TEKA. COMMISSION OF MOTORIZATION AND ENERGETICS IN AGRICULTURE – 2012, Vol. 12, No. 1, 127–130

Effect of knife wedge angle on the force and work of cutting peppers

Elżbieta Kusińska, Agnieszka Starek

Department of Food Engineering and Machinery, University of Life Sciences in Lublin, Poland,
e-mail: elzbieta.kusinska@up.lublin.pl

Summary. The paper presents the method of measurement and the results of tests on cutting the fruits of two peppers cultivars - King Arthur and Bell. It was found that the knife wedge angle had a significant effect on the cutting force and work. Higher values of cutting force and work were obtained for red peppers than for yellow peppers. The cutting force and work were also related to the textural properties of the peppers.

Key words: peppers, cutting, knife wedge angle, cutting force, cutting work, texture.

INTRODUCTION

Peppers (*Capsicum annuum L.*) are a vegetable known and valued by consumers due to their high biological values and specific taste [4, 11]. The fruits of peppers are valued especially for their spice and medicinal properties [16]. Powdered peppers, also known as paprika, are used for colouring spice mixes for soups, smoked meats and for extruded products, as well as for extending the shelf life of ready-to-eat products (ready-to-eat dishes, cooled as well as frozen). The vegetable enhances the taste of food and constitutes a valuable component of healthy diet [1, 2, 13]. The fruits and seeds of peppers are a valuable raw material in the processing and pharmaceutical industries. They are included in the composition of numerous homeopathic preparations [17]. Peppers are particularly rich in organic micro-components with antioxidant properties that have a health-promoting effect on the human organism [7, 12]. Fresh fruits of peppers are the best source of antioxidants. Peppers can be subjected to a variety of technological factors, i.e. freezing, lyophilisation or freeze-drying, cooking, blanching. Proper selection of the parameters of those processes permits to avoid the degradation of valuable compounds [9].

The development of new technologies aimed at reducing the costs of production and at limiting the yield losses (ratio of the mass of cut products to the mass of intact products) permitted the improvement of fragmentation techniques [Kader 2002]. In the case of agricultural and food materials, cutting is a very frequently used form of fragmentation. Cutting forces not only determine the power requirements of the process under given conditions, but also affect the design of transport assemblies of processing machines. The possibility of calculating the cutting forces is a prerequisite for the design of properly operating and energy-saving machines in which the cutting process is realised [3]. In the fruit and vegetable processing industry cutting is applied to obtain products with desired shape and size [5]. The process of cutting fruits and vegetables depends primarily on the design of the cutting assembly, the shape of the cutting edge, the parameters of operation of the device, and on the physical properties of the plant material – its strength properties and structure. Also important are the conditions of cultivation, the duration and method of storage of the material, degree of ripeness, harvest conditions, cultivar-related traits, etc. [15, 19]. The working element that acts on the plant is the knife or cutting blade, whose operating parameters affect the values of operating drag of machines and the quality of cutting [6]. The operation of cutting knives can be considered as that of sharp wedged penetrating the material being cut. Flat knives with straight edge have found the most extensive application [18]. Studies concerned with the processes of cutting and fragmentation of materials comprise, in most cases, the determination of relations between the level of fragmentation of the material, its operating parameters and the energy expenditure [14, 8]. The diversity of designs and principles of functioning of cutting assemblies make it necessary that, for the purposes of their design and operation, determination was performed of the total or unit work of cutting [20].

OBJECTIVE AND SCOPE OF STUDY

The objective of the study reported herein was the determination of the effect of the knife wedge angle on the force and work of the process of cutting peppers. The variable parameters were the peppers cultivars and the orientation of the material being cut. Additionally, the textural properties of the two peppers cultivars were determined and compared.

METHOD

The experimental material was ripe fruits of two peppers cultivars: red peppers cv. King and yellow peppers cv. Bell. The material used in the study was fresh, healthy, free of mechanical damage. The fruits were harvested in the phase of full ripeness in the second decade of September, and tested on the following day. The peppers were subjected to preliminary treatment: washing, cutting along the pod, and removal of seeds. The material for the tests was cut from the central section of the peppers (i.e. in a zone with relatively constant circumference), in the form of half-rings with the height of 40 mm. The thickness of the meat was 5±2 mm. The process of cutting was conducted on the texture analyser, type TA.XT plus, maintaining constant orientation of the cutting knife. The knifes used in the tests were straight edge, with various wedge angles: 2.5°, 5°; 7.5°, 10°, 12.5°; 15°; 17.5° and 20°. Samples of peppers were placed parallel to the base of the analyser, skin down or skin up, and then they were loaded, in the perpendicular direction, with the cutting element at a constant velocity of 50 mm·min^{-1}. The results of the measurements were in the form of graphs representing the relation between the cutting force and knife displacement, from which the values of the cutting force and work were determined. The tests were performed in one hundred replications. Additionally, analysis of the texture of the peppers was performed, also by means of the TA.XT plus texture analyser, equipped with an adapter in the form of a cylinder with diameter of 25 mm. From each vegetable 10 specimens were prepared, in the form of cubes with the side of 5 mm. These were subjected to double compression at head travel velocity of 50 mm·min^{-1}. The process of compression was conducted at constant deformation of the specimens, of 50% of their height; the specimens were positioned skin down. Analysis of the measurement results, in the form of texture-grams, permitted the determination of the following texture parameters: hardness, brittleness, elasticity, cohesiveness, chewability.

RESULTS

The results of measurements of peppers cutting force and work are presented in Fig. 1-4.

The analysis of graphs representing the cutting force in relation to knife wedge angle with the peppers placed skin down revealed significant differences between the cultivars (Fig. 1), which was confirmed by the analysis of variance. The highest values of the cutting force were 53.211 N (cv. King Arthur) and 47.805 N (cv. Bell) for knife wedge angle of α=20°, while the lowest cutting force values were obtained for the knife wedge angle of α=2.5° (22.098 N and 26.641 N). Large differences between the cultivars appeared at the knife wedge angle of α=7.5° (73.95%).

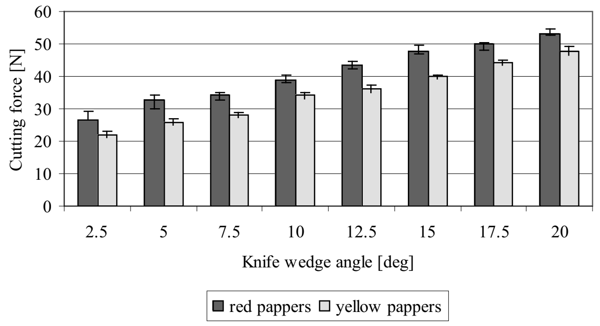

Fig. 1. Relation of cutting force of red and yellow peppers to knife wedge angle with the material positioned skin down

The relations presented in Figure 1 are described by equations (1) and (2):

$$F_{cr} = 25.19e^{0.1\alpha}, \tag{1}$$

$R^2 = 0.98$,

$$F_{cy} = 3.676\alpha + 18.273, \tag{2}$$

$R^2 = 0.99$,

where:
F_{cr} – cutting force of red peppers,
F_{cy} – cutting force of yellow peppers,
α – knife wedge angle.

For the fruits positioned skin up (Fig. 2), with knife wedge angle increase within the adopted range, the cutting force of yellow peppers grew1.82-fold and that of red peppers 1.73-fold, and in the case of material cut from the meat side, the corresponding increases were 2.16 and 1.99-fold. The lowest values of cutting force, 41.91 N (yellow peppers) and 50.845 N (red peppers), were recorded at knife wedge angle of α=2,5°, and the highest at α=20° (76.651 N for cv. Bell and 88.032 N for cv. King Arthur). The cutting force values for both cultivars were higher when the material was cut from the skin side than from the meat side, which was related with the structure of the skin.

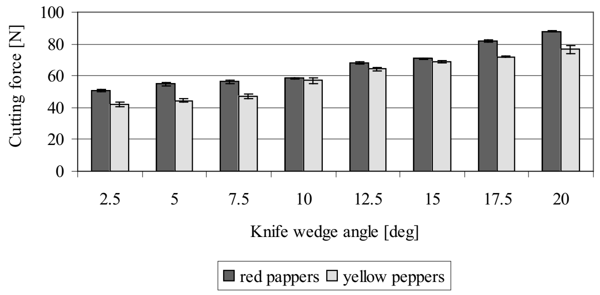

Fig. 2. Relation of cutting force of red and yellow peppers to knife wedge angle with the material positioned skin up

The relations presented in the Figure are described by equations (3) and (4):

$$F_{cr} = 45.433e^{0.079\alpha}, \quad (3)$$

$R^2 = 0.97$,

$$F_{cy} = 37.658e^{0.094\alpha}, \quad (4)$$

$R^2 = 0.97$.

In the experiments on peppers cutting, when the specimens were positioned skin down (Fig. 3) the lowest value of cutting work was 0.085 J for knife wedge angle α=2.5° for cv. Bell. With the reverse positioning of the material (Fig. 4) the cutting work for that peppers cultivar was greater by 45.21%. The highest values of cutting work were recorded for cv. King Arthur, for knife wedge angle α=20° when the cutting was from the side of the skin – 0.471 J. That value was higher by 0.079 J from that for cv. Bell tested with the same method. No significant differences between the results were observed when both peppers cultivars were cut with knives of wedge angles of α=10° and α=12.5°.

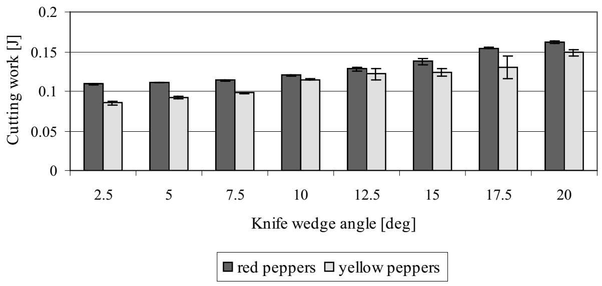

Fig. 3. Relation of cutting work of red and yellow peppers to knife wedge angle with the material positioned skin down

The relations presented in the Figure are described by equations (5) and (6):

$$W_{cr} = 0.097e^{0.06\alpha}, \quad (5)$$

$R^2 = 0.95$,

$$W_{cy} = 0.079e^{0.076\alpha}, \quad (6)$$

$R^2 = 0.97$,

where:
W_{cr} - cutting work of red peppers,
W_{cy} – cutting work of yellow peppers.

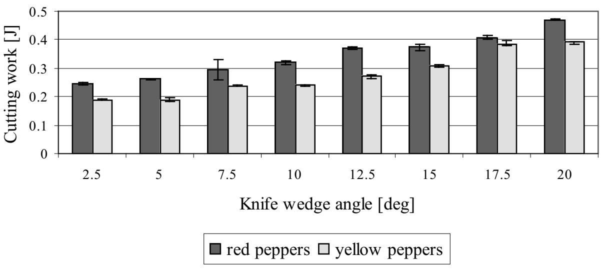

Fig. 4. Relation of cutting work of red and yellow peppers to knife wedge angle with the material positioned skin up

The relations presented in the Figure are described by equations (7) and (8):

$$W_{cr} = 0.224e^{0.09\alpha}, \quad (7)$$

$R^2 = 0.98$,

$$W_{cy} = 0.16e^{0.114\alpha}, \quad (8)$$

$R^2 = 0.97$.

Equations 1-8 were derived at significance level lower than/equal to 0.05.

Table 1 presents the results of measurement of the texture properties of the peppers.

Table 1. Texture properties of red peppers vs. King Arthur and yellow peppers vs. Bell

Variety	Hardness [N]	Brittleness [N]	Elasticity [-]	Cohesiveness [-]	Chewability [N]
Red peppers	81.909	41.824	0.497	0.326	13.271
Yellow peppers	62.096	39.274	0.536	0.326	10.85

Notably higher values of hardness, brittleness and chewability were obtained for the red peppers, elasticity of greater in the case of peppers cv. Bell, and cohesiveness was identical for both peppers cultivars.

The higher values of hardness and chewability and lower values of elasticity of the red peppers corresponded with the greater values of cutting force and work than in the case of the red peppers.

CONCLUSIONS

1. Increase of the knife wedge angle causes an increase in the values of peppers cutting force and work. The highest force value was obtained when cutting with a knife with wedge angle of α=20° - 88.032 N (red peppers cut with the skin up). When cutting with a knife with wedge angle of α=2.5° the lowest values of cutting force were obtained – 22.098 N (yellow peppers cut with the skin down).
2. Irrespective of the positioning of the specimens, in the case of cutting fruits of red peppers, higher values of the cutting force and work were obtained compared to fruits of yellow peppers. Cutting work values were the highest for peppers cv. King Arthur, 0.246 – 0.471 J, compared to cv. Bell at 0.188 – 0.392 J (positioned skin up).
3. The results of texture tests are related with the values of cutting force and work of peppers.

REFERENCES

1. **Buczkowska H., Dyduch J., Najda A., 2001.** Kształtowanie się zawartości niektórych składników chemicz-

nych w owocach papryki ostrej w zależności od odmiany i wielokrotności zbioru. Rolnictwo. Zeszyty Naukowe, 234(46), p. 27-32.
2. **De Marino S., Borbone N., Gala F., Zollo F., Fico G., Pagiotti R., Iorizzi M., 2006.** New constituents of sweet Capsicum annuum L. fruits and evaluation of their biological activity. Journal Agricultural. Food Chemistry, 54(20), p. 7508-7516.
3. **Dowgiałło A., 2006.** Modelowanie operacji cięcia materiałów rolno-spożywczych. Postępy Techniki Przetwórstwa Spożywczego, 1, p. 47-49.
4. **Gajc-Wolska J., Skąpski H., 2002.** Yield of sweet pepper depending on cultivars and growing conditions. Folia Horticulturae, 14(1), p. 95-103.
5. **Fellows P.J., 1996.** Food processing technology. Principles and practice (second end). CRC Press. U.K.
6. **Frączek J., Mudryk K., 2007.** Metoda pomiaru energochłonności procesu zrębkowania pędów wierzby. Inżynieria Rolnicza, 7(95), p. 47-53.
7. **Janeczko Z., 2003.** Owoce i warzywa jako źródło prozdrowotnych substancji o właściwościach antyoksydacyjnych. Folia Horticulturae, 1, p. 23-25.
8. **Kowalski S. 1993.** Badania oporów cięcia wybranych roślin. Zeszyty Problemowe Postępów Nauk Rolniczych, 408, p. 297-303.
9. **Krokida M.K., Philippopoulos C., 2006.** Volatility of apples during air and freeze drying. Journal Food Engineering, 73, p. 135-141.
10. **Lamikandra O., 2002.** Fresh-cut fruits and vegetables. Science, Technology, and Market. CRC Press, Boca Raton, Florida, USA.
11. **Márkus F., Daood H.G., Kapitány J., Biacs P.A., 1999.** Change in the caroteniod and antioxidant content of spice red pepper (paprika) as a function of ripening and some technological factors. Journal Agricultural Food Chemistry, 47(1), p. 100-107
12. **Materska M., Perucka I., 2005.** Antioxidant activity of the main phenolic compounds isolated from hot pepper fruit (Capsicum annuum L.). J. Agricultural Food Chemistry, 53, p. 1750-1756.
13. **Michalik Ł., Wierzbicka B., Kawecki Z., 2002.** Plonowanie i jakość papryki słodkiej w uprawie pod osłonami. Wartość biologiczna owoców papryki. Biuletyn Naukowy, 14, p. 89-99.
14. **Molendowski F., 2005.** Energochłonność procesu rozdrabniania surowców roślinnych na przykładzie rdzeni kolb kukurydzy. Zeszyty Naukowe Akademii Rolniczej. Wrocław.
15. **Nadulski R., 2001.** Wpływ geometrii narzędzia tnącego na przebieg procesu cięcia wybranych warzyw korzeniowych. Acta Agrophysica, 58, p. 127-135.
16. **Perucka I., Materska M., 2007.** Antioxidant vitamin contents of Capsicum annuum fruit extracts as affected by processing and varietal factors. Acta Scientiarum Polonorum. Technologia Alimentaria, 6(4), p. 67-74.
17. **Perucka I., Materska M., 2003.** Antioxidant activity and content of capsaicinoids isolated from paprika fruits. Polish Journal of Food and Nutrition Sciences, 12(53), p. 15-18.
18. **Sykut B., Kowalik K., Opielak M., 2005.** Badanie wpływu kątów ostrza i przystawienia na opory krojenia produktów spożywczych. Inżynieria Rolnicza, 9(69), p. 339-344.
19. **Szot B., Kęsik T., Gołacki K., 1987.** Badania zmienności właściwości mechanicznych korzeni marchwi w zależności od cech odmianowych, czynników agrotechnicznych i okresu przechowywania. Zeszyty Problemowe Postępów Nauk Rolniczych, 316, p. 227-246.
20. **Zastempowski M., Bochat A., 2011.** Badanie energochłonności cięcia materiału roślinnego. Inżynieria i Aparatura Chemiczna, 50(3), p. 91-92.

WPŁYW KĄTA ZAOSTRZENIA NOŻA NA SIŁĘ I PRACĘ CIĘCIA PAPRYKI

S t r e s z c z e n i e. W pracy przedstawiono metodykę pomiaru oraz wyniki badań cięcia owoców papryki dwóch odmian: King Arthur i Bell. Stwierdzono istotny wpływ kąta zaostrzenia noża na wartość siły cięcia i pracy cięcia. Wyższe wartości siły i pracy cięcia otrzymano dla papryki czerwonej niż żółtej. Siła i praca cięcia były również uzależnione od właściwości tekstualnych.

S ł o w a k l u c z o w e: papryka, cięcie, kąt zaostrzenia noża, siła cięcia, praca cięcia, tekstura.