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EFFECT OF PACKAGING AND CONSERVATION CONDITIONS ON SOME PHYSICAL-CHEMICAL PROPERTIES OF ALMONDS

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Abstract

Food quality is a concept that has attracted the attention of Industries and consumers, hence the concern to preserve the products under appropriate conditions, avoiding physical and chemical changes that jeopardize the integrity of the food. In this context, assessments were made of the physical and chemical properties in order to investigate the effects of storage in almonds, under certain conditions of temperature, relative humidity and packaging.

The almonds used were from different origins, namely Spain, Portugal and United States and the conservation processes tested were: storage at room temperature, in a stove at 30 and 50 ^{0}C without control over relative humidity, in a chamber at 30 and 50 ^{0}C with relative humidity of 90%; refrigeration and freezing. The packages used were two types of plastic: linear low density polyethylene (LLDPE) and low density polyethylene (LDPE). The properties evaluated were moisture content, water activity, color and texture.

The principal results show that the storage conditions that best preserve the characteristics of almonds are those at low temperatures, because, while the treatments at high temperatures induced in general more changes, the refrigeration and freezing systems had a lower effect on the products characteristics, particularly moisture, water activity, hardness and friability.

From the results obtained it was concluded that for a good preservation of almonds during storage should be used a packaging material, preferably LDPE, and that with respect to storage conditions the best methods are at room temperature or, alternatively, in refrigeration or freezing.

Key words: *Almond, Color, Texture, Water Activity.*

1. Introduction

Nuts vary widely in size, shape, appearance, colour and brightness, according to species and origin. In terms of nutritional value, nuts in general are rich in carbohydrates, being an excellent source of energy, providing over 600 kcal/100g on average. They are excellent sources of fibre, very beneficial for the intestinal functions. They are major suppliers of polyunsaturated fats, that are about 50% of their weight and, in general, they are also good sources of minerals such as calcium and iron. The polyunsaturated fatty acids are beneficial in cases of cardiovascular disease, increased cholesterol and triglycerides. However, because they are very fattening they are not indicated in cases of obesity and overweight (Janick and Moore [1]).

Regarding texture, almond is among the group of the hard fruits. Almonds present a characteristic aroma and can be consumed with or without the internal skin, depending on the purpose intended or consumer preference (Janick and Moore [1]). In terms of food safety and quality of nuts, the major problems are rodents, pests and the possibility of developing microorganisms adverse to health (Santos and Silva [2]).In order to preserve the fruit characteristics and to slow deterioration should be chosen appropriate storage methods and periods. For storage of dried fruits is recommended a cool and dry place, since, when subjected to high temperatures as well as very high relative humilities of the air, they can deteriorate (Baker and Ripado [3], Casp and April [4], Lidon and Silvestre [5]). Another way of keeping these products for a longer period of time is the use of appropriate packing. The containers can be of different materials, and in the case of nuts the material normally used is plastic. This barrier around the fruit will help reduce the losses or gains of undesirable elements (interaction packaging/food) and acts also as a form of protection against insects and rodents (Santos *et al*. [6], Han [7]).

The objective of this work was to verify the effects of different packages and storage conditions on the characteristics of almonds from different origins, evaluating their chemical characteristics that are more related to conservation, namely moisture and water activity as well as they physical characteristics (colour and texture) more related to product quality.

2. Materials and Methods

2.1 Samples

The fruits evaluated were almonds (*Prunus amygdalus* B.) without the outer shell, but with the inner skin (seedcoat). The samples were from Spain (SP), Portugal (PT) and from United States (US).

2.2 Analysis of water activity and moisture content

The water activity was measured at 25 ºC by a hygrometer (Rotronic Hygroskop BT-RS1) connected to a thermal bath. In all cases four determinations were made to calculate the medium value and standard deviation.

Moisture content was evaluated by drying in a stove (WTB-Binder) at 105 ºC until reaching constant weight. In all cases three determinations were made.

2.3 Evaluation of color

The colour of all samples was measured using a handheld tristimulus colorimeter (Chroma Meter - CR-400, Konica Minolta) calibrated with a white standard tile. A CIE standard illuminant D65 was used to determine CIE Cartesian colour space coordinates, L*a*b* values. This system is suggested by Mendonza *et al*. [8] as the best colour space for quantification in foods with curved surfaces. The parameters measured were the brightness L*, which varies between 0 and 100 (from black to white, respectively), and the coordinates of opposed colour: a* and b*, which vary from -60 to +60, where the a* assumes negative values for green and positive values for red, while b* assumes negative values for blue and positive for yellow. The total colour difference (TCD), was the parameter considered for the overall colour difference evaluation, between a sample and the reference fruit, designated with an index 0 (Guiné and Barroca [9]):

$$TCD = \sqrt{(L_0* - L*)^2 + (a_0* - a*)^2 + (b_0* - b*)^2} \quad (1)$$

The reference values correspond to the fruits without storage, and a larger TXΔ denotes greater colour change in relation to the reference material. In each case 25 measurements were made to access the means value and standard deviation.

2.4 Evaluation of texture

The texture profile analysis (TPA) for all samples was made by a texturometer (TA.XT.Plus from Stable Micro Systems). The text performed was measure force in compression and the probe used was a Blade Set HDP/BS (Warner- Bratzler). The operational parameters were: pre-test speed = 1.50 mm/s, test speed = 1.00 mm/s and post-test speed = 10.00 mm/s, distance = 4 mm, trigger force = 0.147 N, load cell = 5 kg. Twenty measurements were carried for each fruit and each storage condition, by using a cutting blade to break through the fruit, thus allowing the assessment of parameters such as the friability and hardness. The curve force (N) versus distance (mm) (Figure 1) allows calculating the hardness (the force at first peak) and friability (the distance of first peak).

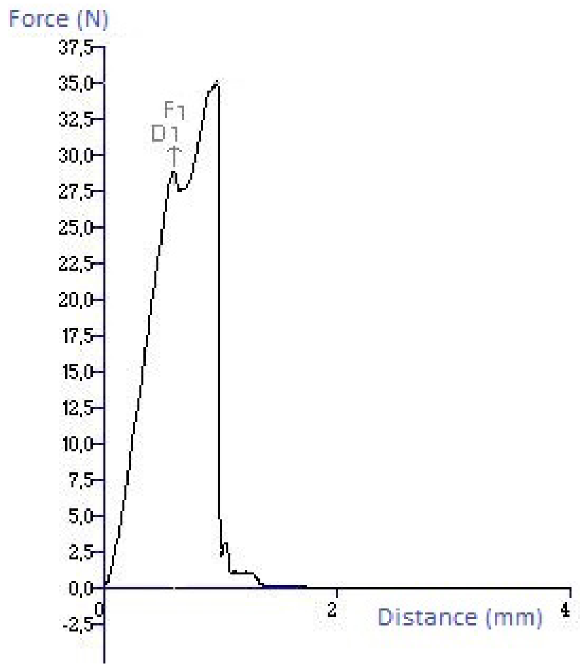

Figure 1. Example of a TPA obtained for nut sample

Hardness is the mechanical strength to crush. It is important as it ensures the physical integrity of the product, allowing it to support the mechanical stress in the process of packing and transportation. The hardness limits are specified according to the diameter and weight of the sample and refers to the minimum resistance to be removed from the container without breaking. The friability respects to the ease with which the fracture occurs in the products (Pereira [10], Almeida [11]).

2.5 Storage conditions

The fruits were stored for 90 days in Spring/Summer season, although some rainy and cold days were observed. The storage was at ambient conditions, in a stove at two temperatures with controlled temperature but no control over relative humidity, in a chamber with controlled temperatures and relative humidity, under refrigeration and frozen. Furthermore, the fruits were stored without any package, and with two commercial plastics: low density polyethylene (LDPE) from ALBERPLÁS with 110 µm thickness (density = 920 - 940 kg/m^3) and linear low density polyethylene (LLDPE) from MGP minigrip with 40 µm thickness. Table 1 summarizes the conditions used to store all fruits.

Table 1. Summary of storage conditions for the almonds studied

Code	Description	Temperature (ºC)	Relative humidity (%)
B	Just acquired (base)		-
AT	Ambient temperature (not controlled)	23.4 ± 2.5	50.5 ± 6.7
S30	Stove (temperature controlled but RH not)	30.0 ± 0.0	36.0 ± 3.6
S50	Stove (temperature controlled but RH not)	50.0 ± 0.0	13.2 ± 1.5
C30	Chamber (temperature and RH controlled)	30.0 ± 0.0	90.0 ± 0.0
C50	Chamber (temperature and RH controlled)	50.0 ± 0.0	90.0 ± 0.0
R	Refrigerated	2.3 ± 3.7	48.1 ± 23.3
F	Frozen	-15.4 ± 2.6	61.7 ± 6.2

3. Results and Discussion

Figure 1 shows the moisture contents of the almond samples from Spain (SP), Portugal (PT) and United States (US) subject to different storage conditions and with different packages: low density polyethylene (LDPE) and linear low density polyethylene (LLDPE). When the samples were stored without package it was observed that the refrigeration and freezing treatments were those where the moisture remained more similar to that of the original samples (before storage), while the storage in a stove at 50 ºC and about 13% relative humidity (RH) produced the samples more different from the original almonds. Moreover, the results also indicate that the trends observed are similar regardless of the origin of the almonds.

As to the moisture contents of the almonds stored with package (Figure 1) once again the results are similar regardless of the origin of the almonds. As to the influence of the storage conditions, is observed that, like seen before for the samples without package, the treatments under refrigeration and freezing allow obtaining products with moisture more similar to the basic products, whereas the stove at 50 ºC and 13% RH originated a higher dehydration. On the other hand, the treatments at 50 ºC and 90% RH produced samples with higher moisture content. This is because the almonds, due to their low water content, are susceptible to rehydration by absorbing the surrounding moisture, thus indicating that the package by itself might not be a sufficient barrier when the products are exposed to excessive relative humidity (90%). Furthermore, by comparing the two types of plastic used, is evident some difference between them, since the LDPE gives better results, not allowing so intense changes in the stored products as compared to the unstored almonds. This is because the LLDPE plastic is much thinner than LDPE (40 µm against 110 µm) and therefore is more permeable to the moisture, thus allowing the inside products to absorb more water.

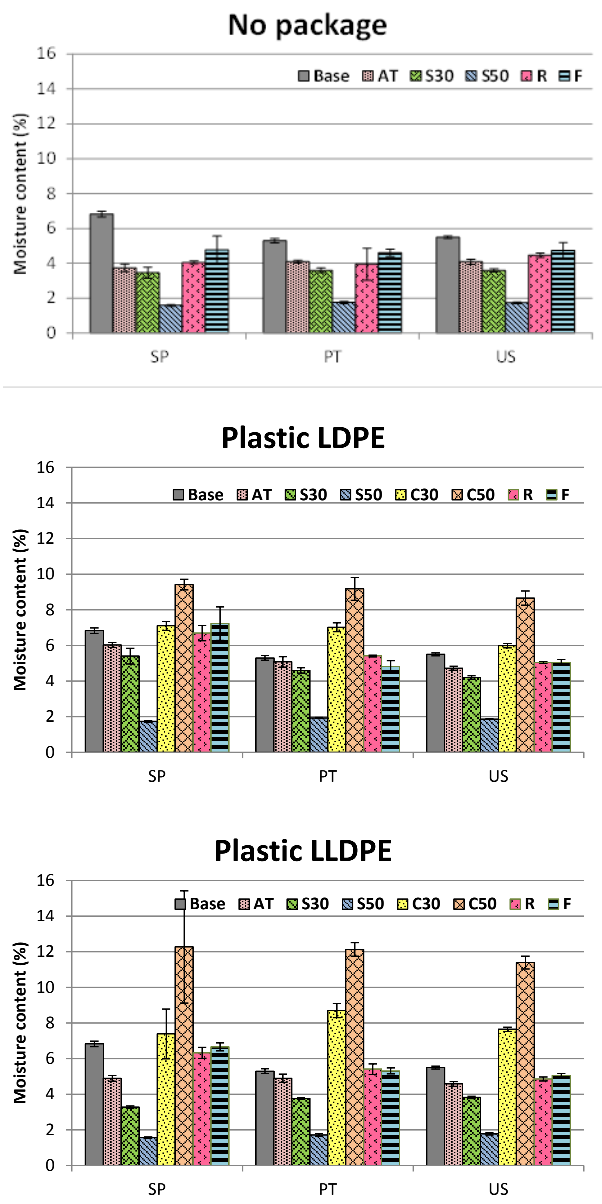

Figure 1. Moisture content of the almonds

Legend: AT – Ambient temperature; S30, S50 – storage at high temperature (30 and 50 ºC); C30, C50 – storage at high temperatures (30 and 50 ºC and 90% relative humidity); R – refrigerated; F – frozen; Almond origin: SP – Spain, PT – Portugal, US – United States

The water activity is very important for the access of the stability of the food products because it accounts for the free water in the product that is available for chemical and enzymatic degrading reactions as well as for microbial development (yeasts, fungi and bacteria). The results presented in Figure 2 relate to the water activity of the almonds and they allow verifying the exact same trends as described before for moisture. In fact, these two variables are quite related to each other and it would be expected that a material with more water would also have more free water, and therefore higher water activity. The water activity is in all cases better preserved in relation to the original samples by the refrigeration and freezing treatments. The values of water activity under 0.6 guarantees that the product is absolutely safe against deterioration processes, and the results show that, although in most cases this limit is not surpassed, there are some cases that might be problematic such as storage at 30 and 50 ^{0}C and 90% RH with both plastics: LDPE and LLDPE.

Colour is a fundamental organoleptic attribute to determine product acceptance by the consumer, giving, together with aroma, the first pleasant or unpleasant sensation about the product. Therefore, storage and

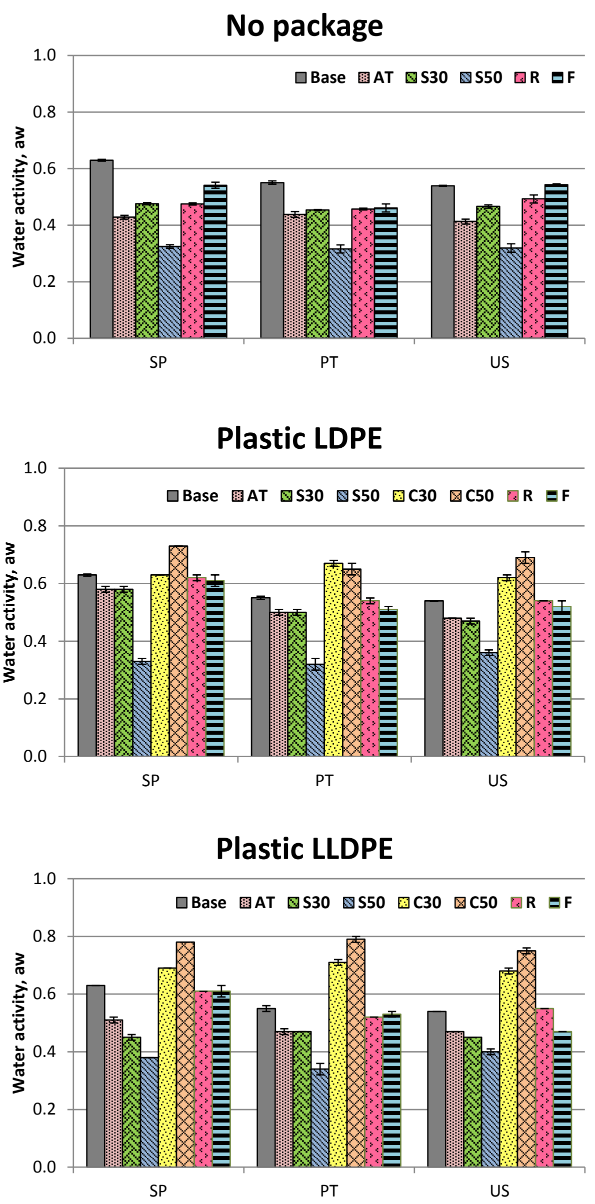

Figure 2. Water activity of the almonds

Legend: AT – Ambient temperature; S30, S50 – storage at high temperature (30 and 50 ^{0}C); C30, C50 – storage at high temperatures (30 and 50 ^{0}C and 90% relative humidity); R – refrigerated; F – frozen; Almond origin: SP – Spain, PT – Portugal, US – United States

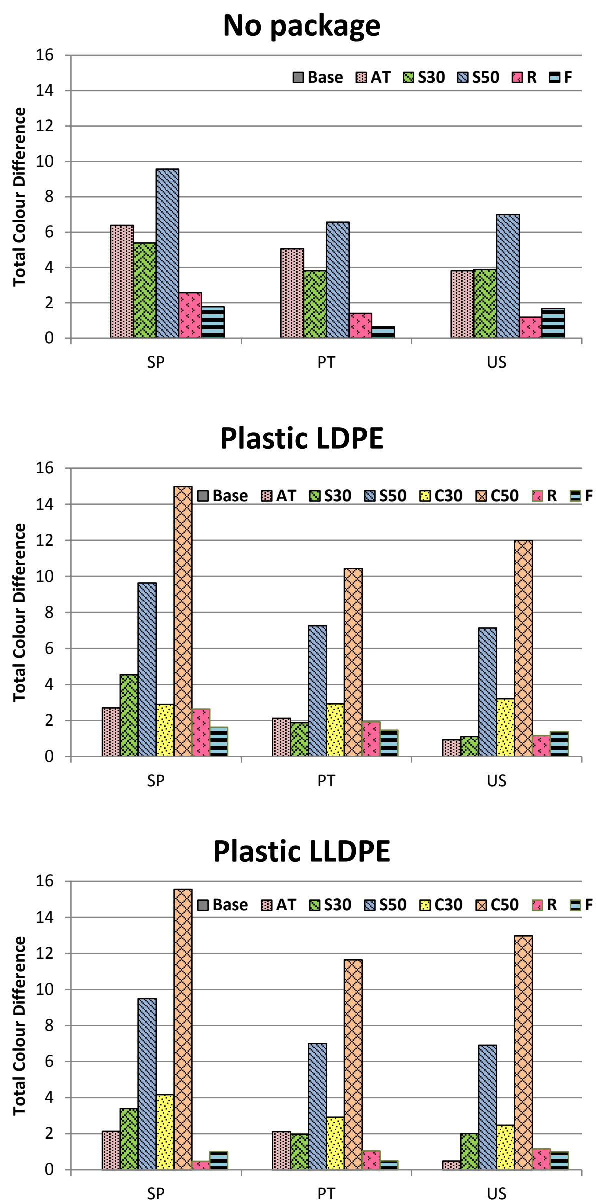

Figure 3. Total colour difference of the almonds

Legend: AT – Ambient temperature; S30, S50 – storage at high temperature (30 and 50 ^{0}C); C30, C50 – storage at high temperatures (30 and 50 ^{0}C and 90% relative humidity); R – refrigerated; F – frozen; Almond origin: SP – Spain, PT – Portugal, US – United States preservation methods aim at best preserve the product characteristics so as to minimize changes in relation to the fresh product. Figure 3 shows the values calculated for total colour difference (TCD), which compare a sample with a reference material, which in the present case was the base product, i.e., before being submitted to any kind of storage. The results show that the values of TCD are incredibly higher when the samples are stored at 50 °C, regardless of the package. This fact is due to the oxidizing mechanisms and browning reactions that occur at higher temperatures, thus originating a darker colour at the surface of the product. Furthermore, when the storage is done at 50 °C and 90% RH, the values increase even more.

Figure 4 shows the results of the hardness determined by a texturometer by means of a compression test. Hardness is a textural attribute that is also very important for determining product acceptability. In the case of nuts in general, and almonds in particular, and because they are already hard in nature, an increase in hardness may be very compromising and determine a high degree of product loss. Therefore it becomes fundamental that the storage conditions will not produce significant changes in this attribute.

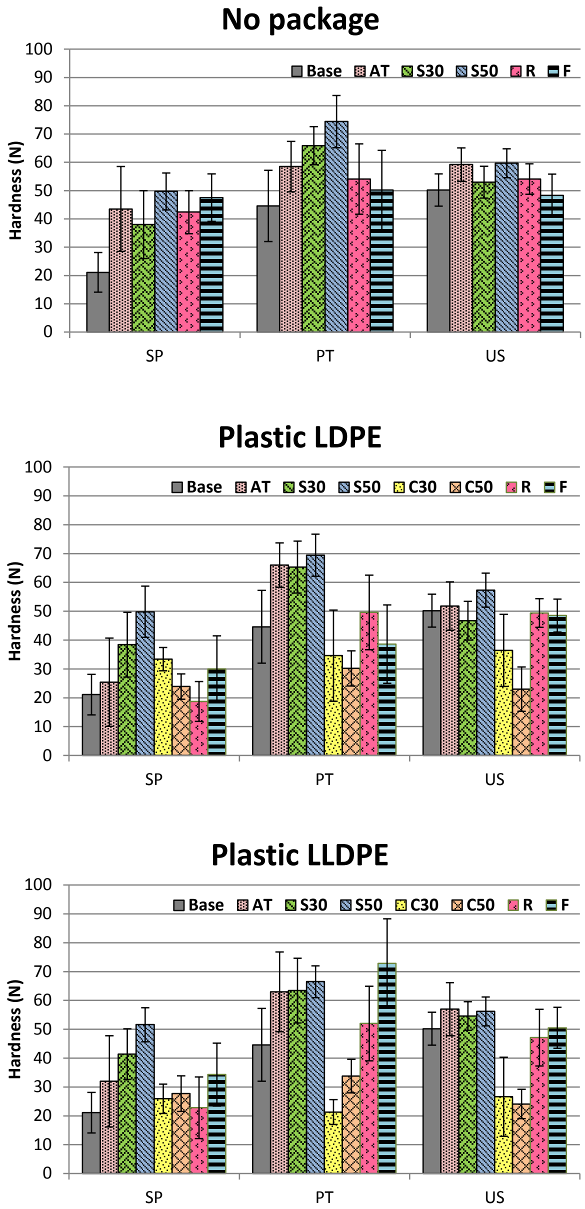

Figure 4. Hardness of the almonds

Legend: AT – Ambient temperature; S30, S50 – storage at high temperature (30 and 50 °C); C30, C50 – storage at high temperatures (30 and 50 °C and 90% relative humidity); R – refrigerated; F – frozen; Almond origin: SP – Spain, PT – Portugal, US – United States

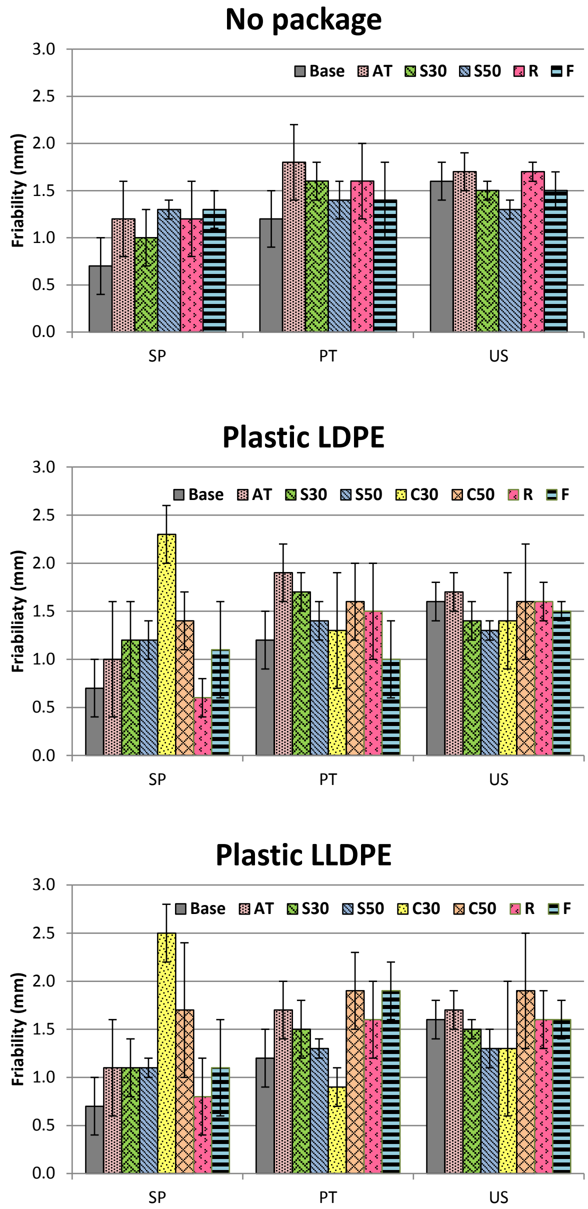

Figure 5. Friability of the almonds

Legend: AT – Ambient temperature; S30, S50 – storage at high temperature (30 and 50 °C); C30, C50 – storage at high temperatures (30 and 50 °C and 90% relative humidity); R – refrigerated; F – frozen; Almond origin: SP – Spain, PT – Portugal, US – United States

The results show that regarding hardness, the sample from Spain is softer when compared with the other two origins, which are quite similar between them, and this remains true independently of the type of package used. As to the effect of the different storage conditions used, the storage at 50 ^{0}C with 13% RH gives in general the harder almonds, whereas the refrigeration is the treatment which allows obtaining values of hardness similar to the unstored almonds. Furthermore, with respect to the different packages, it appears that the results are similar independently of using or not package and of what type of plastic is used.

Friability is another of the textural attributes that was evaluated in the present study and the results are presented in Figure 5. The sample from Spain presents lower values for friability whereas the samples from Portugal and United States are similar and both with higher friability. When the samples are stored without package, there are no important differences to observe between the different storing conditions, since in all cases the friability varies slightly in relation to the unstored samples. Furthermore, this trend is also observed when the samples are stored in packages (LDPE and LLDPE), just with some exceptions, like the case of storage at 30 ^{0}C and 90% RH, in which with both types of plastic a very pronounced increase in friability was observed.

4. Conclusions

- The origin of the almond samples does not have influence on moisture content and water activity or colour, but with respect to hardness and friability, the almonds from Spain present lower values than those from Portugal or United States.

- The best storage conditions to obtain products with characteristics more similar to the unstored almonds are refrigeration and freezing, followed by storage at ambient temperature.

- Among the types of plastic tested, LDPE proved to be better than LLDPE, and therefore it the package recommended to store this type of product.

Acknowledgement

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