14 MeV PROTON ACTIVATION FOR PROTEIN ANALYSIS IN CEREALS

B. Constantinescu, E. Ivanov, D. Ploştinaru, A. Popa-Nemoiu and G. Pascovici
Institute for Physics and Nuclear Engineering
Bucharest MG-6, Romania

INTRODUCTION

The nutritional value for the agricultural products is mainly characterised by their total protein content. Nitrogen to protein content in cereals is related by a 6.25 conversion factor. Thus nitrogen determination in cereals is equivalent to protein analysis.

The classical nitrogen analysis method is the Kjeldahl chemical technique, which is time-consuming, destructive and not suitable for a large number of samples.

A fast nuclear nondestructive method for protein analysis using the 14 MeV proton activation to measure total nitrogen content through the reaction:

$$^{14}N\ (p,n)\ ^{14}O \qquad (T_{1/2} = 71\ s)$$

has been developed in our laboratory.

The 14-O activity is detected by means of its characteristic 2.312 MeV gamma-ray line with a NaI(Tl) detector. The number of gamma-rays to the incident particles ratio for one sample, related to a similar ratio for the adequate standards helps to determine the nitrogen content in that sample.

EXPERIMENTAL

A beam of 14 MeV protons, produced by the INPE U-120 variable-energy fixed-frequency Cyclotron passes through a 50 μm aluminum foil window into the air. Directly behind the window, the irradiation chamber is located, acting also as a Faraday cup. The effective irradiated and analysed mass of the grain is determined by the difference in range of the protons at 14 MeV and at the reaction threshold (~ 6.4 MeV) and amounts to ~ 0.2 g/cm² (1.4 mm for wheat and barley, 1.2 - 1.3 mm for corn and soya - beans). The proton beam hitting the sample (100 ± 10 nA) is measured by the charge collected on the Faraday cup.

A grain sample to be analysed is first put into a disposable aluminum container approximately 25 mm in diameter and 22 mm in length.

For a fast determination samples in a large number the automation of the operations was necessary. A mechanized system able to analyse samples at a rate of one per minute (see Fig.1) has been developed. The sample is gravitationally transported from the magazine to the irradiation area in 3 s., it is irradiated in 27 s., transported again gravitationally to the counter in 3 s., measured in 27 s. and finally gravitationally transported to a lead screened box. The laboratory electronics presented in Fig.2,a Multichannel Analyser (MCA) Nuclear Data, a PDP-8 computer and an electronic module controller - control the entire operation. The MCA is working in the MCS mode (Multichannel Scaling Experiment): in one channel the charge information is stored, and in the next channel the gamma-ray intensity indicator. The electronic module controller acts on the mechanical transport system for the samples and also on the beam pulsing chopper (27 s. irradiation, 33 s. pause for the measurement and sample transport - see Fig.3).

After irradiation, the sample is transported to a scintillation counter with a 10.16 cm diameter x 10.16 cm thick NaI(Tl) crystal. The counter is shielded toward the sample by a 25 mm lead layer in order to reduce dead time losses from the high 0.511 MeV gamma-ray activity.

Finally, the PDP-8 computer calculates the ratio of the number of gamma-ray counts and of the integrated beam charge and multiplies the result by a predetermined normalizing factor (the total protein content of a grain standard) to obtain the total protein content of the sample. This result is typed out.

RESULTS AND DISCUSSION

Several thousands of samples (wheat, corn, barley, bean and soya-bean) have been analysed with this nuclear method. Good correlation has been obtained between the results of the Kjeldahl method and our nuclear determinations for samples of various cereal grains (see Fig.4).

A problem is the analysis of the whole protein region in a seed. Thus, for wheat and barley seeds the region of maximum protein concentration is 0.2 - 0.6 mm in depth /1,2,3/; in corn and soya-bean seeds this region is thicker (0.2 - 2 mm). The effective irradiated and analysed mass is about 0.2 g/cm² (1.2 - 1.4 mm), very suitable for wheat and barley. To realise an accurate measurement for corn and soya-bean, flour should be used to obtain a protein homogeneous sample.

In this case, the irradiation dose for a sample is about 33.000 Gy, mainly (99 per cent) from protons (27 s x 100 nA x 14 MeV). Thus, the radiation damage

is concentrated in a layer of 1.7 - 2 mm under the irradiated surface of the seeds. By protecting the embryo region during irradiation, by the help of a suitable geometry of the samples the future germination of the analysed seeds will be quite normal (70 - 90 per cent normal seedlings) /4/. This is the most important advantage of the present method.

REFERENCES

/1/ D.M. Grodzinski, O.F. Nemets, A.E. Melenevski, V.A. Tihi , Vestnik selskohoziaistvenoi nauki, 7 (1983) 47
/2/ D.A. Dohan, K.G. Standing, Physics in Industry, Pergamon Press, Oxford and New York, 1976, 509.
/3/ B. Sundqvist, L. Goenczi, I. Koeraner, R. Bergman, U. Lindh, Ion Beam Surface Analysis, Plenum Press, New York and London, 1976, 945
/4/ Gh. Dumitru, Ph. D. Thesis, Polytechnical Institute, Bucharest, 1983.

FIGURES

Fig.1. - Outline of the mechanized system for the analysis.

Fig.2. - Experimental electronics:

1 - NaI(Tl) scintillation counter
2 - electronic current integrator
3 - high-voltage supply
4 - linear amplifier
5,6 - single-channel analyser
7 - scaler
8 - electronic module controller
9 - sum module
10 - multichannel analyser
A - Control pulse for relays R_1 and R_3
B - Gate pulse for the gamma-ray measurement system
C - Control pulse for relays R_2 and R_4
D - Gate pulse for beam-pulsing chopper (close)
E - Gate pulse for beam-pulsing chopper (open)
F - MCS advance of MCA
G - start of MCA
H - digital pulse from the current integrator or from the NaI(Tl) scintillation counter

Fig.3. - A typical analysis sequence for a 60 s. cycle A,B,C,D,E,F - see Fig.2

Fig.4. - Comparison between the Kjeldahl method results and our nuclear determinations.

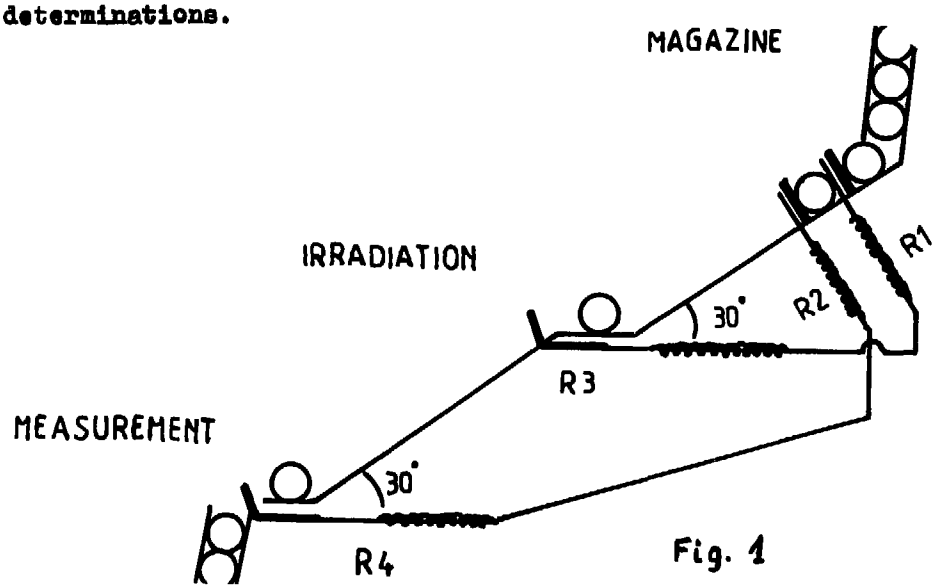

Fig. 1

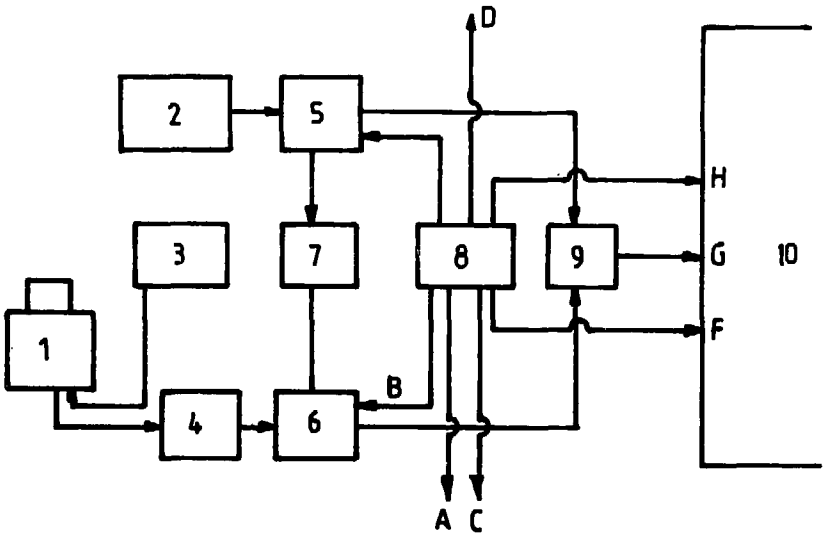

Fig. 2

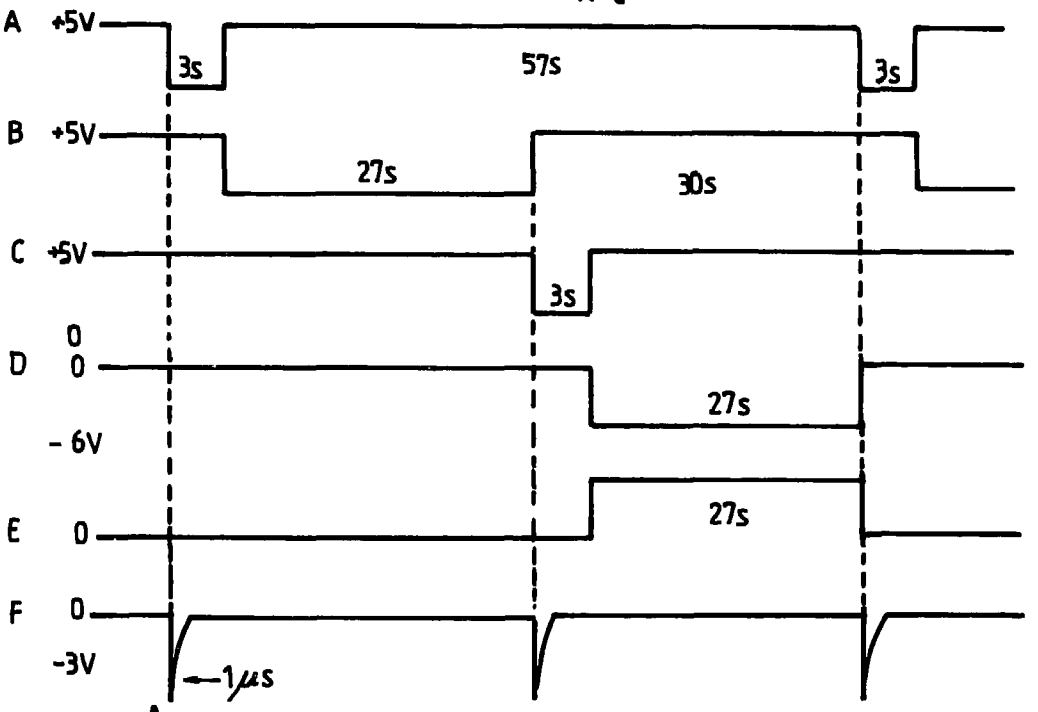

Fig. 3

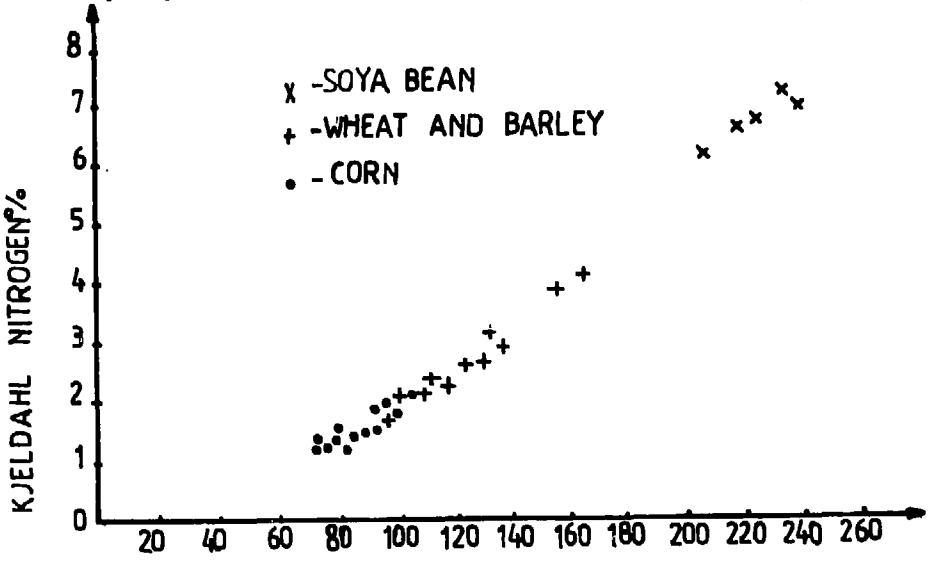

Fig. 4