OSMOTIC DEHYDRATION OF FISH: PRINCIPAL COMPONENT ANALYSIS

Biljana Lj. Lončar1*, Lato L. Pezo2, Ljubinko B. Lević1, Vladimir S. Filipović1, Milica R. Nićetin1, Violeta M. Knežević1, Tatjana A. Kuljanin1

1 University of Novi Sad, Faculty of Technology Novi Sad, Bulevar Cara Lazara 1, 21000 Novi Sad, Serbia, 2 Institute of General and Physical Chemistry, 11000 Beograd, Serbia

Osmotic treatment of the fish Carassius gibelio was studied in two osmotic solutions: ternary aqueous solution – S1, and sugar beet molasses – S2, at three solution temperatures of 10, 20 and 30°C, at atmospheric pressure. The aim was to examine the influence of type and concentration of the used hypertonic agent, temperature and immersion time on the water loss, solid gain, dry matter content, aw and content of minerals (Na, K, Ca and Mg). S2 solution has proven to be the best option according to all output variables.

KEY WORDS: osmotic treatment, Fish, Sugar beet molasses, PCA

INTRODUCTION

Fish meat is very beneficial for human health due to its specific chemical composition (1). This valuable source of nutrients is one of the most perishable foods, and needs to be processed. The main reason for short shelf life of fish meat is high moisture content (2, 3). Advantageous method for water content reduction of cellular material is osmotic treatment (OT) (4). OT is recognized as a mild temperature processing method based on the principle of osmosis, where difference between the sample and its surrounding medium is the main force for dewatering process (5, 6). The rate of water diffusion from the biological material depends upon various factors: type, concentration, temperature and agitation of the osmotic solution, the size and structure of food material and solution to sample mass ratio (7). Multi-components salt-sugar aqueous solutions have been successfully used for OT (8, 9). Meat or fish are usually dehydrated in aqueous solutions with salt as a main component (10, 11), however in some countries are well-known sweet salted fish products obtained by OT in salt and sweet hypertonic solutions (12, 13). According to the recent papers, sugar beet molasses as hypertonic medium is highly effective for OT of fruits (14), vegetables (15) and meat (16, 4, 17). High amounts of solids (>80%), and specific nutrient composition (50% sucrose, 1% raffinose and less than 1% invert sugar, considerable amounts of minerals, proteins, vitamins, glutamic acid, organic acids, pectin, etc.) make sugar beet molasses a unique and efficient hypertonic solution (15, 18).

* Corresponding author: Biljana Lj. Lončar, University of Novi Sad, Faculty of Technology Novi Sad, Bulevar cara Lazara 1, 21000 Novi Sad, Serbia, e-mail: biljacurcic@yahoo.com
The objective of the presented work was to investigate the effects of the processing time, temperature, concentration of osmotic solutions on the mass transfer phenomena during OT of fish *Carassius gibelio* in sugar beet molasses and aqueous ternary solution (concentrated salt and sugar aqueous solution). Principal Component Analysis (PCA) is used to evaluate the quality of the obtained products, processed under different process parameters. The aim was to determine the minerals content (Na, K, Ca, Mg), dry matter (DM) content, water loss (WL), solid gain (SG), and water activity (aw) as a function of the process variables and to find the optimum osmotic treatment conditions.

**EXPERIMENTAL**

**Osmotic dehydration of fish**

The OT was carried out in laboratory jars under atmospheric pressure in a heat chamber at the solution temperatures of 10, 20 and 30°C. Prussian carp (*Carassius gibelio*) was purchased on a local market in Novi Sad, Serbia, shortly prior to the experiment. The initial moisture content of untreated samples was 75.34%. Fish samples were filleted and cut into pieces (1x1cm) using kitchen slicer and scissors. After the preparation, the samples were measured and immersed in hypertonic solutions for 5 hours. The sample to solution ratio was 1:5 (w/w), which can be considered high enough to neglect the changes of solution concentration during the process. On every 15 minutes, the fish samples in the osmotic solutions were stirred to provide better homogenization of the osmotic solution, because of the amount of diffused water from the samples. Aqueous ternary osmotic solution was made from sucrose in the quantity of 1.200 g/kg water, NaCl in the quantity of 350 g/kg water and distilled water. This solution (S1) was diluted with distilled water to the concentrations of 60, 52.5 and 45% w/w. Sugar beet molasses, obtained from the sugar factory Pećinci, Serbia, with the initial dry matter content of 85.04% w/w, was diluted to the concentrations of 60, 70 and 80% w/w (this solution was marked as S2).

After each sampling time (1, 3 and 5 hours), fish samples were taken out from solutions (S1 and S2), lightly washed with distilled water, gently blotted with paper to remove excessive water from the surface and weighted.

In order to describe the mass transfer kinetics of the osmotic dehydration (OD), experimental data from three key process variables are usually obtained: the moisture content, change in weight and the change in soluble solids. Using these, WL and SG, were calculated for different solutions and processing times (4,14,15):

\[
WL = \frac{m_i \cdot z_i - m_f \cdot z_f}{m_i} \left[ \frac{g}{g \ fresh \ sample} \right] \quad [1]
\]

\[
SG = \frac{m_f \cdot s_f - m_i \cdot s_i}{m_i} \left[ \frac{g}{g \ fresh \ sample} \right] \quad [2]
\]

where \(m_i\) and \(m_f\) are the initial and final weight (g) of the samples, respectively; \(z_i\) and \(z_f\) are the initial and final mass fraction of water (g water/g sample), respectively; \(s_i\) and \(s_f\) are the initial and final mass fraction of total solids (g total solids/ g sample), respectively.
ly. The mass loss during OD can be evaluated by subtracting the \( SG \) from the \( WL \). The moisture content in the DM at any time can be calculated by dividing the subtracted initially water present and the WL, with the initial dry solids.

**Physico-chemical analyses**

The DM content of the fresh and treated samples was determined by drying at 105°C for 24 hours in a heat chamber (Instrumentaria Zagreb, Croatia). The value of \( aw \) for the osmotically treated samples was measured using a water activity measurement device (TESTO 650, Germany) with an accuracy of \( \pm 0.001 \) at 25°C. Soluble solids content of the molasses solutions was measured using an Abbe refractometer (Carl Zeis, Jenna, Germany) at 20°C. All analytical measurements were carried out in accordance to the AOAC method (19). All experiments were repeated three times and presented using descriptive statistics (20).

Processing temperature (\( T \)): 10, 20, 30°C, immersion time (\( t \)): 1, 3 and 5h, \( S_1 \) concentration (\( c \)): 60, 52.5 and 45% w/w, \( S_2 \) concentration: 60, 70 and 80% w/w.

**Response Surface Methodology**

The Response Surface Method (RSM) was selected to estimate the main effect of the process variables on the mass transfer variables during the OT of fish. The experimental data used for the optimization study were obtained using a central composite full factorial design (3 level-3 parameter) with 27 runs (1 block). The independent variables were temperature, \( T (X_1) \) of 10, 20 and 30°C; osmotic time \( t (X_2) \) of 1, 3 and 5h; \( X_3 \) is the concentration of osmotic solution, \( c \): 45, 52.5 and 60% w/w for \( S_1 \) solution and 60, 70 and 80% w/w for \( S_2 \) solution; and the dependent variables observed were the response: \( WL (Y_1) \), \( SG (Y_2) \), \( a_w (Y_3) \), \( DM (Y_4) \), Na (\( Y_5 \)), K (\( Y_6 \)), Ca (\( Y_7 \)) and Mg (\( Y_8 \)). A model was fitted to the response surface generated by the experiment. The model used was a function of the following variables:

\[
Y_k = \beta_{k0} + \sum_{i=1}^{3} \beta_{ki}X_i + \sum_{i=1}^{3} \sum_{j=i+1}^{3} \beta_{kj}X_i^2 + \sum_{i=1}^{3} \sum_{j=i+1}^{3} \beta_{kij}X_iX_j, \quad k=1-8, \tag{3}
\]

where: \( \beta \) are constant regression coefficients.

Analysis of variance (ANOVA) and response surface regression method (RSM) were performed using StatSoft Statistica, for Windows, ver. 10 program. The model was obtained for each dependent variable (or response), where factors were rejected when their significance level was \( p<0.05 \).

**Principal component analysis**

The PCA is a mathematical procedure used as a central tool in exploratory data analysis (21). It is a multivariate technique in which the data are transformed into orthogonal components that are linear combinations of the original variables. The PCA is done by eigenvalue decomposition of a data correlation matrix (22). This transformation is defined in such a way that the first component has the largest possible variance. This analysis
is used to achieve maximum separation among the clusters of parameters (17). This approach, evidencing spatial relationship between the processing parameters, enabled a differentiation between the different samples in both solutions (S_1 and S_2). For the PCA, use was made of the program StatSoft Statistica 10 (20).

RESULTS AND DISCUSSIONS

The obtained experimental data were presented using basic descriptive statistics, Table 1. The variables WL, SG, a_w, DM, and the content of Na, K, Ca and Mg varied significantly, implying that fitting of the experimental data could be performed using ANN modeling.

Table 1. Experimental results

<table>
<thead>
<tr>
<th></th>
<th>WL</th>
<th>SG</th>
<th>a_w</th>
<th>DM</th>
<th>Na</th>
<th>K</th>
<th>Ca</th>
<th>Mg</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ternary aqueous solution – S_1</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum</td>
<td>0.36</td>
<td>0.08</td>
<td>0.90</td>
<td>44.08</td>
<td>0.19</td>
<td>0.30</td>
<td>0.01</td>
<td>0.02</td>
</tr>
<tr>
<td>Minimum</td>
<td>0.09</td>
<td>0.02</td>
<td>0.03</td>
<td>7.62</td>
<td>0.03</td>
<td>0.01</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Average</td>
<td>0.19</td>
<td>0.04</td>
<td>0.85</td>
<td>30.69</td>
<td>0.13</td>
<td>0.29</td>
<td>0.01</td>
<td>0.02</td>
</tr>
<tr>
<td>Std. dev.</td>
<td>0.49</td>
<td>0.12</td>
<td>0.95</td>
<td>1.45</td>
<td>0.31</td>
<td>0.31</td>
<td>0.01</td>
<td>0.02</td>
</tr>
<tr>
<td>Variance</td>
<td>7.59×10^{-3}</td>
<td>4.30×10^{-4}</td>
<td>7.27×10^{-4}</td>
<td>5.41×10^{-3}</td>
<td>3.92×10^{-5}</td>
<td>1.45×10^{-7}</td>
<td>3.08×10^{-6}</td>
<td></td>
</tr>
<tr>
<td><strong>Sugar beet molasses – S_2</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum</td>
<td>0.39</td>
<td>0.09</td>
<td>0.88</td>
<td>47.7</td>
<td>0.50</td>
<td>0.78</td>
<td>0.05</td>
<td>0.03</td>
</tr>
<tr>
<td>Minimum</td>
<td>0.11</td>
<td>0.02</td>
<td>0.02</td>
<td>8.32</td>
<td>0.14</td>
<td>0.20</td>
<td>0.02</td>
<td>0.01</td>
</tr>
<tr>
<td>Average</td>
<td>0.14</td>
<td>0.05</td>
<td>0.23</td>
<td>33.51</td>
<td>0.28</td>
<td>0.50</td>
<td>0.02</td>
<td>0.02</td>
</tr>
<tr>
<td>Std. dev.</td>
<td>0.54</td>
<td>0.13</td>
<td>0.92</td>
<td>64.27</td>
<td>0.75</td>
<td>1.15</td>
<td>0.08</td>
<td>0.05</td>
</tr>
<tr>
<td>Variance</td>
<td>1.11×10^{-2}</td>
<td>4.60×10^{-4}</td>
<td>5.27×10^{-4}</td>
<td>6.93×10^{-4}</td>
<td>1.90×10^{-2}</td>
<td>4.01×10^{-2}</td>
<td>4.04×10^{-4}</td>
<td>4.51×10^{-5}</td>
</tr>
</tbody>
</table>

The most intensive increase in the DM content was achieved during the OT of fish in the S_2 solution. The DM content increased from the initial 24.66 to 47.83 % in S_2 solution, concentrated to 80% w/w, or to 44.08% in S_1 solution, concentrated to 60% w/w, after 5 hours of experiment. The large difference in the osmotic pressure between the hypertonic solution and the fish tissue, causes a high initial loss of the water at the beginning of the dehydration process. The maximum of WL and SG was achieved after 5 hours at the maximum concentrations.

The SG value indicates the degree of penetration of solids from the hypertonic solution into the fish sample. The aim of the OT is the achievement of as low as possible solid uptake, and the most acceptable results were achieved by using S_2 solution, concentrated to 80% w/w.

Tables 2 and 3 show the influences of the process variables on the observed responses for the OT of fish in S_1 and S_2 solution. The analysis revealed that the linear terms contributed substantially in most of the cases to the generation of a significant SOP model. The linear terms of SOP model were found significant, at p<0.05 level,
95% confidence limit, and their influence was found as being most important in the majority of model calculations.

Table 2. Analysis of variance (ANOVA) for osmotic treatment of fish in S₁ solution

<table>
<thead>
<tr>
<th>Term</th>
<th>WL</th>
<th>SG</th>
<th>aₕ</th>
<th>DM</th>
<th>Na</th>
<th>K</th>
<th>Ca</th>
<th>Mg</th>
</tr>
</thead>
<tbody>
<tr>
<td>t</td>
<td>0.134*</td>
<td>0.008</td>
<td>0.008</td>
<td>877.350</td>
<td>0.020</td>
<td>0.001</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>t²</td>
<td>0.011*</td>
<td>0.000</td>
<td>0.000</td>
<td>46.856</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>T</td>
<td>0.006*</td>
<td>0.002</td>
<td>0.003</td>
<td>433.077</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>T²</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>4.373</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>c</td>
<td>0.038*</td>
<td>0.001*</td>
<td>0.007*</td>
<td>108.242</td>
<td>0.004</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>c²</td>
<td>0.001*</td>
<td>0.000</td>
<td>0.000</td>
<td>2.851*</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>t × T</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.021</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>t × c</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>13.313*</td>
<td>0.001</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>T × c</td>
<td>0.001*</td>
<td>0.000</td>
<td>0.000</td>
<td>20.185</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>Error</td>
<td>0.001</td>
<td>0.000</td>
<td>0.001</td>
<td>10.551</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>r²</td>
<td>0.993</td>
<td>0.963</td>
<td>0.967</td>
<td>0.993</td>
<td>0.983</td>
<td>0.84</td>
<td>0.980</td>
<td>0.999</td>
</tr>
</tbody>
</table>

*Significant at p<0.05 level, **Significant at p<0.10 level, 95% confidence limit

Table 3. Analysis of variance (ANOVA) for osmotic treatment of fish in S₂ solution

<table>
<thead>
<tr>
<th>Term</th>
<th>WL</th>
<th>SG</th>
<th>aₕ</th>
<th>DM</th>
<th>Na</th>
<th>K</th>
<th>Ca</th>
<th>Mg</th>
</tr>
</thead>
<tbody>
<tr>
<td>t</td>
<td>0.023*</td>
<td>0.002*</td>
<td>0.000*</td>
<td>1.842</td>
<td>0.043*</td>
<td>0.084*</td>
<td>0.000*</td>
<td>0.000*</td>
</tr>
<tr>
<td>t²</td>
<td>0.013*</td>
<td>0.000*</td>
<td>0.001*</td>
<td>2.232*</td>
<td>0.002*</td>
<td>0.003</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>T</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>3.868*</td>
<td>0.034*</td>
<td>0.079</td>
<td>0.001*</td>
<td>0.000</td>
</tr>
<tr>
<td>T²</td>
<td>0.007*</td>
<td>0.000</td>
<td>0.000</td>
<td>3.788*</td>
<td>0.012*</td>
<td>0.011*</td>
<td>0.001*</td>
<td>0.000*</td>
</tr>
<tr>
<td>c</td>
<td>0.001</td>
<td>0.000</td>
<td>0.000</td>
<td>0.607</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>c²</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.422</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>t × T</td>
<td>0.001</td>
<td>0.000</td>
<td>0.000</td>
<td>0.180</td>
<td>0.005*</td>
<td>0.032*</td>
<td>0.000*</td>
<td>0.000*</td>
</tr>
<tr>
<td>t × c</td>
<td>0.001</td>
<td>0.000</td>
<td>0.000</td>
<td>11.653</td>
<td>0.000</td>
<td>0.001</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>T × c</td>
<td>0.011*</td>
<td>0.000</td>
<td>0.000</td>
<td>8.392</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>Error</td>
<td>0.013</td>
<td>0.000</td>
<td>0.001</td>
<td>10.791</td>
<td>0.008</td>
<td>0.036</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>r²</td>
<td>0.955</td>
<td>0.976</td>
<td>0.953</td>
<td>0.994</td>
<td>0.983</td>
<td>0.966</td>
<td>0.978</td>
<td>0.913</td>
</tr>
</tbody>
</table>

*Significant at p<0.05 level, **Significant at p<0.10 level, 95% confidence limit

The most important influences on the response variables exerted the linear term of t, for S₁ solution, while the influence of the other linear terms (T and c) was also found to be statistically significant for the calculation in most of the cases. The linear term of c was more important for the calculation of WL, aₕ, and minerals content, while the linear term of T was more important for the calculation of SG and DM.

The calculation of the observed response variables for the OT of fish in the S₂ solution was mostly influenced by the linear term of t. The influence of the quadratic term was also very important for the calculation of WL, SG, aₕ and DM (statistically significant at p<0.05 level, 95% confidence limit). The linear term of T was important for the calculation of aₕ and DM calculation, as well as for the evaluation of the observed
mineral contents. The quadratic term of \( T \) was influential for the calculation of \( \text{WL} \) and \( \text{SG} \), as well as for the observed mineral contents. The interchange term of \( t \times T \) in the SOP models for mineral calculation was also found to be statistically significant at \( p<0.05 \) level, 95% confidence limit.

### Principal component analysis (PCA)

The PCA applied to the given data set (Table 1) showed a differentiation between the samples according to the process parameters and is used as a tool in exploratory data analysis to characterize and differentiate the neural network input parameters (Fig. 1).

![Eigenvalues of the correlation matrix for OT of Carassius gibelio in S1 (a) and S2 (c) solution and the biplots for treatment in S1 (b) and S2 (d) solution](image)

**Figure 1.** Eigenvalues of the correlation matrix for OT of *Carassius gibelio* in S1 (a) and S2 (c) solution and the biplots for treatment in S1 (b) and S2 (d) solution

Dot captions in Figs. 1b and 1d are defined by the equations [4] for S1 and [5] for S2:

\[
\begin{align*}
\text{eqn 1} & = 1 + \left(1 + \frac{T - 20}{10}\right) + \left(1 + \frac{c - 52.5}{12.5}\right) \cdot 3 + \left(1 + \frac{t - 3}{2}\right) \cdot 3^2, \\
\text{eqn 2} & = 1 + \left(1 + \frac{T - 20}{10}\right) + \left(1 + \frac{c - 70}{10}\right) \cdot 3 + \left(1 + \frac{t - 3}{2}\right) \cdot 3^2,
\end{align*}
\]

where: \( T \) is the processing temperature (10, 20 or 30°C), \( t \) is the immersion time (1, 3 or 5 h), \( c \) is the concentration (60, 70 or 80 % w/w for S1 or 45, 52.5 or 60 % w/w for S2).
As can be seen, there is a neat separation of the observed samples according to used assays. The quality results show that the first two principal components, accounting for 96.89% and 98.37% of the total variability for solution S1 and S2, respectively, can be considered sufficient for data representation and the first two principal components for the integrated chemical and physical quality. The values of \( WL, SG, DM \), and of the mineral contents were more influential for the calculation of the first factor coordinate, while \( a_w \) was more influential for the calculation of the second factor coordinate, for both solutions.

The influence of processing parameters can be observed in Fig. 1, with the samples processed with lower processing parameters located at the left side of both graphs. The PCA graphs showed quite good discrimination between the S1 and S2 solutions. The Na content increased with the increase in all the process parameters for both S1 and S2 solutions, while the other mineral contents tended to increase only in the S2 solution, due to the high amounts of minerals in the molasses. Sugar beet molasses contains about: 3920 mg/100g K, 100 mg/100g Ca, 320 mg/100g Mg, and 680 mg/100g Na (23).

**CONCLUSION**

This paper presents the influence of the process parameters on the kinetics and chemical properties of the processed samples. The observed samples were characterized by physical and chemical analyses, and the parameters used in the statistical analysis were divided into input and output variables. The input variables were the immersion time, temperature and concentration (of ternary solution or sugar beet molasses), while the output variables were the water loss, solid gain, water activity, dry matter content, and the content of Na, K, Ca and Mg. Sugar beet molasses has proved to be a better osmotic solution for the osmotic treatment of fish considering all output variables.

**Acknowledgement**

The authors acknowledge financial support the Ministry of Education, Science and Technological Development of the Republic of Serbia, TR – 31055, 2011-2014.

**REFERENCES**


ОСМОТСКА ДЕХИДРАЦИЈА МЕСА РИБЕ - АНАЛИЗА ГЛАВНИХ КОМПОНЕНТИ

Биљана Љ. Лончар1*, Лато Л. Пезо2, Љубинко Б. Левић1, Владимир С. Филиповић1, Милци Р. Нићетин1, Виолета М. Кнежевић1, Татјана А. Куланин1

1 Универзитет у Новом Саду, Технолошки факултет, Будевар Цара Лазара 1, 21000 Нови Сад, Србија,
2 Институт за општу и физичку хемију, Студентски трг 12-16, 11000 Београд, Србија

Осмотски третман рибе (Carassius gibelio) импеније је у два осмотска раствора (у шећерно-сланом раствору-С1 и раствору шећерне репе-С2), на три температуре раствора (10, 20 и 30°C), при атмосферском притиску. Циљ овог истраживања био је утврђивање утицаја врсте и концентрације осмотског раствора, температуре и времена имерзије на губитак воде, прираштај суве материје, садржај суве материје, a и садржај минерала (Ca, K, Na и Mg). Меласа шећерне репе се показала као бољи осмотски раствор према измереним матраним параметрама.

Кључне речи: осмотска дехидрација, риба, меласа шећерне репе, анализа главних компоненти

Received: 13 June 2014.
Accepted: 26 September 2014.