

MODALITIES TO DETERMINE THE ENERGY CONSUMPTION FOR THE GRINDING OF VEGETABLES PRODUCT WITH VARIABLE TEXTURE

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Abstract: grinding process of vegetable products is complicated. This is explain through the fact that vegetables product are inhomogeneous and with variable properties in time and space. The working methods chosen take into account that the grinding operation must lead to a product qualitative superior as well as low energy consumption.

Keywords: texture, broken, moment of torsion, grinding.

1. INTRODUCTION

The vegetables products are exposed to mechanical strains (forces) in time of majority's technological processes. The vegetables products are viscoelastic and the elasticity degree vary considerable, depending on the maturity degree and humidity content.

In case of the grinding vegetables products it can be observed the existence of simultaneous shearing effects, the appearance of a lateral tension and friction between product and working tools in the contact area between these. This fact helps us to evaluate the textural properties of vegetables products.

Knowing the textural properties of vegetables products permit us to choose the grinding method. The necessary power to compress a material depends very much on the type of forces applied: static or dynamic. The grinding energy is much influenced by the humidity content of products submissive to grinding. The elasticity of products with high humidity is higher and can tolerate a higher deformation without broke.

A part of energy is retained to create new surfaces but the most part is loss under heat form [4, 5, 8, 9].

The studies regarding the determination of energy consumption in the grinding process of vegetable products are realized in laboratory conditions and refer mainly at determination of grinding force. For determination of grinding force one of the following methods can be used:

- texture analyze;
- determination of shearing force;
- determination of torsion moment.

2. Texture analyze

Texture can be watched as rheological properties manifestation of the products. It is an important property in processing vegetable products, it influence the product composition and affect the storage time and acceptance products by the consumer. The vegetable products present a large texture variation spectra, mainly due to variety of fruit and legume sorts for consumption, and also because that a big part of these are used as fresh products.

Texture profile analysis (TPA) is an objectively method of sensorial analyses found out in 1963 by Szczesniak, which defined for the first time the textural parameters for this method of analyze. Later, in 1978, Bourne adapt the INSTRON machine accordingly to TPA by standard dimension at compression food products samples [1, 3, 12].

Texture profile analysis (TPA) is based on the recognition of texture as a multi-parameter attribute. For research purpose, a texture profile in terms of several parameters determined on a small homogeneous sample may be desirable.

The test consists in compressing a cylindrical well on the product, in time, in an alternative motion that imitates the action of a jaw having as result the force-deformation curve of textural parameters. This is well correlated with sensorial evaluation of those parameters.

For this purpose it can be used “Texture Analyzer – TA-XT2i” (fig. 1) measuring instrument, witch supply a complete three-dimensional analyses for force, knife snap and time. These instruments are characterized by a burly structure and a resolution of 0,025% to maintain accuracy. It can be used together with “Texture Expert” software, for different specimens determining the following parameters: cohesion, elasticity, breaking limit, strength of penetration, adhesivity, etc.

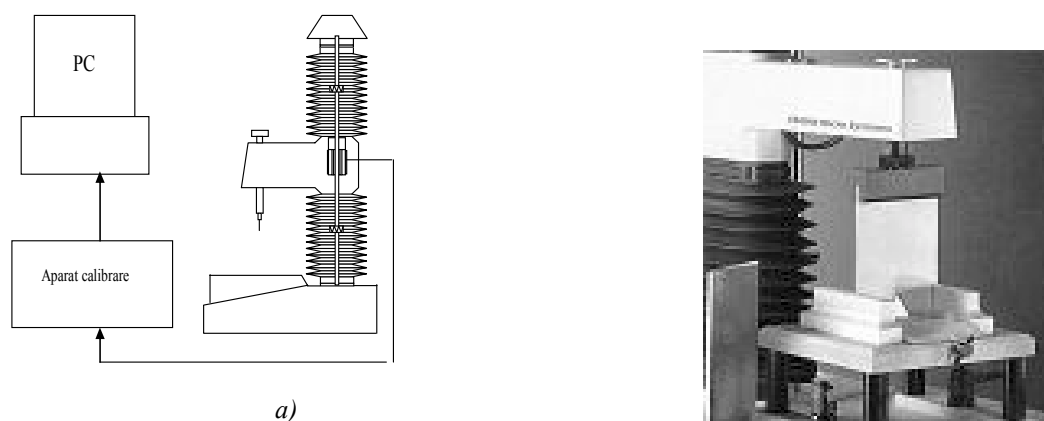


Fig. 1. Texture Analyzer
a) technological scheme of apparatus; b) meter image.

Texture Expert works with Windows™ operation system, for acquisition, visualization and analysis of data from “Texture Analyzer – TA-XT2i”. One of the most important characteristic of this instrument is the capacity to memorize one of the measure procedures and give immediately access to it. A determination can be defined by two work window (fig. 2): one for parameter input and one to define the visualization modality of the results (graphics, tables).

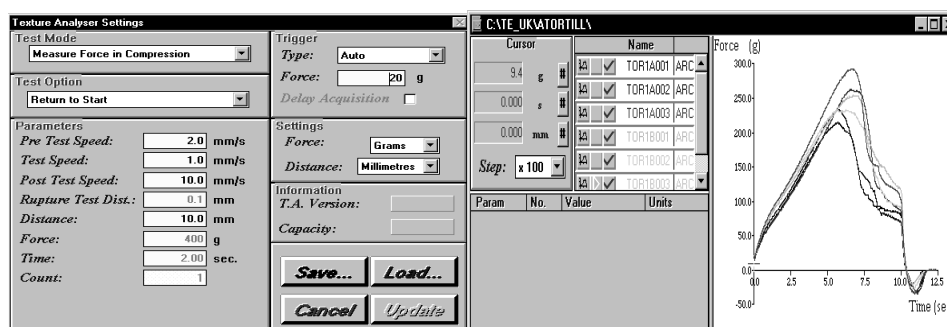


Fig. 2. Instrument work windows

Definition of parameters include: procedure, operation velocity, unit measure. The results obtained are presented as force-time graphics. In order to determine the structure characteristics, Texture Analyzer include a large scale wells and measurement devices (knife of different forms, needles). For reliable and reproducible results some basic rules are taken into consideration: storage, preparation, specimen morphology, the humidity content, temperature, the deformation speed.

3. Fracture test

Fracture tests involve physically deformation of the material until it breaks. Deformation is controlled until the changes in the specimen geometry can be measured. In testing the mechanical fracture properties we must have in mind some basic material science principles. The energy supplied must load the material in order to deform it physically.

The instrument used to determine the shearing force (fig. 3) has the Elmendorf [7, 8, 11] basic broken principles. The sample of product, of certain dimensions is caught in jaws 1 and by driving handle 2, pendulum 3 is released to break the specimen. The value of shearing force is indicated by pointer 5 on graduated scale 4, mounted on pendulum.

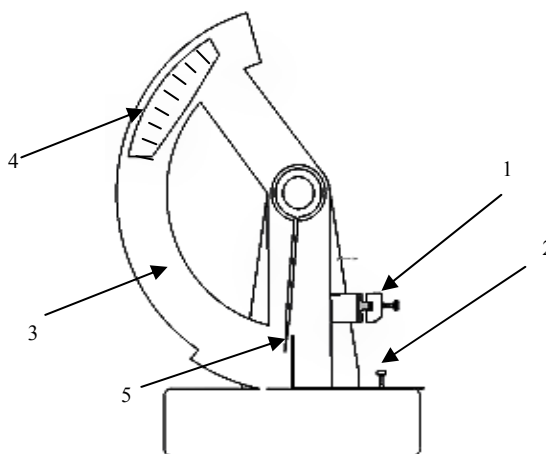


Fig. 3. Machine scheme to realize the broken tests.

4. Determination of torsion moment

The dynamic testing of vegetable product had a quick evolution, having an important impact on products processing [3, 8, 11]. An important function of these types of tests is the determination of products deformation under dynamic load. To study the grinding process of vegetable precuts with variable texture was necessary to

build an equipment in order to determine the energy consumption for different grinding degrees, for different knives types.

Cutting equipment (fig. 4.a and b) are constitute from case 1 which has inside the knife clip disc 2, mounted to permit the set of edge cutting to certain height over disc creating a controlled slip through which the ripper pieces of products goes. Distance between cutting edges of knives and knife clip disc determine thickness of ripper pieces. Rotation of knives disc is chosen in function of product texture submissive to grinding by cutting, the movement being transmitted to an asynchrony motor with static frequency changer 6, by driving belts 5. The products are fed in equipment by removing the lid 7 which has attached the pressure plate 8 which has the function to press the product to knife surface, with the help of springs 9.

The most efficient methods to adjust the rotation of asynchrony motor consist in modification of tension and frequencies so that magnetic flux remaine constant. In this sense we decide to use a static frequency changer (VW3-A58101) with direct reading of rotation. This method offers a large scale of rotations. The torque transducer has strain gages of rosette type (1XK11E-3/350), mounted in complete deck (fig. 5), signal being transmitted to acquisition data system through the collecting-ring 1-SK12 (fig. 6).

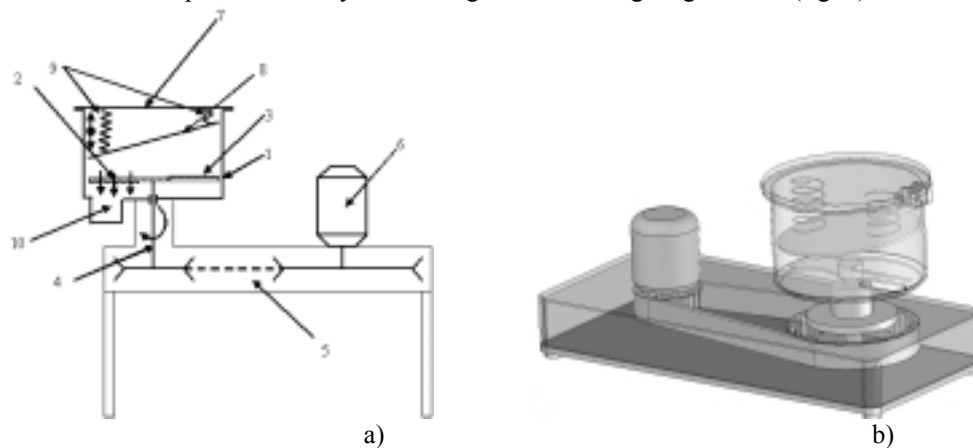


Fig. 4. The scheme of cutting equipment.

a) cinematic scheme of cutting equipment; b) equipment image;

To determine the moment of torsion transmitted by a shaft with electro resistive transducer (TER), we apply in a section of shaft, in exactly contrary two points two electro resistive transducer disposed at 45^0 (or by a rosette with perpendicular branches between the two points disposed at 45^0 against shaft axis (fig. 7). All four transducer are connected in complete bridge (fig. 8).

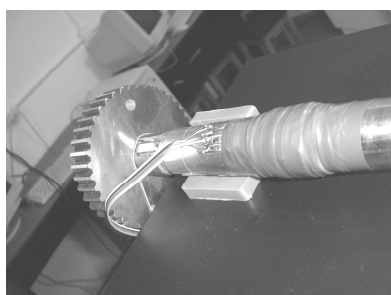


Fig. 5. Strain gages position on shaft of motion transmission.



Fig. 6. Collecting- ring

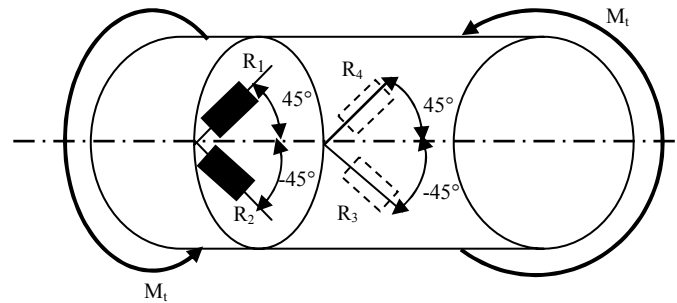


Fig. 7. The electro resistive transducer disposal on movement transmission shaft .

We note with: ε_n , ε_i and ε_t the specific deformation produced by axial force N , M_i – bending moment and M_t – torque moment. Taking into account that all transducer have the same electric resistance $R = 350 \Omega$ and the same constant $k_t = 2,04$ (for the rosettes used 1- XK11E -3/350) variation ΔR of the resistance of these transducers measured by tensometric bridge after the shaft is loaded, is:

$$\begin{aligned}\Delta R_1 &= k_t (\varepsilon_{n_1} + \varepsilon_{i_1} + \varepsilon_{t_1}) = k_t R (\varepsilon_n + \varepsilon_i + \varepsilon_t) \\ \Delta R_2 &= k_t (\varepsilon_{n_2} + \varepsilon_{i_2} + \varepsilon_{t_2}) = k_t R (\varepsilon_n + \varepsilon_i - \varepsilon_t) \\ \Delta R_3 &= k_t (\varepsilon_{n_3} + \varepsilon_{i_3} + \varepsilon_{t_3}) = k_t R (\varepsilon_n - \varepsilon_i + \varepsilon_t) \\ \Delta R_4 &= k_t (\varepsilon_{n_4} + \varepsilon_{i_4} + \varepsilon_{t_4}) = k_t R (\varepsilon_n - \varepsilon_i - \varepsilon_t)\end{aligned}\quad (1)$$

where:

$\Delta R_1, \Delta R_2, \Delta R_3, \Delta R_4$, is resistance variations of all four transducer, Ω ;

$k_t = 2,04$ constant;

$R = 350 \Omega$, electric resistance;

ε_n – shaft specific deformation given by axial force, mm;

ε_i - shaft specific deformation given by bending moment, mm;

ε_t - shaft specific deformation given by torque moment, mm.

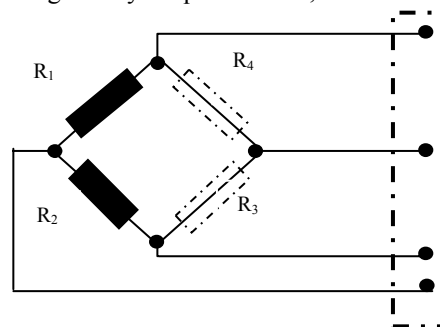


Fig. 8. The electro resistive transducer disposal in complete bridged.

In this expression is taken into account that transducers R_1 and R_3 are disposed in exactly contrary points and therefore, the specific deformations measured by these, produced at bending load are equals and sign contrary. Transducers R_1 and R_3 are disposed at 45° against to shaft axis. As result from Mohr circle (fig. 9) on this two directions (R_1 and R_3) $\sigma_1 = \tau$ (point M_1), transducer R_2 and R_4 being applied at -45° (fig. 8) on direction of principal tensions, $\sigma_2 = -\tau$. Taking into account these observations, from expression 1, result:

$$\varepsilon_{t_1} = \varepsilon_{t_3} = -\varepsilon_{t_2} = -\varepsilon_{t_4}$$

where:

σ_1 is axial tensions on direction 1, N/mm²;
 τ – tangential tension, N/mm²;
 σ_2 – axial tensions on direction 1 2, N/mm²;

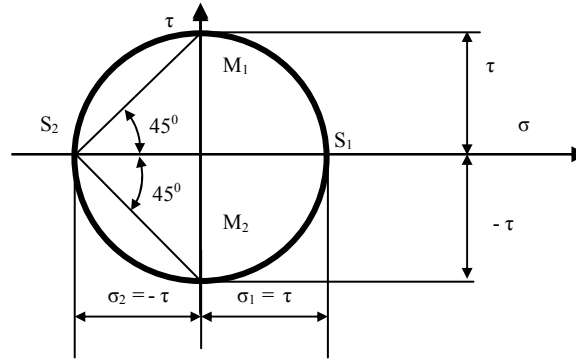


Fig. 9. Mohr circle.

The four transducers being connecting in complete bridge, the variation of transducer resistance, measured by bridge, is:

$$\Delta R_{mas} = \Delta R_1 - \Delta R_2 + \Delta R_3 - \Delta R_4 \quad (2)$$

Replacing relation 1 in relation 2 and taking into account the above observations, result:

$$\Delta R_{mas} = 4k_t \cdot R \cdot \varepsilon_t \quad (3)$$

The specific deformation measured by bridge is:

$$\varepsilon_{mas} = \frac{\Delta R_{mas}}{k_t \cdot R} \quad (4)$$

where: ε_{mas} is the measured specific deformation, mm.

Replacing relation 3 in relation 4, result:

$$\varepsilon_{mas} = 4 \cdot \varepsilon_t$$

result:

$$\varepsilon_t = \frac{\varepsilon_{mas}}{4} \quad (5)$$

From the above relations result:

$$\varepsilon_{t_1} = -\varepsilon_{t_2} = \frac{\varepsilon_{mas}}{4} = \varepsilon_t \quad (6)$$

Taking account to the first equation of Hook law written in case of plane state of tension, result:

$$\sigma_1 = \frac{E}{1-\nu^2} \cdot (\varepsilon_{t_1} + \nu \cdot \varepsilon_{t_2}) \quad (7)$$

where:

σ_1 is axial tension, N/mm²;

ν – Poisson coefficient;

E – longitudinal modulus of elasticity, N/mm².

Or replacing ε_{t_1} and ε_{t_2} , result:

$$\sigma_1 = \frac{1+\nu}{1-\nu^2} \cdot E \cdot \varepsilon_t = \frac{E}{1-\nu} \cdot \varepsilon_t = \tau \quad (8)$$

and result:

$$\tau = \frac{E}{1+\nu} \cdot \frac{\varepsilon_{mas}}{4} \quad (9)$$

where: τ is tangential tension, N/mm².

Have in view that:

$$\tau = \tau_{\max} = \frac{M_t}{W_p} \quad (10)$$

were:

τ is tangential tension, N/mm²;

$\tau_{\max}$ – maximum tangential tension, N/mm²;

M_t – moment of torsion, Nmm;

W_p – modulus of resistance polar, mm³.

Polar modulus of resistance from the circular section, is given by relation:

$$W_p = \frac{\pi \cdot d^3}{16} \quad (11)$$

in which: d is the shaft diameter, mm.

Replacing relation 11 in relation 9, result:

$$\frac{M_t}{W_p} = \frac{E}{1+\nu} \cdot \frac{\varepsilon_{mas}}{4} \quad (12)$$

and result:

$$M_t = \frac{W_p \cdot E}{4(1+\nu)} \cdot \varepsilon_{mas} \quad (13)$$

were:

M_t is moment of torsion, N mm;

W_p – modulus of resistance polar, mm³;

ν – Poisson coefficient;

E – longitudinal modulus of elasticity, N/mm²;

ε_{mas} – measured specific deformation, mm.

Knowing that the moment of torsion is given by force F multiplied by distance l (between force direction and rotation axis, force arm), grinding force are given by relation:

$$F = \frac{M_t}{l} \quad (14)$$

With the value of this force the energy of grinding can be determined, using one of the grinding law [8, 10].

CONCLUSION

1. Each of the methods presented above involve certain conditions of working and have different parameters characteristic for each method applied.
2. Method of texture analysis is a well defined procedure, the analyses of structural characteristics give quantified and reproducible data about textural property of products: cohesiveness, reliability, elasticity, shearing stress, resistance to penetration, masticability, a large scale probe and measuring devices being used, given the possibility to study many characteristics. Obtaining real and reproducible data suppose to take into account some factors like: storage, preparation, specimen morphology, humidity content, temperature of products and speed of deformation.
3. Method of broken test have in view the property of products, property which offer signs about the mode of fracture of products (fragile fracture, ductile fracture or a combination from these two types of fracture). The fragile products show an unstable fracture comparatively with ductile products, which give many signs before broke, presenting a fracture variation in stages until break.
4. Moment of torsion method, allow the determination of products deformation under dynamic forces effect. The method permit to study many aspects of grinding process (property of product submissive to grinding, type and form of working device, constructive parameters at cutting machine), aspects which permit to obtain more realistic experimental results and which to better characterize the grinding process.
5. the differences which appear between energies calculated with the help of different forces of grinding, determined through methods forenamed represent different inutile consumption of energy, which will be considered wastages.

BIBLIOGRAFIA

- [1] Bourne M.C., – Food texture and viscosity. Concept and measurement. Academic Press. New York, 1982.
- [2] Bourne, M.C., - Basic Principles of Food Texture Measurement. Lecture text of Dough Rheology and Baked Products Texture Workshop – Chicago, 1988.
- [3] Brennan, J.G., - Food texture measurement. Taken from: Developments in Food Analysis Techniques 2, pp 1 - 78 (Publ. R. D. King), 1994.
- [4] Dekker N., – Engineering properties of food, New York, 1995.
- [5] Lang Z., – The influence of mass and velocity on the maximum allowable impact energy of apples, J. Agric. Engng. Res. 57, 1994.
- [6] Menesatti P., Paglia G., – Non-linear multiple regression models to estimate the drop damage index of fruit, Biosystems Engineering 83(3), 2002.
- [7] Norman E. Dowling, – Mechanical behavior of materials, engineering methods for deformation fracture and fatigue, Englewood Cliffs, Prentice – Hall, 1993.
- [8] Panainte Mirela, Emilian Moşneguţu, Carmen Savin, coordonator Valentin Nedeff – Mărunţirea produselor agroalimentare, Ed. Meronia, Rovimed Publishers, ISBN 973-8200-88-1, 973-7719-39-5, Bacău, 2005;
- [9] Sharma, S.K., Mulvaney, S.J., Rizvi, S.S.H. Material testing and rheology of solid foods. In: Food process engineering: theory and laboratory experiments (Ed. S. K. Sharma, S. J. Mulvaney, S. S. H. Rizvi) Wiley-Interscience, pp 20-50, 1999.
- [10] Sitkei G., – Mechanics of agricultural materials, Departament of woodworking, University of Forestry and Wood Science Sopron, Hungary, 1986.
- [11] Teodorescu N., - Reologie aplicata, Editura Matrix Rom, Bucuresti, 2004;
- [12] *** - Una finestra sul mondo dell'analisi di struttura, Enco S.R.L. Representante per l'Italia.