Food Chemistry 49 (1994) 187–190

A fast laboratory procedure to assess the hard-to-cook tendency of common bean varieties

C. Reyes-Moreno,[a,b] O. Paredes-López,[a*] & I. Barradas[c]

[a]*Laboratorio Biotecnología de Alimentos, Centro de Investigación y de Estudios Avanzados del IPN, Apartado Postal 629, 36 500 Irapuato, Gto, México*
[b]*Facultad de Química, Universidad Autónoma de Sinaloa, Culiacán, Sinaloa, México*
[c]*Centro de Investigación en Matemáticas, Guanajuato, Gto, México*

(Received 21 October 1992; revised version received and accepted 24 April 1993)

Common beans (*Phaseolus vulgaris* L.) develop the hard-to-cook (HTC) defect during storage at high temperatures and relative humidities. The objective of this work was to develop a fast laboratory procedure to assess the tendency of common bean seeds to become HTC. Four samples of common beans (cv Flor de Mayo, Mayocoba, MAM-13 and MX 2340-5) were grown under irrigation (Etzatlán and Cocula conditions) and rain-fed (Etzatlán) conditions. Two hardening procedures were used: (1) Storage hardening. Samples were stored at 33–35°C, 76% relative humidity for 120 days, sampling every 20 days; (2) Chemical hardening. Materials were soaked in 0·1 M acetate buffer, pH = 4·0, at 37°C for 1–7 h. For both hardening procedures, changes in cooking time and hardness were mathematically estimated with a relative percentage deviation of 4·8–6·0% and 1·8–5·8%, respectively. Chemical hardening might be useful for screening new bean varieties; its advantage over the storage method is its rapidity.

INTRODUCTION

Storage of common beans under adverse conditions of high temperature and relative humidity renders them susceptible to the hardening phenomenon characterized by extended cooking time of the cotyledons (Jones & Boulter, 1983; Hincks & Stanley, 1987; Paredes-López *et al.*, 1989*b*) and seed coat softening (De León *et al.*, 1989; Cárabez-Trejo *et al.*, 1991). In order to prevent the development of the hard-to-cook (HTC) defect in legumes, several procedures have been proposed: (1) appropriate storage; (2) controlled atmospheres; and (3) pretreatments (e.g. steaming, roasting, irradiation, solar drying, microwaving). Only irradiation and low temperature/low humidity storage have been successful, and both of these have practical drawbacks in developing countries (Michaels & Stanley, 1988). It has been suggested that a workable solution to the hardening problem may well be the development of common bean materials less prone to the HTC phenomenon (Reyes-Moreno, 1992). Some researchers (Jackson & Varriano-Marston, 1981; Vindiola *et al.*, 1986; Paredes-López *et al.*, 1989*b*) have proposed the use of accelerated storage to discriminate common beans by their tendency to hardening. An ideal method must be simple and very rapid, it should discriminate bean cultivars according to their hardening tendency, and finally, it should be applicable to plant breeding purposes. The objective of this work was to develop a fast laboratory procedure to assess the HTC tendency of common bean materials.

*To whom correspondence should be addressed.

Food Chemistry 0308-8146/93/$06.00 © 1993 Elsevier Science Publishers Ltd, England. Printed in Great Britain

MATERIALS AND METHODS

Bean samples

Four common bean cultivars (*Phaseolus vulgaris* L.), cv. Flor de Mayo, Mayocoba, MAM-13, MX 2340-5) were seeded at two locations, Etzatlán and Cocula, in Jalisco, México. Etzatlán was tested under irrigation and rain-fed conditions and Cocula only under irrigation. Common bean materials were harvested, shelled and cleaned. All beans were harvested between 12·0 and 12·5% moisture content, but this content was reduced to 11·0% in an oven under a dry stream of air (Reyes-Moreno, 1992). Fresh samples were kept in plastic bags inside air-tight containers at 4°C until utilization.

Hardening procedures

Samples were hardened by two procedures: (1) storage hardening: a portion of seeds from each cultivar was stored at 33–35°C, 76% relative humidity for 120 days. An attempt was made to simulate average conditions prevalent in some bean production areas. Samples were taken every 20 days throughout this storage period; (2) Chemical hardening: common bean seeds were soaked, in a 0·1 M acetate buffer (1 : 4 w/v), pH = 4·0, at 37°C for 1–7 h and then dried at room temperature for 48 h.

Cooking time

A Mattson bean cooker, with some modifications, was used to test twenty-five seeds at a time (Mattson *et al.*, 1950; Proctor & Watts, 1987; Reyes-Moreno, 1988). Cooking time was defined as the mean time, of three replications, when fifteen of the beans were cooked, as indicated by plungers dropping and penetrating individual seeds. This 60% cooked point corresponds to the sensorily preferred degree of cooking (Paredes-López *et al.*, 1989*a,b*).

Texture determination

This measurement, reported here as hardness, was performed in an Instron Universal Testing Instrument, model 1000 (Moscoso, *et al.*, 1984; Paredes-López *et al.*, 1988) using a flat $\frac{1}{8}$ in diameter steel punch, 0·5 and 5 kg load cells, and cross-head speed 30 cm min^{-1}. A total of 30 beans, previously cooked for 60 min in 4 vol of boiling distilled water, were punched individually for each treatment and the mean peak force was calculated.

RESULTS AND DISCUSSION

Cooking time

Storage hardening

The influence of storage on cooking times of common bean seeds from the tested locations is illustrated in Figs 1(A)–1(C). Storage caused a significant increase ($P \leq 0.05$) in the cooking times of all materials. The increase was slow during the first 20 days. Between 20 and 40 days of storage all bean seeds, except Mayocoba, increased their cooking times drastically. At 40 days cooking times ranged from 149 min (Mayocoba Etzatlan irrigation) to 276 min (Flor de Mayo Cocula irrigation). Figures 1(A)–1(C) show that at 60 days and until the end of the storage, Mayocoba seeds had cooking times statistically ($P \leq 0.05$) lower than the other cultivars, while Flor de Mayo had the highest values. Thus, Mayocoba and Flor de Mayo were the least and the most prone to hardening during storage, respectively, and MAM-13 and MX 2340-5 had an intermediate behaviour, the former being more susceptible than the latter.

Chemical hardening

The effect of chemical hardening on the cooking times of bean seeds is shown in Figs 2(A)–2(C). The cooking times of all samples increased significantly ($P \leq 0.5$) by soaking in acetate buffer. After 1–3·5 h of soaking there were no significant differences ($P \leq 0.05$) in cooking times among bean materials, and there were even similar values ($P < 0.05$) between some of them. However, at 5 h of soaking and until 7 h, there were significant differences ($P \leq 0.05$) among all samples; Flor de Mayo and Mayocoba showed the highest and lowest cooking times ($P \leq 0.05$), respectively. Again, Flor de Mayo and Mayocoba were the most and the least prone to chemical hardening, respectively.

The curves generated by chemical hardening (Figs 2(A), 2(B) and 2(C) had shapes similar to those obtained by storage hardening (Figs 1(A), 1(B) and 1(C)). In addition, the cooking time ranges obtained at the end of the time period of either method were of comparable magnitude. This may suggest that both methods are equally capable of discriminating bean cultivars based on their susceptibility to develop the HTC condition, which is supported by the fact that the cultivar ranking resulting from both hardening procedures for all growing conditions was the same. According to this ranking, the bean cultivars studied here are susceptible to showing the HTC defect in the following order: Mayocoba < MX 2340–5 < MAM 13 < Flor de Mayo. Since the chemical hardening procedure requires only 4–7 h in order to obtain the same or an even broader effect as obtained after 120 days of storage, the acetate buffer soaking method would be most useful for screening large numbers of common bean lines and cultivars for their susceptibility to become HTC.

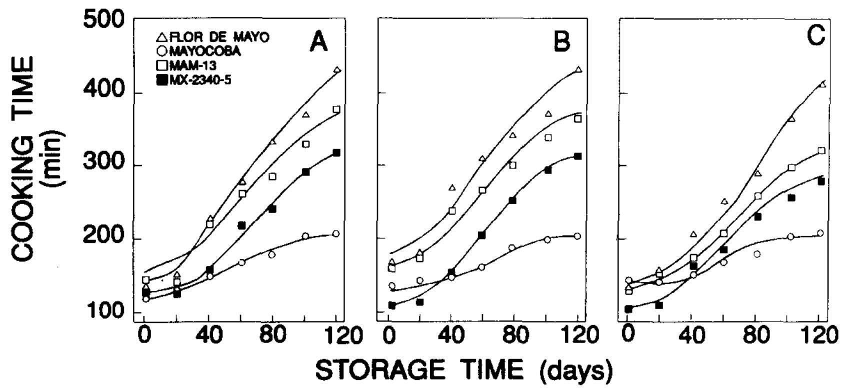

Fig. 1. Influence of storage (33–35°C, RH=76%) on cooking time of common bean seeds. (A) Etzatlán (irrigation); (B) Cocula (irrigation); (C) Etzatlán (rain-fed)(least significant difference (0·05) = 5·5).

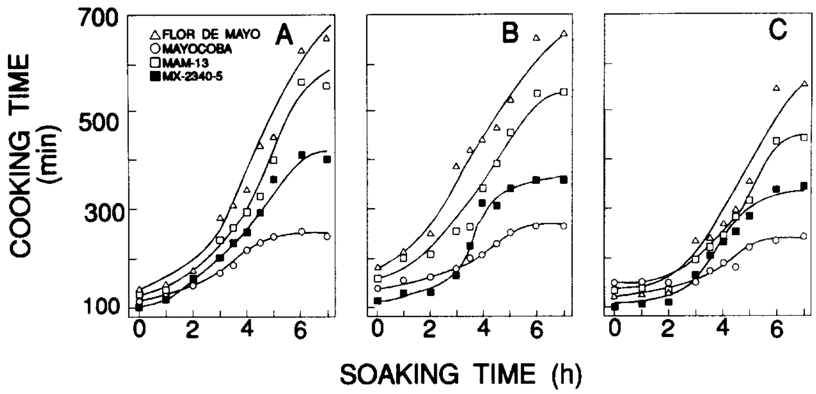

Fig. 2. Influence of soaking in acetate buffer (pH = 4·0, 37°C) on cooking time of common bean seeds. (A) Etzatlán (irrigation); (B) Cocula (irrigation); (C) Etzatlán (rain-fed) (least significant difference (0·05) = 7·1).

Texture determination

The influence of both hardening procedures on seed hardness, as measured using the Instron, of the four common bean cultivars seeded in Etzatlán with irrigation is illustrated in Fig. 3 (A,B). The seed hardness of all materials increased significantly ($P \leq 0{\cdot}05$) during storage (Fig. 3(A)). In newly harvested materials (O days of storage), Flor de Mayo and MAM-13 had similar hardness values ($P \leq 0{\cdot}05$), being higher than those of Mayocoba and MX 2340-5, which had about the same values ($P \leq 0{\cdot}05$). At 20 days, and until the end of storage, Flor de Mayo and Mayocoba were the most and the least susceptible to storage hardening, respectively.

Soaking in acetate buffer referred to as chemical hardening, produced significant increases ($P \leq 0{\cdot}05$) in the hardness of all samples (Fig. 3(B)). At 2–7 h of soaking, all materials showed significant differences in their hardness values ($P \leq 0{\cdot}05$). Flor de Mayo and Mayocoba were the most and the least prone to hardening, respectively. The range of hardness obtained at the end of the soaking method (12·0 Nw/seed for Flor de Mayo to 6·9 Nw/seed for Mayocoba; range = 5·1 Nw/seed) is broader than that of the storage method (10·6 Nw/seed for Flor de Mayo to 6·1 Nw/seed for Mayocoba, range = 4·5 Nw/seed). These results may suggest that the soaking method is not only faster but also more sensitive, i.e. it has more discriminatory power than the storage method. The same kind of comparison can be made with Figs 1 and 2, and actually the same conclusion may be reached. In general, the curves of Fig. 3 followed shapes similar to those of Figs 1 and 2.

Mathematical model for cooking time and hardness changes

For both hardening procedures, changes in cooking time and hardness followed patterns that may be described by a sigmoidal growth equation known as a Logistic Translated Model (Ratkowsky, 1983):

$$x(t) = x(\mathrm{O}) + \frac{a}{(1 + \exp\,(b - ct))} \qquad (1)$$

where $x(t)$ is cooking time or hardness at time t of storage or soaking in acetate buffer, x(O) is initial cooking time or initial hardness, a is maximum cooking time or maximum hardness, c is rate at which cooking time or hardness changed from its 'initial' to its 'final'

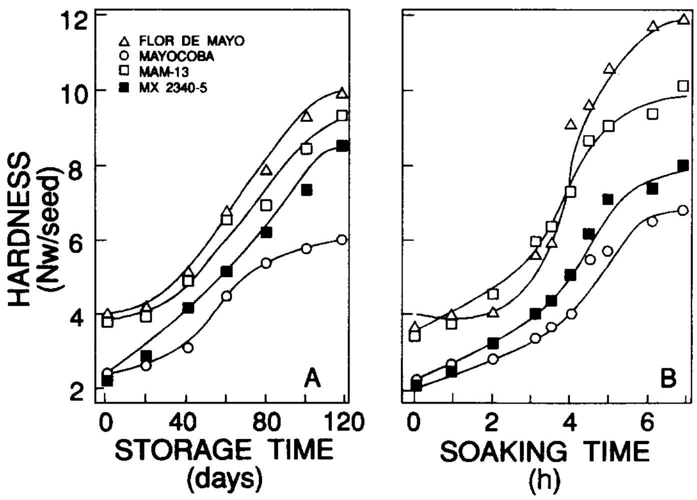

Fig. 3. Influence of storage (33–35°C, RH = 76%) and soaking in acetate buffer (pH=4·0, 37°C) on hardness of common bean seeds (Etzatlán irrigation). (A) Storage hardening; (B) chemical hardening (least significant difference (0·05) = 0·12).

value, b is Intrinsic curvature, which may be assessed with eqn (2):

$$b = \frac{\left| \dfrac{d^2x(t)}{dt^2} \right|}{\left[1 + \left(\dfrac{dx(t)}{dt} \right)^2 \right]^{3/2}} \qquad (2)$$

All values estimated with the mathematical model followed the observed measurements very closely. For both hardening procedures, cooking time and hardness were mathematically estimated with a relative percentage deviation of 4·8–6·0% and 1·8–5·8%, respectively. In conclusion, the results of this study suggest that soaking in acetate buffer (pH = 4·0, 37°C, 4–7 h) might be useful for screening new bean varieties and selecting those less prone to hardening defect, using either a modified Mattson bean cooker or a puncture force method. The advantage of the acetate buffer soak method over the storage method is its rapidity.

ACKNOWLEDGEMENTS

We gratefully acknowledge the Instron facilities made available to us by Dr G. Montejano from Universidad de San Luis Potosí, and the financial support by Consejo Nacional de Ciencia y Tecnología-México.

REFERENCES

Cárabez-Trejo, A., Reyes-Moreno, C., Paredes-López, O. & Palma-Tirado, L. (1991). Endurecimiento del frijol común —Cambios estructurales en la testa durante el desarrollo y la reversibilidad del fenómeno. XXII Congreso Nacional de Ciencia y Tecnología de Alimentos held in Guadalajara, Jalisco (México), Sept. 21–24, 1991.

De León, L. R., Bressani, R. & Elías, L.G. (1989). Effect of seed coat on the hard-to-cook phenomenon of common beans *(Phaseolus vulgaris). Arch. Latinoamer. Nutr.*, **39**, 405–7.

Hincks, M. J. & Stanley, D. W. (1987). Lignification: evidence for a role in hard-to-cook beans. *J. Food Biochem.*, **11**, 41–58.

Jackson, G. M. & Varriano-Marston, E. M. (1981). Hard-to-cook phenomenon in beans: effects of accelerated storage or water absorption and cooking time. *J. Food Sci.*, **46**, 799–803.

Jones, P. M. B. & Boulter, D. (1983). The cause of reduced cooking rate in *Phaseolus vulgaris* following adverse storage conditions. *J. Food Sci.*, **48**, 623–26.

Mattson, S., Akerberg, E., Eriksson, E., Koulter-Anderson, E. & Vahtras, K. (1950). Factors determining the composition and cookability of peas. *Acta Agric. Scan.*, **1**, 40–61.

Michaels, T. M. & Stanley, D. W. (1988). Is the hard-to-cook defect at common beans under genetic control? In *Bean Network. Proceedings of the Third workshop*, held in Termas de Panimavida, Chile. IDRC, Ottawa, Canada, pp. 91–7.

Moscoso, W., Bourne, M. C. & Hood, L. F. (1984). Relationships between the hard-to-cook phenomenon in red kidney beans and water absorption, puncture force, pectin, phytic acid and minerals. *J. Food Sci.*, **49**, 1577–83.

Paredes-López, 0., Maza-Calviño, E. C. & Montes-Rivera, R. (1988). Effect of the hard-to-cook phenomenon on some physicochemical properties of bean starch. *Starch/Stärke*, **40**, 205–10.

Paredes-López, O., Maza-Calviño, E. C. & González-Castañeda, J. (1989*a*). Effect of the hardening phenomenon on some physicochemical properties of common beans. *Food Chem.*, **31**, 225–36.

Paredes-López, O., Reyes-Moreno, C., Montes-Rivera, R. & Cárabez-Trejo, A. (1989*b*). Hard-to-cook phenomenon in common beans—influence of growing location and hardening procedure. *Int. J. Food Sci. Technol.*, **24**, 535–42.

Proctor, J. P. & Watts, B. M. (1987). Development of a modified Mattson bean cooker procedure based on sensory panel cookability evaluation. *Can. Inst. Food Sci. Technol. J.*, **20**, 9–14.

Ratkowsky, D. A. (1983). Sigmoidal growth models. In *Nonlinear egression Modelling*, ed. D. B. Owen. Marcel Dekker, New York, pp. 61–87.

Reyes-Moreno, C. (1988). Influencia de la localidad de siembra sobre la calidad de cocción y propensión al endurecimiento del frijol común. M.Sc. thesis, Unidad Irapuato, CIEA-IPN and Universidad Aut. de Querétaro, México.

Reyes-Moreno, C. (1992). Endurecimiento del frijol común—Desarrollo de procedimientos para su prevención y cambios fisicoquímicos durante la reversibilidad de este fenómeno. Ph. D. thesis, Unidad Irapuato, CIEA-IPN, Irapuato, Gto, México.

Vindiola, O. L., Seib, P. A. & Hoseney, C. (1986). Accelerated development of the hard-to-cook state in beans. *Cereal Foods World*, **31**, 538–52.