Comparative analysis of beet cossettes extraction of different profiles on the industrial extractors

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Abstract

Introduction. The process extraction of sucrose conducted from the beet cossettes of different cross-sections. Quality and mechanical characteristics, sucrose loss in pulp, raw juice quality and energy cost depends on the profile shape beet cossettes.

Materials and methods. It were investigated the beet cossettes of triangle and grooved profiles obtained on centrifugal beet slicers using specially sharpened and set in a special way blades. Research was undertaken on two parallel lines. Installed in this lines extractors DC-12 have same construction, were working in the same process conditions.

Results and discussion. There was made a comparison in the study of major quality indicators of beet cossettes of grooved and triangular cross-sections and determined the sucrose content in the extracted pulp of the cross-sections. The average value of defect ratio of the triange profile pulp is 35 % less comparing to the grooved profile pulp. The average value of the Swedish factor for the triangle cossettes cross-sections is 42 % more than for the actual rate for the grooved cross-sections. Average value of sucrose content in the pulp for triangular profiles is 0.45 % by the weight of pulp and for grooved one - 0.50 %. So the cossettes with a triangular cross-section more than 10 % extracts better in industrial diffusion devices under the same process conditions. This can be explained by increased mechanical strength of triangular cossettes (greater resistance to bending moment) and fewer defect ratio. Increasing the mechanical strength of the cossettes and reducing the number of defect ratio leads to:

- counterwork to the cossettes layer compression by the fluid flow and increasing its porosity, that provides good cossettes washing with extractant;
- reducing dead zones;
- steady transition of the diffusion equipments by transport systems.

Conclusion. The triangular profile cossette being under the same process conditions has better quality characteristics and better extraction compared to grooved one.

Introduction

The extraction of sucrose from beet pulp is one of the most important processes of sugar production. It determines the loss of sucrose in spent beet cossettes (pulp), molasses, energy cost and raw juice quality. Cossettes obtained by cutting sugar beets in beet slicing machines. Cutting food and plant materials devoted to the work of scientists: M. A. Moore, G. C. Jones, Y. D. Yiljep, B. Denkena, M. J. O`Dogerty, P. F. Davis, O. Knaifl and other [1-13].

According to the studies of Terent'eva Y.A., Pushanka M.M., M.D. Khomenko, Kutsenko V.O. the rhomb-shaped (square) profile is considered to be rational among all pulp profiles (that can be get using knives of keningsfeld type), that are used for processing healthy beets and beet-roots of impaired quality Fig. 1.b.

The knives of keningsfeld type of 1011V models manufactured with profile angle of 75 ° and 8.25 mm increments have widely bacame popular in the CIS countries. When getting the rhomb-shaped cossette using these knives of keningsfeld type (each knive is offset by 0.5 step of the previous one, the lifting height of the knive above the control bar is equal to 2 heights of knife blades) the side of the rhomb cossette will be about 7 mm. These cossettes will be too rough, its length is 100 g (Silin number) and will be less than 5 m. Therefore, in most cases sugar factories using keningsfeld knives with a pitch 8,25 mm get cossettes of the grooved cross section (Pic. 1.a) with the side of 3.5 ... 5 mm (length 100 g - 8 ... 10 m).

At the european factories beets are cut in the beet slicing machines into cossettes with a square (rhomb-shaped) and grooved cross-section (V-shaped cross-section) [14]. This demonstrates that the rhomb-shaped and grooved cossette cross-section is the most common in the world.

It was recently suggested a method of producing a triangular (Pic. 1.C) and plane-comb (Pic. 1.d) profiles on existing types of beet slicing machines. It is implemented with knives of keningsfeld type and knives with flat cutting edge, that are alternating in knive chassis [15].

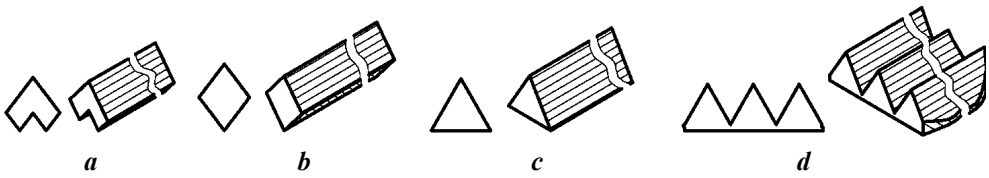
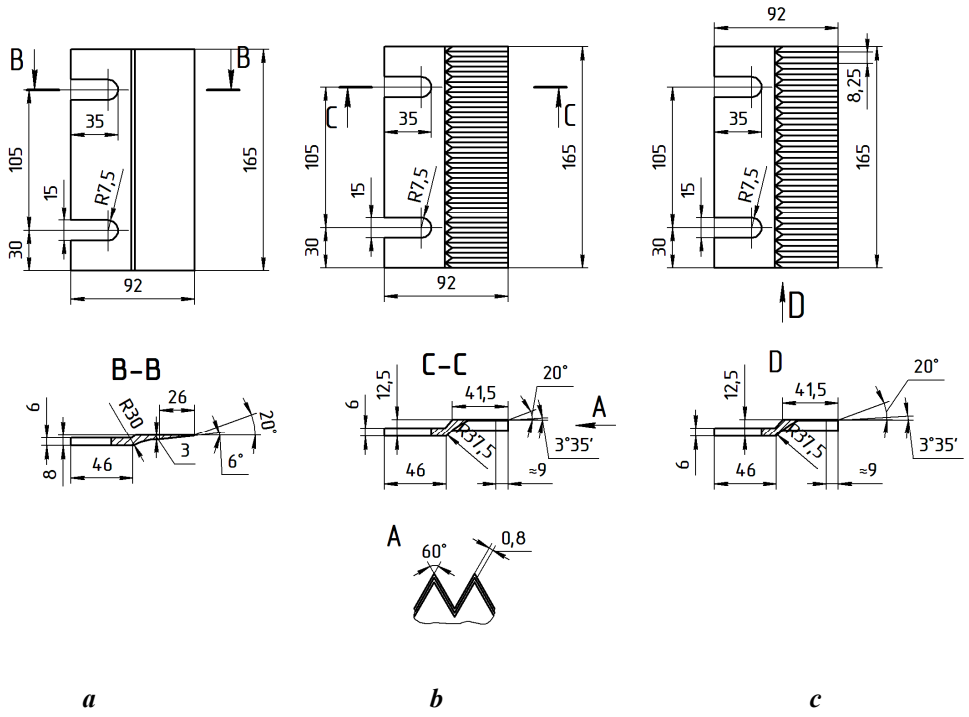


Fig. 1. Profiles beet chips:
a - cossettes of the grooved cross section (V-shaped cross-section);
b - square (rhomb-shaped) cross-section;
c - triangular cross-section cossettes;
d - plane-comb cross section cossettes.

Beet cossettes with a triangular profile compared to the rhomb-shaped cossettes with the same cross-sectional area has a larger perimeter (diffusion area), shorter internal diffusion and greater moment of resistance (greater substantiality for deflection and jam). Based on the above, the triangular cross-section of the cossette is more efficient compared to the others known today. To test the theoretical information in practice, the studies of industrial diffusion apparatus performance of perpetual action were undertaken on the triangular cross-section beet cossettes.

Materials and methods

Materials which was studied. In this work beet cossettes of triangle and grooved profiles were invastigated. Beet cossette was obtained from beets belonging to categories 1 and 2. Category 1 includes fresh, healthy, with normal turgor (water loss is less than 5%), frost-undamaged beet containing less than 1% of roots that blossomed (woody) and a small number (10%) of beet with strong mechanical damage, and those that have less than 3% green material and contamination (quantity of foreign material) to 10% and were collected in late September and early October.



a ***b*** ***c***

Fig. 2. Beet slicing knives:
a - special plane beet slicing knife;
b - a special knife of keningsfeld type with a vertical angle of 60 °;
c - knife of 1011V model manufactured with angle of 75 ° profile and step 8.25 mm.

Beets of 1 category are placed in piles of prolonged storage. 2 category includes frost-undamaged sugar beets, containing less than 5% slightly dried and up to 12% severely damaged roots, containing 3% of green material and those, that were collected in the period up to mid-September and after mid-October. Beets of 2 category are placed in piles of the medium term storage.

During experiments cossettes were obtained on centrifugal beet RBA-2-12 using specially sharpened and set in a special way blades for triangular cossettes (Fig. 1.a, b) and knives of keningsfeld type model 1011V that were manufactured with profile angle of 75 ° and step 8.25 mm (Fig. 1.C).

All knives were manufactured at the company LLC "Company" KORUND "and sharpened by grinding wheels of cubanite on sharpening line of beet slicing knives of the enterprise, consisting of semiautomatic machine-UZN-3 (knives trimming) UZN-1 (thinning) UZN-2 (facet formation).

Geometric characteristics of the blades.

1. Special plane blades:
   a. smooth cutting edge with stepped sharpening of the one side;
   b. thinning angle - 6 ° for length ≈26 mm;
   c. sharpening bevel angle - 20 °;
   d. the sharpness of the blade - 10 microns.
2. Special knives of keningsfeld type with a profile angle of 60 ° and knives model 1011V, with a profile angle of 75 ° and step 8.25 mm:
   a. winding cutting edge is smooth, with one-sided stepped sharpening;
   b. thinning angle ≈3 ° for the length ≈9 mm;
   c. sharpening bevel angle - 20 °;
   d. the sharpness of the blade - 10 microns.

Research procedures. Studies were undertaken in October 2014 at LLC «Novoorzhytskyy sugar beet plant» (centrifugal beet slicing machines RBA-2-12 that supplied extraction apparatus inclining type DC-12 with cossettes).

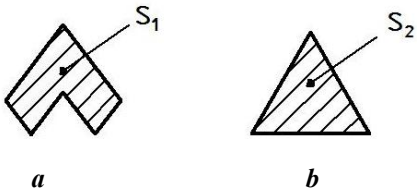


Fig. 3. Cossettes profiles:
a – grooved; b – triangular.

There worked during the studies in the beet processing department of sugar factory two parallel lines with efficiency of of 3000 tons sugar beets processing per day each. Installed in this lines extractors DC-12 have same design, worked in the same process conditions. Each extraction apparatus has been supplied with cossettes by the single centrifugal beet slicing machine.

During the research beet slicing machine RBA-2-12 was set with: each double-row frame of beet slicing machine №1 (that cuts chips for 1st extraction device) was set with knives of keningsfeld type with a vertical angle of 60 ° (the first row of each frame) and plane blades (second number of frames); each double-row frame of beet slicing machine №2 (that cuts chips for 2st extraction device) was set knives of keningsfeld type alternately performing A and B of 8.25 mm increments for grooved cossettes.

After starting the centrifugal beet slicing machines the cross-sectional area of grooved cossettes (Fig. 3.a) and triangular cossettes (Fig. 3.b) was set the same, changing the lift height of the blades. The moment of the expiration of cossettes cross-sectional area regulation was the reference time. Since then with intervals of 1 hour cossettes samples of grooved and triangular profiles (equal parts of each knife frames) were collected and

determined its quality indicators - Silin number (SN), the Swedish factor (SWN) and percentage of defects in cossettes (MC). There have been 3 series of 8 experiments.

After 2 hours from the countdown (extraction device will be completely filled with grooved and triangular profiles cossettes) at intervals of 30 min samples of pulp of grooved and triangular cossettes were selected. The collected samples were separated into groups:

Group №1 - beet cossettes with a triangular cross-section;

Group №2 - beet cossettes with grooved cross- section.

Then by the conventional methods the sucrose content in extracted cossettes of each group was determinated. There have been 3 series of 7 experiments.

Description of research methods. Qualitative characteristics of cossettes with various forms of cross-sections were found according to the typical methodes of determining the Silin number, Swedish factor and the defect ratio in cossettes.

Results and discussion

Comparison of major quality indicators of beet cossettes with grooved and triangular cross-sections, got on the industrial centrifugal beet slicing machines RBA-2-12 are shown in Fig. 4 ... 6.

As shown on Figures 4 ... 6 the cossettes quality increases within1 hour of work (Silin number, Swedish factor increasing and and defect ratio reduces).

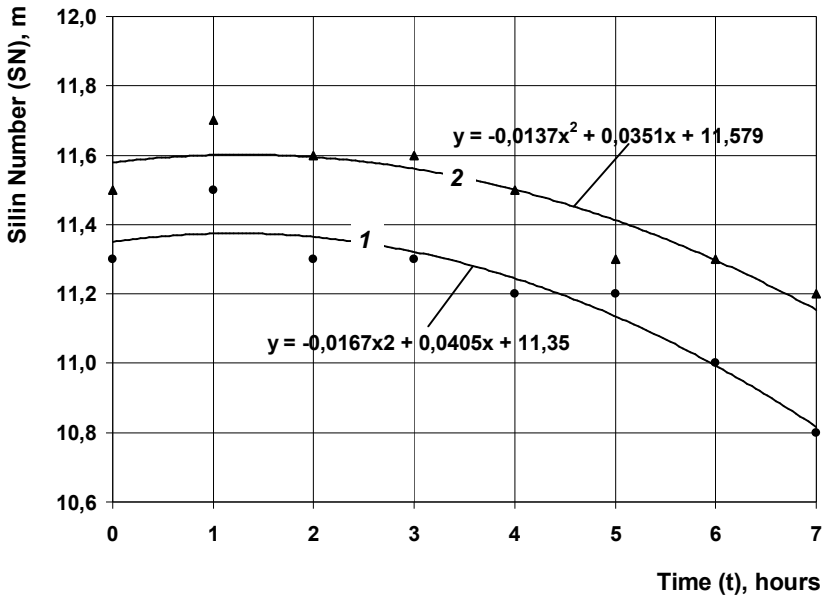


Fig. 4. Dependence of Silin number with grooved and triangular cossettes profiles of the working time of centrifugal beet slicer:
1 – grooved cossettes profiles; 2 – triangular cossettes profiles.

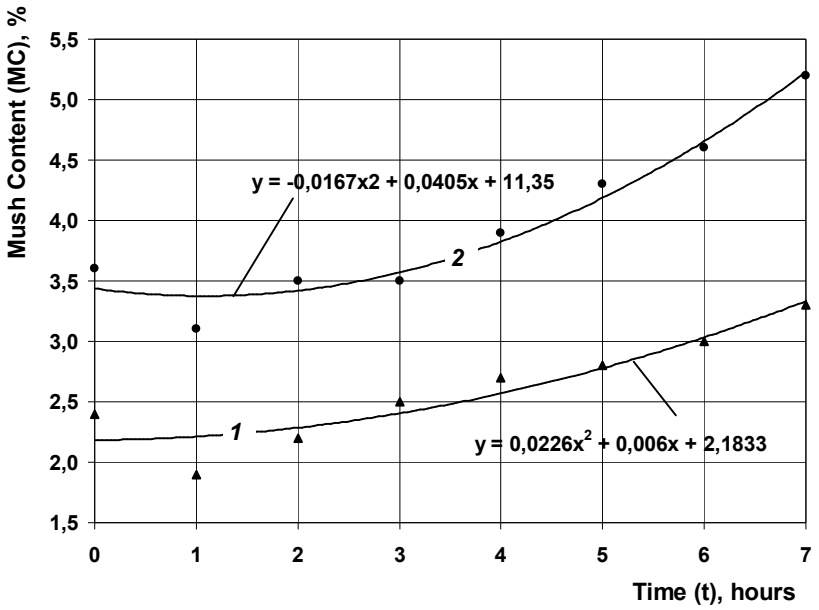


Fig. 5. Grooved and triangular cossettes profiles defect ratio dependence from working time of the centrifugal beet slicer:
1 – grooved cossettes profiles; 2 – triangular cossettes profiles.

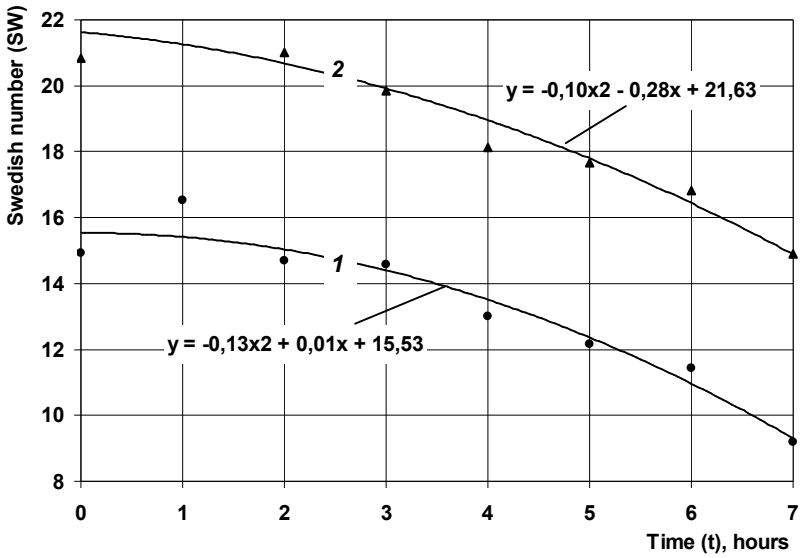


Fig. 6. Grooved and triangular cossettes profiles Swedish number dependence from working time of the centrifugal beet slicer:
1 – grooved cossettes profiles; 2 – triangular cossettes profiles.

Quality improvement during the one hour of work for both profiles is attributable that knives on the initial stage are lapped by beets, they lose scorings and rigidity of incisal surface becomes lower, as a consequence they give best quality of shavings after a while after start of work. In the further work increasing defect ratio, decreasing of Swedish factor and Silin number can be explained that knives are becoming dull and damaged by extraneous contaminants.

The average value of the Silin number beet cossettes of triangle cross-section is 3 % more than when working with grooved profile. The average value for the triangle cossettes is 11.5 m, for the grooved cossettes is 11.2 m according to 3 series of research results.

The average number of the defect ratio of the triangle cossettes profile is 35 % less than in the grooved profile cossettes. The average number for the triangle cossettes is 2.6 %, for the grooved cossettes is 4.0 %, according to 3 series of research results.

The average value of the Swedish number for the triangle cossettes cross-sections is 42 % more than for the actual rate for the grooved cross-sections. The average number of the triangle cossettes is 18.9, for the grooved cossettes is 13.3, according to 3 series of research results.

As cross-sections of the triangle and grooved cossettes profiles have nearly equal square (it's arranged with original setting of the knive's lifting height), so their average values of the Silin number are differed by 3 %. Obviously, the Silin number characterizes the degree of the sugar beet breakage (the cossettes cross-section area) and fractional characterizes the rate of defect ratio in the cossettes, that doesn't have any influence on the Silin number's value. It can be illustrated by estimation of the given rate using by formula [16]:

$$SN = \frac{0.1 \cdot \phi}{S \cdot \rho}$$

where: □ – coefficient, considering the percentage of high-quality cossettes (at 3% MC → □ = 0.97, where 5% MC → □ = 0.95);

S - cross-sectional area of one pulp, m^2;

ρ - the average density of sugar beet material, kg / m^3 (ρ = 1060 kg / m^3).

Table 1

Silin number dependence of the defect ratio for cossettes with averaged cross-sectional area of 9.15 mm^2

Index	Value			
Defect ratio (MC), %	1	3	5	7
Silin number (SN), m	10,2	10	9,8	9,6

As the Table 1 shows the 7 times defect ratio increasing results the Silina number decreasing for only 6%.

Significantly lower rates of cossettes defect ratio of triangular cross-section compared to grooved one can be explained by the fact that while cutting the triangular chips (unlike grooved one) vertical displacement of roots, which occurs during the beet transition from

one blade frame to another does not affect the quality of received cossettes. It means, when cutting on the roots of sugar beet contacting with special knives of keningsfeld type (they are set in the first row of double-row blade frame) winding cuts are formed, and after contacting with special plane blades (set in the second row of double-row blade frame) - straight cuts are formed. Thus, special knives of keningsfeld type always form cossettes on a flat surface of the beet-root cut, providing ideal conditions for the formation of the right shaped cossettes with a minimum of defect ratio, and plane blades cut formed winding print and make the beet surface plane. I.e., while transiting of the beet-roots between frames (distance between two knife frames) beets have plane surface cut, that's why their vertical displacement does not affect the quality of the pulp.

High cossettes rates of Swedish factor with a triangular profile compared to grooved one can be explained by a significantly lower defect ratio of triangular pulp and 28 % higher the average point of resistance (arithmetical value when calculating the moment of resistance for the basis and the top of figure) with relative to the x-axis in Fig. 7. Then with the cross-section area of 9.16 mm^2 the average resistance point relative to the x-axis ($W_{X\,aver.}$) will be will be 4.6 mm^3 for the triangular cross-section, for grooved one - 3.6 mm^3. It means, when standing out the knife frames, when hitting the beet slicer cover, transportation to the extraction device and by transport systems of extraction installations beet pulp of triangular shape will be less grounded, compressed and will have a better filtration capacity compared to the grooved one.

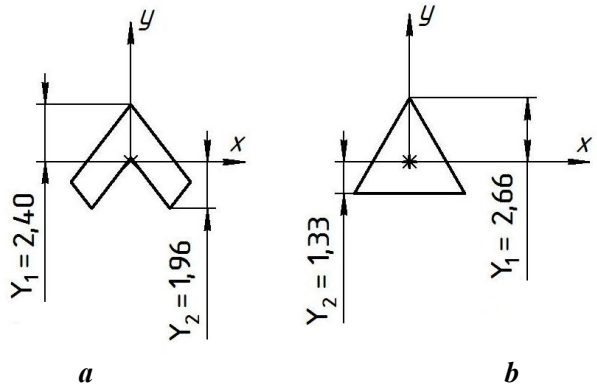


Fig. 7. Scheme to determine resistance profiles of cossettes:
a – grooved; b – triangle.

The sucrose content in extracted cossettes of different profiles. According to the research average value of sucrose content in the pulp for triangular profiles is 0.45 % by the weight of pulp and for grooved one - 0.50 %. So the cossettes with a triangular cross-section more than 10 % extracts better in industrial extraction devices under the same process conditions. This can be explained by increased mechanical strength of triangular cossettes (greater resistance to bending moment) and fewer defect ratio. Increasing the mechanical strength of the cossettes and reducing the number of defect ratio leads to:

– counterwork to the cossettes layer compression by the fluid flow and increasing its porosity, that provides good cossettes washing with extractant;

– reducing dead zones;

steady transition of the extraction equipments by transport systems.

Conclusions

As the result in the studies it is revealing the main inherent specifications and sucrose content in extracted pulp of triangular and grooved profiles obtained in industrial centrifugal beet slicing machines. Results indicate that triangular profile cossettes being under the same process conditions has better mechanical (28 % more the average bending moment of resistance), quality characteristics, less defect ratio (35 %) and better extraction (more than 10 % lower sucrose content in the pulp) compared to grooved one - the most common today.

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