

Use of Decompression Instant Vacuum (DIC) Method into Vegetal Snack Production from Dehydrated Apple (cv. Reineta) and Pear (cv. Conferencia)

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ABSTRACT

One of the raising dehydration techniques more recently developed is instant decompression controlled vacuum (DIC; *Détente instantannée Contrôlée*), which causes a modification of micro- and macrostructure of food causing an expansion of the product, which improves their texture, color and rehydration capacity. The objective of this study was to evaluate specifically cultivars of pear (*Conferencia*) and apple (*Reineta*) from Bierzo (León, Spain) as raw material during processing from dehydrated process (DIC) and determines their suitability for snack industrial applications. To this end, samples of each fruit species were taken at harvest (0 weeks), and after 6 and 12 weeks of storage, peeled and sliced in two formats (2 and 4 mm). Several parameters were measured before (^oBrix, firmness and weight loss) and after (moisture content and water activity) DIC process. Results indicate that apple shows more stable for any format-studied compare to pear during DIC process, since it presented less variability (17%) than pear (46%) according to the applied format. The format modifies aw values registered during the entire DIC process; because 2mm slices have lower water activity and moisture content values than 4mm slices. Apple marks hardness parameters along its storage (<4.5 kg·cm⁻²), that provided greater firmness and consistency than pear along storage, so all studied parameters reflected that apple was more suitable for DIC process than pear.

Key words: Reineta apple, Bierzo, Conferencia pear, DIC process, Activity water, Moisture content, ^oBrix, Snacks dried.

INTRODUCTION

Food dehydration is an ancient process applied for several reasons amongst decreasing water availability for microorganisms in order to inhibit some chemical reactions and favouring the stabilization and preservation of products. During the drying process, it is important to control the changes related to the structure and texture of foods¹. As well as drying processes, there are two factors: a water loss that distorts and creases the product, and a temperature increment, which

causes thermal product degradation, producing a non-enzymatic browning that provides a loss of protein content, color acceptability and the development of unusual flavors inside the products¹.

One of the raising dehydration techniques more recently developed is instant decompression controlled vacuum (DIC; *Détente instantannée Contrôlée*), which causes a modification of micro- and macrostructure of food causing an expansion of the product, improving their texture, color and rehydration capacity. Also, it is a very efficient

process, with kinetics of drying faster than the other methods currently applied in the industry, such as freeze-drying. This technique² is based on a thermo-mechanical effect induced by the abrupt transition from a high steam pressure level to vacuum, applying this process for apple in order to modify its texture.

On the other hand, the application of this technology allows microbial inactivation, which facilitates the decontamination of the products through the combined of two factors: heat treatment and mechanical effect, that this process works in the product, and also increases the availability of active molecules: flavonoids, antioxidants, vitamins, and also, inhibits the enzymatic action, therefore increasing their useful life. In addition to that use for food dehydration, DIC process has other applications, such as the obtaining of essential oils or microbial decontamination of pharmacological products.

Until nowadays, several scientific studies have been carried out based on DIC technology and their adaptation and application of vegetable food products, especially in different potato varieties², carrots, onion, tomato, red pepper, leek and courgette³, but also in apple^{4,5} being very scarce studies in fruit crops, and in any case with varieties grown in Mediterranean climate conditions (e.g. Spain). In fact, a very small number of agro-food companies know this technology, and lower still is the number of companies that have implemented that. In order to preserve the food stability is essential to know their isotherm sorption, which allows relating the moisture content and the water activity⁶ and also describing the thermodynamic equilibrium of water within each food. Likewise, it should be noted that fruit and vegetable pieces are developing during their storage, in such a way that its sorption isotherm is changed along the maturation process.

One of the problems of apple chips produced by dehydration is their high hygroscopicity, possibly due to their chemical composition (mainly fructose, pectin and sucrose) and its porous structure. This hygroscopicity promotes a fast loss of texture (crispy) typical of this variety of snacks, even with less than an hour of exposure at 20°C and at 83% humidity⁷. Several

authors^{7,8} indicated that the optimal moisture content (< 3 - 3.5%) for palatability and texture is according with a water activity between 0.11 and 0.18, low values compares to water activity from other snacks, around 0.35-0.5^{9,10}. Noorbakhsh *et al.*, (2013)¹¹ demonstrated that bacterial stability depends on the dehydration process and with less than 0.35 of activity water (7% moisture content), dried apple slices (40°C air drying temperature) remains stable refer to microbiological activity. Saavedra *et al.*, (2013)¹² showed that apple snacks products during their storage keep stable between 18-35°C if their water activity is close to 0.2-0.26 or moisture content is less than 4%.

These differences in critical values make necessary the study of moisture content and water activity from slices dried apple that will be a key factor on their lifetime product.

Lastly, the properties of *Reineta Bierzo* apples are well considered by their high sugar content and high content in vitamin C, five times higher compares to other apple cultivars (IRTA, 1997) . Apples are always part of a healthy diet because of their high DF content¹³ and the presence of several health beneficial polyphenols, such as procyanidin, catechin, epicatechin, chlorogenic acid, phloridzin, quercetin and their conjugates. Apple phenolic compounds have exhibited anti-inflammatory and anticarcinogenic properties, and the ability to prevent a variety of chronic diseases. Conference pear is also well considered like one of the most warranty quality product by their great nutritional value.

The aim of this project is to evaluate specifically cultivars of pear and apple as raw material during processing from dehydrated process (DIC) and determine their suitability for snack industrial applications.

MATERIALS AND METHODS

After harvesting, apple and pear fruits were preserved into cold storage under 1°C of temperature and 95% relative humidity conditions. The samples were taken at harvest (0 weeks), 6 weeks later and 12 weeks of storage for each fruit species. Before drying processing, five samples of

each fruit and time were selected and their total soluble solids content (TSS or Brix degree) using a manual Abbe refractometer (Zeiss Opton, Germany) and firmness ($\text{kg}\cdot\text{cm}^{-2}$) using a penetrometer fruit pressure tester 011 (Wagner Instrument, USA). All values were measured at labs of Department of Food Hygiene and Food Technology of University of Leon (Spain).

Fruit pieces were manipulated previously to dehydration process trough peeling, core extruding (to avoid any heterogeneity in the mesocarp or flesh) and slicing in two formats (2 and 4 mm width). Afterwards, the slices were blanched in an acid citric solution (1%) for 10 minutes in order to prevent browning. Slices were dried in a hot-air drier (Digitronic P; Selecta, Spain) at 50°C to approximately 15% of moisture content. Lately, pieces were subjected to DIC process at “*Laboratoire Maîtrise des Technologies Agro-Industrielles, Pôle Sciences et Technologies*” University of La Rochelle, (17042 La Rochelle Cedex 1, France) as follow:

The samples (15% db) were introduced in a processing vessel in which a vacuum of 30 mbar was established (Fig. 1). The initial vacuum is carried out to facilitate the diffusion of steam into the product. Saturated steam was then introduced into the vessel at fixed pressure level (Fig. 1b), apple samples were treated at ($P=4\text{bar}$) and pear samples at ($P=5\text{bar}$), these pressures are maintained for 20s (Fig. 1c). This step is followed by a sudden decompression towards vacuum (Fig. 1d). Afterwards, an atmospheric air was injected to return to atmospheric pressure (Fig. 1e). Finally, treated slices were dried in a hot-air dryerto

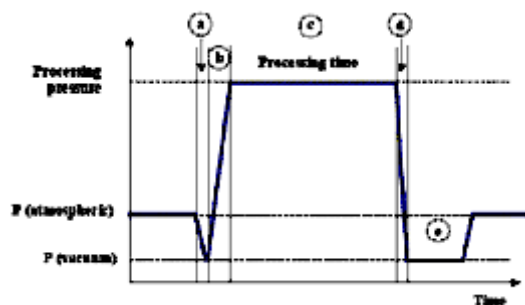


Fig. 1: Pressure time profile of DIC processing cycle (Iguedjtal *et al.*, 2007)²

approximately 180 min at $40\text{-}45^{\circ}\text{C}$ until constant humidity (3% db).

Finally, four treatments were designed depending on vegetal specie (apple vs. pear) and slice format (2 vs. 4 mm). In all samples, water activity (aw) using an aqua Lab Cx2 (Decagon Devices, USA) equipment and water content (Karl Fischer method for vegetal dried products; AOAC/ 967.19 E-G; AOAC 1990 using 870 KF Titrino plus (Metrohm, Switzerland) equipment), and weight loss (%) were measured during the whole process.

RESULTS AND DISCUSSION

Total soluble solids content: Results from apple samples (Table 1) shown a linear relationship with storage, because the $^{\circ}\text{Brix}$ or total soluble solids content after 6 weeks was higher (17%, $P<0.001$) and was rising up to 19% after 12 storage weeks (15 $^{\circ}\text{Brix}$) compared to harvest value. On the other hand, results from pear were more heterogeneous, because $^{\circ}\text{Brix}$ from 6 weeks was lower (11.5 $^{\circ}$ vs. 12.2 $^{\circ}$, $P<0.001$) compared to harvest value, although the content was increased until 13.9 $^{\circ}$ Brix after 12 storage weeks. In other study¹⁴, regardless of the method of storage, the total soluble solids content of Conference pear increased slightly during storage (according with our results), but pear variations were more heterogeneous than the apple. That the reason why this storage process was not the most suitable for pear (conditions: $1\pm 0, 5^{\circ}\text{C}$ and $95\pm 1\%$ HR), as

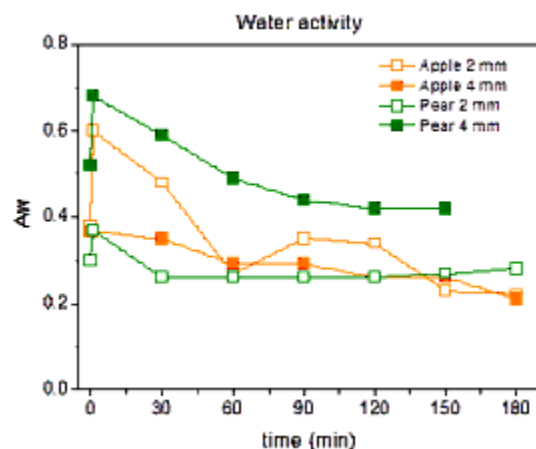


Fig. 2: Water activity (aw) of treatments (fruit and slices) along DIC process.

well as °Brix and hardness values variations reflect for this fruit.

Lastly, the balance between sugars/acidity is the responsible for fruit maturity, also that state in fruits means physical (loss of hardness, increase the juiciness...) and organoleptic characteristics (increase of volatile aromas and change of veraison inside the pericarp) that are determined in a general way, by an increment of sugars despite of acids. Accordingly, in that study apple had higher content in sugars than pear during storage process, although first harvest values were very similar (12.16 vs. 12.17 apple and pear respectively) so apple experimented (underwent) a faster maturity progress than pear with the same time of (camera) storage.

Firmness: Pear hardness parameter (Table 1) reflected similar values to apple pieces at harvest (10.86 vs. 10.65 kg·cm⁻² for pear and apple respectively) undergoing a drastic fall of hardness in fruit of the order of a 91.2% after a period of 6 weeks. Due to the subsequently 12 weeks of storage, losses regarding the value at harvest were maintained in values of 70% (P<0.001). Pear hardness values were significantly lower than the apple throughout the process of storage, included its final value that was also significantly lower than the apple (24.6%; P<0.001). Apple hardness values kept more or less constant along its storage (<4.5 kg·cm⁻²), that provided greater firmness and

consistency than pear along storage without complete maturity (15.0 vs. 13.9 °Brix final for apple and pear, respectively). For new products, formats or designs, it should take into account the low consistency and firmness of the pear when it is kept more than 6 weeks in freeze chamber. On the other hand, the lower total soluble solids content may will not only affect the firmness of the dried finished product, but also its organoleptic characteristics (less sweetness and higher acidity).

Weight (loss): There were no significant differences (Table 1) in weight losses suffered by apples during the drying process in relation to the time of storage. On the other hand, pear showed significant differences being more sensitive to weight loss as storage time progress (<1%; P<0.004). It should be noted that greater weight losses occurred at 6 weeks of storage for both fruit species.

Water activity (aw): Apple average water activity (Table 2) presented less variability (17%) than the pear (46%), even along the entire DIC process (Figure 2), which gave to the product a better textural and stability. Format directly affected to aw during DIC process, because thinner slices maintained lower water activity than the others (3-10%; P< 0.02 differences between 2 mm and 4mm respectively). It should be noted, that slices dried with other methods could reach aw values d^o 0.35 and they were microbiologically stable¹¹, and with

Table 1: Total soluble solids content (°Brix), Firmness (kg·cm⁻²) and Weight loss (%initial weight-final weight/initial weight) during pre- dehydration process for fruit and week of storage

| Storage | ° Brix ¹ | | Firmness (kg·cm ⁻²) | | Weight loss (%) | |
|------------------------|---------------------|--------------------|---------------------------------|--------------------|-----------------|--------------------|
| | Apple | Pear | Apple | Pear | Apple | Pear |
| Harvest (0 weeks) | 12.16 ^b | 12.17 ^b | 10.65 ^a | 10.85 ^a | 17.11 | 16.69 ^a |
| After 6 weeks | 14.67 ^a | 11.50 ^c | 4.77 ^b | 0.95 ^c | 14.62 | 15.49 ^b |
| After 12 weeks | 15.00 ^a | 13.90 ^a | 4.58 ^b | 3.26 ^b | 15.92 | 15,78 ^b |
| EEM ² (n=5) | 0.088 | 0.103 | 0.169 | 0.105 | 0.853 | 0.061 |
| Sig ³ (p) | | | | | | |
| Week | <0.001 | <0.001 | <0.001 | <0.001 | 0,418 | 0,007 |

¹°Brix= Total solids soluble content degree. ² EEM: standard average error for n= 5samples per treatment. ³ Sig: significant differences; ns *, **and *** means to there is no significant differences using ANOVA and P<0,05; P<0,01 and P<0,001 respectively. The values with the same letter are equal (T. Tukey). P-values were determined by analysis of variance.

Table 2: Total moisture content (%) and water activity (aw) during DIC process for fruit and week of storage

| Fruit | Harvest (0 weeks) | | After 6 weeks | | After 12 weeks | |
|----------------------------|-----------------------|--------|---------------|-------|----------------|--------|
| | Moisture ¹ | aw | Moisture | aw | Moisture | aw |
| Apple | 4.22 | 0.321 | 8.79 | 0.368 | 4.10 | 0.236 |
| Pear | 5.27 | 0.273 | 7.21 | 0.374 | 4.46 | 0.260 |
| EEM ² (n=6) | 0.095 | 0.002 | 0.316 | 0.003 | 0.175 | 0.001 |
| Slices | | | | | | |
| 2 mm | 5.51 | 0.285 | 8.35 | 0.372 | 3.85 | 0.236 |
| 4 mm | 4.63 | 0.291 | 7.65 | 0.370 | 4.71 | 0.260 |
| EEM (n=6) | 0.095 | 0.002 | 0.316 | 0.003 | 0.175 | 0.001 |
| Sig³ (p) | | | | | | |
| Fruit | 0.01 | <0.001 | 0.02 | NS | NS | <0.001 |
| Slices | 0.04 | 0.002 | NS | NS | 0.03 | <0.001 |
| Fruit *Slices | NS | NS | 0.01 | NS | 0.03 | <0.001 |

¹Moisture and water activity (Aw) ²EEM: standard average error for n= 5samples per treatment. ³ Sig: significant differences; ns *, **and *** means to there is no significant differences using ANOVA and P<0,05; P<0,01 and P<0,001 respectively. P-values were determined by analysis of variance.

a high level of stability if this parameter will rise up to 0.2 ¹². In our study, final aw values (Fig 2) are lower than 0.26 allowing apple and pear products being considered like microbiologically stable.

Moisture content: Higher average water activity and moisture content were recorded on the second date of storage; this means that the fruit already had higher moisture levels at this stage (6 weeks). In relation to fruit specie used, apple turned out to be more stable than pear during storage due to lower variability in moisture content and average water activity (P<0. 001). On the other hand, according to the format for each fruit, 4 mm (large) slices showed higher moisture content (+ 18%; P=0.03) and, therefore, higher activity water values (+10% aw; P<0.001) after 12 weeks of storage. These differences are very important for microbiological stability and the development of the industrial products. For an air dried process under 40°C of temperature, a moisture content d'' 8% is considered such as stable stage of snacks¹¹. Other studies¹² remarked that moisture content between 1-2.5% is related to high level of microbiological stability for apple snacks production. In our study, the moisture contents were similar (final moisture content< 5%) than these previous studies in apple

and pear, but dehydration process depends so much on drying temperature¹⁵. At 30°C the process is smooth and slow whereas at temperatures above 40 or 50°C it becomes very fast which might give rise several changes respect to physical, morphological and other quality parameters.

CONCLUSION

Apple shows more stable for any format studied compare to pear during DIC process. Apple water activity (aw) presented less variability (17%) than pear (46%) according to the applied format. The format modifies aw values registered during the entire DIC process; because 2mm slices have lower water activity and moisture content values than 4mm slices. Apple marks hardness parameters along its storage (<4.5 kg·cm⁻²), that provided greater firmness and consistency than pear along storage, so all studied parameters reflected that apple was more suitable for DIC process than pear.

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