Enzymatic treatment of Rubus saxatilis L. wild growing berries: technological parameters optimization

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Abstract. The influence of pectolytic (Vinoferm zymex) and cellulolytic (Bryuzaim BGX) enzymes treatment on Rubus saxatilis L. berries’ processing became subject of this study, aimed at forming a complex of technological operations providing for increase in efficiency of Siberian plant raw material processing thus leading to obtaining planned amounts of final product with increased nutritional value from reduced amounts of food stock. Mathematical modeling of the dependence of the juice yield on the duration of the treatment process and the concentration of enzyme preparations was carried out. Application of enzyme preparations of pectolytic and cellulolytic action for increase of level of technological perfection of reception of berry juice is proved.

1. Introduction

The issue of preserving planet’s biodiversity and maintaining natural ecosystems which face significant anthropogenic influence, is closely related to the food problem – gradually growing problem of food shortages caused by various factors, which leads to malnutrition and hunger among the least well-off groups of the planet.

Ways to solve the food problem can be divided into two groups - extensive and intensive. The extensive way leads to expanding agricultural lands whereas the intensive approach implies increasing efficiency of both vegetable stock and animal feed processing thus leading to decrease in anthropogenic influence on ecosystem overall.

Creating effective technologies for processing raw materials allows:

- to reduce amount of food stock necessary to obtain the planned volume of final product;
- to improve efficiency of food stock processing with the aim of producing the final product of higher nutritional value.

One of the modern efficient technologies for processing plant materials is the use of enzymes; however, the lack of universal approach to the technology of enzymatic processing of fruits and berries and their biodiversity raises a number of difficulties.

The use of enzyme preparations for treating fruit and berry raw materials is widely described in the literature [1-3].
Enzymatic processing of fruit and berry raw materials will reduce the risk of haze formation, increase the output of juice and fruit drinks and increase their organoleptic characteristics and durability of beverages in storage [4-5].

One of the promising types of raw materials for the production of functional products are berries, including wild berries of Rubus saxatilis L [6].

The study of the influence of various groups of enzymes and the optimization of the technological parameters of their application to maximize the extraction of juice from wild berries of the Rubus genus determine the relevance of this study, and selection of the optimal concentrations of the multienzyme complex will allow the use of similar technology on other types of berry raw materials.

The task of this study is to perform the optimization of multienzyme processing of berries raw material, which allows to reduce the time and economic costs for choosing technological conditions.

2. Methods and results

The objects of the study were stone bramble berries (Rubus saxatilis L.), collected in the period of technical maturity, growing on the territory of Uyar district of the Krasnoyarsk region in 2017.

Stone bramble berries (Rubus saxatilis L.) processing was performed by enzymatic preparations of pectolytic and glucanolytic action: pectolytic enzyme Vinoferm zymex and Bryuzaim BGX. Before processing, the berries were crushed, enzyme preparations were added to the berries mass in various concentrations and hydrolysis was carried out under conditions optimal for the enzyme action (45 °C) for a different amount of time.

To obtain the mathematical relation of the influence of technological parameters on the yield of juice from the berries, correlation and regression analysis of the data was used. As a subject of modeling, the laws of increasing the yield of berry juice under the action of enzyme preparations to increase the level of technological perfection of berry juice production were taken.

For research on the improvement of the technological process of berry raw materials treatment, two levels, corresponding to the subject of modeling, were determined:

- level of assessment and description of the result indicator: the regularity of the juice output from the berries upon completion of the raw material pretreatment processes;
- level of evaluation of technological parameters (technological perfection): the optimum of processes by duration, by concentration of enzyme preparations.

In accordance with the principle of the similarity of the processes of technological transformation of raw materials biomass, related to one object of research, there is an integral indicator representing a complex of technological processes and summarizing the main performance indicators.

Integral index $F$ of juice yield depending on the duration of the process ($\tau$, min) and concentration of enzyme preparations ($\omega$, %) is represented by the following function of four variables (1):

$$ F(\tau, \omega) = A \cdot \tau^B \cdot \omega^C, $$

where $A, B, C$ — numerical coefficients.

The model explaining the increase in the yield of juice from the stone bramble berries ($G$, %) depending on the duration of the treatment process ($\tau$, min) and the concentration of enzyme preparations ($\omega$, %) is represented by the following function (2):

$$ G(\tau, \omega) = a \cdot \tau^b \cdot \omega^c, $$
where \( a, b, c \) — weighting coefficients, searched for a specific enzyme preparation using regression analysis methods.

To predict the maximum juice yield from berry raw materials and analyze the technological efficiency of the treatment process, two-factor experiments were drawn up, the level of technological excellence was selected, and the results of the regression analysis of these two-parameter dependencies were systematized, which are estimated by the Pearson correlation and determination coefficients to define the proportion of explained variation.

The assessment of the significance of differences in mean values was carried out using Student's t-test. Check for the presence of autocorrelation of residual dependencies performed using the criterion of Durbin-Watson. The significance of the regression coefficients was determined by the Student's t-test at the level of 0.05, and the model adequacy was determined by the Fischer F-test using the Statistics subpackage of the Maple package. Lineup dependencies of the model are determined by 95% and higher (Coefficient of Multiple Determination 0.95728), the relative error of smoothing the experimental data does not exceed 7%.

Increase in the yield of juice from the stone bramble berries (\( G, \% \)) depending on the duration of the treatment process (\( \tau, \) min) and the concentration of the enzyme preparation - pectolytic enzyme Vinoferm zymex (\( \omega, \% \)) is represented by the following function (figure 1):

\[
G(\tau, \omega) = a \cdot \tau^b \cdot \omega^c,
\]

where \( a = 24.881, b = 0.036, c = 0.167 \) — weighting coefficients, found via Maple package.

![Figure 1](image1.png)

**Figure 1.** Dynamics of stone bramble berries juice yield depending on treatment duration and Vinoferm zymex concentration.

![Figure 2](image2.png)

**Figure 2.** Dynamics of juice yield increase depending on treatment duration at Vinoferm zymex concentrations of 0.01, 0.02, 0.03, 0.04 %.

By entering numerical values of the weight coefficients into a general formula, we obtain the calculation scheme of juice yield increase:

\[
G(\tau, \omega) = 24.88125161 \tau^{0.03658541283} \omega^{0.1679202603}
\]
In particular, at pectolytic enzyme Vinoferm zymex concentrations $\omega=0.01, 0.02, 0.03, 0.04 \%$, taken in the experiment, the dynamics of juice yield increase ($G, \%$) depending on treatment process duration ($\tau, \text{min}$) looks as follows (figure 2):

\[
G(\tau, 0.01) = 11.48237437\tau^{0.03658541283},
\]
\[
G(\tau, 0.02) = 12.89973349\tau^{0.03658541283},
\]
\[
G(\tau, 0.03) = 13.80861203\tau^{0.03658541283},
\]
\[
G(\tau, 0.04) = 14.49204830\tau^{0.03658541283}.
\]

At the enzyme concentration of 0.01 \% the increase in juice yield reaches its maximum value of 13.88 \%, at concentration 0.02 \% the yield is 15.60 \%, and at concentration 0.03 \% it is 16.70 \% respectively. The greatest increase in juice yield after enzymatic treatment of raw material makes up to 17.52 \% at enzyme concentration of 0.04 \%.

Increase in the yield of juice from berries ($G, \%$) depending on the duration of the treatment process ($\tau, \text{min}$) and enzyme Bruzaim BGX concentration ($\omega, \%$) is represented by the following functions (figure 3):

\[
G(\tau, \omega) = a \cdot \tau^b \cdot \omega^c,
\]

where $a = 20.198$, $b = 0.033$, $c = 0.270$ — weighting coefficients, found via Maple package.

![Figure 3. Dynamics of stone bramble berries juice yield depending on treatment duration and Bruzaim BGX concentration.](image1)

![Figure 4. Dynamics of juice yield increase depending on treatment duration at Bruzaim BGX concentrations of 0.01, 0.02, 0.03, 0.04 \%.](image2)

By entering numerical values of the weight coefficients into a general formula, we obtain the calculation scheme of juice yield increase:

\[
G(\tau, \omega) = 20.19827979\tau^{0.03393689073} \omega^{0.2704316458}.
\]
In particular, at Bruzaim BGX concentrations $\omega=0.01, 0.02, 0.03, 0.04 \%$, taken in the experiment, the dynamics of juice yield increase ($G, \%$) depending on treatment process duration ($\tau, \text{min}$) looks as follows (figure 4):

$$G(\tau, 0.01) = 5.813679583\tau^{0.03393689073},$$
$$G(\tau, 0.02) = 7.012278066\tau^{0.03393689073},$$
$$G(\tau, 0.03) = 7.824917699\tau^{0.03393689073},$$
$$G(\tau, 0.04) = 8.457989985\tau^{0.03393689073}.$$

At the enzyme concentration of $0.01 \%$ the increase in juice yield reaches its maximum value of $6.93 \%$, at concentration $0.02 \%$ the yield is $8.36 \%$, and at concentration $0.03 \%$ it is $9.33 \%$ respectively. The greatest increase in juice yield after enzymatic treatment of raw material makes up to $10.09 \%$ at enzyme concentration of $0.04 \%$.

Increase in the yield of juice from berries ($G, \%$) depending on the duration of the treatment process ($\tau, \text{min}$) and concentration of enzyme mixture (Bruzaim BGX and Vinoferm zymex) ($\omega, \%$) is represented by the following function (figure 5):

$$G(\tau, \omega) = a \cdot \tau^b \cdot \omega^c,$$

where $a = 24.0055, b = 0.030, c = 0.121 —$ weighting coefficients found via Maple package.

**Figure 5.** Dynamics of stone bramble berries juice yield depending on treatment duration and enzyme mixture (Bruzaim BGX and Vinoferm zymex) concentration.

**Figure 6.** Dynamics of juice yield increase depending on treatment duration at enzyme mixture (Bruzaim BGX and Vinoferm zymex) concentrations $0.01, 0.02, 0.03, 0.04 \%$.

By entering numerical values of the weight coefficients into a general formula, we obtain the calculation scheme of juice yield increase:

$$G(\tau, \omega) = 24.00550172\tau^{0.03020747962} \omega^{0.121081549}$$
In particular, at enzyme mixture (Bruzaim BGX and vinoferm zymex) concentrations $\omega = 0.01, 0.02, 0.03, 0.04\%$, taken in the experiment, the dynamics of juice yield increase ($G,\%$) depending on treatment process duration ($\tau,\text{min}$) looks as follows (Figure 6):

\[
\begin{align*}
G(\tau, 0.01) &= 13.74340920 \tau^{0.03020747962} \\
G(\tau, 0.02) &= 14.94691844 \tau^{0.03020747962} \\
G(\tau, 0.03) &= 15.69920832 \tau^{0.03020747962} \\
G(\tau, 0.04) &= 16.25581889 \tau^{0.03020747962}
\end{align*}
\]

Planned yield of berry juice depends on concentration of mixture of enzymes Bruzaim BGX and Vinoferm zymex. At the enzyme mixture concentration of 0.01\% the increase in juice yield reaches its maximum value of 16.08\%, at concentration 0.02\% the yield is 17.49\%, and at concentration 0.03\% it is 18.37\% respectively. The greatest increase in juice yield after enzymatic treatment of raw material makes up to 19.02\% at enzyme mixture concentration of 0.04\%.

3. Conclusion

Thus, based on the analysis of the identified patterns of stone bramble berries’ treatment, the integral indicator representing various functional aspects of berry raw materials biomass transformation was compiled, including resulting indicators of juice yield as particular cases; an analytical model of technological processes’ complex for producing stone bramble berries’ juice was developed. The model can be applied to the production of juices from other berry raw materials.

The proposed analytical model describes the mechanism for improving the technological perfection of the pretreatment of berry raw materials with enzyme preparations of various concentrations combined with the influence of the main treatment duration on the increase in the yield of berry juice.

The computer implementation of the model allowed to calculate the largest increase in the yield of juice upon the completion of enzymatic treatment of raw materials: 17.52\% at concentration of the pectolytic enzyme Vinoferm zymex of 0.04\%, 10.09\% at concentration of Bruzaim BGX of 0.04\% and 19.02\% when the concentration of the mixture of enzymes Bruzaim BGX and Vinoferm zymex reached 0.04\%.

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