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THE INFLUENCE OF THE KNIFE CONSTRUCTIVE AND FUNCTIONAL PARAMETERS ON THE PROCESS OF CUTTING VEGETABLES

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Abstract: *This paper presents the influence of constructive and functional parameters of the cutting knives on the cutting process. The role of this paper is to highlight that some parameters related to knife geometry (cutting angle, blade shape, blade thickness) affect the operation of cutting vegetables in terms of energy consumption.*

Key words: *knife geometry, cutting, energy consumption.*

1. Introduction

Fresh-cut fruits and vegetables are a relatively new and rapidly developing segment of the fresh produce industry. Fresh-cut products have been freshly cut, washed, packaged, and maintained with refrigeration. They are in a raw state and even though minimally processed, they remain in a fresh state, ready to eat or cook [3].

Consumers expect foods to be not only microbiologically safe but also nutritious, healthy, and easy to prepare for consumption. Because they have not been subjected to harsh processes such as heat treatments, cut vegetables retain their initial freshness and also their nutritional components and the compounds responsible for their healthy properties.

The health-giving potential of fresh-cut vegetables should therefore be the same as that of the whole products from which they come; or the concentrations of some bioactive compounds may even be significantly improved depending on the selection of varieties, agricultural practices, physiological state of the plant of origin, and the stress produced by processing.

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 (modified atmosphere packaging) [5].

The production and consumption of fresh-cut commodities is not new. According to the International Fresh-Cut Produce Association (IFPA), fresh-cut products have been available to consumers

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since the 1930s in retail supermarkets. However, the fresh-cut industry was first developed to supply hotels, restaurants, catering services, and other institutions. For the food service industry and restaurants, fresh-cut produce presents a series of advantages, including a reduction in the need of manpower for food preparation, reduced need of special systems to handle waste, and the possibility to deliver in a short time, specific forms of fresh-cut products. Yet it has not been until the past two decades that fresh-cut fruit and vegetable products have gained popularity and penetration in the produce business as a result of a general trend to increase fresh fruit and vegetable consumption [4].

Fresh-cut vegetable and fruit products differ from traditional, intact vegetables and fruits in terms of their physiology and their handling requirements. Fresh-cut vegetables deteriorate faster than intact produce. This is a direct result of the wounding associated with processing, which leads to a number of physical and physiological changes affecting the viability and quality of the produce. The visual symptoms of deterioration of fresh-cut produce include flaccidity from loss of water, changes in color (especially increased oxidative browning at the cut surfaces). Nutrient losses may also be accelerated when plant tissues are wounded. Little information is available concerning the retention of vitamins and minerals, and other nutritive components in fresh-cut produce during handling, storage, and senescence [2].

The cutting represents the operation of reduction of geometrical dimensions of particles following some exterior mechanical actions. The cutting process of vegetables products is very complicated. This is because vegetables products are inhomogeneous with properties variable in time and space, respectively have variable texture [1].

Vegetable products are visco-elastic and their elasticity varies considerably and depends on maturity degree and the humidity of the product. From all the 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 cutting operation must lead to a superior quality product with low energy consumption [6].

Even the sharpest of knives cause a small amount of cell rupture in the product, but dull knives can cause an even greater amount of cell rupture, resulting in reduced yield and quality. Processors cutting foods for dehydration must pay particular attention to knife sharpness as it is extremely important that nutrients remain in the cells until the product is dried.

It is an established fact that very few products can be “cut” in the true sense that the sharp edge of a knife is always in contact with the product. A sharp edge is most useful in its ability to penetrate the product cleanly to start the cut. Beyond this point, most materials tend to split or separate some distance ahead of the edge.

Thick knives or blunt edge bevels increase splitting and cause loss of cutting control. Thin knives with slender edge bevels allow the knife to enter the product gently, guiding the path of the split more accurately.

There is no economy in operating any cutting machine with dull or unserviceable knives. The cost of lost time and product waste far exceeds the cost of knife maintenance and replacement.

2. Material and Method

A force P acts during knife cutting operations, submerging through a material at a constant speed, further referred to as the cutting speed. This force is comprised of the following: P_e is expended on elastic and plastic deformation; P_f is the force, which overcomes friction; P_d is the disintegration force expended by the cutting edge on the structure of the material. The value of force *P*, which is $P = 0$ at the moment the edge comes into contact with the material, increases to a value of $P_{max} = P_d + P_e + P_f$, which refers to stabilized cutting conditions [1].

Figure 1 presents the changes in force *P* which were recorded by a Zwick/Roell testing machine during a cutting operation.

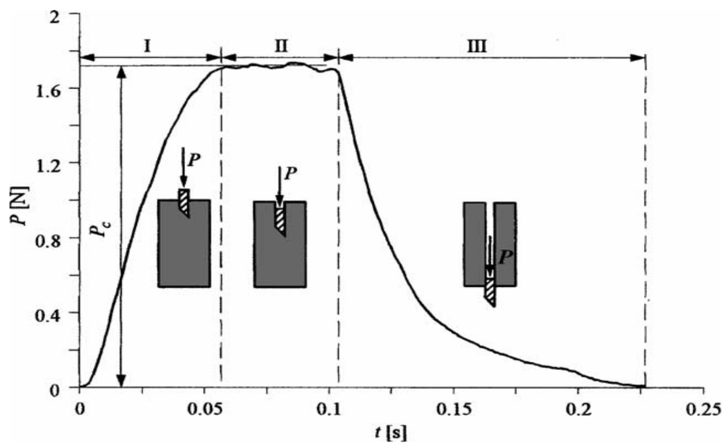

Fig. 1. *Changes in the value of force P acting on the knife during cutting as recorded by the Zick/Roell testing machine: zone I - knife submerges into the material; zone II - cut stabilization; zone III - knife emerges from the material*

By performing experimental research in the laboratory were made some comparisons between cutting resistance force obtained from certain plant products such as potatoes, belonging to different varieties, thus highlighting their influence on the process of cutting. For experimental measurements in laboratory conditions were used different potato varieties, namely Rudolf, Destiny and Arizona.

For the determination of cutting resistance was used a special stand created by Zwick/Roell, which is presented in Figure 2. This equipment works whit software called Test Expert, which stores data in its Windows operating system for acquisition, visualization and data analysis. One of its most important ability is to store one of the measures procedures and have immediate access to it. A determination can be defined by two windows: one by imposing the parameters, and the other one by defining the way to view the results (graphs, tables). The equipment is composed from the frame 1 in which is mounted the drive mechanism of the knife holder, a control panel 2 and a device for vegetables application 4. The knife 3 is presented in Figure 3 and is edged right type with a sharpening angle of 30°.

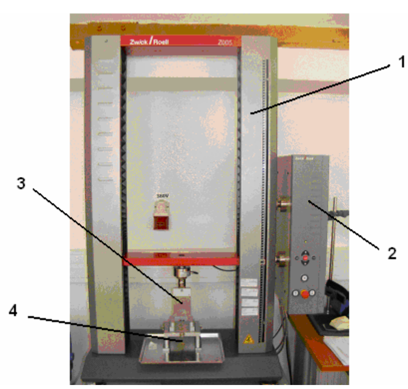

Fig. 2. *Zwick/Roell stands for cutting resistance determination*

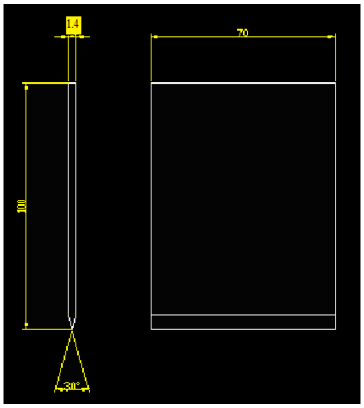

Fig. 3. *The cutting knife of double edged right type with the sharpening angle of 30°*

The cutting of tested products was performed using the double edged knives, whose sharpening angle was 15°, 30° and 45°, and the knife blade thickness was 1.4 mm. For each variety of potatoes were tested five potatoes for each knife in part.

3. Results and Discussions

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

The results obtained from experimental measurements were processed as a graph (Figure 7).

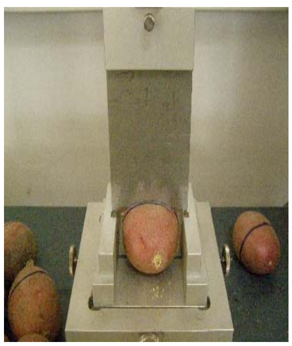

Fig. 4. *The cutting knife with the sharpening angle of 15°*

Fig. 5. *The cutting knife with the sharpening angle of 30°*

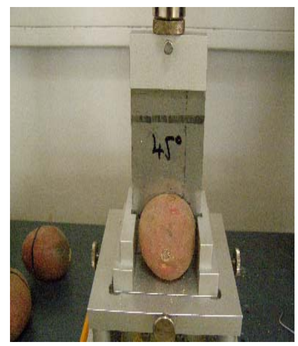

Fig. 6. *The cutting knife with the sharpening angle of 45°*

Values registered at the cutting tests Table 1

Potatoes variety	**Knife sharpening angle, [°]**	**Cutting resistance force, [N]**				
Rudolph	15	54.82	56.38	56.17	55.22	57.63
	30	63.59	57.64	65.58	60.70	64.74
	45	67.38	71.90	63.97	70.72	65.66
Destiny	15	50.89	46.81	37.64	37.32	47.32
	30	81.23	63.31	55.45	75.16	78.72
	45	78.66	83.59	81.45	77.23	83.17
Arizona	15	35.73	36.27	30.08	35.92	37.8
	30	40.88	67.74	54.59	61.44	48.37
	45	69.15	65.38	66.77	68.33	65.95

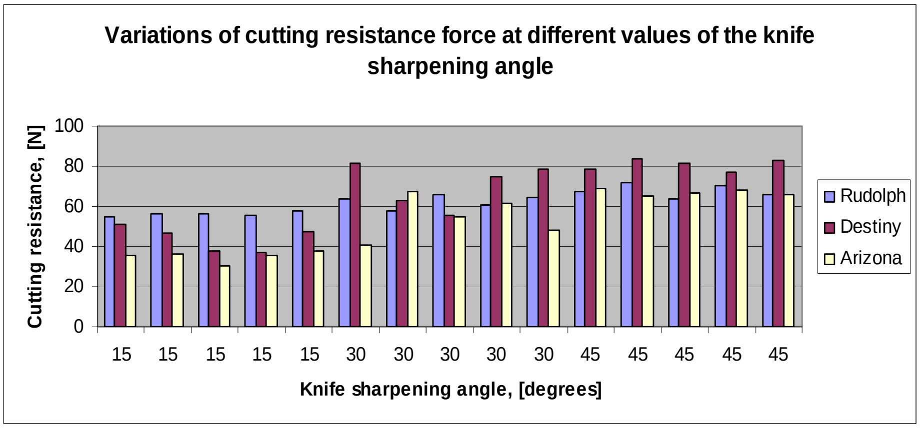

Fig. 7. *Cutting resistance variation*

The graph shows that the lowest cutting force (30.08 N) was obtained for Arizona potatoes variety for the cutting knife with the sharpening angle of 15°, and the higher cutting force (83.59) was obtained for Destiny potatoes variety for the cutting knife with the sharpening angle of 45°.

It also can be observe that higher values were obtained for the cutting knives with the sharpening angles of 30° and 45°, especially for Destiny potatoes variety which had the higher values. For the cutting knife with sharpening angle of 15° were obtained the lowest cutting force for all types of potatoes.

4. Conclusions

1. In many food processes it is frequently necessary to reduce the size of solid materials for different purposes. Size reduction may aid other processes such as expression and extraction, or may shorten heat treatments such as blanching and cooking.

2. The cutting resistance determination depending on the cutting angle presents a grate importance for the designers and builders of equipments used in the food industry at the vegetable processing. Choosing the optimum inclination angle of the cutting knife at these equipments construction will guide to a higher reliability of this machines and also at a lower energetically consumption in the case of vegetable processing.

3. 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.

4. For the same type of potatoes was obtained a double cutting resistance force for the cutting knife with the sharpening angle of 45° in contrast with the cutting knife with a sharpening angle of 15°.

5. For an optimal energy consumption is recommended to use the knife with a sharpening angle of 15° to obtain the minimal cutting force.

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