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Research Article

Influence of the Conservation Method on the Postharvest Quality Indicators of *Phaseolus vulgaris* L

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Abstract:

Phaseolus vulgaris L. is one of the grains that in Cuba enjoys a long tradition of consumption and demand, being essential in the diet of the people, as an alternative source of proteins and minerals. In this sense, the indicators that determine the quality of these orthodox seeds are of great value for their proper post-harvest conservation, since different properties have a negative impact on this food. The work consisted of determining the influence of the conservation method on the postharvest quality indicators of *Phaseolus vulgaris* L. The conservation method used was storage in paper-covered envelopes at ambient temperature and relative moisture for 12 months. The study varieties were CUFIG 48, La Cuba 154, CUFIG 110, CUL 156, CUFIG 145, Delicias 364, Engañador and Quivicán. The quality evaluation was carried out based on the determination of the following different physical properties: permeability of the cover, absorption capacity, water activity, moisture content and chromatic composition. The results showed that of the eight common bean cultivars, Quivicán had the highest absorption capacity, while the Engañador beans have the highest impermeability of the cover. The packaging used did not guarantee that the grain would not absorb moisture over time; however, 50 % retained the chromatic composition that indicated no hardening problems, mainly in the black and cream varieties, which is why it constituted an option for short-term conservation.

Key words: conservation; common bean; postharvest

Introduction

The common bean (*Phaseolus vulgaris* L.) is the most valued legume for human consumption due to its high protein content, the abundance of vegetable fiber, the presence of complex carbohydrates, vitamins and for being a key source of minerals such as zinc and iron (Kangue and Boicet, 2020).

It is one of the basic foods in Cuba and is essential in many countries on the American continent, along with rice and corn flour. Currently, domestic production meets only 3% of consumer demand, requiring around 110,000 tons of grain to be imported each year. For this reason, among the priorities of Cuban agriculture is to increase the production of this crop, allocating large extensions of land both in the state sector, as well as in the cooperative and peasant sectors, with strategies and technologies that are friendly to the environment, improvement of cultivars, increase in seed production, among others (Díaz et al., 2021).

However, although this grain is part of the group of non-perishable foods, its handling after harvest is conditioned by several factors that cause deterioration such as temperature, relative humidity and other elements to consider during conservation.

In this sense, the evaluation of physical indicators of post-harvest quality of stored common bean varieties, for the environmental conditions of Cuba, where high temperatures and relative humidity prevail, would be important to establish technical criteria for prolonged conservation. Among the indicators that determine the culinary quality of this grain are the percentage of seed coat, water absorption capacity, cooking time, conditions and storage time, while those that determine nutritional quality include the content of anti- nutritional factors, as well as proteins, micronutrients, starches and fiber, in others (Abay and Tolesa, 2023).

In turn, within the species *Phaseolus vulgaris* L. there are different types of grains and the commercial value is influenced by characteristics such as size, color, uniformity of the grain, among other indicators. However, the technological, physicochemical and functional quality of grains is determined by the interaction between the genotype and storage conditions; Therefore, not all grains stored for a long period become dark or difficult to cook (Alves et al., 2021). The objective of this work was to determine the influence of the conservation method on the postharvest quality indicators of *Phaseolus vulgaris* L.

Materials and Methods

The experiments were carried out in the Postharvest Biology and Technology laboratory of the Institute for Fundamental Research in Tropical Agriculture "Alejandro de Humboldt" (INIFAT). In the study, the conservation method used was storage in paper-covered envelopes at ambient temperature and relative moisture for 12 months and for this, the eight bean varieties shown in Figure 1 were used.

Figure 1: Bean varieties used in the study

Experimental development:

The quality evaluation was carried out by determining the different physical properties described below:

- Roof permeability

The degree of permeability was evaluated from the type of sorption isotherm as established by Hernández et al. (2021). To determine the curve, the static method (analytical technique of hygroscopic equilibrium) at room temperature was used. To do this, 2.15 ± 1.0 g bean seeds of each variety were placed in triplicate in desiccators with different saturated saline solutions until equilibrium was reached (Table 1). The weight of the sample was determined daily until a constant weight was obtained and subsequently the equilibrium moisture contents were calculated using the method AOAC (1990). The experimental equilibrium data were plotted as a function of water activity to obtain the adsorption curve of each variety (Figure 2).

Saline solution	Relative moisture (%)
Lithium chloride	11.2
Magnesium chloride	33
Magnesium nitrate/Calcium nitrate	53
Sodium chloride	75
Potassium chloride	82.6
Potassium sulphate	92

$$X_e = K_1 a_w^{n_1} + K_2 a_w^{n_2} \qquad \text{Equation 1}$$

Legend:

Xe: Equilibrium moisture content ($g \cdot g^{-1}$ bs)

k1: represents the mass transfer ($g.g^{-1}$ bs)

k2: represents the absorption capacity ($g.g^{-1}$ bs)

n1, n2: constant product characteristics and related to absorption heat.

Table 1: Saline solutions used in hygroscopic balance

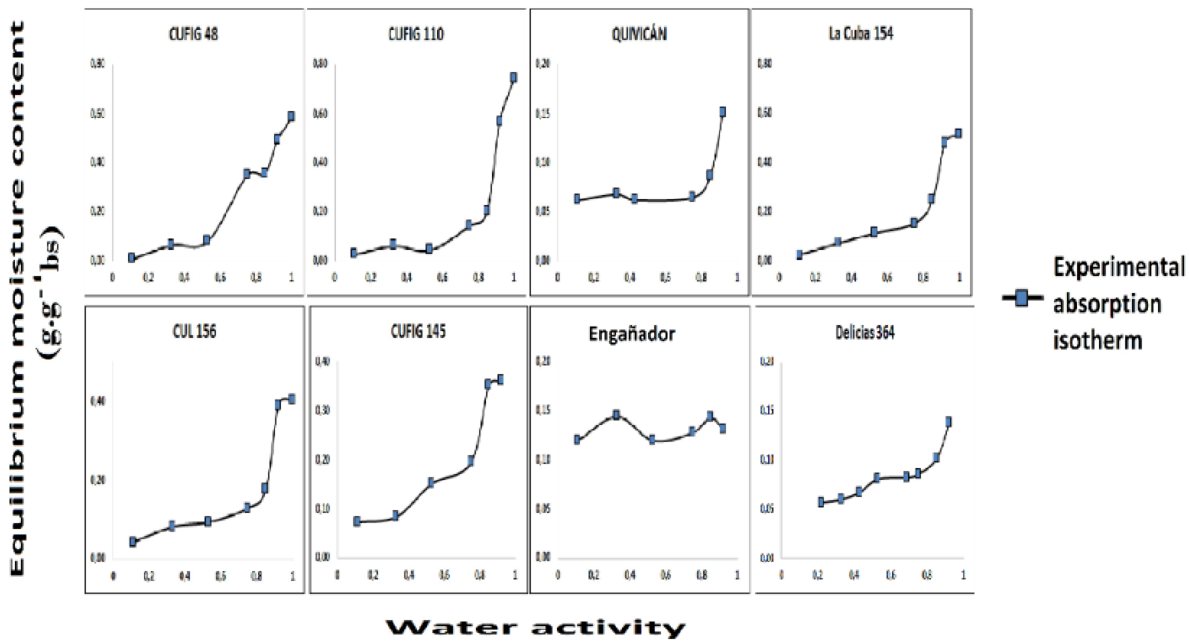

Figure 2: Absorption isotherms of each seed

•Absorption capacity

In determining the absorption capacity, the mathematical interpretation of the coefficients of the Peleg model (Equation 1) was used. For this, the experimental data of the sorption isotherms for the eight varieties were used.

• Water activity content

The determination of water activity (aw) was by direct measurement with a Smart Water Activity Meter brand laboratory water activity meter. With a measurement range between 0 and 0.98 aw, a precision of ± 0.015 aw. The activity is dimensionless and takes values between 0 and 1.

• Moisture content

The initial moisture content of the seeds was determined in triplicate, according to the gravimetric method (2 hours at 130 °C) (AOAC, 1990) and for this an OHAUS Explorer brand analytical balance was used with a precision of 0.0001 g and a MEMMERR brand stove.

• Chromatic composition

The chromatic composition was determined using the CIELAB color space (L*a*b*), measurement equipment used was a Konica Minolta CR-400 colorimeter. Display value range: Y: 0.01% to 160.00% (reflectance) and a standard deviation within ΔE*ab: ±0.07. The instrument was first calibrated using standard white plate with transparent paper placed over the standard plate. After calibration, color measurements were taken at random in triplicates.

Results

In the Engañador cultivar, a sigmoidal behavior was obtained, which indicated impermeability in the cover of these samples. On the contrary, in the rest of the varieties the curves were concave upwards, which demonstrates permeability in the teste of these seeds.

Table 2 shows the mathematical fit of the experimental data of the absorption isotherm of each variety to the Peleg model. The results obtained for the C coefficient demonstrated the variability in the absorption capacity that each of the evaluated varieties presented (Figure 3), so the existence of surface and internal absorption in the seeds was confirmed to exception of the seeds of Engañador.

Coefficients	Quivicán	CUFIG 110	Cuba 154	CUFIG 48	CUL 156	CUFIG 145	Delights 364	Deceiver
k_1	-0,89	0,03	0,10	0,209	0,196	0,267	0,100	0,94
$\mathbf{k_2}$	**0,99**	**0,74**	**0,44**	**0,40**	**0,237**	**0,108**	**0,016**	**-0,81**
n_1	0,27	-0,06	0,47	2,794	1,379	1,102	0,608	0,26
n_2	0,27	6,48	5,10	3,00	7,224	10,571	0,569	0,33
R^2	0.95	0.96	0.94	0.97	0.89	0.86	0.76	0.23

Legend:

k_1: represents the mass transfer (g.g^{-1} bs)

k_2: represents the absorption capacity (g.g^{-1} bs)

n_1, n_2: constant product characteristics and related to absorption heat.

Table 2: Mathematical adjustment of the experimental data to the Peleg model

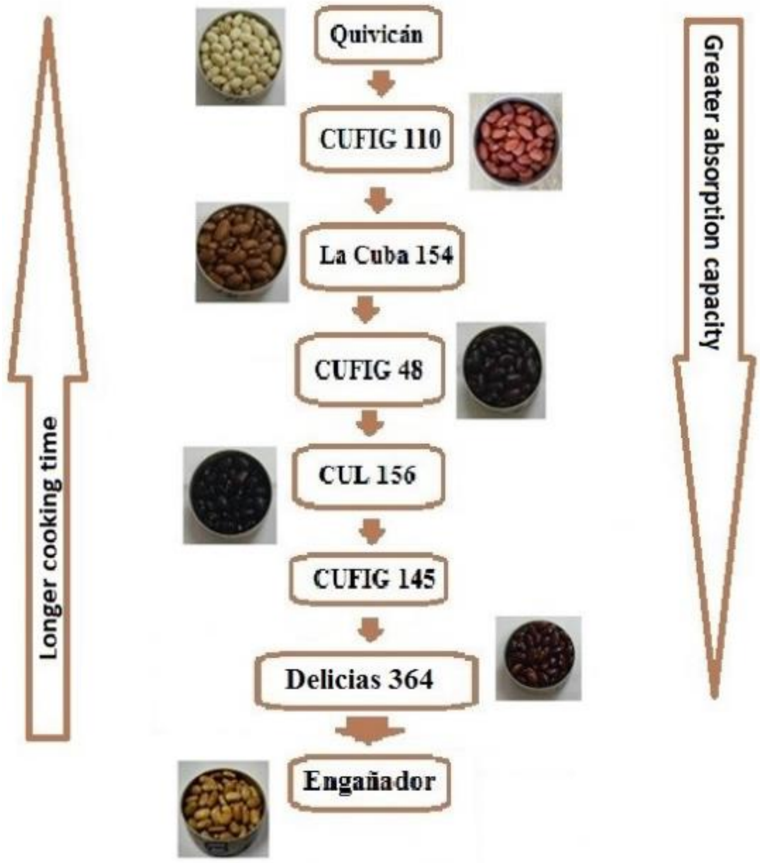

Figure 3: Classification of the varieties studied according to their absorption capacity.

Moisture content remained below 12 % for all grains (Table 3). However, they are above the moisture content that guarantees long-term conservation. Therefore, it was found that these seeds are absorbing moisture in the storage conditions to which they are exposed.

The greatest changes in L* values were obtained for the varieties Quivicán, Engañador, Delicias 364 and CUFIG 110, which indicated at a chromatic level a darkening of the teste of these beans (Table 3). Additionally, as an average, values of 0.63 ± 0.03 of aw were obtained for the evaluated cultivars, which shows high water activity, associated with the permeability of the teste, inadequate technological management during drying or problems during conservation, related to the type of packaging or thermodynamic variables.

Bean varieties	Moisture (%bs)	L*	a*	b*	Water activity
CUFIG 145	9.80	62.81	5.96	14.11	0.616
Quivicán	6.90	25.80	8.03	12.19	0.657
Engañador	11.68	27.62	13.17	22.65	0.669
LA CUBA 154	9.28	51.15	11.76	21.25	0.614
Delicias 364	7.12	12.60	17.24	19.86	0.641
CUFIG 110	10.21	24.73	23.73	12.54	0.598
CUFIG 48	7.59	12.39	1.51	4.83	0.663
CUL 156	9.46	13.41	2.27	5.21	0.605
Average	**9.00**	**28.8**	**10.5**	**14.1**	**0.63**
Standard deviation	**±1.67**	**±18.7**	**±7.6**	**±6.8**	**±0.03**

Legend: L*: Luminosity

a*, b*: Chromatic coordinates.

Table 3: Moisture content of five bean varieties

Discussion

Legume seeds have a complex structure and depending on the degree of permeability of the cover, the equilibrium moisture content curves in general can transition between two standard shapes: concave and sigmoidal. When there is a delay phase in the hydration kinetics, a sigmoidal behavior is obtained and is indicative of impermeability in the cover of the samples as occurred in the Engañador seeds. In the opposite case, when there is permeability in the head, geometrically the absorption shows a concave upward type curve.

Hernandez *et al*. (2021) state that when the grains have an impermeable cover, water enters through the hilum and crosses the hilar groove and the tissue of the tracheid bar to reach the radicle lobe. Water is then distributed into the space between the inner face of the seed coat and the cotyledon. Once the seed coat is hydrated from the inside, it becomes permeable and water penetrates, not only through the hilum, but also through the cover by diffusion. Finally, the cotyledon is hydrated by diffusion and capillarity until equilibrium moisture is reached.

The absorption capacity obtained represented, for the varieties under study, the existence of a large amount of water bound to the adsorption sites of insoluble solids; as well as, in complex aqueous solution. Water absorption is closely linked to the hydration and swelling capacity of the grain in a certain period. The absorption values obtained reflect higher hydration and swelling coefficients than those reported by Wacu *et al*. (2015) for similar thermodynamic storage conditions. However, the author demonstrates that after storage, high temperatures can produce chemical changes in the teste, making it harder and less permeable to water, thus preventing it from spreading and reaching the cotyledons.

The authors Kangue and Boicet (2020) and Socorro *et al*. (2023) suggest that this is related to the "Hard Front" phenomenon, associated with long cooking times, so that the greater the absorption capacity (C), the cooking times are generally shorter. This characteristic can be used in the seed selection process to eliminate in future generations those lines that absorb less water, which allows evaluating the degree of permeability of the bean grain during waterlogging and detecting this phenomenon closely related to the cooking time.

Cooking times can be prolonged by two different processes related to the absorption of water by the seeds: the first “Hard seed coat” which may be due to the low permeability of the seed seed and the second “Difficult to cook” which occurs in those seeds that absorb enough water, but fail to soften after soaking and subsequent cooking time (Abay and Tolesa, 2023).

Moisture content influences several physiological factors essential for controlling grain or seed quality. This is why there is no single satisfactory moisture determination method for all biological materials, where the most efficient technique depends on its chemical composition and structure. According to Hernández et al. (2023) for the varieties under study, the moisture content that guarantees the long-term conservation of these varieties at room temperature is between 0.05 and 0.07 $g.g^{-1}$ bs (5 and 7 %).

On average, 9.27 ± 1.60% moisture was obtained, values that, although higher than the equilibrium moisture content of each variety for the environment to which it is exposed, are lower than those reported by Mora (1980). This author found that the beans can be stored for five months at 25 ºC and with 15.4 % moisture, without detecting hardening problems. On the other hand, generally, it has been found that the higher the storage temperature and moisture, the greater the hardening of the grain in a given time.

The L* values determine the lightness or darkness of the material; That is, the smaller L*, the darker the sample will be and vice versa. Authors such as Wacu *et al*. (2015) state that during storage there is an increase in the darkening of the seed coat associated with the joint action of relative humidity, storage time and temperature, which can lead to the hardening of the bean. This behavior was not evident in 50 % of the samples evaluated despite the shelf period, which may indicate a conservation of this physical property in the type of packaging used, mainly for dark-colored varieties.

Seeds gain or lose water to achieve a hygroscopic balance and this movement of water depends on climatic conditions, such as temperature, moisture, and on the chemical composition of the seed. Microorganisms do not grow at low aw, their growth can occur in foods of intermediate moisture. That is why there are aw that limit the growth of molds, yeasts and bacteria.

The concept of water activity (aw) in a material allows us to express the degree of freedom that the water contained in it has. Thus, a product exchanges with the environment that surrounds it until an equilibrium is established. Under these conditions, the value of the relative moisture of the air is called the water activity of the product. In this sense, for the environmental conditions (mainly temperature and relative moisture) at which the seeds are preserved; the development of yeasts is mainly conducive. However, as paper covers do not guarantee stopping the absorption process, the risk of fungal contamination increases. Hence the importance of drying well after harvesting and using airtight containers for long-term storage. Temperature during storage causes deterioration in the quality of common bean seeds. Wacu *et al*. (2015) states that the main evidence of this is the increase in the hardness of the cotyledons or the loss of the ability to soften with cooking, followed by the deterioration of color, texture and loss of nutritional value. Studies where 35 and45°Ctemperatures were used (higher than those of this study) for different shelf periods, found a reduction in absorption, reflected in lower hydration and swelling coefficients, which in turn decreased the capacity of cooking the seeds (Abay and Tolesa, 2023).

Conclusions

1. Of the eight common bean cultivars preserved at room temperature, Quivicán has the greatest absorption capacity, while the grains of the Engañador variety have the greatest impermeability of the cover.

2. Paper-covered containers do not guarantee that common bean cultivars do not absorb moisture over time; however, 50 % retain their chromatic composition, which may be indicative of the absence of hardening problems, mainly in the varieties of black and cream color.

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