DETERMINATION OF ENERGY CONSUMPTION AT GRINDING THROUGH HEATING AT DIFFERENT SPECIES AND SORTS OF FRUITS WITH VARIABLE TEXTURE

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Produsele vegetale sunt vâsco-elastice iar elasticitatea lor variază considerabil şi depinde de gradul de maturitate şi de umiditatea produsului. Toate produsele vegetale, horticole, respectiv fructe au proprietăţi foarte variabile în timp şi spaţiu. Lucrarea prezintă o metodă pentru determinarea energiei consumate pentru mărunţirea produselor cu textură variabilă (fructe), în cazul mărunţirii produselor prin tăiere. Determinările au fost realizate în condiţii de laborator prin teste de forfecare pe specimene procesate testate.

Vegetable products are visco - elastics and their elasticity vary considerably and depend on maturity degree and the humidity of the product. From all vegetable products, horticultural products, respectively fruits have the most variable properties in time and space. The paper presents a method for determination the energy at grinding of products with variable texture (fruit), in case of the grinding the products through shearing. The determination was performed in laboratory conditions with the help of breaking test, on processing test specimens.

Keywords: grinding energy, energy consumption, broken, vegetable

1. Introduction

The grinding represents the operation of reduction of geometrical dimensions of particles following some exterior mechanical actions.

Then solid basic material, and products resulted following different process of fabrication are used in exceptional way in initial form, respectively resulted from technological process.

The grinding process of vegetable products is very complicated. This is because vegetable products are inhomogeneous with properties variable in time and space, respectively have variable texture [1, 2].

Vegetable products are visco - elastic and their elasticity vary considerably and depend on maturity degree and the humidity of the product [3, 4, 5, 6, 7].

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From all vegetable products, horticultural products, respectively fruits and legumes have the most variable properties in time and space.

When choosing the working method it must be taken into account the fact that grinding operation must lead to a superior quality product with low energy consumption [8, 9].

In breaking test, the material is broken when local force transmitted at impact surpass the broken tension of material and energy transmitted are adequate so as to surpass the force of cohesion at newly created surfaces.

The paper shows the determination of energy consumption in grinding vegetable products with variable texture, with the help of breaking test, meaning the grinding by material shearing. The determinations were realized in laboratory conditions and refer to grinding force determination.

The studies and research done, show in case of grinding by broken of fruits, the harder products are brooked at values higher of force while softer products are brooken at small deformation. The breaking by deformation can be an indicator at humidity content.

The experimental research effectuated at visco-elastic materials show the deformation at these materials depend on loading direction in time of material application.

2. Material and methods

The breaking test involves physical deformation of material until the breaking occurs. Deformation is controlled until the changes in specimen geometry can be measured.

The machines used to determin shearing force follow the Elmendorf broken principles.

The Elmendorf test was introduced sixty years ago and its one of the most utilized test in determination of the broken resistance at different specimens. The specimens of product, at certain dimension are catch in jaws of machine and through driving handle its releases pendulum for broken specimen. Value of shearing force is indicated on graduated scale with precision class 1.

Experiences were realized in laboratory conditions (laboratory at Process Equipment and Environmental Engineering from University of Bacau) on different types of specimens. For these experiences species and sorts of fruits was chosen, productions 2006 (without storage) in order to present a larger scale of vegetable products with a texture qualified as “hard” (table 1).

Table no. 1.

Species and sorts at fruits analyzed

No.	Species	Sort	Maturity	Observation
1.	Apple	Stainer	Complete	With peel
2.	Apple	Stainer	Complete	Less peel

3.	Apple	Idared	Complete	With peel
4.	Apple	Idared	Complete	Less peel
5.	Apple	Golden delicious	Complete	With peel
6.	Apple	Golden delicious	Complete	Less peel
7.	Apple	Jonangold	Complete	With peel
8.	Apple	Jonangold	Complete	Less peel
9.	Pear	Favorite lui Clap	Mellowness	With peel
10.	pear	Favorite lui Clap	Mellowness	Less peel

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.

The humidity was determined through drying with the help of a moisture analyzer with temperature range: 50^0C - 160^0C, electronic display from temperature, humidity, time and weight, precision class 1. The working temperature was 100^0C.

Table no. 2.

Medium density and humidity of fruits analyzed

No. crt.	Specie	Density, (kg/m^3)	Humidity, (%)
1.	Apple	790	88,5
2.	Apple	846	87,5
3.	Apple	920	84,1
4.	Apple	930	83,5
5.	Pear	1028	85,1

3. Result and comments

The shearing force was determined in laboratory conditions with the help of apparatus to broken test. During the determination process the breaking section was varied (respectively specimen thickness). Figures 1 and 2 present the way in which the shearing force vary function of specimen section at different values of humidity for types of fruit studied.

Analyzing the experimental dates presented in figures 1 and 2 can be observed the bigger values of shearing force were obtained at fruit with peel comparatively with fruits without peel. Can be observed that shearing force varied inverse proportionally with the humidity of products, bigger values for shearing force was obtained for products with small humidity.

The considerable differences between shearing force values for the different species and sorts of fruits analyzed are explained through the fact at this present various textural characteristics (peel smooth, hard, pulp crisp or mealy, juiciness).

To calculate the energy consumption the Rittinger relation was used, for species and sorts presented in tables 1 and 2.

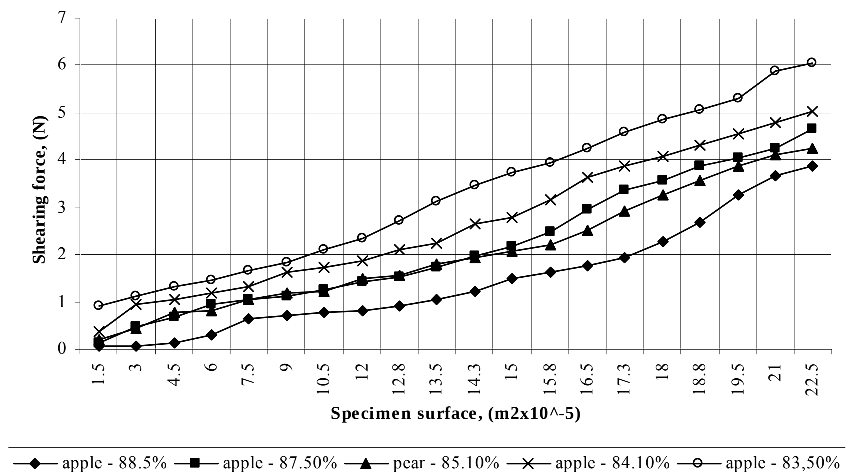

Fig. 1. Variations of shearing force function of specimen surface for species and sorts of fruits (with peel) studied at different humidity.

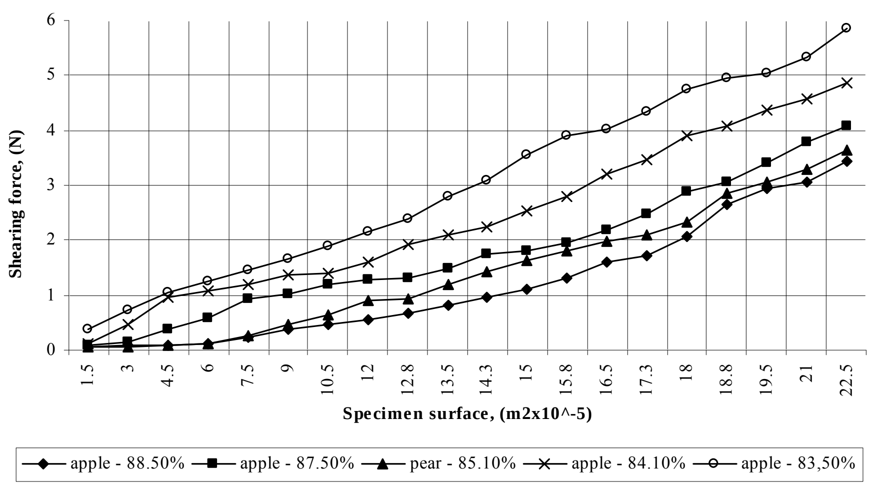

Fig. 2. Variations of shearing force function of specimen surface for species and sorts of fruits (no peel) studied at different humidity.

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 theory take into account all grinding stages. In this case we have:

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

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 [7, 8]. Therefore, in order to develop the Rittinger relation in case of materials with variable texture, we considre the Rittinger constant as follows:

$$k_R = F_m \cdot S_n \quad (2)$$

in which:

F_m is grinding force (shearing force through method presented), N;
S_n – surface new created, m^2.

$$S_n = S_f - S_i = (S_i + 2 \cdot S_r) - S_i = 2 \cdot S_r \quad (3)$$

in which:

S_r is the breaking surface of specimen;
S_f – final surface (after broken) of specimen;
S_i – initial surface (before broken) of specimen.

In figure 3 are represented the specimen breaking surface, may observe the breaking isn't linear.

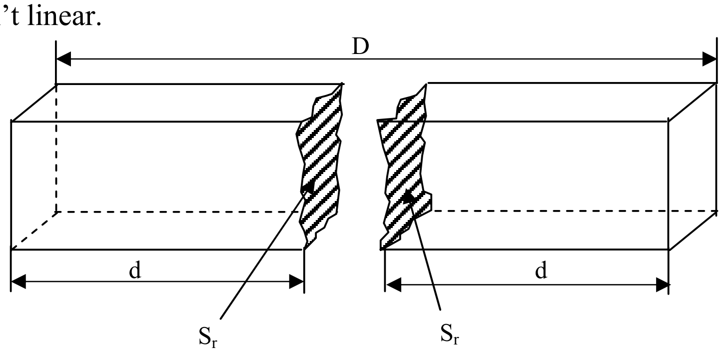

Fig. 3. The specimen breaking surface

But: $S_r \geq S_{str}$, result:

$$K_{snc} = \frac{S_r}{S_{str}} \Rightarrow S_n = K_{snc} \cdot 2 \cdot S_{str} \quad (4)$$

where:

S_{str} is surface of transversal section of specimen;

K_{snc} – new created surface coefficient, $K_{snc} \geq 1$ (it is equal with 1 when breaking is realized exactly on transversal surface).

If relations 2, 3 and 4 are placed in Rittinger relation, the final relation is obtained to to calculate the grinding energy for products with variable texture, respectively legumes and fruits with "hard" texture :

$$E_R = F_m \cdot \left(S_f - S_i\right) \cdot \left(\frac{1}{d} - \frac{1}{D}\right) \quad (5)$$

Taking into consideration that if breaking is produced perpendicular on specimen, (in this case $K_{snc} = 1$), we have:

$$E_r = F_m \cdot K_{snc} \cdot 2 \cdot S_{str} \cdot \left(\frac{1}{d} - \frac{1}{D}\right) \quad (6)$$

After replacing values obtained in laboratory in relation 6 for grinding force F_m, result values of grinding energy for different species and sorts of fruits at different humidity's (fig. 4 and 5).

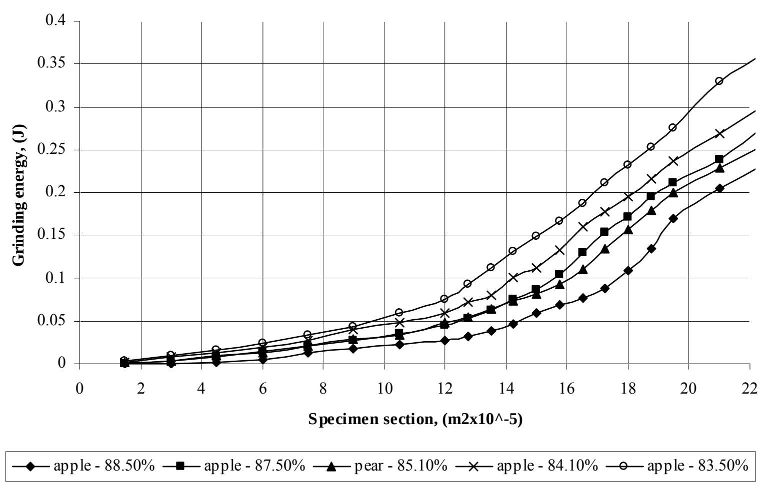

Fig. 4. Variation of grinding energy in function of specimen section for species and sorts of fruits (with peel) studied.

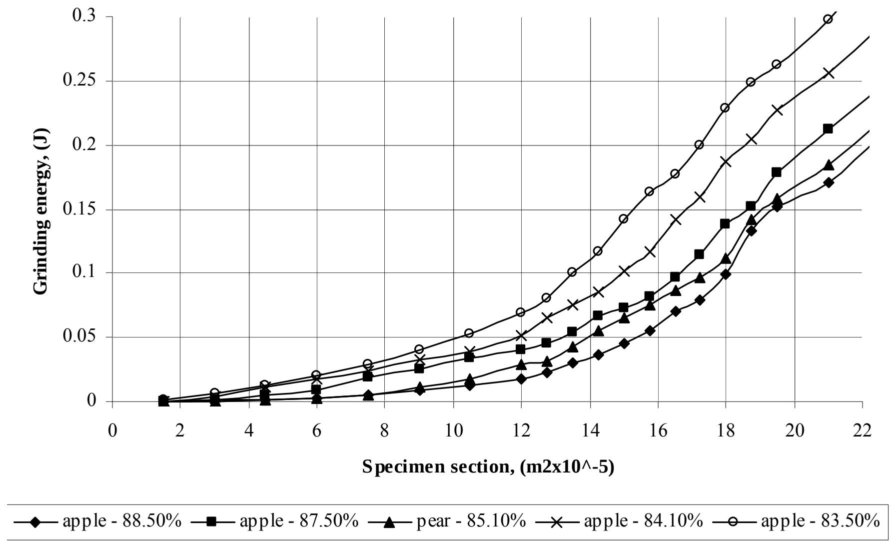

Fig. 5. Variation of grinding energy in function of specimen section for species and sorts of fruits (no peel) studied.

Analyzing the values obtained can be observed the existence of important differences between values of grinding energy at species and sorts of fruits analyzed. The grinding at product with peel involves higher consumption than products without peel, because the peels of fruits oppose an important resistance to breaking. The same products with high humidity involve low energy consumption comparatively to those with great humidity.

4. Conclusion

- Literature does not mention a clear and exactly method for grinding energy determination in case of vegetable products with variable texture, respectively horticultural products (fruits).
- For breaking process description of vegetable products (fruits) the law of Rittinger was developed with relation 6, which was verified in laboratory for studied products.
- Analyzing the results obtained in laboratory it was observed that:
    - The grinding force varies inverse proportional with humidity of products with variable texture, higher values of shearing force being recorded for products with low humidity.
    - The shearing force is influenced by products density, having a different behavior in function of product texture. The highest

variation interval for shearing force was observed at fruit with peel comparatively with shearing force for fruit without peel.

- The grinding energy determined with the help of shearing force, after Rittinger law, is different in function of: sort, product form, humidity and density.

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