Journal of Applied Sciences

ISSN 1812-5654

Journal of Applied Sciences 8 (6): 1103-1107, 2008
ISSN 1812-5654

PC-Based Instrumentation System for the Study of Bean Cooking Kinetic

[1]Bitjoka Laurent, [2]Teguia Jean-Blaise and [3]M.F. Mbofung Carl
[1]Department of Electrical Engineering, Energetic and Automatics,
[2]Department of Process Engineering,
[3]Laboratory of Biophysics and Food Biochemistry, Department of Food Sciences and Nutrition,
National School of Agro-industrial Sciences, The University of Ngaoundéré,
P.O. Box 455, Ngaoundéré-Cameroon

Abstract: The aim of this study was to design and develop an electronic device, which allows the follow up of the complete cooking kinetic of bean and could be used to efficiently measure hard to cock (HTC). A prototype device composed of a modified Mattson bean cooker, interfaced with a computer via displacement sensors and a 4-channel, 8 bits, 1 Hz data acquisition module built around the MIC 640 was achieved. Cooking data obtained with this device shown that the beginning and the end of the cooking period separated a transition region portraying an exponential rise characterized by a time constant, which varies for freshly harvested beans (3 sec) as opposed to that of long stored beans (10 sec). This time constant, identified and measured for the first time, could be used to elaborate an index of the degree of hardening that has taken place in a given sample of beans.

Key words: PC data acquisition, cooking kinetic, cooking time constant, Mattson cooker, beans

INTRODUCTION

Cooking time as well as cooked texture, appearance and flavour are considered to be important cooking quality characteristics. Cooking time (Hsieh *et al*., 1993; Castellanos-Ramos and Guzman-Maldonado, 1995) and protein content (Guzman-Maldonado *et al*., 2000; De Almeida Costa *et al*., 2006) are important characteristics in bean breeding. The consumer desires grains with fast imbibition and short cooking times; that produces broth with good appearance, taste and flavour and with thin seed coat (Jacinto-Hernandez *et al*., 2002). Long cooking times are a major constraint to wider acceptance and consumption of grain legumes. Furthermore, overcooking of grain legumes has been reported to result in a reduction in the nutritive value of the protein. Several methods for measuring the cooking time of grain legumes have been reported. Some methods are subjective, in particular the sensory analysis and the tactile method; others are objective and use the Mattson cooker. The cooking time has been expressed in a number of different ways in the literature (Wang and Daun, 2005). Some researchers record the number of beans that has been penetrated by the plungers at the end of each minute. The cooking time for a sample is then taken as the time required for 50% of the beans to be penetrated. Others report cooking time as the time required for 100% of the beans to be penetrated or as the point where 92% of the beans were penetrated. The objective methods are based on systems of detection of the cooking of grain legumes using a sensor, which gives information on cooked or uncooked state of the grain legumes, but does not provide any information on the intermediate state. These systems of detection of cooking do not therefore allow the study of the complete cooking kinetic of grain legumes. The aim of this work was to design and develop an electronic device that allows the follow up of the complete cooking kinetic of bean.

MATERIALS AND METHODS

Development of the PC-based instrument: The prototype PC-based instrument developed is shows in Fig. 1. It is composed of a Mattson cooker, a Personal Computer (PC), sensors and a data acquisition module. The Mattson cooker (Fig. 2) consists of 19 plungers and a cooking rack with 19 reservoir-like perforated saddles, each of which holds a seed and a plunger calibrated to 82×10^{-3} kg. Each plunger terminates in a stainless steel probe (Fig. 2b, c) 1.6×10^{-3} mm in diameter. The seeds were positioned in the saddles of the rack so that the tip of each plunger rested on top of the seed. The rack was then placed in a 2.15×10^{-3} m^3 metal beaker containing 1.2×10^{-3} m^3 of boiling water. When a seed becomes sufficiently tender, the plunger penetrates the seed and drop through the hole in the saddle.

Corresponding Author: Bitjoka Laurent, Laboratory of Biophysics and Food Biochemistry, Department of Electrical Engineering, Energetic and Automatics, National School of Agro-industrial Sciences, The University of Ngaoundéré, P.O. Box 455, Ngaoundéré-Cameroon Tel: +23799599682 Fax: +23722252751

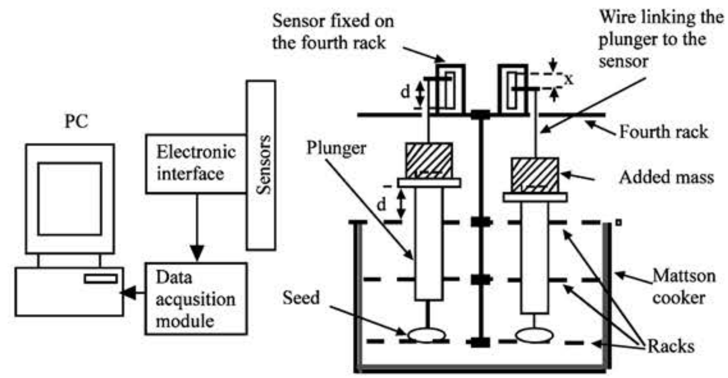

Fig. 1: Schematic block diagram of the PC-based bean cooker system

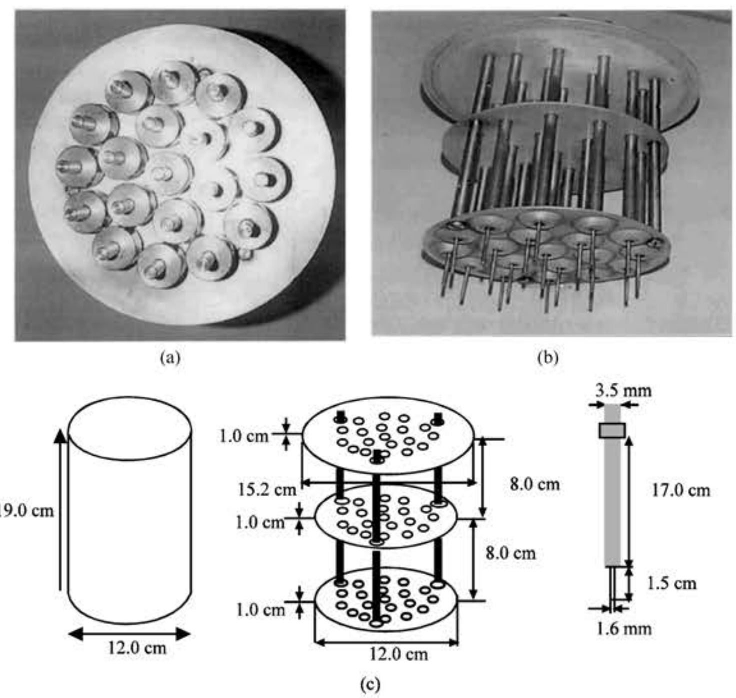

Fig. 2: The Mattson bean cooker (a) top view (b) the racks and the nineteen plungers (under view) and (c) the size

In this study, the Mattson cooker was modified as shown in Fig. 3. A fourth rack was added, onto which were fixed four displacement sensors. Such sensors with high accuracy (resolution: 0.9×10^{-3} m) and long range (15×10^{-3} m) are reported in the literature (Kim *et al*., 2006; Kuijpers *et al*., 2006a, b). In order to achieve a simple and low cost device, the rectilinear displacement (x in Fig. 1) of the plunger penetrating the seed was converted into voltage using a potentiometer as shown in Fig. 4a, according to basic laws of electrical circuits:

$$V = +5\frac{\rho R}{\rho R + (1-\rho)R} = +5\rho$$

Where:
R = Value of the potentiometer
ρ = Which depends on the cursor position of the potentiometer, satisfy $\rho \le 1$

This conversion is obviously linear ($V = 0.122x + 0.116$, $r^2 = 0.987$) as shown experimental results plotted in Fig. 4b. The plunger weight was increased (Fig. 1) to 231×10^{-3} kg, in order to drop freely when a seed becomes sufficiently tender.

The analogical signal coming from each sensor was converted into numerical signal and transmitted to a PC through a 4-channel, 8 bits, 1 Hz data acquisition board.

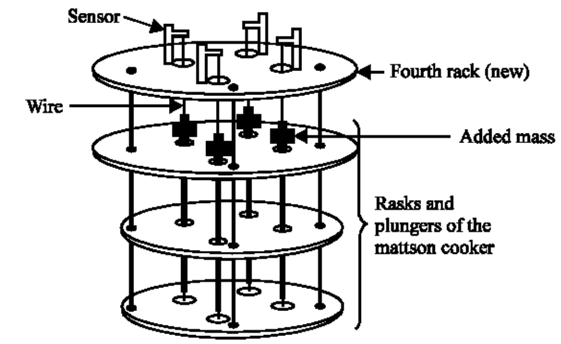

Fig. 3: The modified Mattson bean cooker: new rack arrangement

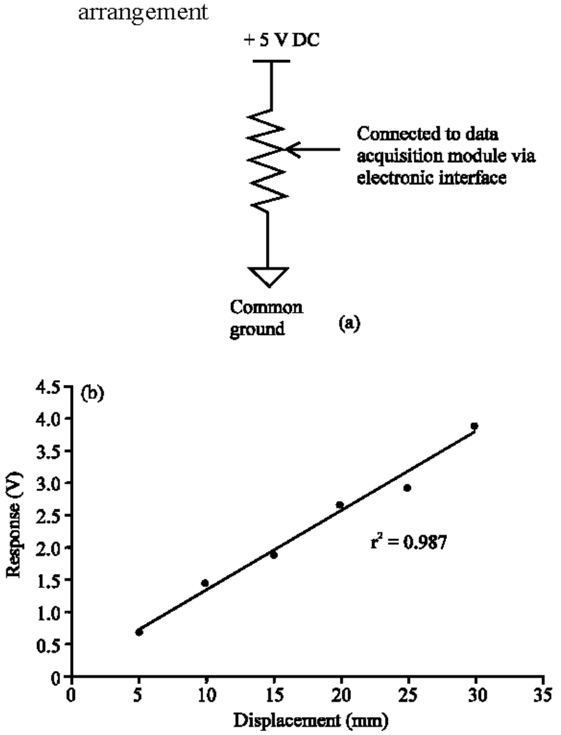

Fig. 4: The sensor (a) electrical circuit and (b) characteristics

This data acquisition board is built around the MIC 640 (IC1 in Fig. 5), a programmable integrated circuit developed by MICTRONICS®. The MIC 640 has four analogical inputs and one standard asynchronous serial output compatible TTL and CMOS. It can function in automatic mode and give a numerical signal at the rate of one sample per second (1 Hz), or in controlled mode and give a numerical signal at a rate determined by an external logical signal. In Fig. 5, the asynchronous serial output (pin number 2) of the MIC640 is connected to receive data (RD) pin (pin number 2) of a serial port via the resistor R1. The output serial data, transmit data pin (pin number 3) of the serial port, when connected to a PC, D3, R3 and C3 as shown in Fig. 5 produce the negative supply voltage-Vdd by half-wave rectification and filtering. The control lines DTR (Data Terminal Ready, pin number 4) and RTS (Request To Send, pin number 7) of the serial port provide the positive supply voltage + Vdd via D1, D2 and C4. This positive supply voltage is controlled with the 5 volts regulator LM2936Z5 (IC2) in order to supply the MIC 640 with a very stable voltage. A software program was developed in Turbo C++ version 3.0, which inputs serial data directly into the PC (DELL Pentium® II).

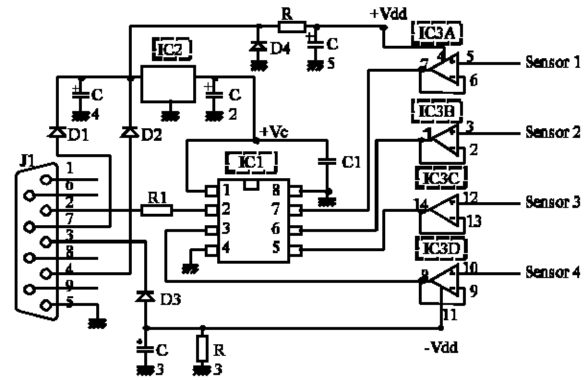

Fig. 5: Electrical circuit of the data acquisition board (Tavernier, 2005). Semiconductors: IC1 (MIC640); IC2 (LM 2936 Z5); IC3 (LF 444), D1, D2, D3, D4 (1N 4148). Resistors: R1 (1 kΩ); R2 (47 kΩ); R3, R4 (10 kΩ). Capacitors: C1 (10 nF); C2 (10 μF); C3, C4 47 μF; C5 (0.22 μF). Connector: J1 (Female DB9)

Table 1: Physical characteristics of the beans used

Bean sample	Length (mm)	Width (mm)	Thickness (mm)	m (g)
Seeds of sample 1	11.5±1.9	7.1±0.7	5.1±0.1	0.375±0.045
Seeds of sample 2	11.5±2.7	7.4±2.2	5.5±0.1	0.404±0.087
Seeds of sample 3	11.9±1.2	7.6±1.1	5.8±0.1	0.428±0.045
Seeds of sample 4	12.9±0.8	7.9±1.5	6.1±0.1	0.465±0.021

The bean sample: The beans (*Phaseolus vulgaris*) were obtained from farm samples in Ngaoundéré (Cameroon). Broken seeds, damaged seeds and foreign material were handpicked from the samples. Four samples of twenty freshly harvested seeds each one and four samples of twenty stored seeds (3 weeks at the room temperature) each one, having on average the same weight and the same morphological characteristics were considered (Table 1).

Methods: The stored beans and the freshly harvested beans were cooked separately, after being soaked in water during 12 h. Four seeds coming from each sample of stored beans were cooked together; in the same way four seeds coming from each sample of freshly harvested beans were cooked together. During cooking, the positions of the four plungers of the modified Mattson cooker placed each one on a seed were recorded second by second and stored on a PC. The data stored were graphically plotted for each grain using SigmaPlot® 8.0 software.

RESULTS AND DISCUSSION

The curves plotted in Fig. 6 and 7, respectively show the kinetic of cooking of four freshly harvested seeds and four stored seeds obtained with the PC-based instrumentation developed. Each curve is based on several thousands of positions of the plunger measured second by second. Each of these curves has three characteristic regions: two steady regions separated by a transition region. The first region corresponds to the beginning of the cooking period; the plunger does not move yet because the seed is not yet tender. The duration of this region is not the same for the four seeds. The second region corresponds to the end of cooking; the plunger has fully dropped. This region appears more or less quickly, according to whether the seed cooks more or less quickly. The time when the second region begins is the cooking time of the seed. The transition region corresponds to the penetration of the plunger in the seed. This penetration is done in a sudden way, like an avalanche, until complete cooking. The bean cooking data recorded in this region follow an exponential law for all the seeds (Fig. 8, r^2>0.97), $x(t) = x_0 + a*\tau* (\exp(t/\tau)-1)$, where $x(t)$ is the position of the plunger at any time, x_0 the position of the plunger at the beginning of the cooking period and τ a time constant. The system was calibrated so that x_0 gives the thickness T (Table 1) of the seed.

The cooking times of the seeds measured are displayed in Table 2. For freshly harvested beans, they vary between 40 and 46 min. Hentges *et al.* (1990) measured for the same variety of beans (*Phaseolus vulgaris*), freshly harvested and soaked during 16 h in deionised distilled water prior to cooking, cooking times varying between 30 and 43 min. Wang and Daun (2005) measured cooking times of less than 25 min after a steeping of 24 h in water. Since the steeping and soaking of bean reduces the cooking time (Hincks *et al.*, 1987), low values of cooking time measured by Wang and Daun (2005) and Hentges *et al.* (1990) are justified. The cooking times measured for stored beans in our experiments (Table 2) vary between 121 and 133 min. Hentges *et al.* (1990) measured cooking times varying from 78.5 min to more than 458 min for the same variety of bean (*Phaseolus vulgaris*) stored for three months at 29°C. We observe that compared to freshly harvested beans, the cooking time of stored beans is longer and depend on the shelf life. This observation is in agreement with earlier reports and is justified by the hard to cook phenomenon, which results from the physicochemical transformations, that undergoes the beans during the storage (Kyriakidis *et al.*, 1997; Berrios *et al.*, 1999).

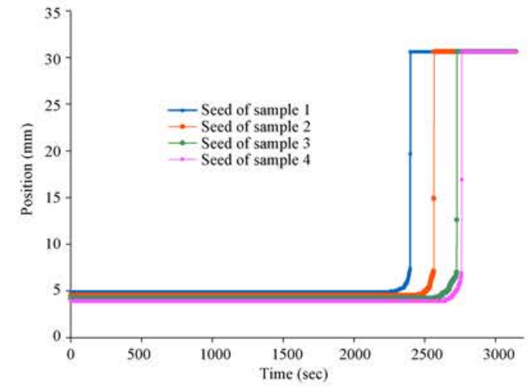

Fig. 6: Bean cooking kinetic of four freshly harvested seeds

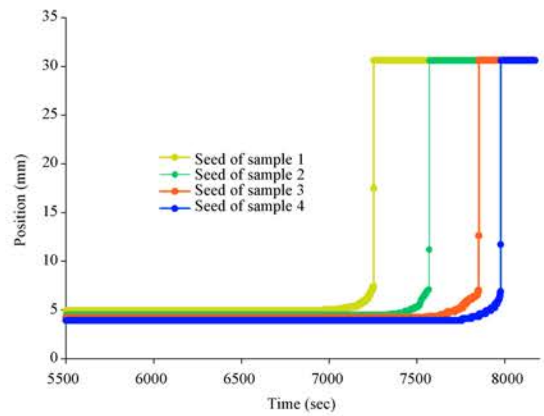

Fig. 7: Bean cooking kinetic of four stored seeds

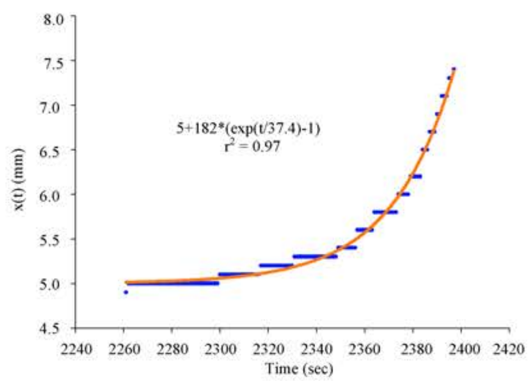

Fig. 8: Bean cooking kinetic in the transition region (freshly harvested seed of sample 1)

Table 2: Cooking time of freshly harvested beans and three weeks stored beans at the room temperature

Cooking time (sec)	Seed of sample 1	Seed of sample 1	Seed of sample 3	Seed of sample 4
Freshly harvested	2564	2397	2726	2761
Three weeks stored	7254	7569	7852	7977

Table 3: Cooking time constant τ of freshly harvested beans and three weeks stored beans at the room temperature

Cooking time constant (sec)	Seed of sample 1	Seed of sample 2	Seed of sample 3	Seed of sample 4
Freshly harvested	37.1	30.6	34.60	36.3
Three weeks stored	104.0	106.0	108.00	110.0
x_0 (mm)	5.2	5.4	5.75	6.0

Table 3 shows the time constant τ measured in the transition region. It varies for the freshly harvested beans (35 sec) as opposed to that of stored beans (107 sec). This time constant, identified and measured for the first time, has been called the cooking time constant. Since it varies according to the shelf life of beans and consequently the physicochemical transformations that they undergo during the conservation, it could be used to elaborate an index of the degree of hardening that has taken place in a given sample of beans.

CONCLUSION

A PC-based system has been developed which allows the follow up of the bean cooking kinetic. It is a real-time system built around a PC and a 4-channel, 8 bits, 1 Hz data acquisition board. The kinetic plot obtained using this system has revealed a transition region between two steady regions corresponding to the beginning and the end of the cooking period. This transition region portrays an exponential rise characterized by a time constant which varies according to the shelf life of beans. This result suggests that this cooking time constant, identified and measured for the first time, could be used to elaborate an index of the degree of hardening that has taken place in a given sample of beans.

REFERENCES

Berrios, J., B.G. Swanson and W.A. Cheong, 1999. Physicochemical characterization of stored black beans. Food Res. Int., 32 (10): 669-676.

Castellanos-Ramos, J.Z. and H. Guzman-Maldonado, 1995. Effects of hardshell character on cooking time of common beans grown in the Semiarid highlands of Mexico. J. Sci. Food Agric., 69 (4): 437-443.

De Almeida Costa, G.E., K. da Silva Queiroz-Monici, S.M.P. Machado Reis and A.C. de Oliveira, 2006. Chemical composition, dietary fibre and resistant starch contents of raw and cooked pea, common bean, chickpea and lentil legumes. Food Chem., 94 (3): 327-330.

Guzman-Maldonado, S.H., J. Acosta-Gallegos and O. Paredes-Lopez, 2000. Protein and mineral content of a novel collection of wild and weedy common bean (*Phaseolus vulgaris* L). J. Sci. Food Agric., 80 (3): 1874-1881.

Hentges, D.L., C.M. Weaver, S.S. Nielson, L.R. Weaver, B.H. Evans and J.M. Jacob, 1990. Automation of a Mattson bean cooker for testing the hard-to-cook defect in legume seeds. Trans. ASAE., 33 (2): 625-628.

Hincks, M.J., A. Mc Cannel and D.W. Stanley, 1987. Hard-to-cook defect in black beans. Soaking and cooking process. J. Agric. Food Chem., 35 (4): 576-583.

Hsieh, H.M., Y. Pomeranz and B.G. Swanson, 1993. Composition, cooking time and maturation of Azuki (*Vigna angularis*) and common beans (*Phaseolus vulgaris*). Cereal Chem., 69 (3): 244-248.

Jacinto-Hernandez, C., H. Hernandez-Sanchez, H.S. Azpiroz-Rivero, J.A. Acosta-Gallegos and L. Bernai-Lugo, 2002. Characterization of a common bean population of inbred lines regarding cooking quality and some nutritional components. Agrociencia, 36 (4): 451-459.

Kim, M., W. Moon, E. Yoon and K.R. Lee, 2006. A new capacitive displacement sensor with high accuracy and long-range. Sensors and actuators. A: Physical, 130/31: 135-141.

Kuijpers, A.A., G.J.M. Krijnen, R.J. Wiergerink, T.S.J. Lammerink and M. Elwenspoek, 2006a. A micromachined capacitive incremental position sensor: Part 1. Analysis and simulations. J. Micromech. Microeng., 16 (6): 116-124.

Kuijpers, A.A., G.J.M. Krijnen, R.J. Wiergerink, T.S.J. Lammerink and M. Elwenspoek, 2006b. A micromachined capacitive incremental position sensor: Part 2. Experimental assessment. J. Micromech. Microeng., 16 (6): 125-134.

Kyriakidis, N.B., A. Apostolidis, L.E. Papazoglou and V.T. Karathanos, 1997. Physicochemical studies of hard to cook beans. J. Sci. Food Agric., 74 (2): 186-192.

Tavernier, C., 2005. Programming PIC in C Language. Dunod, Paris.

Wang, N. and J.K. Daun, 2005. Determination of cooking times of pulses using an automated Mattson cooker apparatus. J. Sci. Food Agric., 85 (10): 1631-1635.