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Final report: vacuum packaging and storage of green Columbian coffee

1. Purpose of the experiment:

The aim of the experiment was to investigate a new type of packaging for green Columbian coffee beans. The dried coffee beans were vacuum packaged with a high barrier plastic packaging film and stored during 6 months in extreme climate conditions (30°C and 90% relative humidity). The coffee beans were preliminarily tested for respiration activity, but no significant respiration rate was found for the dried products. In this way, a complete barrier plastic packaging film could be defined towards oxygen, carbon dioxide and water vapour.

Typical quality characteristics of dried green coffee were followed during the storage period to guarantee the quality of green Columbian coffee. These characteristics are the water activity (as a measure for free water available for microbial spoilage) and the water content. To evaluate the characteristics of the packaging film, the internal atmosphere inside the packages was analysed for O_2 and CO_2-content.

The analyses were performed every month (month 0, 1, 2, 3, 4, 5 and 6) and in duplicate (2 packages per analysis), except for month 3 and month 6 as only 1 package was available. The determination of the water activity and the water content was conducted as well in duplicate.

2. Materials and methods:

2.1. Measurement of water activity (a_w) and water content

The water activity was measured by the Novasina Thermoconstanter at 25°C. The water content was determined using the classical gravimetric method in which the difference in weight between a humid and dried product (dried at 105°C) was measured. The water content is expressed as % H_2O on dry mass basis (g H_2O per 100 g dry matter) which are the units applied in literature (% H_2O s.s., g H_2O/100 g de substance sèche). For month 6, the determination of the water content was also performed following the ISO 6673-1983. The difference between the 2 methods exist in the non-grinding of the beans and the difference in weight is weighed after 16h of drying at 105°C by the ISO method.

2.2. Measurement of headspace gas composition

As the packages are vacuum packaged, a small headspace is only available for analysis. A gas chromatograph was used to determine the amount of O_2, CO_2 and N_2 inside the package via a thermal conductivity detector (TCD).

2.3. Vacuum packaging of the packages

The applied packaging film was a transparent high barrier film for O_2, CO_2 and water vapour.
The packages (scale ½) of 29 × 19.25 × 8.25 cm, filled with 3.125 kg of green Columbian coffee beans, were vacuum packaged by applying a Multivac A/300 vacuum machine.

2.4. Simulation of the extreme climate conditions

To simulate the extreme climate conditions, closed jars were constructed in which an over-saturated solution of the salt $BaCl_2$ was added. In this way, a relative humidity of 90% was simulated. In these jars, the packages of green Columbian coffee were stored over the 6 months. Every month, the jars were opened to take out 2 packages to analyse. The jars were put in a climate room of 30°C.

2.5. Statistics

In order to be able to detect a significant change in the typical characteristics of the packaged green Columbian coffee, the mean, standard deviation and the 95% of confidence interval was calculated for the duplicates (2 packages) and the duplicates of analysis (water activity and water content).

3. Results:

3.1. Evolution of the headspace gas composition inside the vacuum packages of green Columbian coffee.

In Figure 1, an overview is given of the different analysis of the headspace gas composition during the different months of the storage experiment.

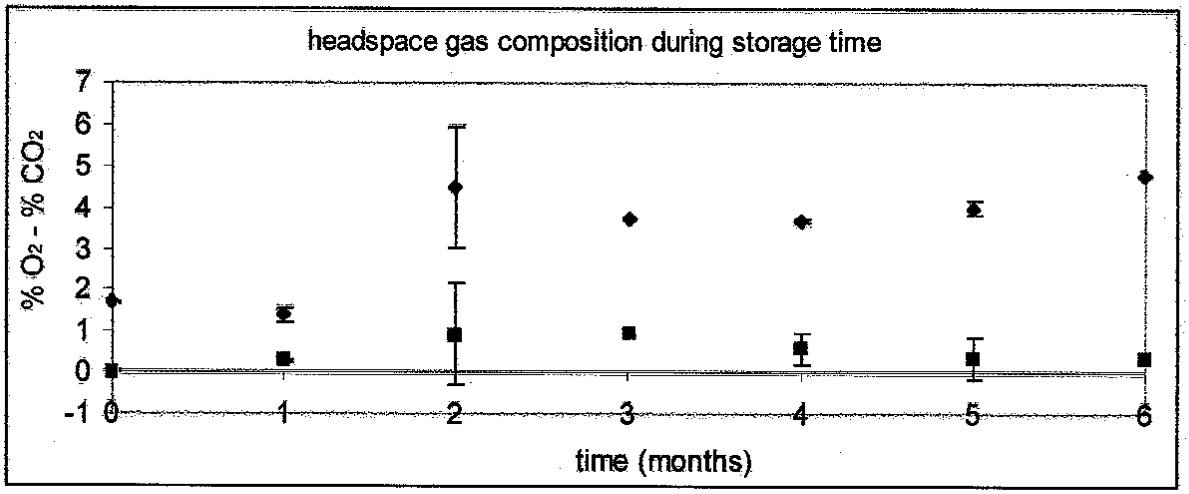

Figure 1. Headspace gas composition in vacuum packaged green Columbian coffee beans, stored at 30°C and 90% relative humidity, during 6 months (♦ % O_2, ■ % CO_2).

The O_2-concentration inside the packages is increasing fast from month 1 to month 2, but is then stabilizing during the further storage period. At month 6, almost 5% O_2 accumulated inside the packages but taking into account the water activity and the water content of the packaged green coffee beans at that moment, this O_2-concentration can be considered as acceptable. However, prudence is called for more moisture coffee beans. In this case, it is possible that the moisture content and water activity of the beans becomes too high during the storage period resulting in an unsafe situation towards microbial growth by the combination with O_2-concentrations around 5%.

The CO_2-concentration remains around 1% throughout the whole storage period. As the dried green coffee beans are not significantly respiring, no accumulation of CO_2 was as well expected.

3.2. Evolution of the water activity of the green coffee beans

The water activity of the green coffee beans packaged in a vacuum system was followed during the storage period of 6 months. The water activity is an important indicator of the microbiological stability of a (food) product. Every micro-organism has a certain, specific minimum water activity for growth, toxin formation,... Moulds can sustains low water activities and are in this case of dried green coffee beans the most important group of spoilage micro-organisms.

To evaluate a possible distribution of water in the vacuum package during storage, samples were taken every month on the surface and in the middle of the package. Both samples were analysed in duplicate. This was performed every month for 2 packages, except for month 3 and month 6 where only 1 package was opened.

In figure 2, the evolution of the water activity of the green coffee beans is illustrated, situated on the surface of the vacuum packages.

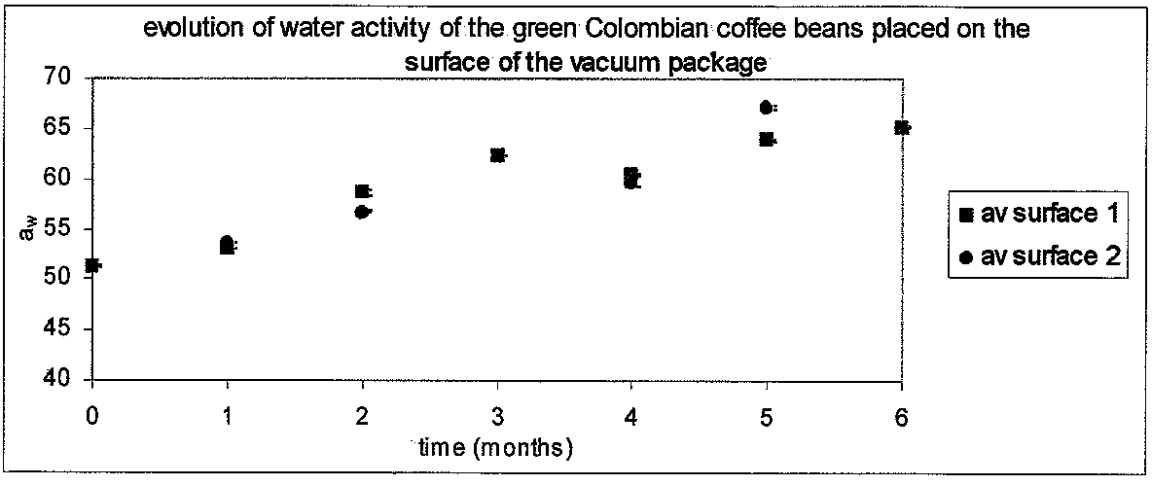

Figure 2. Evolution of the water activity (± standard deviation) of green Colombian coffee beans, situated on the surface of vacuum packages during a storage period of 6 months, in extreme climate conditions (30°C and 90% relative humidity).

An increase was found over 6 months from $a_w = 51.35$ to $a_w = 65.40$ of the green Colombian coffee beans situated on the surface of the package. Initially, the water activity of the green Colombian coffee beans was very stable ($a_w < 60$).

During storage a rehydration was occurring resulting in an increase in the water activity. After 6 months, the water activity was higher but the product can still be accepted as microbiological stable.

Note as well that no big difference was found in the water activity of the coffee beans situated on the surface between the duplicate packages.

In Figure 3, the evolution of the water activity is illustrated of green Colombian coffee beans placed in the middle of the vacuum packages.

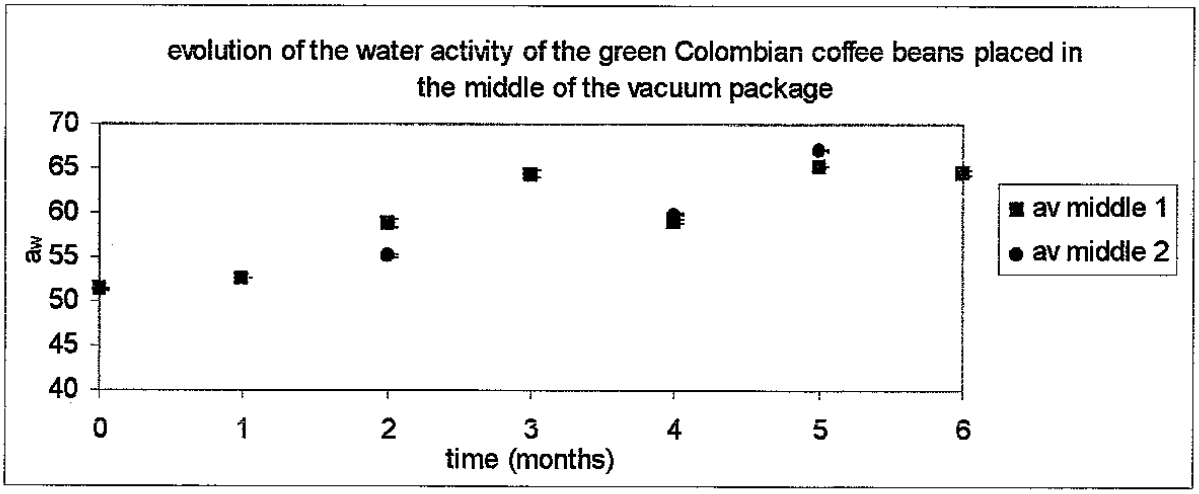

Figure 3. Evolution of the water activity (± standard deviation) of green Colombian coffee beans situated in the middle of the vacuum package during the storage period of 6 months in extreme climate conditions (30°C and 90% relative humidity).

An increase from a_w = 51.35 to a_w = 64.2 was found for the green Colombian coffee beans situated in the middle of the vacuum packages. Again, no difference was found in the water activity between the 2 duplicated samples.

A slight but significant lower water activity was measured for the coffee beans, situated in the middle of the package, compared to the water activity of the coffee beans on the surface of the package (figure 2 and 3).

3.3. Evolution of the water content (%H_2O s.s.) of the green coffee beans

The water content of the green coffee beans packaged in a vacuum system was followed during the storage period of 6 months. The water content is another important indicator of the quality of dried products. The water content is giving an indication of the total amount of water of the beans.

As for the water activity, also the water content was determined from green Colombian coffee beans, situated in the middle and on the surface of the package. The determination was conducted in duplicate and every month 2 packages were analysed (except month 3 and month 6).

In Figure 4, the evolution of the water content of green Colombian coffee beans is illustrated during the storage period of 6 months in a vacuum packaging system and in extreme climate conditions (30°C and 90% relative humidity). The beans were situated in the middle of the packages.

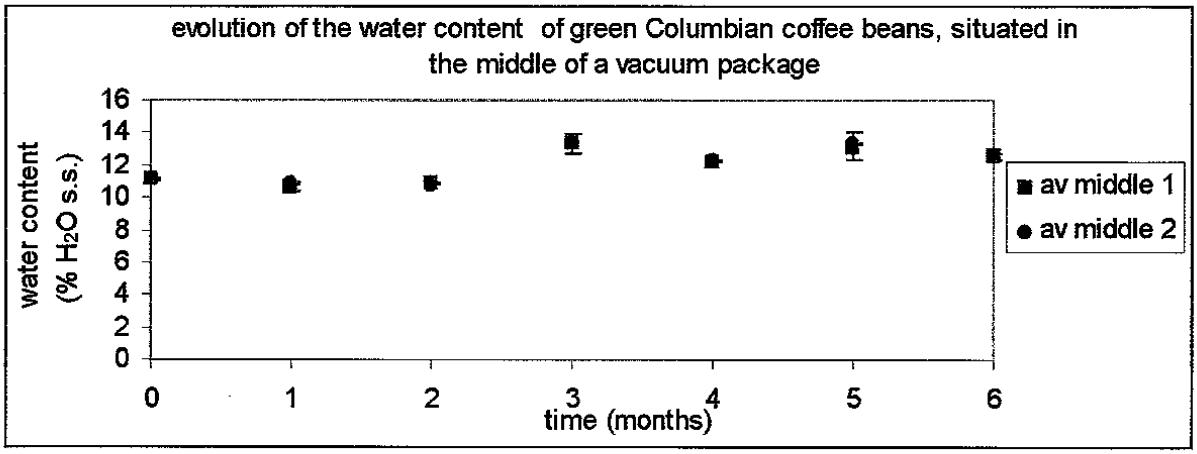

Figure 4. Evolution of the water content (± standard deviation) (%H_2O s.s.) of green Colombian coffee beans during a storage period of 6 months.

During the storage period of 6 months, the water content of the beans is increasing from 11 to 12.8. This is a relative small increase indicating the good barrier of the packaging film for water vapour. Also in the water content, no difference was detected in between the 2 analysed packages.

In figure 5 the determined water content of the green coffee beans, situated on the surface of the vacuum package is illustrated.

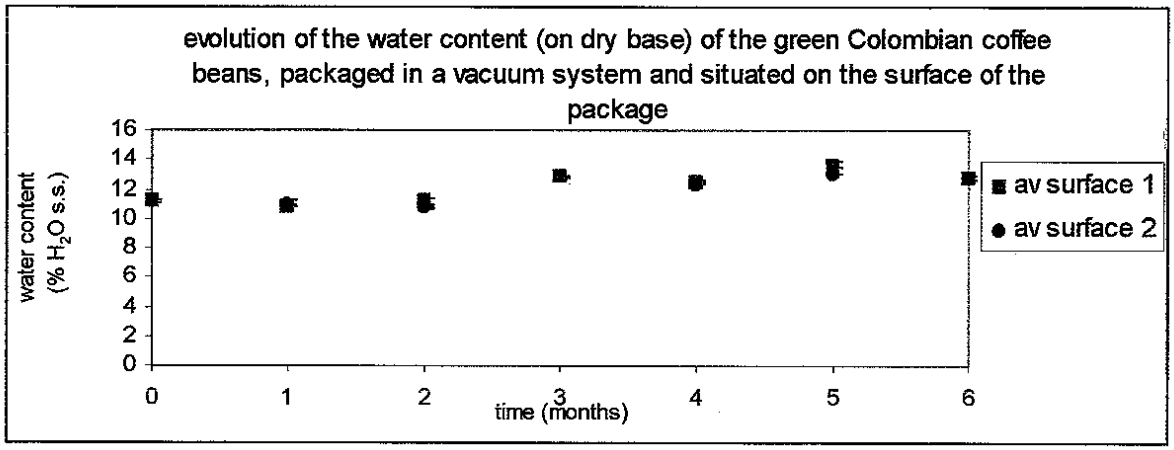

Figure 5. Evolution of the water content (± standard deviation) of green Columbian coffee beans, packaged in a vacuum system and stored under extreme conditions (30°C and 90% relative humidity).

The water content of the coffee beans situated on the surface of the package is increasing in the same way as for the coffee beans placed in the middle of the package (figure 4). Again, no difference could be found between the beans of the 2 analysed packages (duplicates).

In general, no significant difference was measured in between the water content of the coffee beans, situated in the middle and on the surface of the packages throughout the 6 months of storage.

3.5. Comparison of the method for measuring the water content of green coffee beans

The water content was measured for the month 6 by the 2 proposed methods in Materials and Methods 2.1.

In Table 1, an overview is given of the results, indicating that there is a small but significant difference in the values, obtained by the ISO method (ISO 6673-1983, determination of loss in mass at 105°C) and the method applied by the Laboratory of Food Microbiology and Food Preservation.

The big difference in procedure is the fact that in the ISO method the beans are complete while in the other method the beans are ground.

Table 1. Comparison of methods for the determination of water content of green coffee beans

ground beans (% H_2O s.s.)		**complete beans (% H_2O s.s.) (ISO 6673-1983)**	
surface	middle	surface	middle
12.69	12.45	12.34	11.72
12.84	12.66	12.35	12.14
12.83	12.78	12.22	12.02
12.87	12.64	12.48	12.15
average = 12.81	average = 12.63	average = 12.35	average = 12.01
stdev = 0.08	stdev = 0.14	stdev = 0.11	stdev = 0.20
95% conf = 0.08	95% conf = 0.13	95% conf = 0.10	95% conf = 0.20

3.6. Sorption-isotherm

The sorption-isotherm (relation water activity / water content) (figure 6) was derived from all the obtained points during the storage experiments.

The blue points in figure 6 indicate the sorption-isotherm from the fresh beans that were artificially rehydratated. The green points are the combinations of water activity/water content from older beans, also artificially rehydratated. The pink points are representing the measurements obtained during the storage period in the vacuum packages.

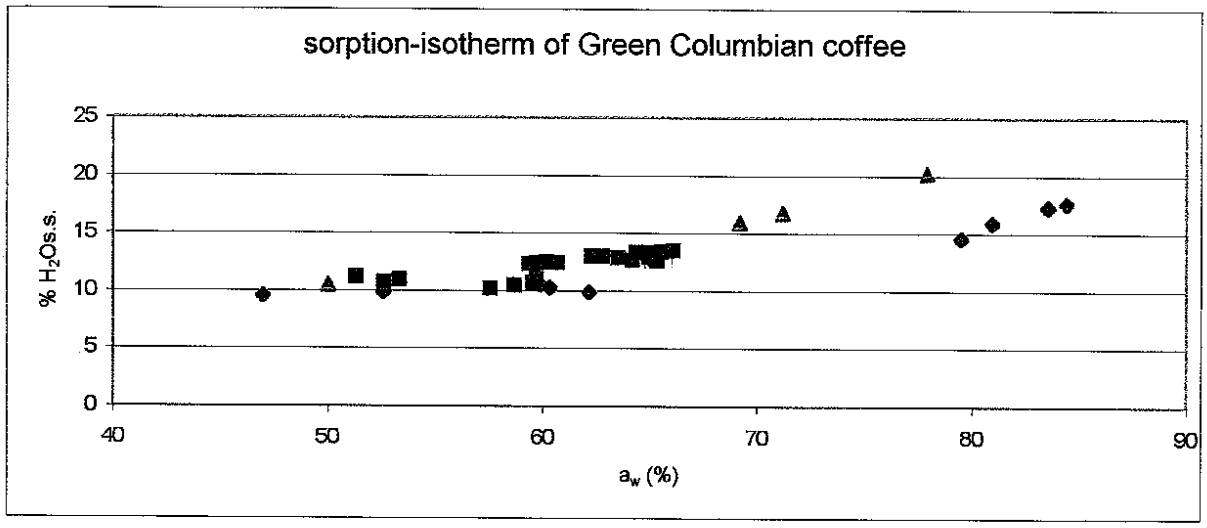

Figure 6. Sorption-isotherm of green Columbian coffee beans

From Figure 6, it can be derived that the water activity is decreasing as a function of storage time for a certain water content. This can possibly be explained by an enzymatic fragmentation of compounds in the coffee beans resulting in a higher amount of bounded water and consequently, a decreasing water activity.

4. Conclusion:

It can be concluded that a vacuum packaging system is a good possibility to package and preserve dried green coffee beans. If the packaging film is adapted to the needs of the green coffee beans, a sufficient protection against rehydratation and oxidation can be performed. Rehydratation can result in a poor microbiological stability, enzymatic activity and intense respiration activity of the beans. The applied packaging film had enough barrier properties to provide a small, acceptable increase in O_2-concentration in the headspace of the package and a small, acceptable increase in water content and water activity of the green Colombian coffee beans, stored in extreme climatic conditions (30°C and 90% relative humidity over 6 months.

If the water activity of the starting material would be higher than applied for this experiment, it is possible that a higher barrier for oxygen and water vapour of the packaging material would be requested to ensure microbial stability during the 6 months of storage.

When the water activity of the product is at the same level of the analysed sample, it can be concluded that a vacuum packaging system is a good possibility to package and preserve dried green coffee beans