IOP Conf. Series: Materials Science and Engineering **147** (2016) 012150 doi:10.1088/1757-899X/147/1/012150

The study behavior of food materials with soft texture subjected to shredding by cutting

M Panaite-Lehadus[1], C Olaru[1], V Nedeff[1], I Olaru[2] and E Mosnegutu[1]

[1]Department of Mechanical Engineering and Environmental Engineering, Faculty of Engineering, "Vasile Alecsandri" University of Bacau, Bacau, Romania
[2]Department of Industrial Systems Engineering and Management, Faculty of Engineering, "Vasile Alecsandri" University of Bacau, Bacau, Romania

E-mail: mirelap@ub.ro

Abstract. Studies and experimental research in the field of shredding of food materials with soft texture by means of metal wire cutting heated to 97°C are particularly important, their results can bring more clarification regarding the shredding analysis, analysis of cutting aspect, analysis of quantitative and quality of juice and / or material loses, determining of necessary shredding forces. For a better understanding of the phenomenon occurring in the shredding of food materials with soft texture, have been selected for study a large variety of materials with different textures and properties. In the experimental determinations by heating of metal wire cutting, the resulted surfaces after the cutting are more regular, are needed lower cutting forces necessary to shred the material and results reduces quantities of juice or material losses.

1. Introduction

The food material is that naturally product from vegetable or animal origin, which represents a raw material for processing in an industrial process or can be, consumed as such [1, 2, 3].

Tissues which make up the mass of food materials are associated between them under the name of texture and size and arrangement of cells represent the structure. Structure and texture of food materials express their firmness [4, 5, 6, 7, 8, 9]. The shredding implies the possibility to divide food materials with soft texture in many smaller components. Preoccupation of food experts is to design equipment's and technologies to make optimal shredding (realization the desired degree of shredding with lower power consumption). While, during the cutting process of food material should not be broken or not be lost material [10].

Many manufacturing processes from the food industry require the shredding in advance of food material with soft texture. Generally it's used the concept of particle to illustrate a volume of material; these particles can be the result of a natural process (fruits and vegetables) or obtained from the technological processes (cheese, butter, Turkish delight, marmalades, jellies etc.) [11]. Regarding of shredding process, it should be noted that during of this operation, the state of solid changes, they are subjected to mechanical and thermal strain. Inside the shredded material appear deformations and stresses. The shredding of food materials is very complicated; this is explained by the fact that food materials are inhomogeneous and the properties are variable in time and space [12, 13].

Requirements for shredding of food materials refer to main factors that influence the process of shredding, such as: mechanical and textural characteristics of the material (their consistency), the shredding regime and geometric parameters of the shredding devices [12, 13].

Few studies in the literature have investigated in detail the behavior of food materials with soft texture during the shredding operation. Generally was used the testing of deflection of cheese with soft texture and the study of behavior at low temperatures [14, 15, 16, 17, 18, 19, 20].

When choosing the shredding scheme and shredding machine types, should be considered: state of tension, the temperatures and ambient conditions [21, 22]. The research will be focused on the food materials with soft texture because those have a wide range of textural properties, structure and composition; they require an elucidation of how the material reacts under the action of the shredding devices.

This paper aims to study the behavior of the material food textured soft shredding cut using metal wires heated at 97^0C and working speed 2.5 mm /sec. After shredding result cutting surfaces with less roughness, cutting forces low also the loss of juice and material is low.

2. Experimental method

For the study of experimental research was conceived, designed and made a laboratory stand equipped with a metal wire cutting device. For a better relevance of the determinations were made sets of measurements using a metal wire cutting device with different diameters (0.2 mm, 0.3 mm, 0.4 mm) heated to 97°C and cutting speed v = 2.5 mm/s.

For a better understanding of the phenomenon occurring in the shredding of food materials with soft texture, at this study was used different materials with different textural properties (table1).

Table 1. Food materials with soft texture used in the study.

No.	Food materials with soft texture	Type/variety
1	Curdled cheese	Sheep cheese
2	Tomato	Unibac
3	Peeled oranges	Valencia
4	Strawberries	Elsanta
5	Peeled banana	Cavendish
6	Turkish delight	By Bucharest

The scheme of shredding by cutting with metal wire device is shown in figure 1. By the action of the force F, the metal wire is moved perpendicular to penetrating through a mass of food material.

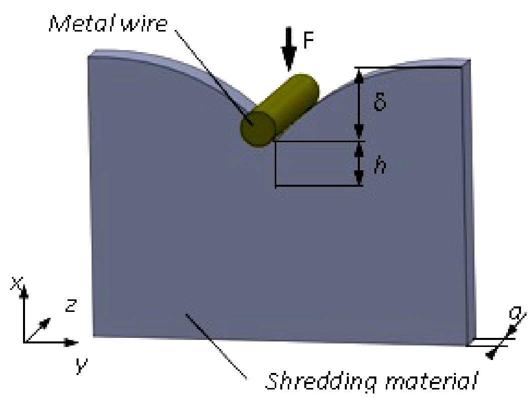


Figure 1. Shredding by cutting with metal wire device.

The material initially deforms on the length δ, called penetration length. Depending on the material, the deformation can be composed of two components, one elastic and one plastic.

When is applying a higher cutting force, is initiated the cutting or detachment of material layers, the metal wire moving to the newly created opening in the mass of material. This process will continue by increasing the cutting force until the steady state cutting.

IOP Conf. Series: Materials Science and Engineering **147** (2016) 012150 doi:10.1088/1757-899X/147/1/012150

Length of separation material layer before metal wire is noted with *h* and material thickness is noted with *a*.

The manner in which the food material has reacted at the penetration of the metal wire cutting device is shown schematically in the form of captured frames during the shredding process in figure 2.

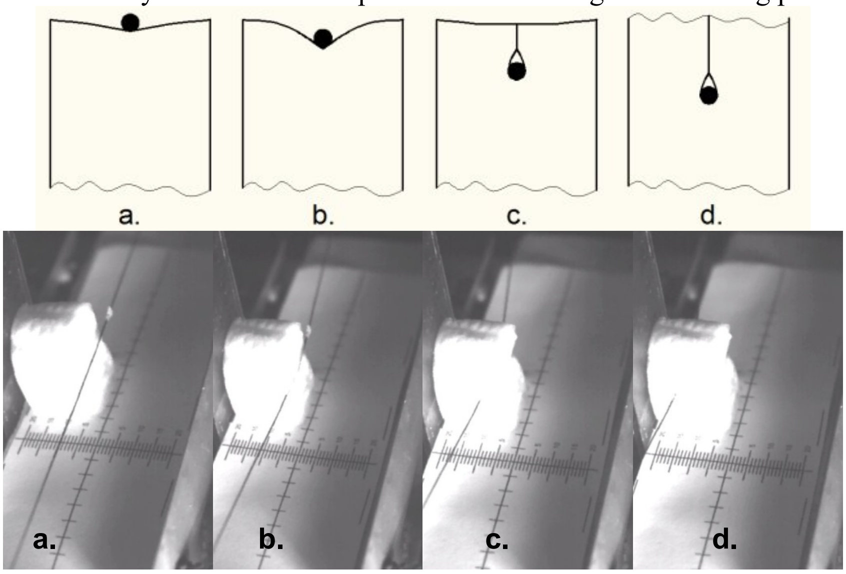
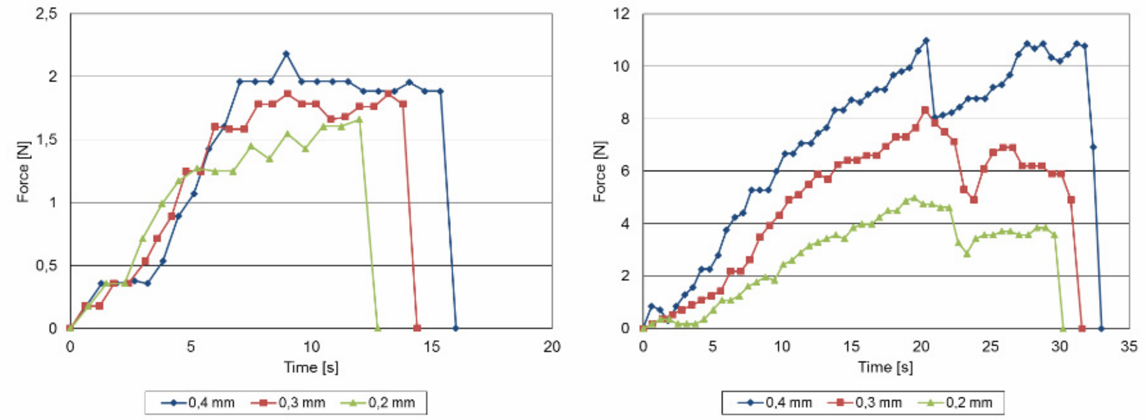


Figure 2. Various stages of cutting:
(a) cutting initialization, (b) intermediate point of cutting; (c) beginning steady state of cutting , (d) steady state of cutting.

3. Experimental results

For food materials with soft texture studied shredded with metal wire cutting heated to 97°C temperature and with cutting speed v = 2.5 mm/s, we obtain the following graphs of variation of cutting force in time (figures 3 ÷ 5).

By metal wire heating at higher temperatures (97°C) in the case of curdled cheese (figure 3.a) it was found that the maximum of cutting forces necessary to shred register more reduced values (2.2N, 1.8N and 1.6N), in time interval between 13 ... 15 seconds.



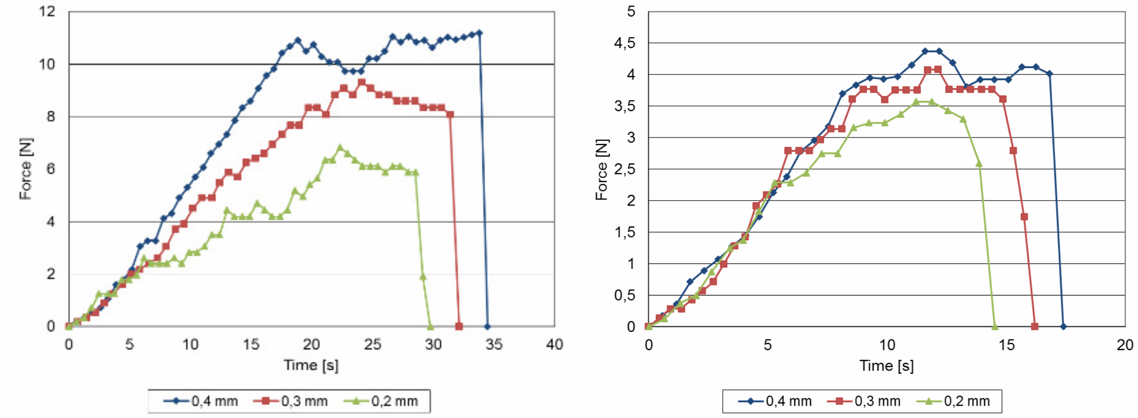
(a) (b)

Figure 3. The variation of cutting force in time at shredding with metal wire cutter:
(a) curdled cheese; (b) tomatoes.

In the case of the cutting force analysis in time at tomatoes (figure. 3.b) by heating the metal wire at temperature 97°C, the graphs present the same configuration with increasing levels of forces in the

IOP Conf. Series: Materials Science and Engineering **147** (2016) 012150 doi:10.1088/1757-899X/147/1/012150

beginning of cutting area and at the breaking area, respectively a decreasing level of cutting forces in the middle zone. However by the heating of metal wires were recorded lower values of cutting forces 11 N; 8.3 N and 5 N, the time period required to complete the cutting hovering around 30 … 34 seconds for all three wire diameters analysed.

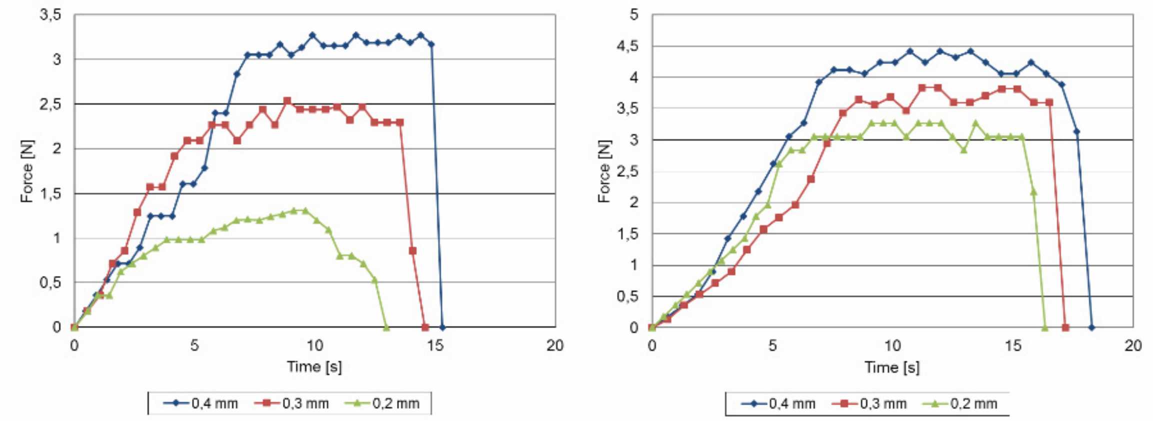


(a) (b)

Figure 4. The variation of cutting force in time at shredding with metal wire cutter: (a) peeled oranges; (b) strawberries.

At the peeled oranges graph of force variation are maximum values by 11.1N, 9.3N and 6.8 N in the range of 30 ... 35 seconds (figure 4.a). From the beginning to the end of cutting process the graph has an increasing configuration until the braking moment of material.

From the analysis of the graph of the forces variation in time in case of strawberries (figure 4. b) it has been found that due to the homogeneous constitution, the breaking is produced constantly, is recorded a level in which the force increases to the penetrate of metal wire in the material mass, then that can be remarked a constant of the force throughout the material thickness. Maximum recording forces for three types of diameters used was 4.3 N, 4 N and 3.5 N in the range of 14 ... 17 sec.



(a) (b)

Figure 5. The variation of cutting force in time at shredding with metal wire cutter: (a) peeled banana; (b) turkish delight.

The curve of the variation forces in time at peeled banana (figure 5.a) shows three distinct areas: initiating of wire penetration, cutting area and complete breaking of the material. The value of forces was recorded at 3.2 N, 2.5 N and 1.3 N and the time required from the cutting initiation to the complete breaking of material hovering around 15 sec.

By the heating of metal wire and due to the homogeneous structure of the Turkish delight is obtained the uniform curve of the variation of cutting forces in time, materialized in this case by three well-defined specific areas (figure 5.b): initiating of cutting, the constant advance of the wire through the mass of material. Maximum cutting forces value was recorded at 4.4 N, 3.8 N and 3.2 N, the average of breaking time was 16 sec.

By using the analytical balance and by the visual analysis of the cutting aspect of food materials with soft texture having undergone metal wire shredding at a temperature of 97°C, we examined a series of indicators such as the adherence to the cutter, the cutting aspect, loss of juice and/or material (tables 2÷4).

Table 2. Working indices obtained for the shredding of food materials with soft texture by means of a metal wire with, v=2.5mm/s; t=97°C; d=0.2 mm.

No.	Food material	Average cutting surface a x b [mm^2]	Mass before cutting [g]	Mass after cutting [g]	Percentage of losses [%]	Adherence to the cutter	Cutting aspect
1	Curdled cheese	30 x 30	32.8	32.73	0.21	Small	Smooth
2	Tomatoes	50 x 50	85.88	85.21	0.78	Small	Few rough
3	Peeled oranges	60 x 60	99.64	99.1	0.54	Small	With rough
4	Strawberries	25 x 25	25.53	25.51	0.07	Small	Smooth
5	Peeled bananas	30 x 30	48.32	48.29	0.06	Small	Very Smooth
6	Turkish delight	35 x 35	40.67	40.66	0.02	Small	Smooth

Table 3. Working indices obtained for the shredding of food materials with soft texture by means of a metal wire with, v=2.5mm/s; t=97°C; d=0.3 mm.

No.	Food material	Average cutting surface a x b [mm^2]	Mass before cutting [g]	Mass after cutting [g]	Percentage of losses [%]	Adherence to the cutter	Cutting aspect
1	Curdled cheese	30 x 30	33.8	33.72	0.24	Small	Smooth
2	Tomatoes	50 x 50	84.5	83.78	0.85	Small	Few rough
3	Peeled oranges	60 x 60	103.78	103.15	0.61	Small	With many rough
4	Strawberries	25 x 25	18.32	18.30	0.10	Small	Smooth
5	Peeled bananas	30 x 30	51.42	51.38	0.08	Small	Very Smooth
6	Turkish delight	35 x 35	41.34	41.32	0.05	Small	Smooth

The analysis of tables with work indices obtained from shredding of food materials with soft texture through the metal wire was found that significant losses (juice/material) were recorded at shredding tomatoes (0.78% ÷0.89%) and oranges (0.54% ÷ 0.64%) due to high content of juice, value decreases with decreasing the metal wire cutting diameter and increase the wire cutting temperature.

For other types of materials analysed (curdled cheese - 0.21% ÷ 0.27%, Turkish delight - 0.02% ÷ 0.06%, strawberries - 0.07% ÷ 0.12%, peeled banana – 0.06% ÷ 0.10%) due to the homogeneous composition, they have low percentage of losses from shredding.

Table 4. Working indices obtained for the shredding of food materials with soft texture by means of a metal wire with, v=2.5mm/s; t=97°C; d=0.4 mm.

No.	Food material	Average cutting surface a x b [mm^2]	Mass before cutting [g]	Mass after cutting [g]	Percentage of losses [%]	Adherence to the cutter	Cutting aspect
1	Curdled cheese	30 x 30	30.1	30.02	0.27	Small	Smooth
2	Tomatoes	50 x 50	83.5	82.76	0.89	Small	Few rough
3	Peeled oranges	60 x 60	110.1	109.4	0.64	Small	With many rough
4	Strawberries	25 x 25	17.52	17.50	0.12	Small	Smooth
5	Peeled bananas	30 x 30	35.22	35.19	0.10	Small	Very Smooth
6	Turkish delight	35 x 35	45.64	45.61	0.06	Small	Smooth

4. Conclusion

By using of the heated metal wire cutting for the food material with soft texture we attempting to remove the inconveniences that arise when using metal knives for cutting, because the shredded material no longer adheres to the cutting device due to the decrease of the contact surface between it and the material and the fact that by heating the metal wire cutting, this penetrates more easily through the mass of material. By the analysis of the graphs it was found that by the decrease in diameter of the metal wire cutting was obtained reduced values of cutting forces. By using of the heated metal wire cutting was followed to limit losses of material, the maintaining of shape and the textural properties of the material, so that the shredding efficiency to be as high. Depending on the rheological domain: viscous, elastic and plastic, each food material has a specific behaviour during breaking, peeled bananas with characteristics mainly on viscous domain, curdled cheese is close to the elastic-plastic domain, strawberries and Turkish delight to the visco-elastic domain, while oranges and tomatoes being found between these three domains (visco-elastic-plastic). Depending on the degree of homogeneity and structural properties of the materials analyzed, it was found that food materials are most suitable for wire cutting were Turkish delight, bananas, strawberries and curdled cheese. At this materials, the cutting was smooth from start to finish because of their relatively uniform composition, heating of metal wire cutting at higher temperatures (97ºC) leading to reduced cutting forces by reducing adherence of materials to the metal wire and improve the surface quality resulting from shredding with reduced loss of material or juice. The structure of tomatoes and oranges reflected by the presence of skin, seeds and interior composition, the cutting was not uniform; the metal wire cutting must overcome the additional resistance, thus results the highest values for the shredding force. Due to the sudden exit of the metal wire from the material, given that the cutting forces are higher, the resulting cutting surface is more irregular. However in the case of these fruits were registered lower losses of juice with increasing temperature of metal wire cutting. It was found significant losses of juice in the case of tomatoes and peeled oranges, which is explained by the interior composition rich in liquid and lower losses in the case of curdled cheese, strawberries, peeled bananas, and Turkish delight, mainly due to homogeneous composition of these materials. Thus shredding with metal wire is more suitable to food materials with soft texture with a uniform composition. As a result of using heated wire method were obtaining cutting surfaces with few rough, reduce cutting forces, and also reducing losses juice and material resulting from shredding.

5. References

[1] Abbott J A 1999 Quality measurement of fruits and vegetables *Postharvest Biological Technology* **15** pp 207–225
[2] Edwards M 1999 Vegetables and fruit. In Food Texture: Perception and Measurement *Aspen Publishers, Gaithersburg*
[3] Heldman D and Lund D 2007 Handbook of food Engineering, Second edition *CRC Press Taylor & Francis Grop*
[4] Alvarez M D, Saunders D E J, Vincent J F V and Jeronimidis G 2000 An engineering method to evaluate the crisp texture of fruit and vegetables *Journal of Texture Studies* **31** pp 457–473
[5] Bouton J O 2000 Une nouvelle generation d'appareils de controle pour la texture *12th Agoral Meeting, Montpellier* pp 199-204
[6] Gipsy T–M and Barbosa-Canovas G V 2005 Rheology for the food industry *Journal of Food Engineering* **67** pp 147–156
[7] Goh S M 2002 An engineering approach to food texture studies *PhD thesis, Imperial College London*
[8] Sharma S K, Mulvaney S J and Rizvi S H 1999 Material testing and rheology of solid foods, Food process engineering: theory and laboratory experiments *Wiley-Interscience* pp 20–50
[9] Van Vliet T 1999 Rheological classification of foods and instrumental techniques for their study *Aspen Publishers, Gaithersburg*
[10] Atkins T 2009 Food and Food-Cutting Devices and Wire Cutting *The Science and Engineering of Cutting* pp 849–860
[11] Olaru C 2012 Contribuţii la studiul regimului de mărunţire a materialelor agroalimentare cu textură moale *Teză de doctorat, Universitatea "Vasile Alecsandri" din Bacău*
[12] Panainte M, Mosneguţu E, Savin C and Nedeff V 2005 Echipamente de proces în industria alimentară. Mărunţirea produselor agroalimentare *Editura Meronia şi Rovimed Publishers*
[13] Panainte M 2008 Cercetări privind optimizarea procesului de mărunţire a produselor agroalimentare *Teză de doctorat, Universitatea Tehnică „Gh. Asachi" Iaşi*
[14] Atkins A G, Xu X and Jeronimidis G 2004 Cutting by pressing and slicing of thin floppy slices of materials illustrated by experiments on cheddar cheese and salami *Journal of Material Science* **39** pp 2761–2766
[15] Brown T 2005 Cutting forces in foods: experimental measurements *Journal of Food Engineering* **70** pp 165–170
[16] Charalambides M N, Williams J G and Chakrabarti S 1995 A study of the influence of ageing on the mechanical properties of Cheddar cheese *Journal of Material Science* **30** pp 3959–3967
[17] Charalambides M N, Goh S M , Lim S L and Williams J G 2001 The analysis of the frictional effect on stress–strain data from uniaxial compression of cheese *Journal of Material Science* **36** pp 2313–2321.
[18] Imbeni V, Atkins A G, Jeronimidis J and Yeo J 2001 Rate and temperature dependence of the mechanical properties of Cheddar cheese *Proceedings of 10th International Conference on Fracture*
[19] Kamyab I, Chakrabarti S and Williams J G 1998 Cutting cheese with wire *Journal of Material Science* **33** pp 2763–2770
[20] Walstra P and Van Vliet T 1982 Rheology of cheese *Bull IDF* **153** pp 22–27
[21] Lana M, Tijskens L M and Kooten O 2005 Effects of storage temperature and fruit ripening on firmness of fresh-cut tomatoes *Postharvest Biology and Technology* **35** pp 87–95
[22] Thompson M 2005 Procesul de mărunţire, Curs *Universitatea Politehnica Bucureşti* 2005