THEORETICAL CONSIDERATION REGARDING THE DETERMINATION OF ENERGY CONSUMPTION AT CRUMBLING BY CUTTING OF PRODUCTS WITH VARIABLE TEXTURE

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Abstract: The crumbling products with variable texture its frequent using in food industry and it's important thanks to the great quantities of products processing, as well as of energy consumption, from which only a trifling part (0,1-0,2 %) are consumed effectively from surmount the forces of cohesion by particles, the scrap dissipating in vain and injurious by heat form.

Keywords: energy consumption, textural property, crumbling by cutting.

1. INTRODUCTION

In case of products with variable texture (fruits and vegetables), texture which variation from hard (roots, carrot etc.) until as soft texture (tomatoes, apricots etc.), so crumbling process then and actives work mechanism of crumbling varied very much, thus can affirm that crumbling operation it's one the most expensive operations from food industry.

Effects of crumbling by cutting at vegetable products can by praised from diminution of products dimension.

The studies and researches effectuated prove that the energy consumed at crumbling it is only in part useful, the rest refer to produce the elastic and plastic deformation, at friction between particles and the active organs of equipment, as well as to mechanical intern wastage of equipment.

2. THEORETICAL CONSIDERATION

The crumbling by cutting it's realized at action of shearing forces, these producing the product breaking, realizing the energy applied in the most as heat.

In attend to study realized was ascertaining existence some theories from study at possibility to reducing the energy consumption.

These theories to start up of supposition fundamental the consumption of specific energy represents energy necessary to obtain a certain crumbling degree of unit mass from product submissive at crumbling.

Establish of energy consumption can by realized from two modalities:

1. Itself starting at differential general equation of energy consumption necessary in grinding process (Charles equation), and specially:

$$dE = -\frac{C}{x^n}dx \tag{1}$$

when:
dE it's variation of crumbling energy;
dx – variation of particle dimension;
C, n – experimental coefficients and depends at particles status, velocity and standing at forces applied.

The useful energy of crumbling will by:

$$E_0 = \int_0^E dE = -\int_{x_1}^{x_2} C\frac{dx}{x^n} \tag{2}$$

when:
E it's crumbling energy;
x – particules dimension.

To integrate relation 2, obtain the general equation of crumbling:

$$E_0 = -C\int_{x_1}^{x_2} x^{-n}dx = -C\cdot\frac{x^{1-n}}{1-n}\Bigg|_{x_1}^{x_2} \tag{3}$$

If in relation 3, n = 0,25, integrating and replace at x_1 and x_2 through value of medium dimension of particles submissive of crumbling (D) and of crumbling particle (d), it obtain:

$$E_A = K_A\left(\sqrt[4]{d^3} - \sqrt[4]{D^3}\right) \tag{4}$$

From n = 1, integrate relation 2 and make the same replacing like in relation 3, have:

$$E_k = K_k \log\frac{D}{d} \tag{5}$$

Relation 5, represent law of Kick and the report at crumbling energy necessary to particle until break moment. It's confirmed in practice from big particles crumbling ($99<\lambda<999$).

If in relation 2, n = 1,5 replaced and integrating obtaining:

$$E_B = K_B\left(\frac{1}{\sqrt{d}} - \frac{1}{\sqrt{D}}\right) \tag{6}$$

in which:
D its dimension of particle between at crumbling;
d – dimension of particle after to crumbling.

The equation obtained represents equation at law of Bond.

If in relation 2, n = 2 and it integrated and makes the same replacing like in relation 3, result:

$$E_R = K_R \left(\frac{1}{d} - \frac{1}{D} \right) \tag{7}$$

Relation 7, represent equation at law of Rittinger and indicate the energy consummated in crumbling process, it is directly proportionally with new surface create in crumbling process and she is confirmed in practice from finely grinding ($99<\lambda<999$).

In this relation the coefficients k depend at nature of particles.

2. The second modality of calculus starting from total consumption of specific energy. This can by placed under form given from Rebinder:

$$L_{sp} = L_1 + L_2 \tag{8}$$

in which:
L_1 it's mechanical work consumed at crumbling equipment from personal consume;
L_2 – mechanical work consumed of product submissive to crumbling.

Relation 8, can be writhed like a sum of matrix elements $\left(L_{ij}\right)_{i=\overline{1,2},\ j=\overline{1,2}}$:

$$L_{ij} = \begin{pmatrix} L_{11} L_{12} \\ L_{21} L_{22} \end{pmatrix} \tag{9}$$

when:
L_{11} its mechanical work consumed from elastic deformation at work organs;
L_{12} - mechanical work consumed from wear at active organs of crumbling machine;
L_{21} – mechanical work consumed for elastic deformation at particles;
L_{22} – mechanical work consumed for creating new surfaces.

Mechanical work consumed for deformation and wears of active organs at working, L_1, must by to much small and represent a percentage of total consumption of energy necessary of crumbling.

The last term of equation 8, represent only useful work (the remainder consumption comply losses from heat and wear) and can be write:

$$L_2 = L_{21} + L_{22} \tag{10}$$

in which:

$$L_{21} = zE_d \tag{11}$$

$$E_d = \frac{\sigma_r^{\ 2}}{2E} \cdot V_f \tag{12}$$

$$L_{22} = \sigma_r \Delta A \alpha \tag{13}$$

when:
z – represent number of crumbling cycles;
E_d – strain deformation, (J);
V_f – volume of particle deformation, (mm^3);
σ_r – breaking strain of particle, (N/mm^2);
E – coefficient of elasticity at particle, (N/mm^2);
ΔA – specific area of surface new created, (cm^2/cm^3);
α - coefficient at which value is conditioned at constructive particularity of crumbling machine and working process.

$$\alpha = \left(\frac{A_2}{A_1}\right)^n \tag{14}$$

when:
A_2 its surface area of particle resulted after crumbling, (cm^2);
A_1 – surface area of particle before crumbling, (cm^2);
n – exponent what depend at crumbling conditions.

Considering if particle its spherical, then:

$$V_f = \frac{1}{\lambda} \cdot \frac{\pi D^3}{6} \tag{15}$$

and replacing in relation 11, after some simple transformations obtain:

$$L_{21} = zK_{21} \frac{\sigma_r^{\ 2}}{2E} D^3 \tag{16}$$

k_{21} – proportionality coefficient.

From relation of crumbling degree obtain:

$$d = \frac{D}{\lambda} \tag{17}$$

Surface of particle (consideration spherical), before of crumbling will by $A=\pi D^2$, and after crumbling will by:

$$a = \pi d^2 \cdot Z = \pi \left(\frac{D}{\lambda}\right)^2 \cdot \frac{D^3}{\left(\frac{D}{\lambda}\right)^3} = \pi D^2 \lambda \tag{18}$$

thus:

$$\Delta A = a - A = \pi D^2 \lambda - \pi D^2 = \pi D^2 (\lambda - 1) \quad (19)$$

Replacing relation 19 in relation 13, after some simple's transformations, have:

$$L_{22} = K_{22} D^2 \alpha^n \quad (20)$$

when:
k_{22} its coefficient of proportionality.

$$K_{22} = \pi D^2 \sigma \quad (21)$$

To make in account at relations 20 and 16, relation 8 will by:

$$L_{sp} = L_1 + z k_{21} (\frac{\sigma_r^{\ 2}}{2E}) D^3 + k_{22} (\lambda - 1) \alpha \quad (22)$$

which represent crumbling law.

Relation 22, takes in consideration both crumbling degree, through size ΔA, and conditions in which make crumbling from sizes z and n.

3. CONCLUSION

Researches show that relations are complementary, that is energy consumed from creation at new surfaces its equal with total energy from reduction of particles volume.

The study and researches realized show that in time of crumbling by cutting of products with variable texture take place in product variable deformations, deformations that depend at form of works organ, elastic ratio of products submissive at crumbling by cutting.

The same it's know that vegetables product are viscose-elastics and elastic ratio variation remarkable in function of maturity degree and degree of humidity.

So in the crumbling by cutting process from to realizing small consumption at energy and a good productivity, must by realized correlation between:

- construction of active parts;
- the nature of product which are crumbling;
- the textural property of products
- the crumbling regime

REFERENCES

[1] Dekkker N.: *Engineering properties of food*, New York, 1995.
[2] Ioancea L., Dinache P., Popescu Gh., Rotar I.: *Maşini, utilaje şi instalaţii*, Ed. Ceres, Bucureşti, 1986.
[3] Mohsenin N., 1986 - *Physical Properties of plant and animal materials*, Second Edition, New York.
[4] Nedeff V.: *Procese de lucru, maşini şi instalaţii pentru industria alimentară*, Ed. Agris, Redacţia Revistelor Agricole, Bucureşti, 1997.

[5] Sitkei G., 1986 – *Mechanics of agricultural materials,* Departament of woodworking, Univerity of Forestry and Wood Science Sopron, Hungary.
[6] *** - http://www.unitoperations/sizereduction1.htm
[7]. *** - *Food science and Technology*, vol 1 – 12, 2003, 2004.