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EXPERIMENTAL REGARDING THE DETERMINATION OF THE OPTIMUM CUTTING ANGLE USING A SINGLE EDGED KNIFE

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Abstract: *This paper presents the manner of determining the cutting resistance force in the cutting process of certain vegetables. The role of this paper is to highlight the influence of the sharpening angle of single edged cutting knife. To achieve this experimental measurements were performed consisting of cutting samples of plant product using single edged knives with different sharpening angle, respectively 15°, 30°, 45°. The determination of the optimum cutting angle for different types of vegetables will lead to a lower energy consumption required for the cutting processes.*

Key words: *cutting, cutting resistance force, vegetable products, cutting equipment.*

1. Introduction

The fresh-cut fruit and vegetable industry is constantly growing mainly due to the consumers' tendency to consume healthy and convenient foods and their interest in the role of food in improving human well-being.

Fresh-cut fruits and vegetables are commodities with a rapidly growing sector in the food industry, with both retail and food service outlets. At the moment, the main factor that has promoted and maintained fresh-cut sales is technology. However, permanent innovations are necessary to generate new growth in this sector.

Worldwide, there is a wide range of vegetables that could be used to broaden and increase the product range available on the market. However, in many countries, it is necessary to improve preparation and preservation techniques with the purpose of keeping the product safe and of high quality long enough to make the distribution of fresh-cut commodities feasible and achievable.

These products offer considerable advantages to present-day consumers in that they are easy and convenient to prepare and retain their original freshness of color, texture, aroma, and flavor without loss of their nutritional and health-beneficial properties. Fresh-cut vegetables are prepared for direct consumption by means of simple processes (selection, washing, peeling, cutting, hygienizing etc.); they are packed under plastic film and are stored chilled in modified atmospheres [1].

The food cutting process used in the food industry may serve as a bypassing operation of division of raw material and semi-

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finished products to pieces of specified shape and size during formation, batching and milling.

The reference books often lack information on the choices of cutting conditions. That is why equipment producers pick geometry parameters of working organs of cutting machines and mode conditions of their work in an empirical way. This does not lead to the cutting quality improvement and economy of energy resources.

Food products have various structural and mechanical properties. They perceive the cutting load in different ways. It is known, that when cutting the products, they get deformed prior to being destroyed. If the comparative deformation of product under the razor face is plastic, but after being cut, the product jams, it does not return to the previous shape and therefore loses its consumer attractiveness. If the product is delicate, its destruction takes place without plastic deformation [2].

The blade (Figure 1) is modelled as a sharp wedge of included angle θ. For cutting it is not the included angle that is important but rather the inclination α of the *rake face* along which the offcut travels. The rake angle α is defined with respect to the perpendicular to the cut surface; in agricultural engineering and some other fields α is often measured from the cut surface. The *clearance* (or *relief*) *angle* between the lower face of the blade and the cut surface is ζ. Hence $\alpha + \theta + \zeta = 90°$. When the clearance angle is small, it is sometimes ignored or assumed to be contained within θ [3].

Forces in rectangular samples are expected to be steady, particularly with soft solids. Forces will vary when samples having varying toughness are microtomed. Thus the outer regions (cortex) of fresh carrots are tougher than the interior (medulla).

Non-rectangular samples, even for constant R materials, will give varying forces according to the variation of w with δ. In an

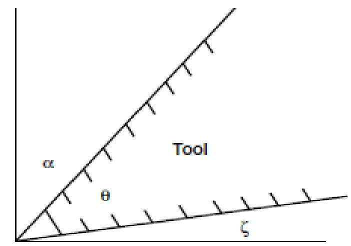

Fig. 1. *Sharp tool represented by a wedge of included angle θ. The rake angle of the tool is α; the clearance* (*relief*) *angle is ζ*

unmounted circular sample, the force will increase from zero at the start of the cut, take the greatest value at mid-section, and fall to zero again at the end of the cut.

Experiments show that the same material can exhibit very different behavior during cutting depending on the tool rake angle α, the depth of cut *t*, cutting speed, temperature and environment.

The load-displacement behavior during cutting tells us a lot about what is happening from a fracture mechanics point of view. First, it is important to appreciate that variations in cutting load may be real and reflect what is happening during cutting, or may be spurious caused by the characteristics of the force measuring system and method of display [2].

2. Material and Method

For the determination of cutting resistance, a special stand created by Zwick/Roell was used. The cutting of tested products was performed using the simple edged knives, whose sharpening angle was 15°, 30° and 45° (Figures 2-4), and the knife blade thickness was of 1.4 mm. For each of the three knives, ten cuts were performed, and the tested material had the similar diameters on the cutting area.

This was necessary to obtain optimal results.

Aspects from the experimental research are shown in Figure 5.

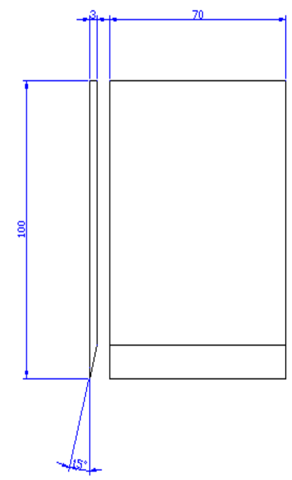

Fig. 2. *Graphic representation of the cutting knife with the sharpening angle of 15°*

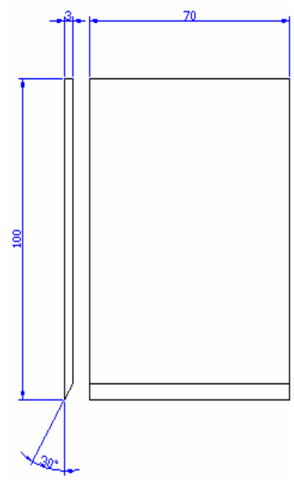

Fig. 3. *Graphic representation of the cutting knife with the sharpening angle of 30°*

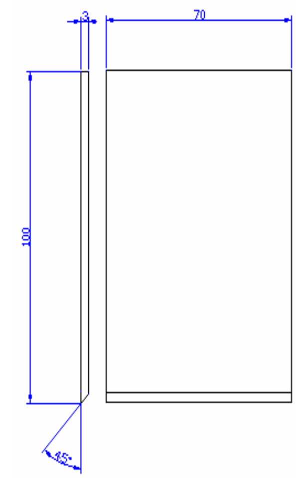

Fig. 4. *Graphic representation of the cutting knife with the sharpening angle of 45°*

Fig. 5. *Aspects from the experimental research*

3. Results and Discussions

After measurements, the experimental research equipment displays the results in the form of graphs representing the variation of cutting resistance depending on the depth covered by the cutting knife.

An example of such a graphic is presented in Figures 6, 7 and 8.

The experimental research results for those vegetables used in the experimental research were displayed in Table 1.

The table shows that the lowest cutting force (39.72 N) was obtained for the cutting knife with the sharpening angle of 15°, and the higher cutting force (123.71 N) was obtained for the cutting knife with the sharpening angle of 45°. For the cutting knife with the sharpening angle of 30° the higher cutting force was 94.97 N.

The results obtained from experimental measurements were processed as a graph (Figure 9). For graphical representation of these results, the average values for each

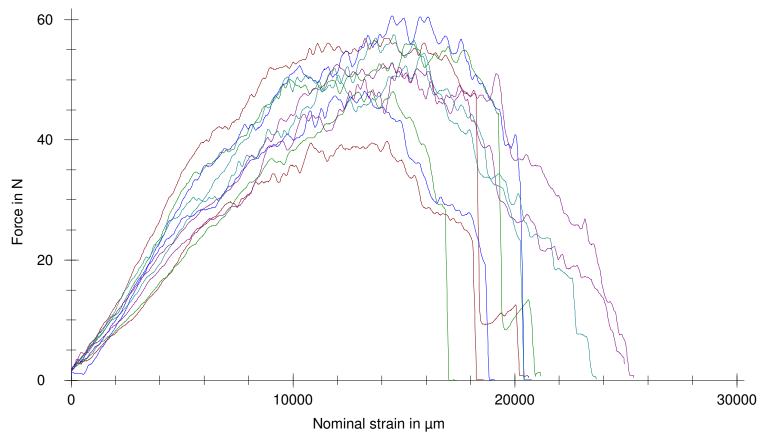

Fig. 6. *Variation of cutting resistance for the knife with sharpening angle of 15°*

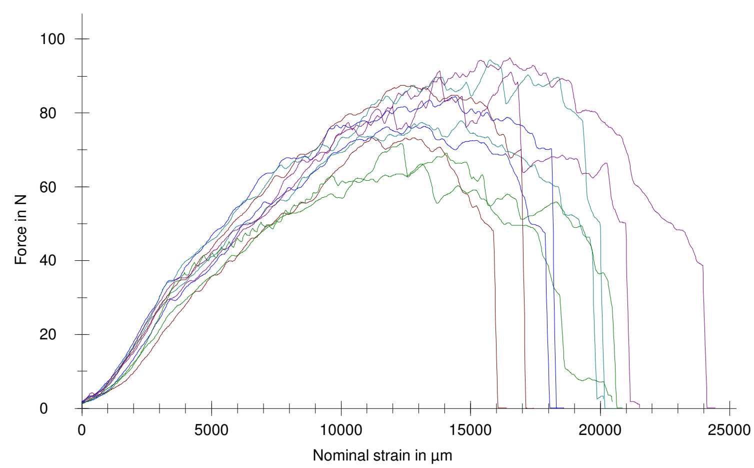

Fig. 7. *Variation of cutting resistance for the knife with sharpening angle of 30°*

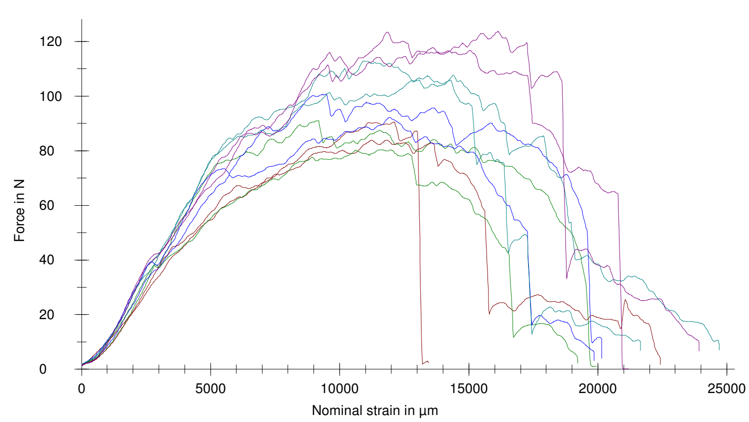

Fig. 8. *Variation of cutting resistance for the knife with sharpening angle of 45°*

Values registered at the cutting tests Table 1

	Cutting resistance force, [N]									
	Carrots									
Knife sharpening angle 15° [N]	56.86	56.00	60.63	53.91	52.70	39.72	48.05	48.07	57.48	52.06
Diameter, [mm]	25.87	25.81	26.62	26.06	25.90	21.82	21.81	22.52	25.16	27.46
Knife sharpening angle 30° [N]	73.28	66.19	76.35	77.86	94.97	87.55	71.73	84.40	94.43	91.40
Diameter, [mm]	21.27	21.59	21.85	25.07	27.83	22.87	25.06	24.92	26.17	26.82
Knife sharpening angle 45° [N]	90.50	90.98	100.86	112.93	123.71	83.89	80.36	92.18	107.41	117.82
Diameter, [mm]	22.09	23.33	25.29	26.15	28.07	20.16	21.03	20.79	24.31	26.16

type of knife was calculated thus for the cutting knife with sharpening angle of 15°, the medium value was 52.548 N, for the cutting knife with the sharpening angle of 30° the value was 81.816 N and for the knife with the sharpening angle of 45° the calculated value was 100.064 N. Also, the medium diameter calculated was about 24.5 mm.

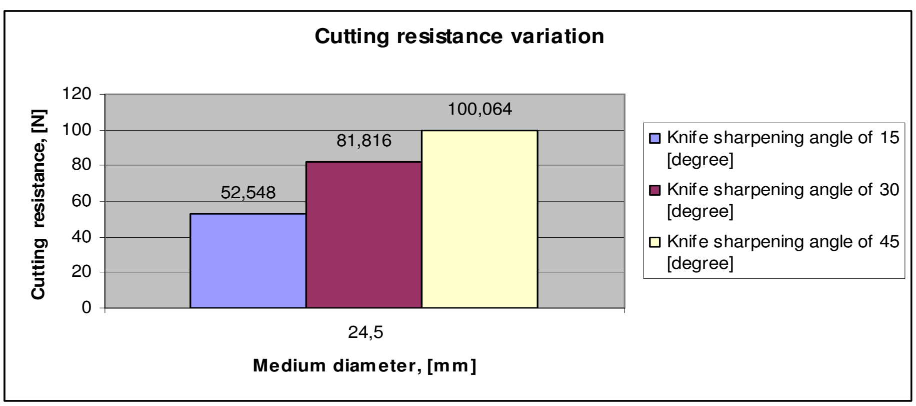

Fig. 9. *Variations of cutting resistance force at different values of the knife sharpening angle*

This graph shows that a double value for the cutting knife with the sharpening angle of 45° was obtained as compared to the knife with the sharpening angle of 15°.

4. Conclusions

1. At the same cutting diameters, about 21.5 mm, the resistance force obtained for

the cutting knife with the sharpening angle of 45° was 80.36 N higher by 50 percent compared to the resistance force obtained for the cutting knife with the sharpening angle of 15° - 39.72 N.

2. Following the experimental measurements it can be seen that the cutting resistance force is directly proportional with the value of the sharpening angle of the cutting knife. As the cutting edge is sharper, the cutting resistance force is lower.

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