambient temperature
With regard to storage at 7 °C, storage time and ionization dose did not have any ominous effect on dry matter content for the studied varieties. This is confirmed by the absence of significant statistical difference since the value of P is higher than 0.05 (figure 9).

During the storage period the variety Navel lane late had less significant acidity changes than the Morocco late variety. Nevertheless, the effect of storage on the acidity of the two varieties did not cause any crucial change (figure 10). This was confirmed by the P value (> 0.05) and reaffirmed by the ANOVA statistical analysis performed on the different pH of the samples treated with different ionization doses.

The variation of the total acidity during storage at 7 °C is similar to the one of the pH. The P value of both parameters is higher or equal to 0.05, confirming that the ionization has no menacing influence on both organoleptic parameters. Thus a greater acidity perceived for the dose 375 Gy remains reasonable (Figure 4 and 11).

IV. CONCLUSIONS

Preservation of typical sensorial qualities of irradiated fruit is one of the important requirements in terms of consumer acceptability. This study showed that the irradiation, as treatment of quarantine during the four weeks of storage, did not affect the technological quality of Citrus sinensis var. Morocco late and var. Navel lane late meaningfully. It can be used as a technique of conservation of these citrus fruits in alternation to other classic techniques, particularly if they are less expensive and allow storage during longer time.

According to the optimization of the different parameters of valorisation of the technological quality of the studied citrus fruits it can be said that the doses used for the combined ionization treatment of the refrigeration during the storage, do not have ominous harmful effect on their quality.

Indeed, the modification of certain physico-chemical parameters (sugars, dry matter) is not due to the irradiation, but can be related to other factors such as storage temperature and storage period.

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