DETERMINATION OF GRINDING ENERGY TO VEGETABLE PRODUCT THROUGH TEXTURE ANALYSIS METHOD

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Abstract: The vegetable products are visco-elastics with variable properties in time and space. The capacity of deformation of these products varies appreciably, depending of maturity degree and humidity content of products. Energy necessary to grinding these products is influenced by specie, sort as well as humidity content of products submissive to grinding. The paper presents a method from determination the grinding energy using texture analysis of vegetable products.

Key words: grinding energy, humidity, texture, grinding.

1. GENERALITIES

Texture can be looked like manifestation of rheological property of products. These properties are important relative to working and processing of vegetable products, affect product composition, the storage period and product acceptation by consumer [1, 2, 4].
Vegetable origin based products present a big specter of texture variation, due, mainly to the variety of fruit and legume sorts and species fated to consumption.
Texture hereunto to characteristics witch confers to the product resistance to the action of some exterior forces (compression, fragility, cutting, straining). The resistance of the product is expressed by means of elasticity, fibrosis, fragility or viscosity, properties which have an important role in product quality.

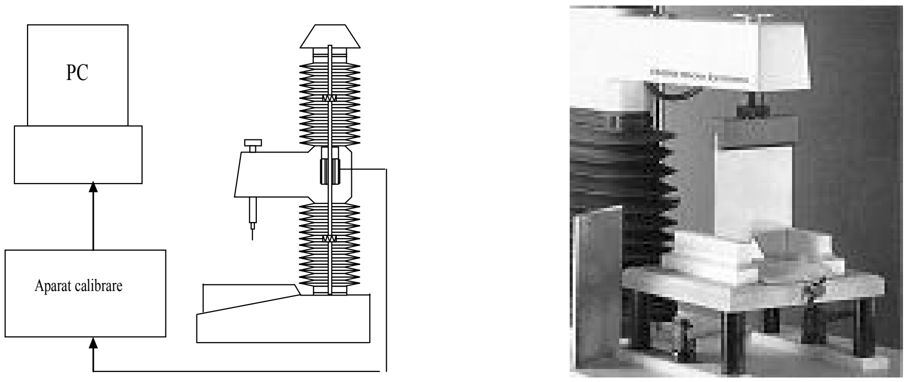
2. TEXTURE PROFILE ANALYSIS

The goal of the researches is to obtain a correlation between sorts, species, humidity and energy consumption.
In order to study the grinding process of products with variable texture, the texture analyses method was chosen. Texture profile analysis (TPA) is an objective method for sensorial analysis discovered in 1963 by Szczsneiak who defined for the first time textural parameters for this method of analysis [4].

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 pressing a bite-size piece of food two times in a reciprocating motion that imitates the action of the jaw and extracting from the resulting force-time curve a number of textural parameters that correlate well with sensory evaluation of those parameters.

Texture analyzer TA-XT2i (fig. 1) can be used together with “Texture Expert” program, for different specimens types at which can be determines: cohesion, elasticity, strength of broken, strength of penetration, adhesively, etc.



a) *b)*

Fig. 1. Texture Analyser – TA-XT2i
a) technological scheme of apparatus; b) meter image.

Texture Expert work with Windows operating system, for acquisition, visualization and data analysis transmitted from “Texture Analyzer – TA-XT2i”. One of the most important characteristic of it is the capacity to memorize a measuring procedure and access it immediately. A determination can by defined through two work windows (fig. 2): one for parameter constraints and one to define the visualization modality of results (graphics, tables).

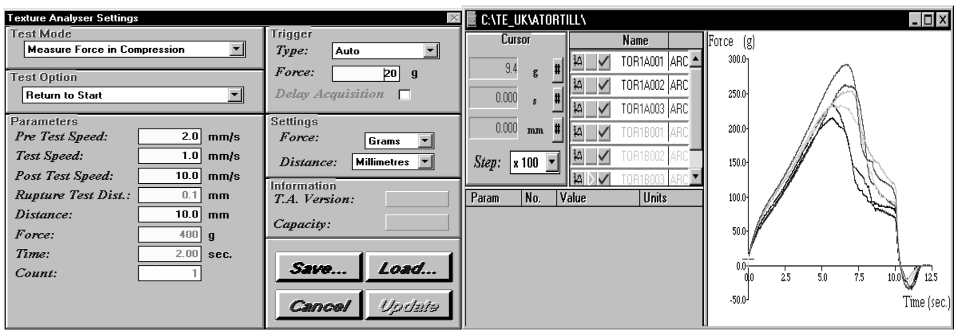


Fig. 2. Meter windows work.

For reliable and reproducible results some basic rules are taken into consideration [2, 4, 6]:

- storage, preparation and environment can give rise to discrepancies as can differences in experimental techniques and conditions;
- specimen morphology. Natural materials like meats, fruit and vegetables are extremely variable in their material and structural properties which greatly influence the texture;
- each test specimen have to be of comparable size and shape, otherwise in product are distribute variable tensions and broken take place;
- some material can be anisotropic, for example their mechanical properties can vary according to the direction they are loaded in. is much easier to fracture meat in between the fibres that through fibres, hence the perception of texture in these two directions is extremely different;

- the moisture content within materials has a major influence on its mechanical and fracture properties and hence its texture. Fleshy products how are be fruit flesh tends to lose apace from humidity in several minutes. If the test takes several minutes to complete, the material at the end of the test will have a very different mechanical behavior than at the start of the test. Such discrepancies must be minimized by either reducing the exposure to air, or testing them in a constant humidity environment;
- like humidity, temperature plays an important part in affecting the mechanical properties of food and other products. Even minor variation in ambient temperature affects the stiffness of vegetable specimen. Larger fluctuations affect the glassiness (brittleness) of materials ;
- for almost all such the speed at which is deformed (strain rate) affects its fracture properties. If a material is deformed quickly, generally the strength and toughness values are unrealistically high. This is because more energy has to be supplied and a large proportion of this is the residual strain energy;
- slow deformation enable energy to be more realistically partitioned. Most materials are strain rate dependent at higher strain rates and independent at lower strain rates. The softer the material the more strain rate dependent it is and it is advisable to use a slow deformation rate for such tests.

3. EXPERIMENTAL RESEARCH

The paper proposes the determination of grinding energy in grinding the vegetable products (fruits and legumes) and consists mainly in grinding force determination using texture analyses method.
Experiences were realized in laboratory conditions on different types of specimens. For these experiences species and sorts of legumes was chosen in order to present a larger scale of vegetable products with a texture qualified as “hard” (table 1).

Species and sorts of fruits and legumes analyzed. Table 1

No. crt.	Specie	Sort	Maturity	Observations
1.	Apple	Jonangold	Complete	Crusted
2.	Apple	Jonangold	Complete	Without crusted
3.	Pear	Clapp favorite	Complete	Crusted
4.	Pear	Clapp favorite	Complete	Without crusted
5.	Carrot	Nassan	Complete	Crusted
6.	Carrot	Nassan	Complete	Without crusted
7.	Celery	Victoria	Complete	Crusted
8.	Celery	Victoria	Complete	Without crusted
9.	Parsnip	Alb lung	Complete	Crusted
10.	Parsnip	Alb lung	Complete	Without crusted

The properties of studied particles vary function of species and sort. In table 2, the medium humidity and medium density values for analyzed sort are presented.

Medium density and humidity of fruits analyzed. Table 2

No. crt.	Specie	Density, kg/m^3	Humidity, %
1.	Apple	930	83,5
2.	Pear	1028	85,1
3.	Carrot	1040	88,8
4.	Celery	964	87,0
5.	Parsnip	994	89,5

In laboratory conditions the grinding force was determined with the help of texture analyzer TA-XT2i, for products pre presented, using probe”HDP/BSK – blade set with knife”. During the experience grinding speed was varied in interval (0,001 ÷ 0,01) m/s.

In order to calculate the energy consumption, the Rittinger relation was used (completed for vegetable products) [3, 5].

The Rittinger relation was applied, because in this theory it is considered that the necessary energy for grinding is direct proportional with the surface new created in grinding process and not with the variation of particle dimension, meaning this is theory which take into account all grinding stages. In this case the Rittinger constant was particularized for products with variable texture:

$$E_R = k_R\left(\frac{1}{d}-\frac{1}{D}\right) \tag{1}$$

where:

k_R is Rittinger constant;

D - particle dimension before grinding;

d – particle dimension after grinding.

Rittinger constant takes into account the nature of material. In literature, Rittinger constant is indicated just for mineral materials [5, 6]. Therefore, in order to develop the Rittinger relation in case of materials with variable texture, we consider the Rittinger constant as follows:

$$k_R = F_m \cdot S_n \tag{2}$$

in which:

F_m is grinding force give for the torsion application, N;

S_n – surface new created for ideal particles, grinding after maximum diameter, m^2.

Taking into account that the grinding energy depend on the surface new created, we have:

$$S_n = S_p + N_p \cdot S_c \tag{3}$$

where:

S_p represent particle surface submissive to grinding, m^2;
N_p – number of new particles created.
S_c – surface at cutting section (was take into account that particle are spherical and any cutting section proceed through centre of particle), m^2.
Replacing relations 3 and 2 in relation 1, equation of grinding energy become:

$$E_R = F_m \cdot (S_n - S_i)\cdot\left(\frac{1}{d}-\frac{1}{D}\right) \tag{4}$$

With the help of relation 4, was calculate grinding energy through sorts processed in tables 1 and 2, obtaining variation of grinding energy in function to working revolution (figures 3 and 4).

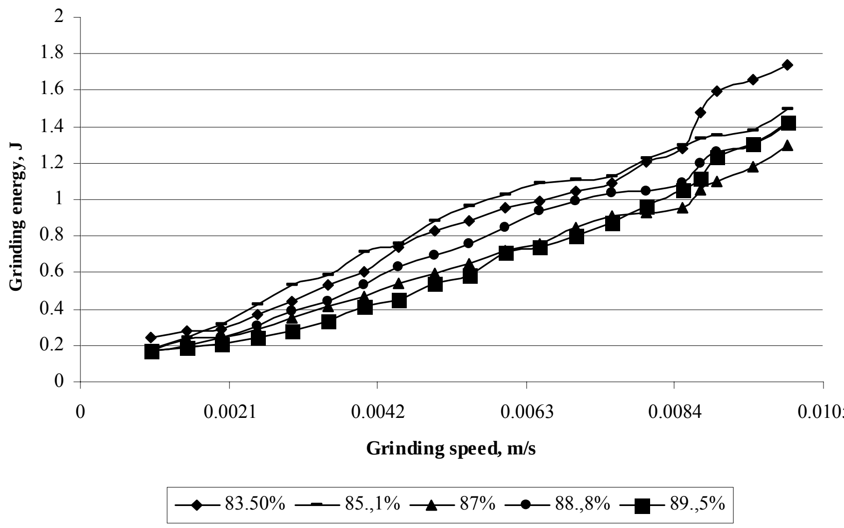


Fig. 3. Variation of grinding energy in function to grinding speed for sort studies (with less).

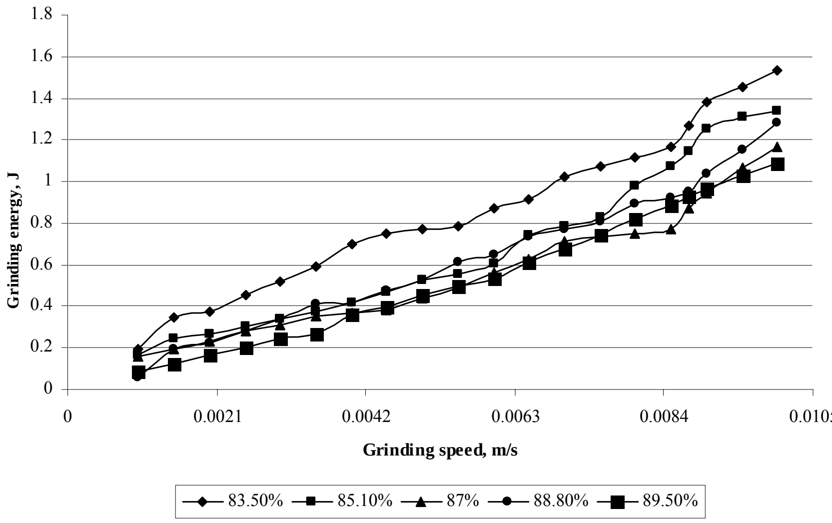


Fig. 4. Variation of grinding energy in function to grinding speed for sort studies (without less).

Using the program for generating linear and nonlinear equations TableCurve 3D, it was obtained the mathematical model for variation of grinding energy for all species and sorts analyzed, studies in function of application force and grinding speed (fig. 5).

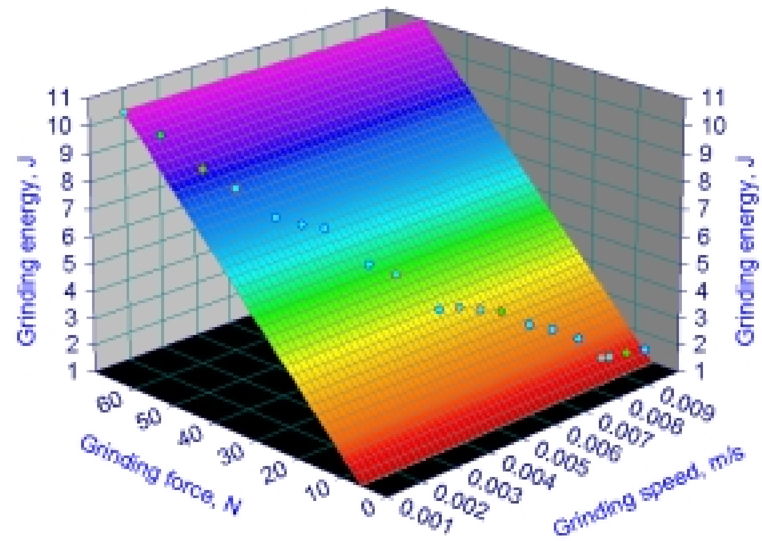


Fig. 5. Variation at grinding energy in function at grinding speed and grinding force for species and sorts studied through texture analyses method.

Surface obtained in grinding follow, are characterized by equation 5.

$$z = a + b \cdot \ln x + c \cdot (\ln x)^2 + d \cdot (\ln x)^3 + e \cdot (\ln x)^4 + f \cdot (\ln x)^5 + g \cdot \ln y + h \cdot (\ln y)^2 + i \cdot (\ln y)^3 + j \cdot (\ln y)^4 + k \cdot (\ln y)^5 \quad (5)$$

in which:

x represent grinding speed, m/s;
y – grinding force, N

4. **CONCLUSION**

- choosing the research method was done in order to take into account many factors which influence the grinding by cutting of vegetable products;
- To description the grinding process of vegetable products are developed Rittinger law with relation 4, which was certified in laboratory through products at which study the grinding;
- From analyses at results obtained in laboratory was observed:
  - Grinding energy vary inverse proportionally with products humidity, big values at grinding energy was obtained to small values at humidity;
  - grinding energy calculate with the help of grinding force, determinate with the help of texture analisys, show considerable differences influenced to materials submissive to grinding (sort, humidity), working regime (grinding speed;
  - grinding energy are influenced at products density, have a differential bearing in function to product texture. The big interval at variation for grinding energy are observed at celery, fact which are explain through in that are the most big difference at structure, descendent at exterior to interior.

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