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АГРОНАУКА И ТЕХНОЛОГИЯ

НАЦИОНАЛЬНЫЙ АГРАРНЫЙ УНИВЕРСИТЕТ АРМЕНИИ



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Theoretical Justification of the Dynamic Parameters in Plant Stems Sliding Cutting

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ABSTRACT

The first article of the series considers the opportunities of finding theoretical solutions to the issue of plants stem cutting via sliding method with account for the rheological properties of the substance.

Throughout the problem solution, cutting process was viewed as a transitional step for forced crack propagation in the body.

Analytical expressions have been derived, which enable to analyze the stress state of the material in the cutting zone, to identify the principal stresses causing abrasions in case of sliding cutting. Intensity coefficient, sliding coefficient and their value domains have been identified, whereby the sliding cutting is implemented with minimum energy consumption.

Introduction

The theory developed through the scientific experimental data serves as a base for conducting research on the cutting process of the plants' different organs, particularly plants stem cutting with blades. Some of the founders of the mentioned theory are the academician V.P. Goryachkin (Goryachkin, 1965) and his successor – academician V.A. Zheligovsky (Zheligovsky, 1941), and this theory was surely later developed by a number of other scientists (Reznik, 1975, Tarverdyan, 1996, O'dogherty and Cale, 1986, Dowgiallo, 2005, etc.).

It is apparent that in order to disclose the cutting nature and to identify the optimal values of cutting process and

hence, those of the kinematic and geometric parameters for blade, it is necessary to investigate the physicommechanical properties of the material. Though this approach was developed still in the start of the previous century, yet, intensive investigations in this direction has been initiated since 1970 (Klaus Dobler, 1972, Reznik, 1975, Osobov and Noreiko, 1984, Tarverdyan, 1996). The mentioned research works have enabled to make adjustments to the current outlooks, develop cutting theories and consequently update the cutting devices.

The long-term theoretical and scientific experimental research activities implemented in this area (Tarverdyan, 1996) have provided opportunities to precisely determine

the physicochemical properties of slender-stemmed and rigid thick-stemmed plants at different developmental stages. By combining the research results of anatomical and morphological structure of stems and study results of the physicochemical properties of the given substance, mechanical models have been developed which helped make considerable adjustments and corrections to the analytical expressions in the cutting theory.

Nevertheless, it is worth mentioning that in the investigations conducted thereto, mainly some constant values of the indicators characterizing the physicomaterial properties of the cutting material are assumed as a base, while throughout deformation process they undergo changes; in other words, the rheological properties of the material are not considered. In some research papers (Reznik, 1975, Tarverdyan, 1996, Tarverdyan, 2004, Altunyan., 2008) this issue was addressed but the results of the problem solutions are not finalized and generalized enough to set the optimal cutting parameters and to develop cutting apparatus operating with minimum energy consumption.

Upon the current and classical analysis of the stress states, rheological modeling methods of the materials can be added to the description of the material cutting process, where the provisions of elasticity theory are mainly used, which are of no less importance, but are hardly applied in the theory of plant-based raw stuff cutting.

Taking into account the abovementioned and also based on the further comparison of the obtained results, we find it relevant to introduce one more approach of the theoretical study for plants stem cutting, which will further enable to interpret the cutting problem on the principle of rheological modeling and with minimum energy consumption more comprehensively.

The problem of cutting with minimum energy consumption is solved for the individual case, that is, for the case of oblique front cutting (Tarverdyan, 2014), whereas, it is known that effective blade cutting is ensured in case of sliding cutting. It is noteworthy that the majority of current cutting devices cut the plants stems and other plant materials just in conditions of slide provision. In this regard the study of the problem related to the blade sliding cutting and its specified solution is quite justified and relevant from both theoretical and practical perspectives.

The goal of the current work is to study the stems cutting via blade sliding by analyzing the stress-strain state of the procedure and to substantiate the values of dynamic parameters providing minimum critical cutting force.

Materials and methods

Based on the afore stated facts an attempt has been made

to adjust the stems blade cutting theory by applying the approach of analyzing the stress states of the material to be cut. The problem has been formulated and the expressions resulted from its solution, have enabled to determine the minimum value of the cutting force and the value of cutting speed, which ensures accurate blade cutting with minimum energy consumption.

It is necessary to consider that during the sliding cutting of stem (Figure 1), the stress-strain state of the material in the zone of the blade edge, i.e., at the tip of cutting (crack) (I), on the facet (II) and in both planes (III and IV) of the body (blade spine) are different, and hence, the basic stresses (σ) and extreme friction stresses τ_{\min}^{\max} on those planes are determined through various expressions.

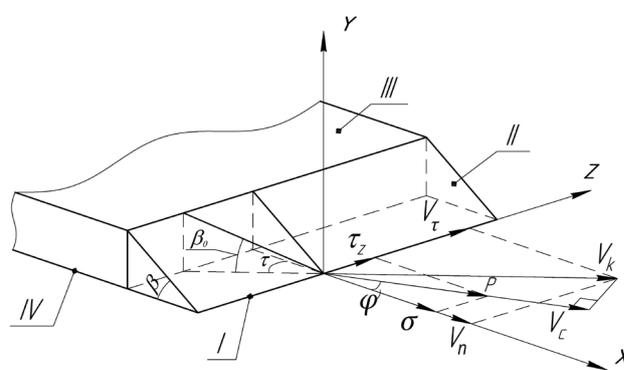


Figure 1. The simplest diagram for introducing the nature of sliding cutting (composed by the authors).

In the discussed issue the interpretation and proper modeling of the objective picture for the stress-strain state in the direct interaction zone of the blade edge and the cut material (stem) is of vital significance.

The results of empirical research conducted through the high-speed/fast microscopic imaging of the stem cutting process (10 000 frames per second/fps/) and synchronous recording of cutting force data (Tarverdyan, 1996) give grounds for stating that cutting process can be viewed as a forced crack (fracture) propagation with a certain velocity. When assuming such model, the problem of stem cutting with minimum energy consumption leads to the determination of the kinematic and dynamic optimal parameters upon the favorable conditions of crack (fracture) forced propagation in the body. It is worth mentioning that the introduced approach is appropriate to apply starting from the wax maturation phase of the plants stem development, since the rheological models of the stem matter are extremely different related to the developmental stages: elastic-plastic adhesive, elastic-plastic and elastic.

In the mechanics of solid body abrasion three cases of crack surface deformation are accepted (Figure 2).

It is vivid that in the mentioned three cases the shift of the crack planes towards each other is related to the stress state in the vicinity of the crack/cutting tip (Figure 3).

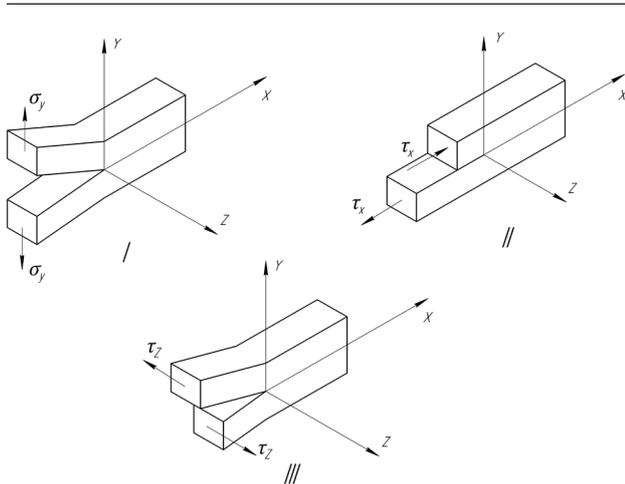


Figure 2. Deformation modes of the crack (cutting) surface. I – regular tearing, II – latitudinal sliding, III – longitudinal sliding (composed by the authors).

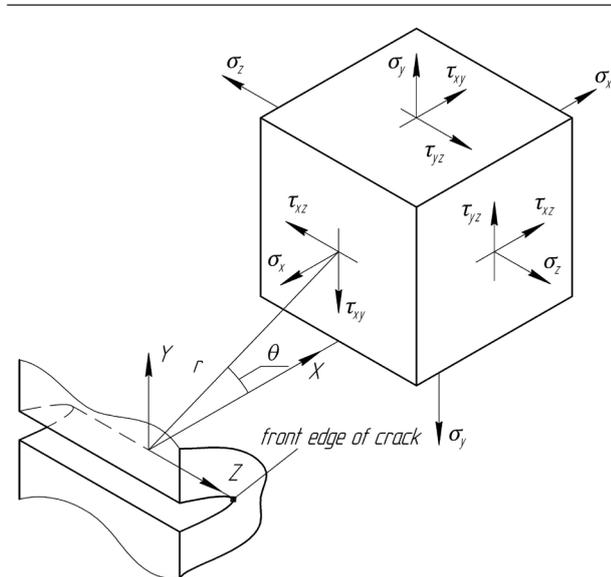


Figure 3. Diagram of the stress state in case of sliding cutting through the vicinity of the crack front edge (composed by the authors).

The stress state in the sector adjacent to the crack front edge is described through the famous Sneddon (Sneddon and Berry, 1961) or Irwin (Irwin, 1957) equations:

1. In case of regular tearing: ($K_1 \neq 0, K_2 = K_3 = 0$),

$$\left. \begin{aligned} \sigma_x &= \frac{K_1}{\sqrt{2\pi r}} \cdot \cos \frac{\theta}{2} \left[1 - \sin \frac{\theta}{2} \cdot \sin \frac{3\theta}{2} \right] \\ \sigma_y &= \frac{K_1}{\sqrt{2\pi r}} \cdot \cos \frac{\theta}{2} \left[1 + \sin \frac{\theta}{2} \cdot \sin \frac{3\theta}{2} \right] \\ \tau_{xy} &= \frac{K_1}{\sqrt{2\pi r}} \cdot \sin \frac{\theta}{2} \cdot \cos \frac{\theta}{2} \cdot \cos \frac{3\theta}{2}, \end{aligned} \right\} \quad (1)$$

$\sigma_z = 0$ in case of flat stress state and $\sigma_z = \nu(\sigma_x + \sigma_y)$ in case of flat deformation.

2. In case of latitudinal sliding: ($K_1 = K_3 = 0; K_2 \neq 0$),

$$\left. \begin{aligned} \sigma_x &= -\frac{K_2}{\sqrt{2\pi r}} \cdot \sin \frac{\theta}{2} \left(2 + \cos \frac{\theta}{2} \cdot \cos \frac{3\theta}{2} \right) \\ \sigma_y &= \frac{K_2}{\sqrt{2\pi r}} \cdot \sin \frac{\theta}{2} \left(\cos \frac{\theta}{2} \cdot \cos \frac{3\theta}{2} \right) \\ \tau_{xy} &= -\frac{K_2}{\sqrt{2\pi r}} \cdot \cos \frac{\theta}{2} \left(1 - \sin \frac{\theta}{2} \cdot \sin \frac{3\theta}{2} \right), \end{aligned} \right\} \quad (2)$$

$\sigma_z = \nu(\sigma_x + \sigma_y), \tau_{xz} = \tau_{yz} = 0$.

3. Longitudinal sliding ($K_3 \neq 0; K_1 = K_2 = 0$),

$$\left. \begin{aligned} \tau_{xz} &= \frac{K_3}{\sqrt{2\pi r}} \cdot \sin \frac{\theta}{2}, \quad \tau_{yz} = \frac{K_3}{\sqrt{2\pi r}} \cdot \cos \frac{\theta}{2}, \\ \sigma_x = \sigma_y = \sigma_z = 0, \tau_{xy} &= 0. \end{aligned} \right\} \quad (3)$$

In the (1), (2) and (3) expressions K_1, K_2 and K_3 are intensity coefficients for the above mentioned deformations, respectively and have specific role in force or energy estimation, θ is the angle formed by the radius vector of the considered point with XOZ plane, r is the radius of the assumptive plastic zone in the front part of the cutting/crack. In the problem solution of stem blade cutting, the geometric linearization of the boundary conditions and linear theory of elasticity entail to stresses and infinite values/quantities of their gradients; then the concentration coefficient becomes meaningless.

The only way of problem solution is the disclosure of the strain state nature and intensity in the cutting zone, where the mechanism of material abrasion is concentrated. In this case, the only characteristics of stress distribution is the stress intensity coefficient – K, which is not dependent on the coordinates of the points arranged in the cutting zone. Unlike concentration coefficient, the stress intensity coefficient is endowed with measurability $\left(N \cdot m^{\frac{3}{2}} \right)$.

Results and discussions

Based on the aforementioned interpretations and the circumstance that the intensity coefficient for each individual case is determined differently, the problem related to its determination is still unsolved and actual.

A great number of problems for the determination of intensity coefficient with analytic methods are tackled, the detailed description and analysis of which are presented in the voluminous research work issued under the general editorship of G. Liebowitz (Liebowitz, 1975). Anyhow, it should be mentioned that those problems are solved mainly for infinite domains, while in conditions of finite values they produce insufficient results. The details about the described statements are introduced in the research work of A.V. Malik (Malik and Lavit, 2018).

Related to the issue under discussion, when it refers to the cutting extension in the plant material (stem), determination of intensity coefficient becomes a specific problem. This problem was previously addressed as well (Tarverdyan, 1996) and it was stated that among the expressions developed for the determination of intensity coefficient when solving stem cutting issue, the expression developed with the method recommended by D. Broek is the most preferable one, which considers the body finite sizes (Broek, 1974):

$$K = Y\sigma\sqrt{\pi l},$$

where Y is the polynomial considering the finite sizes of the cut body/material, σ is the regular stress in the front zone of cutting and l is the cutting depth.

The problem solving accuracy is mainly related to the accurate selection of Y polynomial and correct calculation of the coefficients. In our problem, the numerical coefficients of the polynomial have been determined empirically with the support of analytic expressions developed by Srawley-Gross (Srawley, et al., 1964) and Walsh’s methodology for finite cracks study (Walsh, 1971).

In the result of investigations polynomial’s expressions have been derived, which enable to determine the intensity coefficient of the knife blade cutting for both thin-stemmed and rigid thick-stemmed plants. Besides, these expressions provide opportunity to consider not only the changes in the cutting line length (stems’ latitudinal cross-section is a circle), but also, which is most important, to establish relationship between the cutting speed and intensity coefficient. By means of tensile deformation of the samples produced from the stems with preliminarily simulated cuttings at different depths, the numerical values of polynomial’s (Y) coefficients were determined

(Tarverdyan, 2004). Particularly, the expression of intensity coefficient for the wheat stem looks as follows:

$$K_1 = \sigma\sqrt{V_c \cdot t} \left[\begin{matrix} 1.77 - 0.36 \frac{V_c \cdot t}{d} + 16.70 \left(\frac{V_c \cdot t}{d} \right)^2 - \\ - 34.34 \left(\frac{V_c \cdot t}{d} \right)^3 + 48.08 \left(\frac{V_c \cdot t}{d} \right)^4 \end{matrix} \right], \quad (4)$$

where V_c is the cutting speed, t is the current cutting time ($0 \leq t \leq t_c$), d is the diameter of the stem latitudinal cross-section.

From the K_i expressions a significant conclusion is inferred, that is, the intensity coefficient is a variable value depending on time and cutting depth.

In case of sliding cutting the mentioned three modes of deformations take place simultaneously, and although under such circumstances the identification of the principal stresses and extreme friction stresses becomes complicated, after some allowable assumptions, the problem solution turns out to be simple.

Taking into account that in case of sliding cutting σ_y and τ_{yz} have anyhow decisive roles and their maximum values are simultaneously fixed in case of $\theta=0$ and also the fact that in case of abrasive deformation the radius of plastic zone is determined through the following expression (Broek, 1974):

$$r = \frac{\sigma^2}{2\pi\sigma_{yr}^2},$$

after some modifications, from the expressions of (1), (2) and (3), we’ll get:

$$\begin{aligned} \sigma_x &= \sigma_y = Y\sqrt{\sigma_{yr}^2 + 0.5\sigma^2}; \\ \tau_{xy} &= \frac{\tau_x}{\sigma}\sqrt{\sigma_{yr}^2 + 0.5\sigma^2}; \\ \tau_{zy} &= \frac{\tau_z}{\sigma}\sqrt{\sigma_{yr}^2 + 0.5\sigma^2}, \end{aligned} \quad (5)$$

where $Y = \frac{K}{\sigma\sqrt{\pi l}}$, σ , τ_x , τ_z are the external force factors in the interaction zone of knife blade and fracture of the cutting material (σ is the stress towards y axis, τ_x and τ_y are the friction stresses towards the directions of x and y respectively), σ_{yT} is the flow point/limit of the material.

In the result of determining the basic stresses $\sigma^3 + a\sigma^2 + b\sigma + C = 0$ or solution of $R^3 + pR + q = 0$ equation through trigonometric method, the following expression has been derived for the principal stresses:

$$\sigma_i = \frac{\sigma_x + \sigma_y}{3} \pm 2R \cos \left[\psi + \frac{2\pi(i-1)}{3} \right], \quad (6)$$

where $i=1,2,3$, $R = (\text{Sign}q) \sqrt{\frac{|P|}{3}}$, $\cos 3\psi = \frac{q}{2R^3}$,

$$P = \frac{Y^2}{3} (\sigma_{yr}^2 + 0.5\sigma^2) \cdot \left[1 + \frac{3}{\sigma^2} (\tau_x^2 + \tau_y^2) \right],$$

$$q = \frac{Y^3}{3} (\sigma_{yr}^2 + 0.5\sigma^2)^{\frac{3}{2}} \cdot \left(\frac{2}{9} + \frac{\tau_z^2 + \tau_x^2}{\sigma^2} \right),$$

hence: $R = \frac{Y}{3} \sqrt{(\sigma_{yr}^2 + 0.5\sigma^2) \cdot \left[1 + \frac{3}{\sigma^2} (\tau_x^2 + \tau_z^2) \right]}$;

$$\cos 3\psi = \frac{1 + \frac{4.5(\tau_x^2 + \tau_z^2)}{\sigma^2}}{\sqrt{\left[1 + \frac{3(\tau_x^2 + \tau_z^2)}{\sigma^2} \right]^3}}, \quad (7)$$

where ψ is the angle formed by the main planes of the stress state with XOZ plane.

In the blade facet, the stress state of the material is also dimensional. The peculiarity of the mentioned zone consists in that the normal (σ) and friction (τ_x) force factors are related via the following expression:

$$\frac{\tau_x}{\sigma} = \frac{tg\varphi_T}{\cos\beta}, \quad (8)$$

where φ_T is the angle of the cut material and the blade surface friction, β is the blade acute angle.

In this case the expression of $\cos\psi$ determination will have the following interpretation:

$$\cos 3\psi = \frac{1 + \frac{4.5tg^2\varphi_T(1 + \varepsilon_c^2)}{\sigma^2}}{\sqrt{\left[1 + \frac{3tg^2\varphi_T(1 + \varepsilon_c^2)}{\cos^2\beta} \right]^3}}. \quad (9)$$

In both platforms of the blade body (spine) the stress states are identical, while the relation of the friction stress (τ_x) and regular stress (σ) is manifested through the following expression:

$$\tau_x = \sigma \cdot tg\varphi_T. \quad (10)$$

The expression for determination is as follows:

$$\cos 3\psi = \frac{1 + 4.5tg^2\varphi_T(1 + \varepsilon_c^2)}{\sqrt{\left[1 + 3tg^2\varphi_T(1 + \varepsilon_c^2) \right]^3}}. \quad (11)$$

By inserting the values of obtained units in (6) we'll get the expressions of the principal stresses in the zones of blade edge, facet and body/spine.

$$\sigma_{1(i)} = m \left[1 + \sqrt{1 + \frac{3\tau_z^2}{\sigma^2} (1 + \varepsilon_c^2)} \cdot n \right], \quad (12)$$

$$\sigma_{1(ii)} = m \left[1 + \sqrt{1 + \frac{3tg^2\varphi_T}{\cos^2\beta} (1 + \varepsilon_c^2)} \cdot n \right], \quad (13)$$

$$\sigma_{1(iii)} = \sigma_{1(iv)} = m \left[1 + \sqrt{1 + 3tg^2\varphi_T (1 + \varepsilon_c^2)} \cdot n \right], \quad (14)$$

where $m = \frac{2Y}{3} \cdot \sqrt{\sigma_{yr}^2 + 0.5\sigma^2}$, $n = \cos \left(\psi + \frac{2\pi(i-1)}{3} \right)$.

From (12), (13) and (14) expressions of the principal stresses it can be inferred, that the changes of their values are related to the sliding coefficient (ε_c) and intensity coefficient (K), $Y=f(t)$ through the polynomial's correction function.

It should be taken into account that if there is an objective to determine the stress loads during the cutting process, then only the current (instantaneous) values of the stresses can be considered, since they are functions from the cutting depths ($V_c \cdot t$). That parameter constitutes the expression of correction function [$Y=f(t)$], and hence, that of stress intensity coefficient. That is, when determining the stresses during the cutting process, the specified time moment should be definitely mentioned ($t=t_i$).

We find it relevant to introduce a number of numerical values for principal stresses estimated through this method to compare them with the results obtained via other theoretical and empirical ways.

The computations have been conducted based on the following baseline data: The stem of wheat variety Bezostaya-1 served as the material to be cut, which was at ripening stage with the diameter $d=4x10^{-3} m$, cutting speed was $V_c=20 m/s$, the friction coefficient of the stem substance and blade surface was $tg\varphi_T=0.31$, the acute angle of blade facet – $\beta=18^\circ$, the tensile strength of stem substance – $\sigma_n=320 MPa$, flow limit/fluidity – $\sigma_{yT}=270 MPa$, $\tau_z=180 MPa$.

In case of the abovementioned parameters the stem cutting time is $t_c=2 \cdot 10^{-4}$ second, in the considered example let's assume $t=1 \cdot 10^{-4} s$ (in the middle of the cutting process). The most important factor of sliding cutting is $\varepsilon_c=8$ (the experiments have shown that the sliding cutting is most efficient in the domain of $6 \leq \varepsilon_c \leq 10$) (Tarverdyan, 1996, Tarverdyan, 2004).

In case of the mentioned numerical values the critical values of the stresses intensity coefficients make

$K_{cr} = 6.33 \cdot 10^6 N \cdot m^{\frac{3}{2}}$, while the numerical value of the correction function's polynomial will be:

$$Y = \frac{K_{cr}}{\sigma_{cr} \sqrt{\pi \cdot V_c \cdot t}} = \frac{6.33 \cdot 10^6}{320 \cdot 10^6 \cdot \sqrt{3.14 \cdot 20 \cdot 1 \cdot 10^{-4}}} = 0.25.$$

In case of the aforementioned baseline data, for the maximum values of three principal stresses, the following values have been derived:

$$\sigma_{1(I)} = 430.5 MPa, \quad \sigma_{1(II)} = 315 MPa, \quad \sigma_{1(III)} = \sigma_{1(IV)} = 275 MPa.$$

Since the values of principal stresses (σ_i) are mainly related to the critical values of intensity coefficient (K_{cr}) and to sliding coefficient (ε_c), it is required to disclose their impact nature on the former factor. For the critical value of the intensity coefficient we have received the following expression:

$$K_{cr} = \sigma_{cr} \sqrt{\pi \cdot V_c \cdot t \cdot (V_c, t, d)},$$

where σ_{cr} is the regular stress, which opens the cutting, V_c is the cutting speed, $V_c \cdot t$ is the cutting depth, d is the thickness of the cut material (stem diameter).

In the result of the trials on pulling samples from the stems with complete and preliminarily implemented cuttings at different depths (Tarverdyan, 1996), it became possible to establish relation between the values of $\frac{V_c \cdot t}{d}$, and σ_{cr} , and hence, between the K_{cr} as well. It turned out that along with cutting depth increase the σ_{cr} declines and consequently also K_{cr} , e.g., if in case of $\frac{V_c \cdot t}{d} = 0.1$ $K_{cr} = 11.1 \cdot 10^6 N \cdot m^{\frac{3}{2}}$

then in case of $\frac{V_c \cdot t}{d} = 0.8$ $K_{cr} = 3.5 \cdot 10^6 N \cdot m^{\frac{3}{2}}$.

As regard to the sliding coefficient (ε_c), it comes forth not only as an important but also a critical factor affecting the values of principal stresses. Upon the experiments it has been proved that in the domain of $0 \leq \varepsilon_c \leq 4.0$ the basic stresses do not exceed the material strength limit and the cutting is implemented in relatively higher values of cutting force. In case of $\varepsilon_c = 0$ the cutting is directly frontal (cross-sectional), and it is known that this is the least efficient way among the stem cutting methods. In the domain of $4.0 \leq \varepsilon_c \leq 16$ the principal stress, parallel to the increase of ε_c , grows up (in 2÷3 times); though the further increase of ε_c results in the growth of basic stress, it takes place gradually with decreasing intensity. Though in case of the values of $\varepsilon_c > 16.0$ cutting is implemented with relatively

lower force, under such conditions cutting is inefficient, since the blade motion, and hence, the cutting growth towards the regular direction gradually decreases which ultimately leads to the increase of energy consumption during the cutting process.

Conclusion

In the result of stress states analysis conducted for the discussed cutting zones, theoretical expressions have been derived, which enable to identify the principal stresses in the blade cutting edge, facet and body platform zones; besides, a relationship has been established between those stresses, intensity coefficient and the main descriptor of the sliding cutting, i.e., sliding coefficient.

It has been proved that the most significant index of the forced propagation of the crack/cutting (K) – the stress intensity coefficient – which determines the values of the basic stresses, is reduced along with cutting depth increase $\frac{V_c \cdot t}{d}$ and its maximum value complies with the start of sticking process of blade cutting edge into the body being cut. This is why the basic stress gets its maximum value at the start of cutting process, which considerably exceeds the limit strength of the cut body. Parallel with the cutting depth increase the basic stresses gradually decline.

In case of sliding cutting, the basic stresses are greatly affected by sliding coefficient (ε_c) and together with its growth the principal stress increases as well. Theoretically it has been stated that in the domain of $4.0 \leq \varepsilon_c \leq 14.0$ the growth of the basic stresses is intensive. The results of experiments have proved, that the optimal values of sliding coefficient are in the domain of $6.0 \leq \varepsilon_c \leq 10.0$; in such conditions the required cutting force is 2.0 times lower than in case of regular frontal cutting. If $\varepsilon_c > 10$, then, though the cutting force decreases, the cutting becomes inefficient due to the restriction of blade motion towards the regular direction.

References

1. Altunyan, A. V. (2008). To the Theory of Cutting by an Edge of Plants Stalks // Annals of Agrarian Science, - vol. 6. № 4, - pp. 46-48 (in Russian).
2. Broek, D. (1974). Elementary Engineering Fracture Mechanics. Noordhoff International Publishing, Leyden.
3. Dowgiallo, A. (2005). Cutting Force of Fibrous Materials // Journal of Food Engineering, 66(1), - pp. 57-61: <https://doi.org/10.1016/j.jfoodeng.2004.02.034>.

4. Goryachkin, V.P. (1965). Collected Works in Three Volumes, Moscow, "Kolos" (in Russian).
5. Irwin, G.R. (1957). Analysis of Stresses and Strains near the End of a Crack Traversing a Plate. *Appl. Mech.*, V. 24, № 3, - pp. 361-364. <https://doi.org/10.1115/1.4011547>.
6. Klaus Dobler (1972). *Der freie Schnitt beim Mähen von Halmgut, Höhenheimer Arbeiten*. Stuttgart, № 62.
7. Liebowitz, H. (1975). *Fracture, Volume II. Mathematical Fundamentals*, School of Engineering and Applied Science, George Washington University, Washington, D.C. Academic Press. New York and London.
8. Malik, A.V., Lavit, I.M. (2018). On the Computation Method for the Stress Intensity Factor of a Stationary Crack in Mode I under Dynamic Loading, *Bulletin of Tomsk State University. Mathematical Mechanization*, Vol. 54, - pp. 88–102 (in Russian). <https://doi.org/10.17223/19988621/54/8>.
9. O'dogherty, M.J., & Cale, G.E. (1986). Laboratory Studies of the Cutting of Grass Stems // *Journal of Agricultural Engineering Research*, 35(2), - pp. 115-129: [https://doi.org/10.1016/0021-8634\(86\)90033-8](https://doi.org/10.1016/0021-8634(86)90033-8).
10. Osobov, V.I., Noreiko, V.G., (1984). Pressing Coarse Feeds. *Agricultural Mechanization and Electrification*. 10, - pp. 50-51 (in Russian).
11. Reznik, N.E. (1975). Theory of Cutting with a Blade and Basic Calculations of Cutting Devices. Moscow, "Machinery Construction" (in Russian).
12. Sneddon, I.N., Berry, D.S. (1961). *Classical Theory of Elasticity*. Moscow, "Handbuch der Physik" (translated into Russian).
13. Srawley, J.E., Jones, M.H., & Gross, B. (1964). Experimental Determination of the Dependence of Crack Extension Force on Crack Length for a Single-Edge-Notch Tension Specimen, NASA TN D-2396.
14. Tarverdyan, A.P. (1996). *Technical and Technological Bases for the Creation of Cutting Devices for Harvesters and Mowers*. Ph.D, Yerevan (in Russian).
15. Tarverdyan, A.P. (2004). *Essential Principles for Development of Rotary Cutting Devices*. Verlag Grauer, Beuren, Stuttgart.
16. Tarverdyan, A.P. (2014). *Application of the Vibration Theory in Agricultural Mechanics*. Yerevan, "Gitutyun" (in Russian).
17. Walsh, P.F. (1971). The Computation of Stress Intensity Factors by a Special Finite Element Technique, *Intern. J. Solids and Structures*, Vol. 7, Issue 10, - pp. 1333-1342: <https://doi.org/10.17223/19988621/54/8>.
18. Zheligovsky, V.A. (1941). *Experimental Theory of Blade Cutting*. Proceedings of Moscow Institute of Agricultural Mechanization and Electrification (MIAME), Issue IX, Moscow (in Russian).

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Economic Efficiency of Drip Irrigation System in Case of High-Value Crop Cultivation

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ABSTRACT

In current conditions of significant reduction in underground water basin reserves in Ararat Valley, there is a need to introduce effective irrigation technologies and provide their economic justification.

In this research paper it has been shown, that in case of surface irrigation of high-value crops in Ararat Valley and its low-lying (irrigated) zone, 457.8 mln m³ water, and in case of drip irrigation – 171.7 mln m³ water is required. The total costs of introducing drip irrigation system in these fields ranges from AMD 742609-1995000, with a payback period of 1 to 1.5 years.

Introduction

Local supply of irrigation water to a plant root zone is the basic point of drip irrigation in terms of peculiarities of its biological development phases and soil-climatic conditions. The first research works on drip irrigation in open fields were conducted in Israel in the 1950s, as a result of which this technology was intensively introduced in the country's agricultural sector (Magersa and Abdulahi, 2015). Currently, drip irrigation systems have been introduced in many economically developed countries of the world, which has been a great impetus for the development of irrigated agriculture and efficient use of water resources (Velasco-Munoz, et al., 2019, Kooij, et al., 2013). Studies have shown that in case of drip irrigation, the water norm can be reduced in 2 times compared to the traditional irrigation method, and

if the best conditions are provided, the payback period for drip irrigation system expenses would be one year. With the introduction of this system, there is no problems with crop water stress and soil overmoistening. Optimal soil moisture level promotes crops balanced growth and development, which leads to an increase in yield and crop quality. In case of drip irrigation, small volume of water allows to provide soil moisture indices in a root system of a crop, under which it is possible to obtain the maximum yield with minimum water consumption.

The first attempts to introduce a drip irrigation system in Armenia were made by E. Akopov (Akopov, et al., 1985), and later these works were continued by G. Yeghiazaryan and V. Kobelyan (Yeghiazaryan and Kobelyan, 2011, Kobelyan, 2011).

Over the past few years, due to the improvident consumption of water resources in the underground water basin of Ararat Valley, there is a severe shortage of irrigation water in the Republic of Armenia. It has a negative impact on sustainable irrigation water supply and socioeconomic conditions of the population. Relevant measures are implemented by the government to solve the problem, such as construction of new reservoirs, recharge of groundwater resources, but these processes require significant financial resources and take considerable time to implement.

The problem can be solved by introducing drip irrigation system in lands, that are used for the cultivation of high-value crops. However, the introduction of this system requires economic justification for different crops, which will allow farmers to estimate credit risks accurately. The aim of this paper is to make comparative analysis of surface and drip irrigation methods, as well as to justify economic efficiency of drip irrigation system introduction.

Materials and methods

Within the framework of the research, water-economic indicators in Ararat valley and its low-lying (irrigated) zones have been studied, the costs of drip irrigation system introduction in the field of high-value crops, the irrigation norm for 1 ha area, cost of irrigation water, as well as payback periods and net present values have been calculated.

Systematic, comparative, case study analytic, calculation and statistical tabular methods have been used within the studies. Researches have been implemented on the basis of our studies and statistical data published in the reports of the RA National Statistical Committee.

Results and discussions

In order to reveal the efficiency of different irrigation types in Ararat valley and its low-lying zone, water-economic indicators have been studied, which are summarized in Table 1.

Table 1. Irrigation norms for high-value crops in Ararat valley and its low-lying (irrigated) zone and required water volumes in case of surface irrigation*

Marz (Province)	Crop	Land used for cultivation	Irrigation norm	Required water volume
		Ha	m ³ /ha	mln m ³
Ararat Marz	Fruit-	5821	5120	29.8
	Grape	4536	7500	34.0
	Cucurbits -	6091	8450	51.5
	Potato	508	3290	1.7
Armavir Marz	Fruit -	7963	5120	40.8
	Grape	6444	7500	48.3
	Cucurbits -	11465	8450	96.9
	Potato	1182	3290	3.9
Aragatsotn Marz, Ashtarak province	Fruit -	1116	4960	5.5
	Grape	650	6280	4.1
	Cucurbits -	206	6720	1.4
	Potato	134	3450	0.5
Kotayk Marz, Nairi province	Fruit -	1546	4960	7.7
	Grape	24	6280	0.2
	Cucurbits -	118	6720	0.8
	Potato	17	3450	0.1
Total		47821		327.0
Total (Taking into account 40 % water loss)				457.8

* 1. "Sown areas of agricultural crops, planting area of permanent crops, gross harvest and average crop capacity for 2019" Statistical report, Statistical committee, B. Terteryan and others, 2007.

The lands, that are used for the cultivation of high-value crops in the mentioned region take up 47821 hectares, for the irrigation of which 327.0 mln m³ of water is required. Taking into account 40 % water losses in the system, 457.8 mln m³ of irrigation water is required in case of surface irrigation method. In case of drip irrigation method 163.5 mln m³ of water is required (the norm of irrigation water is reduced by 50 %). Considering the 5 % water losses in the system, the water demand makes 171.7 mln m³ (Table 2).

Table 2. Required volume of irrigation water for high-value crop cultivation in Ararat Valley and its low-lying (irrigated) zone in case of different irrigation methods

Irrigation method	Required water volume, mln m ³	Average irrigation norm, m ³ /ha	Cost of irrigation water per ha, AMD
Surface irrigation	457.8	9573	105303
Drip irrigation	171.7	3590	39490

*Composed by the author.

Table 3. Approximate calculation of costs required for drip irrigation system installation in 1hectare apple orchard (4x2.5 m)

The name of installation item	Measurement unit	Quantity	Cost (AMD)	Amount AMD)
1. Distribution Network				
Main polyethylene /PE/ pipeline, d=63 mm	m	100	700	70000
PE connection, d=16 mm	ps	25	200	5000
Irrigation PE pipeline, d=16 mm	m	2500	150	375000
Irrigation ring PE pipeline dripper	m	3000	120	360000
Hose tee PE d=16mm	ps	1000	150	150000
Double stopper	ps	1000	30	30000
Clamping stakes	ps	4000	50	200000
Final stopper d=16 mm	ps	25	100	2500
Total - 1				1192500
2. Head Unit				
Pump unit	ps	1	42000	42000
Fertilizer system	collection	1	50000	50000
Filtration system	ps	1	85000	85000
Valve	ps	1	10000	10000
Plunger	ps	1	12000	12000
Manometer	ps	2	12000	12000
Shaped parts	collection	1	16500	16500
Separation PE pipeline	m	10	1100	11000
Total - 2				238500
3. Design and installation works				
Locality research	ha	1	12000	12000
Design	ha	1	35000	35000
Earthworks	ha	1	100000	100000
Installation	ha	1	210750	210750
Total - 3				357750
Unforeseen expenses		5 %		89438
Total				1878188

*Composed by the author.

Irrigation water requirements for 1 ha and the costs according to the tariff of 11 dr/m³ have been calculated. In case of mechanical irrigation it is 9573 m³/ha, and water cost is 105303 AMD/ha, in case of drip irrigation, respectively, 3590 m³/ha and 39490 AMD/ha.

Thus, upon the introduction of a drip irrigation system, the required water volume and the cost of irrigation water per hectare is reduced by 2.67 times.

Table 3 presents the calculation of costs based on the example of 1 hectare apple orchard to identify the amount of materials, equipment, design and installation operations required for the introduction of drip irrigation system and the amount of financial investment.

Discussing the data in the table 3, it can be stated that AMD

1878188 is required for the introduction of drip system for 1 hectare apple orchard. The total cost includes the distribution network, construction of which requires AMD 1192500 or 63.5 % of the total costs, AMD 238500 for the head unit or 12.7 % of the total costs, AMD 57750 for design and installation works or 18.8 % of the total costs.

To justify the economic efficiency of drip irrigation, the costs of installation of drip irrigation system for 1 ha high-value crop field is given in Table 4.

The fluctuation of distribution network costs (from AMD 455900 to AMD 1192500) is conditioned by sowing density of crops. Higher costs are required for apple and onion fields (AMD 1192500 and AMD 1425000), where sowing density is significantly higher (4x2.5 and 0.4x0.1 m).

Table 4. Calculation of costs of drip irrigation system introduction for 1 hectare orchard in Ararat Valley and its low-lying (irrigated) zone*

Crops	Planting scheme, mxm	Quantity in 1 ha, pcs	Expenditures, thousand AMD			
			Distribution network	Head unit	Design and installation	Total
Fruits						
Apricot	8x8	170	455.900	227.55	319.13	1002.58
Cherry	6x6	290	614.300	245.720	337.865	1197.885
Peach	5x5	400	720.000	252.000	426.600	1398.600
Apple	4x2.5	1000	1192.500	238.500	357.750	1788.750
Nut	6x5	333	529.637	254.000	292.000	1075.637
Grape	3x1.5	2267	587.820	235.128	352.692	1175.640
Melons and Vegetables						
Watermelon	3x0.75	4400	207.609	239.000	296.000	742.609
Cucumber	1 x 0.5	13400	364.196	263.000	354.000	981.196
Tomato	0.8 x0.8	15625	775.000	193.750	348.750	1317.500
Onion	0.4 x 0.1	250000	1425.000	213.750	356.250	1995.000
Patato	0.8 x 0.2	6250	775.000	193.750	348.750	1317.500
Berries						
Strawberry	1x 0.3	33333	357.000	266.000	354.000	977.000

Table 5. Costs of introduction of drip irrigation system, cultivation of high-value crops, the income and payback period for 1 hectare orchard in Ararat Valley and its low-lying (irrigated) zone*

Crops	Drip irrigation system cost, AMD	Cultivation costs, AMD	Gross income, AMD	Net income, AMD	Payback period Year
Fruits					
Apricot	1002580	852000	1875000	1023000	1.0
Cherry	1197885	1222380	2375000	1152620	1.0
Peach	1398600	954 000	3000000	2046000	0.7
Apple	1788750	1346000	2434000	1088000	1.6
Nut	1075637	1154660	2500000	1345340	0.8
Grape	1175640	1573000	3300000	1727000	0.7
Melons and Vegetables					
Watermelon	742609	952000	3400000	2448000	0.3
Cucumber	981196	1235000	2757000	1522000	0.6
Tomato	1317500	1597000	4675000	3078000	0.4
Onion	1995000	1575000	3086400	1511400	1.3
Patato	1317500	1799 000	3173000	1374000	1.0
Berries					
Strawberry	977000	1273000	10000000	8727000	0.1

*Composed by the author.

Thus, the total cost of drip irrigation system for one hectare land used for cultivation of high value crops fluctuates between AMD 742609-1995000. Lower costs are required for watermelon cultivation and higher for onion cultivation, which is also due to the sowing density of the crop.

Table 5 shows the costs required for the cultivation of these crops, gross output and revenue, as well as the payback period for the introduction of a drip irrigation system.

It is important to note, that in case of cultivation of perennial plants, the income fluctuates in the range of AMD 1-2 mln, in case of melons and vegetables – in the range of AMD 1.374 and 3.078 mln. Cultivation of grapes and peaches is more distinguished in terms of profitability, the incomes of which, respectively, make about AMD 1.73 and 2.05 mln.

The highest income is provided via cultivation of tomatoes, and in cultivation of potatoes it is significantly lower – AMD 1.37 mln. Strawberry cultivation stands out with its high profitability, the income of which makes AMD 8.73 mln.

The payback period (PP) for the installation of a drip irrigation system has been calculated, which ranges from 1 to 1.5 years.

Thus, in case of high-value crop cultivation, expenditures

of drip irrigation system introduction are reimbursed averagely within up to one year.

In order to justify the economic efficiency of the system introduction, the net present values (NPV) of the investments have been calculated using the following well-known formula (Table 6):

$$NPV = \sum_{i=1}^0 \frac{CF_t}{(1+r)^t} - CF_0, \quad (1)$$

where: CF_t is a cash flow during a single period, r is a discount rate or return that could be earned in alternative investments, t is a number of time periods, CF_0 is an initial investment.

The data presented in Table 6 confirm, that in case of one year period the NPV is negative for crops with a payback period of 1 year or more. In case of two year period, the NPV is positive for all crops, because the investment costs are lump sum. Thus, the lowest index is for the apple orchard, the highest - for strawberries. The regularity is the same as for PP.

Conclusion

- The lands used for cultivation of high-value crops in Ararat Valley and its low-lying (irrigated) zone take up 47821 hectares, for the irrigation of which 586.9 mln m³ water in case of surface irrigation, and 244.4 mln m³ water in case of drip irrigation is required. Irrigation water average requirement is 10090 m³ in case of mechanical irrigation, and the cost of water is AMD 110990. It has been proved that in case of introduction of drip irrigation system these indicators make, respectively, 4202 m³ and AMD 46222.

- It has been shown, that the total cost of drip irrigation system introduction for one hectare land, that is used for apple cultivation, makes about AMD 1878000, 63.5 % of which is needed for construction of distribution network, 12.7 % for head unit, and 18.8 % for design and installation.

- The total costs of introduction of drip irrigation system in lands, that are used for cultivation of high-value crops fluctuates in the range of AMD 742609-1995000, the payback period of which constitutes 1-1.5 years.

References

1. Akopov, E.S., Uzinyan, V.A., Arzoyan, K.E. (1985). Drip Irrigation and its Introduction in the Armenian SSR, Hayastan, Yerevan, - 58 p. (in Russian).

Table 6. NPV of the investment for 1 hectare orchard in Ararat Valley and its low-lying (irrigated) zone*

Crops	NPV, AMD /during 1 year period/	NPV, AMD /during 2 year period/
Fruits		
Apricot	-72580	772875
Cherry	-150049	802529
Peach	461400	2152309
Apple	-799659	99514
Nut	147399	1259251
Grape	394360	1821633
Melons and Vegetables		
Watermelon	1482846	4991204
Cucumber	402440	1660292
Tomato	1480682	4024483
Onion	-621000	628091
Patato	-68409	1067128
Berries		
Strawberry	6956636	14169033

*Composed by the author.

2. Kobelyan, V.U. (2011). Drip Irrigation Problems and Implementation in Conditions of RA. PhD Thesis, Yerevan, - 176 p. (in Armenian).
3. Megersa, G., Abdulahi J. (2015). Irrigation System in Israel: A Review, International Journal of Water Resources and Environmental Engineering, - Vol. 7(3), - pp. 29-37, <https://doi.org/10.5897/IJWREE2014.0556>.
4. Statistical Committee of the Republic of Armenia, 2019. Sown Areas of Agricultural Crops, Planting Area of Permanent Crops, Gross Harvest and Average Crop Capacity for 2019, - Yerevan, - 76 p. (in Armenian).
5. Terteryan, B., Petrosyan, N., Grigoryan R. (2007). Irrigation Norms and Regimes of Agricultural Crops for Irrigated Lands of the Republic of Armenia. NUACA Bulletin, Yerevan, - 286 p. (in Armenian).
6. Van der Kooij Saskia, Zwarteveen Margreet, Boesveld Harm, Kuper Marcel (2013). The Efficiency of Drip Irrigation Unpacked, Agricultural Water Management, Volume 123, - pp. 103-110, <https://doi.org/10.1016/j.agwat.2013.03.014>.
7. Velasco-Muñoz, J.F., Aznar-Sánchez, J.A., BattlesdelaFuente, A., Fidelibus, M.D. (2019). Sustainable Irrigation in Agriculture: An Analysis of Global Research. Water, 11, 1758. <https://doi.org/10.3390/w11091758>.
8. Yeghiazaryan, G. M., Kobelyan, V. U. (2011). Patterns of Soil Moisture Distribution in the Root System of Grapes under Drip Irrigation. Agriscience - Yerevan, - № 1-2, - pp. 93-96 (in Armenian).

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Towards Circular Economy: Conceptualization and Common Practices in the Food Industry

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ABSTRACT

Circular Economy (CE) is a newly emerged concept in the food industry and it proposes a system, where resources are allocated in an efficient way ensuring sustainable economic growth and environmental protection. To reduce the waste and energy use in the food industry, proper policies and strategies should be enacted through close cooperation between the government and the business sector.

This article studies the CE concept through an integrated literature review. Specifically, the current conceptualizations by scholars and international organizations are presented, followed by a set of recommended practices from the perspective of waste management, resource and energy use.

Introduction

Exponential growth of the global population, food shortage and environmental degradation are the major issues the world faces nowadays. To tackle these challenges more complex policies and management practices should be undertaken especially in the agri-food business environment to ensure food security while relaxing the environmental pressure on scarce resources.

Armenia, as a developing country, is more vulnerable to the environmental degradation and climate change, which can have a significant impact on agriculture (Ludwig, et. al, 2007). Thus, adaptation is urgently needed to maintain the economic growth in the country. In this sector, the majority

of the companies have the linear production models, which may not ensure competitiveness and efficient resource allocation for the firms, hence the transition to circular and innovation-run business models is crucial for improved productivity with limited resource depletion.

During the recent decade, some local and international organizations have attained rightful recognition on the perks of sustainability and prioritized funding in developing countries. In this context Armenia also took corresponding actions towards a smooth transition and even adoption of circular principles.

Albeit this emerging trend, the number of sustainable firms is not sufficient yet. Currently, structural changes need to

be implemented at a larger scale, so that the firms survive in an extremely competitive environment. This action will help the firms to meet the rising demand for goods and services.

It is noteworthy that the Government of RA has also increased its funding for the environmental protection to mitigate the environmental degradation, which can be noted in Figure 1 (ArmStat, 2022). On the other hand, it is noteworthy that the amount of the produced waste is increasing as well without being treated and reused properly by the organizations (Figure 2).

Back in 2000, the expenditure intended for the environmental protection was only 904 million drams, while in 2020 the same figure was 11 times higher than in 2000.

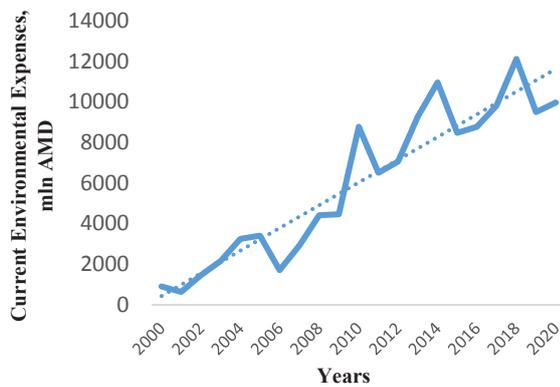


Figure 1. Current expenses for environmental protection and fixed assets by indicators and years (composed by the author).

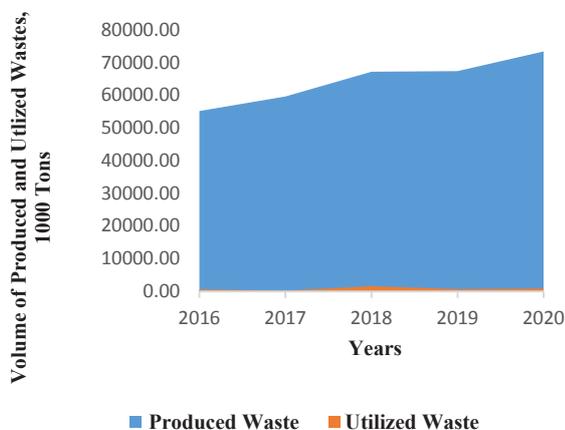


Figure 2. Produced and Utilized Waste by Organizations (composed by the author).

Although there is a lacking data on the waste amount and committed funding for the waste treatment in the agrifood sector, however, the Government of RA has emphasized the role of the environmental sustainability in the policies and state-funded programs. Ensuring sustainability in implementation of new technologies towards innovation is crucial from the perspective of efficient resource allocation, food security, and profit maximization as a major operational value (FoodDrinkEurope, 2020). In addition, addressing the issues of transmission towards circular business models can be leveraged to achieve a few of the Sustainable Development Goals and their respective targets, such as SDGs 2, 3, 8, 9,12.

However, there are a number of barriers for implementing sustainable practices including the principles of CE in Armenia. Particularly, there is a lack of information on circular practices and an enterprise-level analysis in the literature (Gedam, et al., 2021). Some international organizations have promoted the implementation of CE practices through pilot programs, however, transmission at a larger scale is still missing. This study can significantly contribute to the scientific dissemination of this topic and could be applied by the private and public sectors.

The objective of this study is to explore the widely used definitions of circular economy, identify the expected key impact, as well as explore the key circular practices that can be applied by the firms in the agri-food sector within the bigger context of green economy and environmental sustainability. These practices are mainly suggested in the scientific literature by prominent scholars or in the reports prepared by international organizations.

Materials and methods

The literature review plays a key role in this research study in order to extract the most widely used definitions of the circular economy by examining articles and documents published in local and international prominent scientific journals. The reports of the international non-governmental organizations were also included in the literature review. The following key words have been applied to find journal articles and other publications with this topic: “circular economy” and “business models”, “circular economy” and “environmental impact”, “circular economy” and “agri-food”. As a result of the study, 5 different definitions of “circular” economy were filtered, and the key words of each were given by the author aligned with the pillar of its major impact.

Due to the rapid development of the concept of circular economy, the chronological order of the papers was also taken into consideration. The reviewed articles are mainly published within the past 20 years.

Table. Some definitions for circular economy*

Definition	Key impact	Reference
<p>“A circular economy decouples economic activity from the consumption of finite resources. It is a resilient system that is good for business, people and the environment”</p> <p>The overall aim of the circular economy is “enable effective flows of materials, energy, labor and information so that natural and social capital can be rebuilt”</p>	<ul style="list-style-type: none"> • Resilient system • Regenerative social and natural capital • Effective materials flow 	Ellen Macarthur Foundation (EMF, 2022)
<p>“The circular economy helps to decouple economic growth from resource use, protecting Europe’s natural resources while boosting sustainable growth. It will help the European Union to strive to reduce its consumption footprint and double its circular material use rate in the coming decade”</p>	<ul style="list-style-type: none"> • Sustainable economic growth • Protected natural resource capital • Reduced consumption 	European Commission www.ec.europa.eu (EU, 2020)
<p>“A circular economy provides opportunities to create well-being, growth and jobs while reducing environmental pressures. The concept can, in principle, be applied to all kinds of natural resources including water and land.”</p>	<ul style="list-style-type: none"> • Reduced environmental pressure • Well-being • Economic growth 	EEA
<p>“The Circular Economy represents the most recent attempt to conceptualize the integration of economic activity and environmental wellbeing in a sustainable way.”</p>	<ul style="list-style-type: none"> • Economic Integration • Sustainable Economy • Environmental well-being 	Murray, Skene and Haynes, 2015
<p>“Circular Economy is a mode of economic development whose purpose is to protect the environment and prevent pollution, thus facilitating sustainable economic development”</p>	<ul style="list-style-type: none"> • Economic Development • Environmental Protection • Sustainable development 	Ma S., Wen Z., Chen J., Wen Z.C.

*Composed by the author.

According to the Ministry of Environment, Decree № 430-N of 2006, waste in Armenia is classified according to the following degrees of danger: 1st, 2nd, 3rd, 4th and

5th. The most dangerous wastes are of the first degree, and wastes of the 5th degree are not considered hazardous. On the other hand, waste in agriculture can be in different forms starting from the production of raw agricultural materials and ending with losses in packaging process.

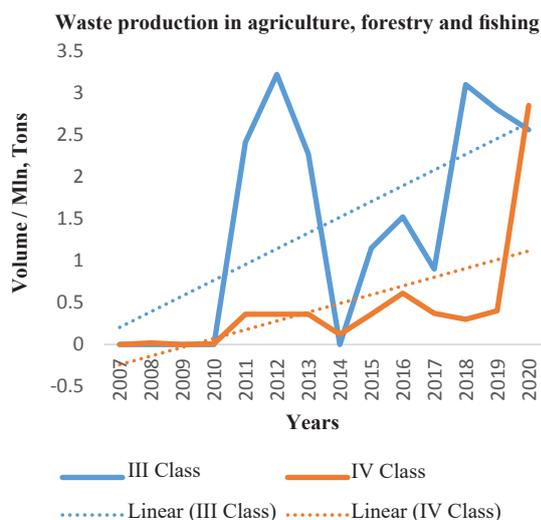


Figure 3. Waste generated in Agricultural Sector (composed by the author).

The waste amount generated by the most strategic agri-food chains in the country is depicted in Figure 4, in line with FAO report:

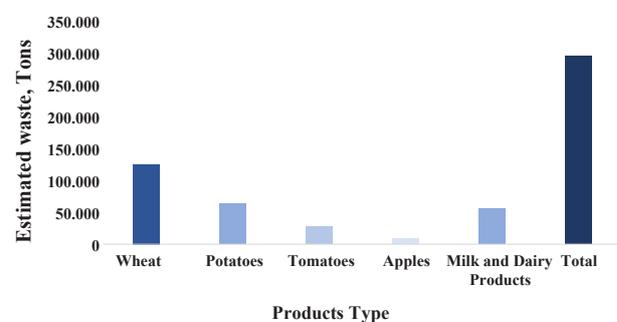


Figure 4. Estimated waste amounts and losses of five produce (entire food chain) in 2009 (composed by the author).

As can be noted in the figure, the amount of waste generated has an increasing trend not only in the entire world, but also in Armenia. However, since the size of farms in Armenia is mostly small or medium with low financial situation, the amount of chemicals and animal drugs in the waste is low making it safe to recycle the waste and reuse (Bolagen, 2020).

If all the waste generated in the agri-food sector were recycled, we could have powered around one million households with renewable electricity, as usually leftovers from food are energy and nutrition-rich. Based on the integrative literature review, the following major circular practices can be applied in the food industry through an efficient waste management:

Composting

Composting is a biological degradation of the organic matter, when aerobic and anaerobic microorganisms break down the waste into manure, which can enrich the soil for improved productivity. This substance improves the soil structure providing the plant with necessary nutrients such as nitrogen (N), phosphorus (P) and potassium (K), it improves the physico-chemical and biological properties of the soil.

Researchers found that the cost of transportation of the organic waste is very high, which is an obstacle for scaling up its use, however, producers and processors can use it on their own farms, which can cut the cost of the fertilizers and improve the quality of the soil (Narasimmalu and Ramasamy, 2020).

Bioenergy production

Food and agricultural sector are one of the greatest contributors of the greenhouse gas emissions having negative impact on the environment (Barros, et al., 2020). Compared to developed countries, developing countries have more supply chain losses in the food industry. However, recently many companies have adopted their own policies to switch to renewable energy sources. Bioenergy generation is one of the ways that waste in food supply chains can contribute to.

In food industry there is a huge potential to generate bioenergy with the form of biogas through anaerobic digestion, that produces methane (Urutyán, 2013). This entire process is very similar to what happens when the waste is dumped in the landfills. Even small-scale generation of biogas is important especially in those areas, where deforestation is a huge problem.

Subproducts design

Agricultural production produces high amount of waste and by products, which are very harmful for the environment. In fruit processing, the byproducts which are bagasse, peels, trimmings, stems, shells, bran, and seeds compose around 50 % of the raw fruit product and they are mostly wasted (Torres-León, et al., 2018). However, those byproducts are very nutritious and energy-rich, which can be used in development of other products.

By products generated in food industry can be used to minimize the issue of food security and malnutrition around the globe, since they are rich in proteins, lipids, carbohydrates and microorganisms, which can be used to produce new forms of foods or additives. Many byproducts in fruit processing sector, for instance, can be used in oil production (seeds, peels) for cosmetics, pharmaceutical operations and food industry. Animal feed is among the most frequently made subproducts in the food supply chain.

2.2. Energy use

Achieving resource efficiency is an important step towards more circular economy so that the businesses maintain the highest values of the resources and keep those in the production cycle as long as possible, which will allow to reduce waste significantly and the cost associated with incremental resource integration into the production.

Closed-loop system is one of the major ways of ensuring resource efficiency through minimizing the extraction of materials used in the production, as well as reduce the amount of the waste through treatment activities and material recycling (OECD, 2021). Slowing the resource use, on the other hand, helps to extend the lifespan of the products through repairs, remanufacturing and reuse. In this context, resources are always regenerative and renewable in Circular Economy.

Noteworthy, that energy is one of the key resources in every sector including Agriculture. Currently, our country has three major gaps in the energy sector: supply gap; reliability of the energy supply; and the stability of the tariffs (Figure 5).

Armenia doesn't have oil and gas resources; thus, it is dependent on the imported resources. On the other hand, generation of renewable energy is still emerging in the country and the current volume is not satisfactory (IEA, 2021).

To properly address this issue, Armenia needs to solve the energy disbalance through identifying not only the

needs of the economy, but also that of the society and environment. The following three elements are especially important in the context of “reduce-reuse-recycle” model: energy conservation, efficiency and renewable energy.

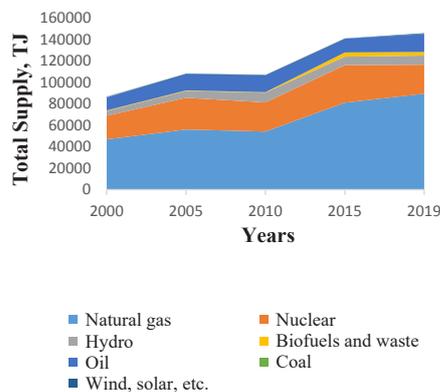


Figure 5. Total energy supply by source (IEA, 2022) (composed by the author).

Energy conservation includes the set of practice meant to use less energy. This happens due to the adjustment in the organizational behavior (Shinduja and Shanmugaraj, 2020).

According to Wang, the following strategies can be applied to reduce the energy demand in food processing (Wang, 2008):

1. Design new methods of food production that don't require energy-intensive preservation technologies
2. Reduce the heat load during the processing
3. Improve the performance of the equipment in use
4. Use waste heat during the processing.

Energy efficiency helps to reduce the energy costs through eliminating the waste. Due to efficiency the energy consuming activity can be performed at lower costs (ACE, 2016). It helps to cut the greenhouse gas emissions, the needs for import and compared to the costs of installing renewable energy, the cost of maintaining energy efficiency is considerably low.

To ensure energy efficiency in the production facilities, the following activities should be carried out:

1. Install energy efficient doors and windows
2. Implement thermal insulation (roofs, doors, walls, floor, ground floor, ceilings)
3. Improve the internal thermal distribution.

Renewable energy

Agri-food industry is one of the biggest consumers of the world energy, which is around 30 % and it is responsible for the one third of global emissions, therefore transformation of energy in the food industry is essential to meet the rising demand of food. Renewable energy is a promising resource in Agriculture, as it can create better job opportunities, cut the losses and support the global actions for the climate mitigation.

According to International Energy Agency, renewable energy composes around 8.8 % in the energy mix of the country, while around 32 % of the electricity generation relies on the renewables.

Renewable energy is one of the core components of the circular economy. The major renewable energy type utilized in Armenia is solar due to the favorable climatic conditions. Solar energy can be used especially in fruit processing sector (dried fruit processing), which can significantly cut the cost of the electricity and gas needed in production. Implementation of the wind energy is limited in Armenia and currently no geothermal energy is extracted in the country.

Generation of biomass and waste energy has a large potential in the country especially in the agricultural sector, however, they are not widely used yet. The application of the bioenergy can reduce the energy costs in the processing sector, improve the welfare of the rural population and overall, increase the energy independence of the country.

Conclusion

Circular economy is a comparatively new concept in food industry in the Republic of Armenia; thus, this paper is aimed at discovering the current conceptualizations of the circular approach. The major methodology applied in this paper was integrated literature review. The major elements covered in the paper were the widely used definitions from different sources including reports prepared by international organizations and websites specifically committed to circular economy.

Five different definitions of circular economy were extracted from the literature and the key impact of each definition was highlighted. Overall, based on the most common definitions, identified circular economy ensures sustainable economic growth with a regenerative social and natural capital.

This paper contributes to the literature of circular economy through highlighting the widely accepted practices in the pillars of waste management and energy use. As a result,

the following activities can be implemented in circular economy to minimize waste:

- Composting
- Subproduct design
- Bioenergy production.

While, there are many other practices, the ones mentioned above are mostly common in the literature. As for the energy use, the following practices are recommended for the enterprises in the food industry:

- Energy conservation
- Energy efficiency
- Application of renewable energy.

References

1. ACE (2016). Technical Solutions for Energy Efficiency.
2. ArmStat (2022). <https://armstatbank.am/pxweb/hy/ArmStatBank/> (accessed on 04.02 2022).
3. Barros, M.V., Salvador, R., Antonio Carlos de Francisco, Piekarski, C.M. (2020). Mapping of Research Lines on Circular Economy Practices in Agriculture: From Waste to Energy. Renewable and Sustainable Energy Reviews. <https://doi.org/10.1016/j.rser.2020.109958>.
4. Bolagen, L.L. (2020). Waste Quantity and Composition Study.
5. Carter, R.C., Rogers, D.S. (2008). A Framework of Sustainable Supply Chain Management: Moving Toward New Theory. International Journal of Physical Distribution & Logistics Management. Vol. 38, -pp. 360-387. <https://doi.org/10.1108/09600030810882816>.
6. Ellen MacArthur Foundation. Retrieved from <https://ellenmacarthurfoundation.org/> (accessed on 15 March, 2022).
7. EU (2020). Circular Economy Action Plan.
8. FoodDrinkEurope (2020). Food Drink Europe Recommendations on the Implementation of the New Circular Economy Action Plan.
9. Gedam, V., Rakesh, D. Raut, Ana Beatriz Lopes de Sousa Jabbour, Ajinkya, N. Tanksale, Balkrishna, E. Narkhede (2021). Circular Economy Practices in a Developing Economy: Barriers to be Defeated. Journal of Cleaner Production. <https://doi.org/10.1016/j.jclepro.2021.127670>.
10. IEA (2021). Armenia Energy Profile.
11. IEA (2022). <https://www.iea.org/countries/armenia> (accessed on 05.03 2022).
12. Ludwig, F., Terwisscha Van Scheltinga, C., Verhagen, J., Kruijt, B., Ierland, E.C. van, Dellink, R.B., Bruin, K. de, Bruin, K.C. de, Kabat, P. (2007). Climate Change Impacts on Developing Countries - EU Accountability. <https://doi.org/10.9774/gleaf.978-1-907643-29-3>
13. Masi, D. Kumar, V., Jose Arturo Garza-Reyes, Janet Godsell (2018). Towards a More Circular Economy: Exploring the Awareness, Practices, and Barriers from a Focal Firm Perspective, Production Planning & Control, 29 (6). <https://doi.org/10.1080/09537287.2018.1449246>.
14. Narasimalu, A., Ramasamy, R. (2020). Food Processing Industry Waste and Circular Economy. IOP Conference Series: Materials Science and Engineering. <https://doi.org/10.1088/1757-899x/955/1/012089>.
15. OECD (2021). Towards a More Resource-Efficient and Circular Economy.
16. OECD (2021). COVID-19 and Greening the Economies of Eastern Europe, the Caucasus and Central Asia. <https://doi.org/10.1787/40f4d34f-en>.
17. Rizos, V., Tuokko, K., Behrens, A. (2017). The Circular Economy: A Review of Definitions, Processes and Impacts.
18. Shinduja, V., Shanmugaraj, G. (2020). Energy Conservation Techniques for Food Processing and Manufacturing Industries.
19. SMO (2018). Barriers and Best Practices for the Circular Economy.
20. Torres-León, C., Ramírez-Guzman, N., Londoño-Hernandez, L., Martínez-Medina, A.G., Díaz-Herrera, R., Navarro-Macias, V., Alvarez-Pérez, B.O., Picazo, B., Villarreal-Vázquez, M., Ascacio-Valdes, J., and Aguilar, N.C. (2018). Food Waste and Byproducts: An Opportunity to Minimize Malnutrition and Hunger in Developing Countries. <https://doi.org/10.3389/fsufs.2018.00052>.
21. Urutyán, V. (2013). Food Losses and Waste in Armenia. Yerevan.
22. Wang, L. (2008). Energy Efficiency and Management in Food Processing Facilities.

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Forecasting Crops Yield Capacity in Changing Agroclimatic Conditions of Ararat Valley and Piedmont Zones

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FAO-56 methodology,
atmospheric precipitations*

ABSTRACT

The current research work considers the results of investigations conducted for projecting and planning crops yield capacity based on statistical indicators of the yield amounts and changes in agroclimatic conditions throughout 2006-2020 years.

To forecast the crop's yield capacity, the data on the results of crops yield amount, agroclimatic characteristics of their allocation and atmospheric precipitations for the previous years have been processed. Finally, an algorithm has been developed, which has been applied for potato crops and, as a result, changing tendencies in the potato yield capacity, when deviated from the best soil and climatic conditions, has been demonstrated.

Introduction

The global climate change, scarce soil reserves, decline in water supply and the growing tendency of population increase vulnerability of the food safety system in the Republic of Armenia. Almost 14 % GDP (gross domestic product) of Armenia is provided by the agricultural sector, moreover, plant breeding sector accounts for its 46.9 %. More than 80 % of plant-based products are obtained in irrigated conditions. Eventually, among the primary factors of crops yield capacity increase, moisture supply index, soil fertility and ameliorative conditions are distinguished. The moisture supply index is usually estimated through the ratio of atmospheric precipitation fallen in that area and evaporation level. In view of generic

index, soil fertility can be addressed as the indicator of soils' qualitative evaluation. Ameliorative conditions of soils are manifested through salt, nutritional, air, thermal and humidity regimes. For the projection of crops yield capacity, yield amounts of different years, agroclimatic characteristics, atmospheric precipitations, water supply rate and characteristics of soil reclaiming regimes can serve as a background.

Materials and methods

For research implementation, agroclimatic changes of the Ararat valley, piedmont zones and partially those of mountainous areas for 2006-2020 years have been studied.

The data of 10 hydrometeorological stations, including Artashat (829 m), Yerevan Agro (942 m), Yeghvard (1336 m), Hrazdan (1756 m), Urtsadzor (1046 m) and Jermuk (2064 m) stations have been used to study the climatic conditions of the investigated areas. The scheme of the stations' allocation is introduced in figure 1.

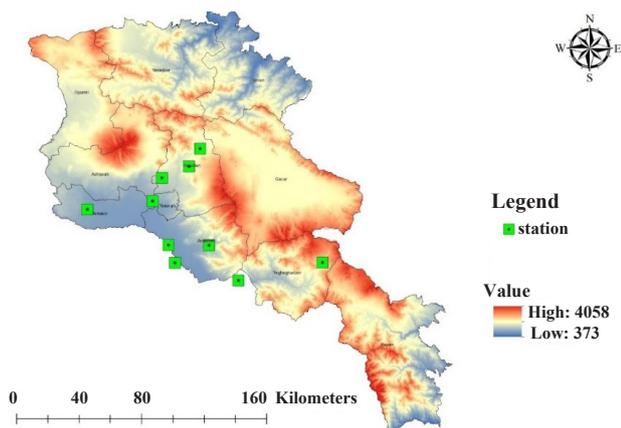


Figure 1. Allocation of hydrometeorological stations in the territory of Armenia.

Making use of the data on agroclimatic indicators, the maximum estimated evaporations per years have been calculated through FAO-56 method developed on the bases of Penman-Monteith equation.

For the projection of crops' yield capacity the following dependence is considered to be the most applicable one:

$$y = y_{max} \cdot K_0 \sum_{i=0}^n K_{ri} \cdot K_{gi} \cdot K_{ci} \cdot K_{sari} \cdot \alpha_i, \quad (1)$$

where y_{max} is the maximum crop yield capacity in the specific soil and climatic conditions, K_0 is a coefficient, which considers the crop yield capacity decline in case of deviation from the best agrotechnical terms, K_{ri} – considers it in case of deviation from the best moisture conditions in that very development stage, K_{gi} – in case of high level of ground waters, K_{ci} – in case of availability of harmful salts, K_{sari} – in case of alkalization and α_i is the specific weight of the agricultural crop's developmental stage.

In case of deviation from the best agrotechnical terms, the amount of crop yield decrease is estimated through K_0 coefficient, for the determination of which the following dependence is suggested (Dmitrenko, 1971, Gorbunova

and Utina, 1968, Zhukovsky and Sanoyan, 1977, Konstantinov, et al., 1974, Kozlovskiy, 1969, Cowan, 1965, Scotler and Kerr, 1973, Goldstein and Mankin, 1972, Cowan, 1972, Day, 1947):

$$K_0 = 1 - \frac{\sum_{i=0}^n \Delta T_i}{\sum_{i=0}^n T_i - \sum_{i=0}^n T_{0i}}, \quad (2)$$

where $\sum_{i=0}^n \Delta T_i$ is the total loss of biologically active temperatures due to the delayed agricultural activities implemented on the irrigated croplands, $\sum_{i=0}^n T_i$ is the sum of biologically active temperatures (from 10 °C) during the vegetation period, $\sum_{i=0}^n T_{0i}$ is the sum of minimum active biological temperatures required for the maturation of the agricultural crops.

The values for $\sum_{i=0}^n \Delta T_i$, $\sum_{i=0}^n T_i$ and $\sum_{i=0}^n T_{0i}$ are described in Table 1.

Table 1. Values of $\sum_{i=0}^n \Delta T_i$, $\sum_{i=0}^n T_i$ and $\sum_{i=0}^n T_{0i}$, in conditions of the Ararat valley*

Name of agricultural crops	$\sum_{i=0}^n \Delta T_i$	$\sum_{i=0}^n T_i$	$\sum_{i=0}^n T_{0i}$
Row crops	150...360	1000...1500	3800...4200

*Composed by the author.

The maximum yield capacity of the agricultural crops is determined based on the radiation balance, a number of soil and climatic indicators, fertilization background and a number of values related to biophysical processes recorded on that specific area (Tupichev, 1973, Filipov, 1982, Frid, 1974):

$$y_{max} = 10 \frac{R \eta_1 \eta_2 \eta_3}{C_h (1-r)}, \quad (3)$$

where R is the radiation balance observed on the soil surface (kJ/cm² a year), which is identified via the following equation:

$$R = LE + B + S, \quad (4)$$

where LE is the heat amount spent on the physical evaporation and transpiration, B is the heat exchange value between the soil surface and atmosphere, S is the heat exchange value between the soil strata and substrata, η_i is the coefficient of photosynthetically active radiation,

η_2 is a coefficient that estimates the fertility index of irrigated land area based on the natural, soil and climatic conditions and fertilization background, η_3 is the ratio between the mass of fruit-producing organs and the sum of the crops' under- and above-ground weights, C_h is the heat capacity of dry matter per yield unit, r is the weighted humidity of the marketable yield (Dzekunov, et al., 1987, Golovanov and Novikov, 1974, Golochenko, 1976). The values of abovementioned factors and coefficients are presented in Table 2.

Table 2. Values of coefficients*

R	η_3	η_3	η_3	C_h	r
4000...4200	0.01...0.04	20...100	0.4...0.9	18.1...20.2	0.14...0.80

The values of K_{ri} , which identify the decreasing tendency of crops yield capacity in case of deviation from the best soil humidity conditions, are determined through the following pattern:

$$K_{ri} = \left(\frac{r_i(x)}{r_{good}} \right) \left(\frac{1-r_i^0(x)}{1-r_{good}} \right)^{\gamma_i(1-r_{good})}, \quad (5)$$

where

$$r_i^0(x) = \frac{r_i(x) - B3}{A - B3}. \quad (6)$$

Here $r_i(x)$ is the average volume humidity in the soil active stratum for the given phase of crop development, A is the porosity, $B3$ is the crop withering moisture, r_i is the best soil moisture, γ_i is a degree index, which characterizes the plant sensitivity in that specific development stage, when the soil moisture deviates from the index of best moisture (Yeghiazaryan, et al., 2021, Danielyan, 2021). For the row crops $r_{good} = 0.68 \dots 0.75$, and the values of γ_i per the developmental stages assume the following mean values: 3.2; 5.8; 5.6; 6.0. Ground waters are located at the depths of more than 2 m, and in case of drainage systems availability the values of K_{gi} fluctuate within the range of 0.8...1.0. The yield capacity decrease of the agricultural crops is also related to the total amount of harmful salts in the medium and to the alkalization degree, the effects of which are evaluated by means of K_{Ci} and K_{sari} coefficients (Table 3) (Khruslova, 1983, Shulgin and Masharipov, 1969).

Table 3. Values of K_{Ci} and K_{sari} *

$\sum C, \%$	0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40
K_{Ci}	0.98	0.96	0.85	0.79	0.65	0.55	0.38	0.25
SAR	0	1	2	3	4	5	6	7
K_{sari}	1	0.98	0.96	0.96	0.80	0.68	0.35	0.28

Table 4. Values of α_i for the row crops*

Developmental stages	1	2	3
α_i	0.33	0.34	0.33

*Composed by the author.

Results and discussions

The analyses and discussions have been conducted on the example of potato crop. Studies show that the areas under potato fields got reduced monotonously during the observation period. The maximum sown area made 34298 ha, minimum sown area – 20477 ha in 2019, hence, the cropland area was reduced by about 40.3 %. Yield capacity fluctuated within the range of 163.4-231.6 c/ha, besides, the yield reduction against the maximum value made 29.4 %, minimum deviation was about 6 %, which was recorded in 2015.

y, c/ha

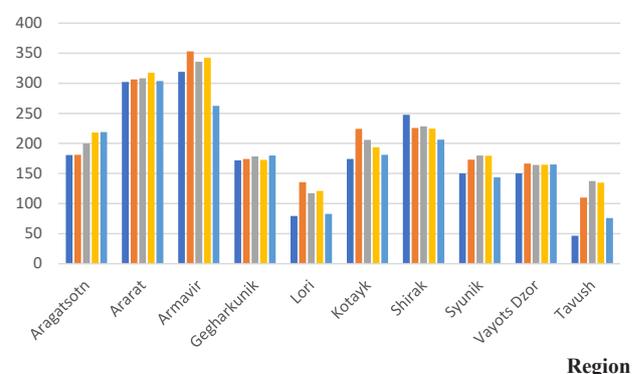


Figure 2. Potato yield capacity per the regions of the RA within 2006-2020 years (composed by the author).

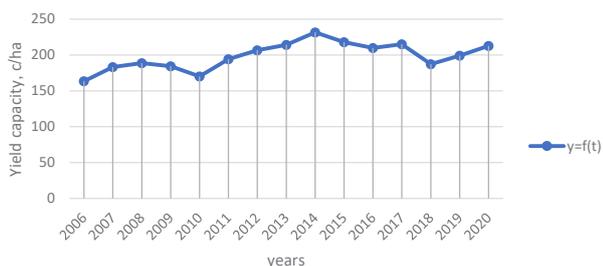


Figure 3. Dynamics of average potato yield capacity (composed by the author).

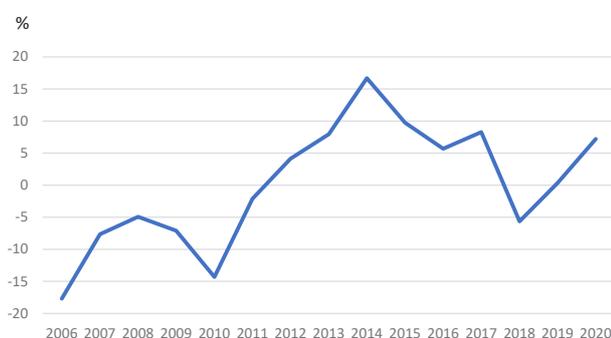


Figure 4. Increasing and decreasing dynamics of potato yield capacity per years (composed by the author).

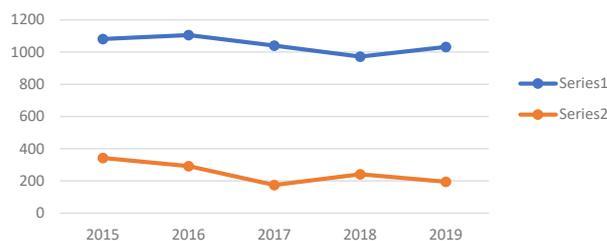


Figure 5. Dynamics of maximum evaporation and average atmospheric precipitations per the data of hydrometeorological stations (composed by the author).

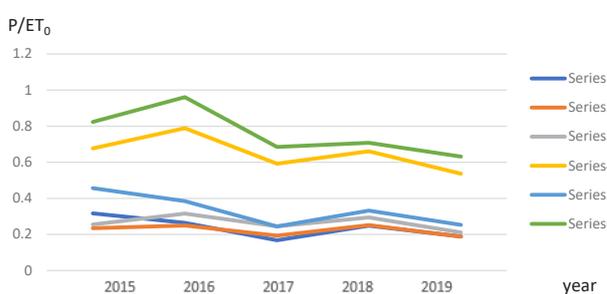


Figure 6. The change of moisture supply per years and observation data: 1-Artashat (829 m); 2-Yerevan Agro (942 m); 3-Yeghvard (1336 m); 4-Hrazdan (1756 m); 5- Urtsadzor (1064 m); 6-Jermuk (2064 m) (composed by the author).

The studies on increasing and decreasing tendencies for potato yield capacity disclose that these variations are related to the complex impact of numerous factors. Anyhow, among the considered factors the hydrometeorological ones for that very period have the highest specific weight. For the evaluation of their complex effect, the estimated total evaporation and the dynamics of atmospheric precipitation have been used as a base. As it is depicted in Figure 4, throughout 2006-2011 different degree of yield capacity decline was observed with the maximum index of 18 % recorded in 2006.

There is a certain regularity between the relations of yield capacity decrease and P/ET_0 . It is observed that within 2015-2019 years the coefficient of moisture supply fell from the value of 0.8 down to 0.2. In case of 40 % decrease in moisture supply potato yield capacity declines by 43 %. Parallel to the gradual increase of the altitude from the sea level, the yield capacity reduction makes 20-25 %.

Estimations of the yield capacity projections for the agricultural crops are introduces in the Tables 5 and 6.

Table 5. Forecasting potato yield capacity related to different factors in crop stress conditions (potato, $y_{max}=20.1$ c/ha)*

Name of agricultural crop	Ameliorative indicators	Development stages of the agricultural crops		
		1	2	3
Potato	K_{ri}	0.77	0.88	0.82
	K_{ri}	1.00	1.0	1.00
	K_{Ci}	0.25	0.25	0.25
	K_{sari}	0.28	0.28	0.28
	α_i	0.33	0.34	0.33
$K_{ri} \cdot K_{gi} \cdot K_{Ci} \cdot K_{sari} \cdot \alpha_i$		0.018	0.021	0.019
$\sum_{i=1}^n K_{ri} \cdot K_{gi} \cdot K_{ci} \cdot K_{sari} \cdot \alpha_i$		0.058		
K_0		0.869		
$K_0 \cdot y_{max}$		346.47		
Expected yield capacity y_{max} (c/ha)		20.1		

*Composed by the author.

Table 6. Forecasting the potato yield capacity in crop stress-free conditions (potato, $y_{max}=398.7$ c/ha)*

Name of agricultural crop	Ameliorative indicators	Development stages of the agricultural crops		
		1	2	3
Potato	K_{ri}	0.85	0.88	0.84
	K_{ri}	1.00	1.00	1.00
	K_{Ci}	0.96	0.98	0.96
	K_{sari}	0.98	0.98	0.98
	α_i	0.33	0.34	0.331
$K_{ri} \cdot K_{gi} \cdot K_{Ci} \cdot K_{sari} \cdot \alpha_i$		0.264	0.287	0.261
$\sum_{i=1}^n K_{ri} \cdot K_{gi} \cdot K_{Ci} \cdot K_{sari} \cdot \alpha_i$		0.812		
K_0		0.945		
$K_0 \cdot y_{max}$		376.77		
Expected yield capacity y_{max} (c/ha)		356.05		

*Composed by the author.

Conclusion

With the aim of planning and forecasting the crops' yield capacity, a computational and analytical algorithm has been developed based on the agroclimatic factors and statistical indices of yield capacity. It has been applied for the crops grown in conditions of Ararat valley and piedmont zones along the territory of Armenia. Theoretically, the effect of different soil and climatic factors on the crop's yield capacity indices has been identified. The developed algorithm has been practically used for the potato crop, thereupon the changing tendencies in the crop yield capacity, when deviated from the best soil and climatic conditions, has been demonstrated.

References

- Goldstein, R.A., Mankin, T.B. (1972). Prosper: A Model of Atmosphere-Soil-Plant-Water Flow. In: Proceedings of the 1972 Summer Computer Simulation Conference, San Diego, California, U.S.A., - pp. 1176-1181.
- Cowan, I.R. (1965). Transport of Water in the Soil-Plant-Atmosphere System. – J. Appl. Ecol. "J. Appl. Ecol." Vol. 2, - pp. 221-239.
- Cowan, I.R. (1972). An Electrical Analogue of

Evaporation from and Flow of Water in Plants. –Planta, - Vol. 106, - pp. 221-226. <https://doi.org/10.1007/bf00388099>.

- Danielyan, R.A. (2021). Software Package for Determining the Capillary Adsorption Potential in Irrigated lands // Agriscience and Technology, Yerevan, N 4/76, - pp. 336-440. <https://doi.org/10.52276/25792822-2021.4-336>.
- Day, P.R. (1942). The Moisture Potential of Soils. Soil Sci. -Vol.54, - pp. 391–400.
- Dmitrenko, V.P. (1971). About Calculation Models of Yield Capacity of Agricultural Crops Taking into Account Hydrometeorological Factors. "Meteorology and Hydrology", - pp. 84-91.
- Dzekunov, N.E., Zhernov, I.E., Faibishenko, B. A. (1987). Thermodynamic Methods for Studying the Water Regime of the Aeration Zone. Moscow, Nedra, -174 p. (in Russian).
- Filipov, L.A. (1982). Water Regime of Plants and Soil Irrigation Diagnosis. - Novosibirsk, Nauka, -152 p. (in Russian).
- Frid, A.S. (1974). Mathematical Model as a Method for Studying Root Uptake of Substances by Plants. "Agrochemistry", - pp.122-131(in Russian).
- Golochenko, M.G. (1976). Moisture Supply and Irrigation of Lands in Belarus. – Minsk, Harvest, -189 p. (in Russian).
- Golovanov, A.I., Novikov, O.S. (1974). Mathematical Model of Moisture and Salts Solutions Transfer in Soils on the Irrigated Lands. Agricultural Reclamation: Collection of Scientific Works. Moscow, MGMI, Vol. 36, - pp. 87–95.
- Gorbunova, I.G., Utina, Z.M. (1968). Effect of Meteorological Factors on Irrigation Rates. – Proceedings of GTO, Edition 226, - pp. 64-72 (in Russian).
- Khruslova, T.N. (1983). Scientific Basis for Increasing Crop Yields and Soil Fertility in Fodder Crop Rotations when Irrigated with Wastewater. – Abstract. Ph.D. Kishinev, - 35 p. (in Russian).
- Konstantinov, A.R., Shcherban, A.V., Rudenko, L.G. (1974). An Empirical Model of the Winter Wheat Root System with Consideration for Weather Conditions and the Distribution of Moisture Reserves by Strata. – Meteorology and Hydrology, - pp. 88-95 (in Russian).

15. Kozlovskiy, T. (1969). Water Exchange of Plants. – Trans. from English. - M.: Kolos, - 247 p. (in Russian).
16. Scotler, D.R., Kerr, J.P. (1973). Weather and Growth of Maize: Evapotranspiration. – Symp. Meteorol and Food Wellington, - pp. 85-100.
17. Shulgin, D.F., Masharipov, R.O. (1969). The Prediction of the Salt Regime of Saline Soils in Drainage Conditions via Computer. – Hydroengineering and Land Reclamation, - pp. 90-94 (in Russian).
18. Tupichev, V. A. (1973). On the Asymptotic Solution of the Diffusion Equation for the Radial Flow of Water to Plant Roots. – Proceedings of IEM, No 3, - pp. 43-49 (in Russian).
19. Yeghiazaryan, G.M., Khachatryan, A.Kh., Danielyan, R.A. (2021). Analytic Assessment of the Moisture Capacity Dynamics in the Aeration Zone of Irrigated Lands // Agriscience and Technology, Yerevan, - N 3/75, - pp. 235-240 (in Armenian).
20. Zhukovsky, E.E., Sanoyan, M.G. (1977). The Static Interpretation of Finite Differences of Meteorological Elements. – Collected Works on the Agronomist. Physics, No 43, - pp. 147-152 (in Russian).

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Usage of Nvidia Jetson Nano in Agriculture as an Example of Plant Leaves Illness Real-Time Detection and Classification

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ABSTRACT

Early prediction of plant illnesses can reduce the spread of the disease through efficient resource management and treatment planning. The goal of this article is to integrate the Jetson nanomachine with software based on a pre-trained CNN machine learning model which has been trained via healthy and diseased plant image data. The created video server uses the RTSP protocol to send video data to the Detection Engine. Detected diseases of the host are sent through the SMTP server at an adjustable frequency to the emails of the users.

The developed system can be widely used in agriculture, making the fight against plant diseases more profitable and effective.

Introduction

Nowadays, the majority of the world’s residential lands are used for agricultural purposes. In such an immense terrain it is impossible to avoid problems and complications related to crop diseases which cause a serious decline in the quantity and quality of agricultural products. The detection of these diseases in large farms requires a lot of time and human resources (www.bitrefine.group). Nowadays, Artificial Intelligence is becoming widespread due to its robust applicability in problems solution, especially

those that cannot be handled by humanity. It achieves considerable progress in almost all fields, including agriculture. An automatic plant disease detection system offers obvious advantages in monitoring large fields, since this is the only approach that makes it possible to detect diseases at an early stage, enabling to prevent its spread and avoid financial losses (Gouravmoy, et al., 2018).

Jetson Nano: The Jetson Nano Developer Kit (Figure 1) is a small budget high performance AI device which provides new scope for a lot of compact, energy-

efficient AI systems. It also allows to parallelly run multiple neural networks for applications such as image classification, object detection, etc. It is an easy-to-use platform with low power consumption (up to 5V) and includes a complete Linux desktop with NVIDIA drivers, AI and artificial vision libraries, APIs and developer tools (www.ximea.com).



Figure 1. A view of the Nvidia Jetson Nano (www.developer.nvidia.com).

Materials and methods

Model training and dataset software application for the detection of plant diseases has been developed, which is integrated into the Jetson nanomachine. The developed system is based on the Convolutional Neural Network (CNN) (Albawi, et al., 2017) deep learning model. The “Plant Village” dataset from Kaggle has been selected for the model training (www.kaggle.com). The dataset consists of about 87000 RGB images of healthy and ill crop leaves, which are classified into 38 categories. Keeping

Table 1. Jetson Nano parameters*

Module	Parameters
Processor	128-core NVIDIA GPU, quad-core ARM Cortex-A57 1.43GHz processor
RAM	4 GB 64-bit LPDDR4 25.6 GB/s + SD card slot
Ports	Gigabit Ethernet, MIPI CSI-2 DPHY lanes video camera connector, HDMI 2.0 and eDP 1.4, 4x USB 3.0, etc.

*www.ximea.com

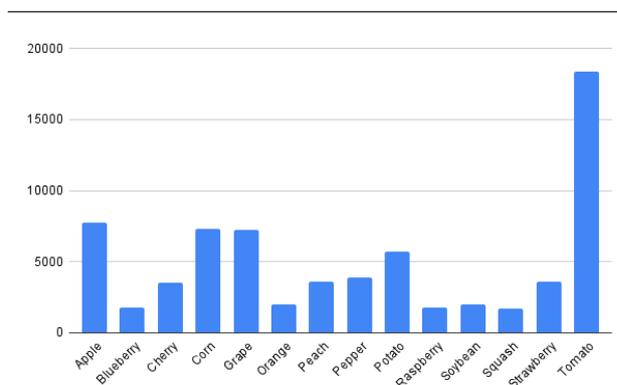


Diagram. Supported plants types and the number of their pictures in the dataset (*composed by the authors*).

the directory structure intact, the dataset is partitioned into 80/20 training and validation sets. The test dataset contains 38 images. The dataset contains 14 types of plant images. The quantitative ratio of plant images available in dataset is given in Diagram.

Some examples of the dataset images are also introduced in Figure 2.



Figure 2. Examples of healthy and ill leaves from the dataset.



Figure 3. RandomRotation data augmentation example.

Data augmentation

When we have a limited number of elements in the dataset, we must apply data augmentation techniques in order to get a good performance out of the AI model (Figure 3). Moreover, the number of parameters required by your model depends on the complexity of the task it has to perform. We have applied RandomPerspective and RandomRotation methods from the Python PyTorch library to our dataset.

System workflow

The system can be divided into three main parts: RTSP Video Stream Server, AI-Based Detection engine for the disease detection, and SMTP mail server (Figure 4). For the uninterrupted work of system, the cameras used and the Jetson Nano device must be connected to the same network.

RTSP Video Stream Server: RTSP (Real-Time Streaming Protocol) is an application layer protocol designed to control the delivery of multimedia data (Schulzrinne, et al., 1998).

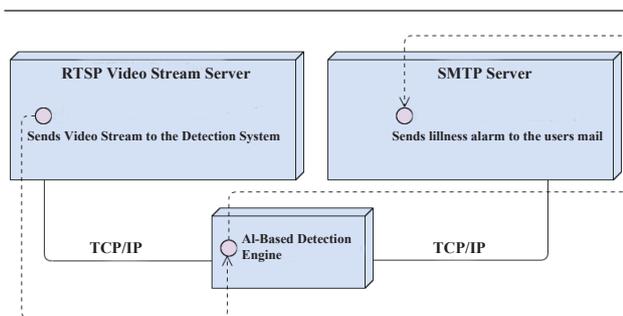


Figure 4. Examples of healthy and ill leaves from the dataset (composed by the authors).

A video stream server using the RTSP protocol was created in this work that will send video data to our detection engine. We have used the OpenCV library (Bradski & Kaehler, 2000) for creating precise stream servers. All cameras that are located in the same network with Stream Server can be used in the system.

SMTP Server: SMTP protocol (Hoffman, 2002) was used to send the alarms to the user. With the help of this protocol, alarms are sent to users in the form of emails. An SMTP Server was created which is responsible for sending the alarms from the engine to the user. The email list is received by the server via the configuration file described in the following chapters.

AI-Based Detection Engine: The AI model described above is the unit responsible for detecting and recognizing plant diseases. In its turn it is divided into two parts. The first part is the Detection, which tries to find parts of the images that resemble some kind of disease. The other part is Classification, the input of which is the crop images obtained after the detection phase. It tries to recognize the type of disease on these crops, and, in case of success, sends collected information as an alarm to all users registered in the system.

System Configuration: A configuration file format has been developed (Figure 5) which contains:

- *Camera groups* - characterized by a unique identification number (GroupId), work schedule (Schedule), additional camera data (Path, Name)
- *Detection Engine* - is an array of numbers in the range [0, 1] that regulates the accuracy of the model. The size of this module should correspond to the number of diseases recognizable by the model
- *Email Addresses* - the addresses to which alarms should be sent in the form of emails.

```

{
  "Groups":
  [
    {
      "GroupId": 0,
      "Schedule": "08:00, 11:00",
      "Cameras": [
        {
          "Path": "rtsp://0.0.0.0:554/streaming/channels/101",
          "Name": "Camera1"
        },
        {
          "Path": "rtsp://0.0.0.0:556/streaming/live",
          "Name": "Camera2"
        }
      ]
    }
  ],
  "Thresholds": [0.8,0.8,0.8,0.8,0.8,0.8,0.8],
  "Emails": [
    "example1@mail.com",
    "example2@mail.com",
    "example3@mail.com"
  ]
}

```

Figure 5. Configuration file (composed by the authors).

When uploading this file into the system the required working data are received.

Results and discussions

The most important parts of any AI-based system are the Detection and Classification models. In the current research work state-of-the-art, efficient artificial intelligence algorithms have been used to obtain a fairly accurate working model. As an activation function for the hidden layers, the ReLU (Rectified Linear Unit) has been chosen. ReLU (Schmidt-Hieber, 2020) has several advantages the most important being the ease of computation and scale invariance. Besides, for networks with randomly initialized weights, as it happens when network only starts the training, only about half of hidden neurons are being activated. So, the addition of the ReLU layer helps to add some non-linearity to the network.

As an activation function for output layers the Sigmoid function (Marreiros, et al., 2008) has been chosen. The main reason for using sigmoid function is that it exists between [0 to 1]. Therefore, it is especially used for models where we have to predict the probability as an output. Since probability of anything exists only between the range of 0 and 1, Sigmoid is the right choice.

As an optimization algorithm, Keras Adam (Diederik and Jimmy, 2015) optimizer was used. The full list of the hyperparameters of the model is provided in Table 2.

Plot, showing results achieved during training, is introduced in Figure 6. It indicates accuracies achieved during the training phase. Model was trained with 50 epochs. The best accuracy obtained during training phase was found on epoch 15 and equals to about 98.7%. It's clear that practically, such a result is fairly suitable for the system use on a daily basis in different agricultural farms.

Table 2. The hyperparameters of the AI model used for detection and classification tasks*

Hyperparameter		Value
optimizer	batch size	64
	optimizer	Adam
	learning rate	0.001
hidden layers count		18
hidden layers activation function		ReLU
output layers count		3
output layers activation function		Sigmoid

*Composed by the authors.

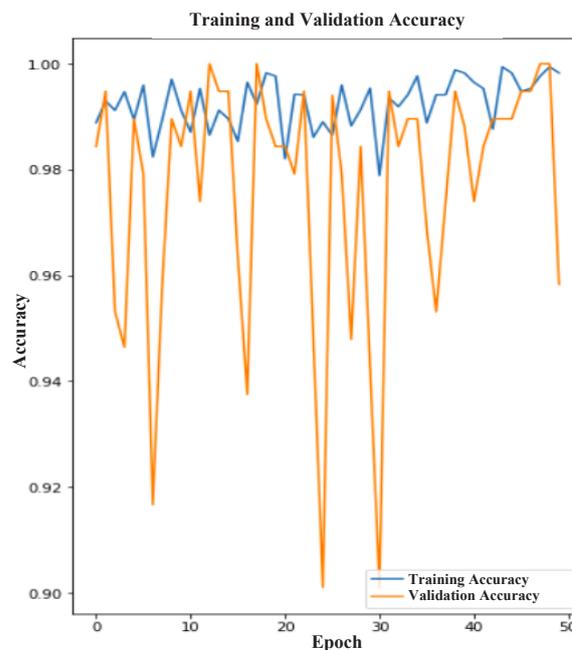


Figure 6. Graphical representation of model accuracy (composed by the authors).

Conclusion

In the result of current research work, the possibility of creating AI-based system has been introduced that will promote automation of disease detection in gardens, greenhouses and other agricultural structures using quite a few financial resources. The proposed system is cost-effective, since it requires Jetson Nano devices, which cost about \$340. This is much more profitable and efficient than the computers ensuring similarly smooth and efficient operation of such systems.

In order to improve the system and make it easier for the user, it is planned to create a mobile app and website in the future, where the user can follow his plants and trees in real-time. It is planned to create a new dataset in which images of the most common plants and trees in Armenia should be added. It will enable to improve the efficiency of the AI model and enhance its working capacities.

References

1. Albawi, S., Mohammed, T. A., & Al-Zawi, S. (2017). Understanding of a Convolutional Neural Network. In 2017 International Conference on Engineering and Technology (ICET), - pp. 1-6. <https://doi.org/10.1109/icengtechnol.2017.8308186>.
2. Bradski, G., & Kaehler, A. (2000). OpenCV. Dr. Dobb's Journal of Software Tools, 3, 2.
3. Diederik, P. Kingma, Jimmy, Ba (2015). Adam: A Method for Stochastic Optimization. 3rd International Conference for Learning Representations, San Diego.
4. Gouravmoy Bannerjee, Uditendu Sarkar, Swarup Das, Indrajit Ghosh (2018). Artificial Intelligence in Agriculture: A Literature Survey. West Bengal, India.
5. Hoffman, P. (2002). SMTP Service Extension for Secure SMTP over Transport Layer Security. RFC 3207, February. <https://doi.org/10.17487/rfc3207>.
6. <https://developer.nvidia.com/embedded/jetson-nano-developer-kit> (accessed in March, 2022).
7. https://www.ximea.com/support/wiki/apis/Jetson_Nano_Benchmarks (accessed in March, 2022).
8. Marreiros, A. C., Daunizeau, J., Kiebel, S. J., & Friston, K. J. (2008). Population Dynamics: Variance and the Sigmoid Activation Function. Neuroimage, 42(1), - pp.147-157. <https://doi.org/10.1016/j.neuroimage.2008.04.239>.
9. Plant Disease Detection: <https://bitrefine.group/industries/precision-agriculture/88-industries/agriculture-food/agriculture-solutions/184-plant-disease-detection> (accessed in March, 2022).
10. Plant's Dataset: <https://www.kaggle.com/arjuntejaswi/plant-village> (accessed in March, 2022).
11. Schmidt-Hieber, J. (2020). Nonparametric Regression Using Deep Neural Networks with ReLU Activation Function. The Annals of Statistics, 48(4), - pp. 1875-1897. <https://doi.org/10.1214/19-aos1875>.
12. Schulzrinne, H., Rao, A., & Lanphier, R. (1998). Real Time Streaming Protocol (RTSP). <https://doi.org/10.17487/rfc2326>.

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Increasing the Efficiency of Chili Pepper Cultivation through an Effective Fertilization System

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ABSTRACT

The irrigated brown meadow soils of the Ararat valley are poor in humus content and other important plant required nutrients; hence, the application of scientifically justified quantities of the fertilizers becomes a priority measure. Considering the afore stated fact, the effect of various fertilizers' combinations (*N*; *NP*; *NPK*; *NPK* + complexon via foliar feeding, thrice) on the plant growth, yield capacity and its quality has been studied. The best result has been recorded in the option of $N_{120}P_{120}K_{120}$ +complexon. The fruit quality has also improved: the content of dry matters and sugars has increased, while the nitrate content has decreased.

Introduction

The sown areas of the vegetable crops in Armenia currently make up to 21 272 ha land area, out of which 1972 ha (9.2 %) are cultivated under sweet and hot/chili peppers (www.armstat.am, 2021). Pepper is a high value crop, which contains a great amount of vitamins *C* and *A* throughout its biological ripening period and is a source for the vitamins of *B* complex, particularly for vitamin *B*₆. It is also rich in potassium, magnesium and iron. Apart from capsaicin, 1.5 % essential oils and fats have also been detected in the fruits of hot pepper. Besides, a number of medications are manufactured from the chili pepper (Tilahun, et al., 2013, Mamedov, et al., 2009).

Pepper is a warm-weather/ heat-loving crop, and therefore, is mainly cultivated in the Ararat valley and piedmont zone, where, yet, the soils are poor in humus and macro (*NPK*) – and micro – nutrients (*B*, *Mo*, *Mn*, *Zn*, *Co*) required for the plants growth. Thus, in order to improve its growth and to increase its yield capacity, it is important to use complex fertilizers (Aliyeva, 2020, Aliyu, 2000, Tuti, et al., 2014). This is also justified upon the pepper's considerable demand for the main nutrients. So, for each 10 c yield and accessory mass the nitrogen yield makes 6.1 kg, phosphorus – 2.7 kg and the potassium yield – 8.2 kg. In case of harvesting 350-400 c/ha yield, the nitrogen yield makes 213-244 kg/ha, phosphorus – 94.5-108 kg/ha and potassium – 287-328 kg/ha. It is evident that the soils of

the Ararat valley do not contain such amounts of nutrients and hence, the application of fertilizers becomes an indispensable measure for the increase of pepper yield capacity in those soils.

There are a few research works regarding the pepper's fertilization methods in the Republic of Armenia, while the studies related to the foliar feeding are completely missing. It is known that in case of applying such a fertilization method, the fertilizers are actively imbibed by the leaves and consequently exert a rapid effect on the plant's nutrition, growing and yielding processes (Vasilyev, 2013, Glazova, 2018, Khoroshkin, 2015). Considering the significant role of the fertilizers in the increase of pepper's yield capacity in the nutrient-poor soils of the RA Ararat plain, an objective has been set up to study and recommend an efficient fertilization system for chili pepper to the production, which is implemented through the fertilizers' introduction in the soil and via foliar feeding. There are multiple popular study works about the crops foliar feeding, which indicate the significance of this system for the plants growth, yield capacity increase and improvement of the yield chemical composition. Such kind of investigations are also carried out in Armenia (Aslanyan, 1988).

Materials and methods

The field experiments were conducted throughout 2020-2021, in the soils of Arshaluys community in the Armavir region/marz, located to the right of Yerevan-Armavir highway. For the experiment a mid-ripening variety of chili pepper (*Capsicum annum L, Sp. Annuum*) "Artsiv" was selected; its ripening time from mass sprouting to technical maturity period lasts 100-110 days and the biological ripeness – up to 130-140 days. The mentioned pepper variety can be cultivated in the open field and protected ground. It is relatively resistant to the diseases, and the yield capacity, depending on the cultivation terms, fluctuates within 300-600 c/ha. In the stage of technical maturity its fruits are green and in that of biological ripeness they become red. The pepper variety "Artsiv" was sown on March 10 in solar greenhouse and transplanted to the field on May 5, in the phase of 4-5 leaves.

The experiment was implemented in four replications, the experimental beds in the field were arranged randomly through the following pattern:

1. Without fertilization (control)
2. N_{120}
3. $N_{120}P_{120}$

4. $N_{120}P_{120}K_{120}$
5. $N_{120}P_{120}K_{120}$ + complexon via foliar feeding, once
6. $N_{120}P_{120}K_{120}$ + complexon via foliar feeding, thrice with an interval of 10-12 days.

The size of an experimental bed was 64 m² (6.4m x 10m) and the feeding area of a plant was 0.21 m² (0.7m x 0.3m).

During the experiments double superphosphate and potassium chloride were applied in the soil pre-treatment period, while the ammonium saltpeter was applied twice in the plant vegetation period upon weeding and hilling procedures.

The complex water-soluble fertilizer (complexon), which contains macro – and micro-nutrients, was introduced during the vegetation period per the experimental scheme with the dose of 40 g per 10 L water.

The first treatment with the complexon was implemented 15 days after seedling on the eve of flowering, the second was introduced during the fruiting period, the third and the fourth – after every 10-12 days.

During the plant vegetation period observations, measurements and calculations were conducted (Melikyan, 2005). The chemical composition of the yield was also determined. The content of dry matters was determined through weighing method from the third harvest by drying them at 100-105 °C temperature, those of sugars were determined through Bertrand's method and vitamin C – per the Mohr's method (Yagodin, 1989). The yield was calculated per each replication by harvesting and weighing the yield of an experimental bed. Harvest was organized ten times with an interval of 10-12 days. The yield data were subjected to mathematical processing via the dispersion analysis method developed by Dospekhov. The experimental error ($Ex\%$) and the least significant difference ($LSD_{0.95}$) between the variants was calculated (Khachatryan, 2020).

For the agrochemical description of the experimental plot, the humus content was determined via Turin's method, the mechanical composition – through the Kachinsky method (pipette method), soil reaction (pH) – by means of pH -meter, the content of Ca and Mg in water solution through the trilonometric method (Yagodin, 1987). The plants available nitrogen was determined through Turin-Kononova's method, phosphorus – through Machigin's method and potassium content was determined in the extraction of Machigin's solution (Yagodin, 1987). The soil nutrients supply rate was assessed per the threshold values for the soil nutrients provision adopted in the Republic of Armenia.

Table 1. Agrochemical description of the experimental plot*

Soil type	Depth, cm	Humus, %	Carbonates (CaCO ₃), %	pH	Content of physical clay, %	Available nutrients mg in 100 g soil		
						N	P ₂ O ₅	K ₂ O
Irrigated brown meadow	0-31	2.11	3.7	7.7	48.4	3.43	1.41	21.6
	31-44	0.96	4.8	7.8	49.3	132	0.92	19.4

*Composed by the authors.

Results and discussions

The experiments were conducted in the irrigated brown meadow soils, where the humus content makes only 2.15 %, the mechanical texture is clay and sandy, heavy, the soil reaction is weakly alkaline, while the content of carbonates makes 3.7 %-4.8 %. The calcium-magnesium ratio in the soil solution is favorable and the content of soluble salts are in permissible limits. The mentioned soils are poorly provided with plant available nutrients-nitrogen and phosphorus, while the content of potassium is at the medium level (Table 1). It is obvious that under such soil conditions when the supply of nutrients is rather poor, it is not likely to receive economically justified yield without applying fertilizers.

As the table data indicate (Table 2), the application of fertilizers has somehow affected the developmental phases and transitional periods, while the effect is more significant on the plants yielding time. So, in case of individual application of nitrogenous fertilizers or the application of complexon on the background of fertilizers, the developmental phases have been partially delayed amounting to the highest index when complexon was used thrice. The effect of complexon and fertilizers is obvious on the plant fruiting times. So, in the control variant this time period makes 75 days, in the fertilized variant it is 83-85 days, and in the variant where complexon has been applied, this period lasts 95-115 days.

The effect of fertilizers on the plant growth is introduced in Table 3. According to the table data the fertilizers have promoted the plant growth and emergence of the yield elements, whereas the effect size is related to the fertilization variant. So, in the fertilized variants the plants height has exceeded the control variant by 12-21 cm, the mean shrub width – by 18-31 cm, while the highest result has been recorded, when complexon on the background of mineral fertilizers was applied thrice during the vegetation period. Whereas, in case of applying only mineral fertilizers or when using complexon on that background only once, the plants growing index is much lower. The

Table 2. The effect of different fertilizers' combinations on the phenological peculiarities of chili pepper*

Variants	Days to 50 % anthesis (DAT)	Days to 50 % maturity	Days to first harvesting (DAT)	Fruiting period, day
Without fertilization (control)	34	41	65	75
N ₁₂₀	36	42	64	83
N ₁₂₀ P ₁₂₀	34	41	63	83
N ₁₂₀ P ₁₂₀ K ₁₂₀	33	40	63	85
N ₁₂₀ P ₁₂₀ K ₁₂₀ + complexon via foliar feeding, once	37	43	66	95
N ₁₂₀ P ₁₂₀ K ₁₂₀ + complexon via foliar feeding, thrice	37	45	67	111

Note. DAT-days after transplanting.

*Composed by the authors.

mentioned exuberant plants developed more and relatively larger fruits (Table 3). The number of fruits per a plant and the average weight of a fruit is higher in the variant where complexon on the background of mineral fertilizers was applied thrice. The same indices are much lower in the control variant. In the variants where only nitrogen, nitrogen-phosphorus or nitrogen-phosphorus-potassium patterns are used the number of fruits per a plant and the average weight of a fruit are all the same lower.

According to the data of Table 3, the fertilizers have affected the fruiting times as well. This is significant, since the yield capacity is also related to the fructification time. It is known that nutrient-rich and healthy plants stay biologically active for a rather long time, which can last

until the onset of cold weather. As to the data of Table 3, the fruiting period of a plant is remarkably longer in the variant where complexon on the background of $N_{120}P_{120}K_{120}$ was applied thrice throughout the vegetation period. While in the control variant the mentioned time period lasted only 75 days, and in the variant where only mineral fertilizer was applied it lasted 83-85 days.

Table 3. The effect of different fertilizers' combinations on the growing peculiarities of chili pepper*

Variants	Average plants height, cm	Average shrub width, cm	Average weight per a fruit, g	Number of fruits per a plant, n	Fruiting period, day
Without fertilization (control)	36	33	7.9	75.1	75
N_{120}	48	51	8.8	81.2	83
$N_{120}P_{120}$	49	51	9.1	84.5	83
$N_{120}P_{120}K_{120}$	48	55	9.6	86.6	85
$N_{120}P_{120}K_{120}+$ complexon via foliar feeding, once	52	58	9.7	89.9	95
$N_{120}P_{120}K_{120}+$ complexon via foliar feeding, thrice	57	64	10.8	95.7	151

*Composed by the authors.

The application of fertilizers promotes the plants growth and the increase of fruits number and weight per a plant which entails to yield increase (Table 4). Besides, the fruit size completely depends on the fertilization variant and the mentioned pattern holds true irrespective of the experimental year. So, according to the two-year average data, the yield amount makes 249 c/ha in the control variant, while in the fertilized variants it fluctuates within the range of 312-468 c/ha. Among the fertilized variants the highest yield (468 c/ha) was harvested in the variants where complexon on the background of NPK was applied in the form of foliar feeding thrice throughout the vegetation period. The other fertilization variants irrespective of their combinations provided much lower yield (312-396 c/ha), which exceeds the control variant by 63-147 c/ha, whereas compared to the variant of $N_{120}P_{120}K_{120}+$ complexon (thrice) it sits behind by 72-156 c/ha.

Table 4. The effect of different combinations of fertilizers on the yield capacity of chili pepper*

Variants	2020	2021	Average yield, c/ha	Yield surplus, c/ha
	Yield, c/ha	Yield, c/ha		
Without fertilization (control)	269	229	249	-
N_{120}	326	299	312	63
$N_{120}P_{120}$	352	328	340	91
$N_{120}P_{120}K_{120}$	381	341	361	112
$N_{120}P_{120}K_{120}+$ complexon via foliar feeding, once	412	380	396	147
$N_{120}P_{120}K_{120}+$ complexon via foliar feeding, thrice	490	446	468	219
LSD _{0.95}	4.55	4.18	-	-
Ex%	1.22	1.24	-	-

Table 5. The effect of different fertilizer combinations on the fruit's chemical composition*

Variants	Dry matters, %	Vitamin C, mg/%	Sugars, %	mg/kg in fresh mass
Without fertilization (control)	5.2	76.5	2.9	39
N_{120}	5.9	83.6	2.5	65
$N_{120}P_{120}$	6.2	88.1	3.4	48
$N_{120}P_{120}K_{120}$	6.4	88.3	4.0	37
$N_{120}P_{120}K_{120}+$ complexon via foliar feeding, once	6.5	94.1	4.0	35
$N_{120}P_{120}K_{120}+$ complexon via foliar feeding, thrice	7.6	141.6	4.7	24

*Composed by the authors.

The effect of fertilizers on the fruit qualitative indicators has also been studied, where the content of dry matters, vitamin C and sugars has been considered as prior indices (Table 5). It is apparent that the increase of dry matter content in the fruits ensures the storage of more nutrients

in a unit mass, whereas the increase in vitamin C amount enhances its nutritional value, since the latter is of vital significance for the human organism. The results are summarized in Table 5. Per the table data it can be inferred that the fruit's chemical composition to some extent is related to the applied fertilization variant. Thus, the contents of dry matters, vitamin C and sugars are higher in the option where complexon on the background of NPK was applied thrice during the vegetation period. Accordingly, in the mentioned variant the content of dry matters amounted to 7.6 %, vitamin C – 141.6 mg/%, sugars – 4.7 %, while the nitrate content declined to 24 mg per one kg of fresh mass. In the control and other fertilization variants the mentioned indicators are considerably lower, while the nitrate content is rather high, which affects the fruit quality.

Conclusion

Based on the experimental results it can be concluded that the application of fertilizers has produced a considerable effect on the growth, yield capacity and fruit quality of the chili pepper. To ensure higher yield and yield quality it is necessary to use water-soluble complex fertilizer (complexon) on the background of the main mineral fertilizers in the form of foliar feeding thrice during the vegetation period with 10-12-day of interval.

References

1. Aliyeva, A. (2020). Effectiveness of Organic Fertilizers for Pepper Growing // Bulletin of Science and Practice, 6(3), - pp. 241-244. <https://agris.fao.org/agris-search/search.do?recordID=R22020200091> (in Russian).
2. Aliyu, L., (2000). Effect of Organic and Mineral Fertilizers on Growth, Yield and Composition of Pepper (*Capsicum annum L.*), Biological Agriculture & Horticulture, 18:1, 29-36. <https://doi.org/10.1080/01448765.2000.9754862>.
3. Aslanyan, G.H. (1988). Vegetable Cultivation in Greenhouses. Yerevan. Armenia, - 102 p. (in Armenian).
4. Glazova, Z.I. (2018). The Prospect of Applying Foliar Feeding in the Lentil Cultivation // Agriculture - № 4, - pp. 24-26. (in Russian).
5. Khachatryan, A.R. (2020). Agronomic Research Methods, Yerevan, Astghik, - 238 p. (in Armenian).
6. Khoroshkin, A.B. (2015). Foliar Feeding of Potatoes (Brief Review) // Potatoes and Vegetables, - № 11, - pp. 25-26 (in Russian).
7. Mamedov, M. I., Pyshnaya, O. N., Golubkina, N., Dzhos, E. A. (2009). Capsaicin Content and the Pungency Level at Different Hot Pepper Varieties of the Genus *Capsicum L.* Scientific Papers “Breeding and Seed Production of Vegetable Crops”, - vol. 42, - pp. 24-30 (in Russian).
8. Melikyan, A.Sh. (2005). Vegetable Growing. Yerevan. “Dar”, - 503 p. (in Armenian).
9. Sown Areas of Agricultural Crops, Planting Area of Permanent Crops, Gross Harvest and Average Crop Capacity for 2021. www.armstat.am (assecced in March 2022).
10. Tilahun, S., Paramaguru, P., Rajamani, K. (2013). Capsicum and Ascorbic Acid Variability in Chili and Paprika Cultivars as Revealed by HPLC Analysis // Journal of Plant Breeding and Genetics, - Vol.1, - № 2, - pp. 85-89.
11. Tuti, M.D., Hedau, N.K., Bisht, J.K., Bhatt, J.C. (2013). Effect of Organic and Inorganic Sources of Nutrients on Yield, Economics and Energetics of Pepper and Soil Properties in Naturally Ventilated Polyhouse. Archives of Agronomy and Soil Science 60:7, - pp. 1005-1014. <https://doi.org/10.1080/03650340.2013.861899>.
12. Vasilyev, A.A. (2013). Efficiency of Potato Foliar Feeding // “Potatoes and Vegetables”, - № 3, - pp. 24-25 (in Russian).
13. Yagodin, B.A. (1987). Workshop on Agricultural Chemistry, M.: Agropromizdat, - 512 p. (in Russian).
14. Yagodin, B.A. (1989). Agrochemistry. Textbook for Agricultural Universities. M.: Agropromizdat, - 656 p. (in Russian).

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The Prevalence of Leishmaniasis in Dogs in the Districts of Yerevan

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ABSTRACT

Leishmaniasis is a transmissible parasitic disease of dogs that poses a great danger to humans. The aim of the current study was to determine the prevalence of leishmaniasis in dogs in the districts of Yerevan. The results of the research are described and considered in the article. Several recommendations have been developed to prevent the spread of this disease.

Introduction

Visceral and cutaneous leishmaniasis is a transmissible parasitic disease of dogs and humans caused by parasites of Protozoa group, genus *Leishmania* and family Trypanosomidae (Lobzin, 2008, Fioretti, et al., 1994). Leishmaniasis is transmitted through the bite of phlebotomine sandflies (*Phlebotomus*). *Leishmania* parasitize in the organism throughout their lifetime (Tsachev, 2009, Gallego, 2004). The main carriers of leishmaniasis under natural conditions are field rodents, dogs and other mammals (Jazic, et al., 1998).

When bitten by animals with leishmaniasis, the pathogen enters certain stages of development in sandflies and is subsequently transmitted through bites to other mammals, such as humans (Alvar, 2001, Sotira, 2000, Baneth, et al., 1998, Garifallou, et al., 1989).

There are two types of leishmaniasis: cutaneous and visceral. The cutaneous form is manifested with the

formation of nodules on the skin of animals, which later develop into unhealable ulcers and such adverse effects like hair loss, skin itching and scars are observed. The visceral form has more severe course and is accompanied with dry skin, peeling, rhinitis, conjunctivitis, infection of the liver, spleen, bone marrow, lymph nodes, as well as with blood and digestive disorders, paresis, paralysis and emaciation of animals (Boutsini and Ptakakis, 2001, Carlotti, 2003, Faghieh, et al., 2002).

Materials and methods

The aim of the study was to investigate the prevalence of leishmaniasis in dogs in different districts of Yerevan. The study was carried out in 11 administrative districts of Yerevan (Shengavit, Center, Erebuni, Nork-Marash, Arabkir, Nor-Nork, Avan, Ajapnyak, Kanaker-Zeytun, Nubarashen, Davtashen). The studies were conducted in the “Republican Center of Veterinary and Phytosanitary

Laboratory Services” SNCO. Animals with suspected visceral leishmaniasis showed weakness, depression, dry skin, peeling, conjunctivitis, rhinitis, signs of anemia, pneumonia, infection signs in liver and lymph nodes, vomiting, diarrhea and emaciation. Blood samples were taken from these animals to further confirm the diagnosis. To diagnose the disease, rapid tests were performed to determine the presence of antibodies to visceral leishmaniasis in dogs (rK39 (RDTs), IT LEISH, BIO-Rad). Express immunochromatographic testing (rK39) was performed according to the manufacturer’s instructions: a positive test result was recorded if the control and test lines were colored red.

Results and discussions

Dogs and canines are known to be natural deposits for visceral leishmaniasis and have a very high infection rate.

Table 1. Results of immunochromatographic examinations*

Yerevan districts	Number of tested animals	Number of detected animals with leishmaniasis infection	Disease percentage, %
Shengavit	20	6	30
Center	30	5	16.6
Erebuni	20	6	30
Nork-Marash	25	8	32
Arabkir	15	6	40
Nor-Nork	15	5	33.3
Avan	15	6	40
Ajapnyak	25	8	32
Kanaker-Zeytun	25	9	36
Nubarashen	25	8	32
Davtashen	35	8	22.8

Table 2. Seasonality of the infection of animals with leishmaniasis*

Total number of infected animals	Number of infected animals detected in spring	Infection rate, %	Number of infected animals detected in summer	Infection rate, %	Number of infected animals detected in autumn	Infection rate, %	Number of infected animals detected in winter	Infection rate, %
75	25	33.3	40	53.3	10	13.3	0	0

*Composed by the author.

Table 3. Infection of animals with leishmaniasis per age group*

Age groups	Number of tested animals	Number of infected animals	Infection rate, %
From 3 months to 1 year old	50	10	20
From 1 to 6 years old	125	45	36
Over 6 years old	75	20	26.6

*Composed by the author.

From September 2020 to October 2021, 250 dogs were tested in 11 districts of Yerevan. Seventy-five cases of leishmaniasis were detected. The results of the study are presented in Table 1.

Thus, as a result of serological examination conducted in the dogs’ blood, 30 % infection of Leishmaniosis was detected in Shengavit district, 16.6 % – in Kentron, 30 % – in Erebuni, 32 % – in Nork-Marash, 40 % – in Arabkir, 33.3 % – in Nor-Nork, 40 % – in Avan, 32 % – in Ajapnyak, 36 % – in Kanaker-Zeytun, 22.8% – in Davtashen and 32 % – in Nubarashen districts.

As shown in Table 2, there were 25 infected animals (33.3 %) in spring, 40 (53.3 %) – in summer, 10 (13.3 %) – in fall, and no infected animals (0 %) in winter. The data in the table show that the most intensive infection of animals occurred during the warm seasons, which is associated with high activity of sandflies that transmit pathogens during these seasons.

As shown in Table 3, 50 of the 250 examined dogs belonged to group 1 (from 3 months to 1 year old), 125 – to group 2 (from 1 to 6 years old) and 75 dogs – to group 3 (over 6 years old). According to the results of the examination, 10 cases (20 %) of leishmaniasis were registered in the first group, 45 cases (36 %) – in the second group, and 20 cases (26.6 %) – in the third group.

Conclusion

Studies have pointed out the high occurrence rate of dogs in various districts of Yerevan. The disease of dogs leishmaniasis is recorded in animals of all age groups and is widespread in various districts of Yerevan. The infection rate grows up during warm periods of the year due to the high activity of sandflies - transmitters of the pathogens.

To get a complete insight into the disease source, the following directives should be observed to:

1. Carry out registration of all dogs with owners.
2. Develop an appropriate reporting form and require that veterinarians, treating dogs, should report cases of dog leishmaniasis infection.
3. Vaccinate dogs against leishmaniasis, if possible.
4. Test the dogs of the settlements where leishmaniasis has been reported in recent years, (with rK39 immunochromatographic rapid tests) to identify the source of infection.
5. If the result is positive, put the dogs down (use insecticide-treated collars, as a last resort).
6. Activate the fight against stray dogs.
7. Possibly minimize the accumulation of organic wastes to reduce the population of disease-transmitting sandflies, keep dog kennels and habitats clean, and conduct treatments with long-acting (residual) insecticides in the areas where cases of leishmaniasis have been recorded.

References

1. Alvar, J. (2001). *Las Leishmaniasis: de la Biología al Control: 2da edición*. Salamanca: Laboratorios Intervet S.A., - 200 p.
2. Baneth, G., Dank, G., Keren-Kornblatt, E., Sekeles, E., Adini, I., Eisenberger, C.L., Schnur, L.F., King, R., Jaffe, C.L. (1998). Emergence of Visceral Leishmaniasis in Central Israel. *Am J Trop Med Hyg*, 59, - pp. 722-725. <https://doi.org/10.4269/ajtmh.1998.59.722>.
3. Boutsini, S., and Ptakakis, M. (2001). Dog Leishmaniasis in Attiko between 1995-2000. 6th Hellenic Symposium of Small Animal Practitioners, March 2001, - p. 117.
4. Carlotti, D. (2003). Canine European Leishmaniasis, 9th FECAVA Congress, Scientific Proceedings, Estrol, Portugal: 82.
5. Faghih, N.F., Mohebali, M., Javadian, E. (2002). Epidemiology of Visceral Leishmaniasis in Kordan, Tehran: 28, Pejouhandeh; - Vol. 7, N 2, - pp. 159-164.
6. Fioretti, P., Chircop, S., and Moretti, A. (1994). Canine Leishmaniasis in the Maltese Islands: Statistical Findings from 1989 to 1992. *Parassitologia* 36:109.
7. Gallego, M. (2004). Emerging Parasitic Zoonoses: Leishmaniasis. *Rev. Sci. Tech. Off. int. Epiz.*, 23, 2, - pp. 661-676.
8. Garifallou, A., Hadziantoniou, M., Schnur, L., Yuval, B., Warburg, A., Jacobson, R., Pateraki, E., Patrikoussis, M., Schlein, Y., and Serie, C. (1989). Epidemiology of Human and Canine Leishmaniasis on the Island of Zakynthos, Leishmaniasis. Plenum Publishing Corporation, - pp. 1011-1015. https://doi.org/10.1007/978-1-4613-1575-9_131.
9. Jazic, A., Zuko, A., Cankovic, M. (1998). Leishmaniasis in Dogs in the Area of Blagai (Mostar), Bosna-Herzegovina. *Giornale Italiano di Medicina Tropicale*, - Vol. 3, 3-4, - pp. 59-60.
10. Lobzin, Yu. (2008). *Parasitic Diseases of Human*. St. Petersburg: Foliant Publisher, - 592 p. (in Russian).
11. Sotira, B. (2000). Zoonotic Diseases of Major Concern in Albania. Epidemiological Overview. In: *Inf. Circ.-WHO Mediterr. Zoon. Control Cent.*, 49:6-8.
12. Tsachev, I. (2009). Exotic Zoonoses of Dogs in Bulgaria (Monocytic Ehrlichiosis, Granulocytic Anaplasmosis, Visceral Leishmaniasis): Detection and Study. Dissertation for Doctor of Veterinary Medicine. Trakia University, Stara Zagora, - 315 p. (in Russian). <https://doi.org/10.21474/ijar01/2044>.

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Some Epizootological Peculiarities of Chicken Eimeriosis in the Small Poultry Farms

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ABSTRACT

The prevalence of chicken eimeriosis has been investigated per the geographical and climatic zones of Armenia and housing type of poultry, while the infection rate with eimeriosis has been determined according to the age group and zoohygienic conditions.

The data of investigations indicate that eimeriosis infection is observed mainly in the chickens aging from two weeks up to 45 days old and is associated with well pronounced clinical signs, being the main reason for the animal death.

At the same time, it can be mentioned that the relation of the causative agent of pathogenesis with the age of the host is eventually due to the adaptability developed throughout the evolution of the pathogens towards the animal body.

Introduction

It is well known that nowadays poultry farming is one of the profitable branches of livestock sector, which supplies high quality, dietary, protein-rich and animal-based meat and egg products to the population of the republic.

Eimeriosis is a widespread animal and human disease, the pathogens of which are sporing protozoa belonging to the subfamily of Eimeriinae. The pathogens of this subfamily

parasitize and end up their biocycle in one host organism (Lazareva and Perepelkina, 1999, Naghashyan, et al., 2017).

Young animals at the age of 10-90-day old are more susceptible towards the mentioned infection. Initially the pathogens propagate in the chickens' intestine asexually (merogony), and together with quantitative growth sexual propagation also takes place. The formed embryo is excreted to the external medium together with the poultry feces in the form of oocyst (allantoic sac) and surviving

the sporogonic period, it becomes already contagious (Khovanskikh, et al., 1999, Chernukha and Gostev, 1987, Braunies, 1984, Jadhav, et al., 2011). Eimeriosis is mainly a disease of juvenile chicks and is spread worldwide, including Republic of Armenia.

It is known that the intensity of chickens' eimeriosis infection is different in various geographic and climatic zones related to temperature, relative air humidity and precipitations (Mkrtychyan, 1995, Naghashyan, et al., 2017, Rakhimzhanov, 1988, Nematollahi, et al., 2008, Novikov and Safiullin, 2015).

The egg production capacity of the eimeriosis-diseased and recovered laying chickens is reduced by 10-80 %, while the meat yield per a broiler makes 270 g (Bakulin, 2006, Bolotnikov, 1979, Naghashyan, et al., 2017).

In the adult chickens the clinical manifestation of the disease is absent but they are infection carriers. K.L. Abuladze (1999) reports, that in the large poultry farms no seasonality of eimeriosis is observed.

Materials and methods

The research was conducted from October 2021 to March 2022 within the frame of the topic encoded as 21T-4A007 in the laboratories of the Chair of Epidemiology and Parasitology at the Armenian National Agrarian University and ANAU Research Center of Veterinary Medicine and Veterinary Sanitary Examination.

Feces samples of the chickens kept in cage and floor housing conditions taken from the poultry farms of Yerevan city, Aragatsotn, Lori, Gegharkunik and Tavush regions of the RA have served as a study subject. To determine the prevalence of chicken eimeriosis among different age groups, 180 samples of bird droppings were studied, while 135 samples of droppings, taken equally from the mountainous, piedmont and lowland belts of the republic, were studied to determine the infection rate of chicken eimeriosis per housing type and climatic-geographical zones. The disease of eimeriosis was diagnosed in the chickens based on the epidemiological data, clinical signs, as well as on the laboratory research data of the feces samples. The samples have been investigated through flotation methods – Fuelleborn's and Darling's methodologies.

It is worth mentioning that implementing investigations through the Darling's method is more relevant, since in that case the studied field of view is more clearly visible under the microscope. The micro-preparations were viewed with the microscopes of 80x magnification and if

required we covered them with coverslips and viewed with that of 400x magnification.

Results and discussions

The prevalence of chicken eimeriosis has been studied per the geographical and climatic zones of the republic, as well as according to the poultry housing type, while the eimeriosis infection level has been determined per the age group and zoo-hygienic conditions.

During the investigations the sanitary-hygienic conditions of livestock house, i.e., ventilation, lighting, feeding facilities and other factors have been taken into account. The data introduced in Table indicate the infection rate of chicken eimeriosis per the age group.

Throughout the investigations it has been found out that in the chickens of up to 14 days old, the infection rate has made 24 % in case of floor housing, while in conditions of cage housing the same index makes 15 %. In the 14-45-day chickens the mentioned index has amounted to 51 % and 36 %, while in those of 45-90 years old – 27 % and 20 % respectively.

The research results indicate that the high infection rate with eimeriosis is mainly recorded in the poultry aging from two weeks up to 45 days old associated with well pronounced clinical signs, which causes animal death for the most cases.

Table. The infection rate of chicken eimeriosis per the age groups (30 samples from each farm have been investigated)*

Farms	Up to 14 days old chickens		14-45 days old chicken		45-90 days old chicken	
	Infection rate %		Infection rate %		Infection rate %	
	Floor housing	Cage housing	Floor housing	Cage housing	Floor housing	Cage housing
Tsovagyugh	4	1	6	5	3	2
Sevan	4	2	8	5	5	2
Dilijan	5	4	10	6	6	4
Ijevan	4	4	10	7	6	6
Stepanavan	4	3	10	8	6	4
Aparan	3	1	7	5	1	2
Total	24	15	51	36	27	20

*Composed by the authors.

Meanwhile, it can be inferred that the relation of causative agent's pathogenesis with the age of the host organism is possibly due to the adaptability of the pathogens towards the animal organism formed throughout their evolution process, i.e., the eimeriosis pathogens are adapted mainly to a specific medium, which exists particularly in the poultry of the abovementioned age group.

While examining the litter samples, a huge number of oocysts were found in a field of the microscope view (Figure 1).

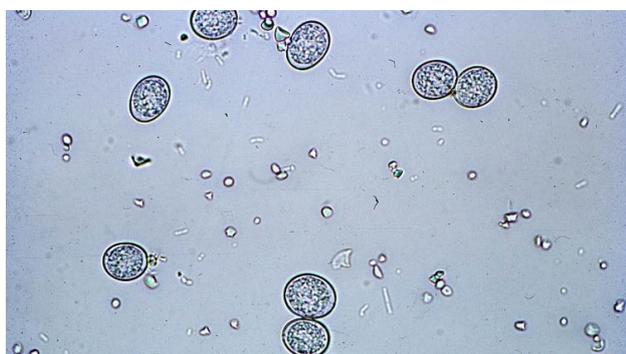


Figure 1. Oocysts of eimeria in chickens.

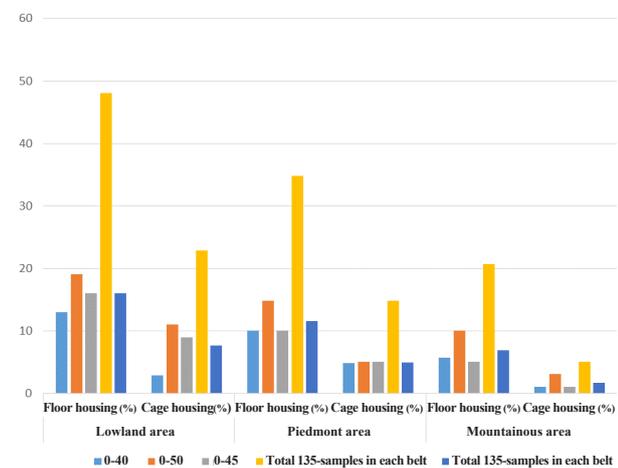


Figure 2. Determination of chickens eimeriosis infection rate per the geographical and climatic zones and housing type (composed by the authors).

According to the geographical and climatic zones, the incidence of the chickens' eimeriosis in the lowland area has made 48 % in case of floor housing and 22.9 % in case of cage housing. In the piedmont zone it makes 34.8 % and 14.8 % and in the mountainous area – 20.7 % and 5.1 % respectively.

The research results make it evident (Figure 2) that the highest incidence rate of the eimeriosis disease has been recorded in conditions of floor housing in the lowland areas. So, on the whole, the infection indices in the lowland, piedmont and mountainous areas have subsequently decreased by 13.2 % and 14.1 % in case of floor housing, while in conditions of cage housing – by 8.1 % and 9.7 % respectively. The infection rate of 40 feces samples taken from the floor housed animals in lowland geographical zone averaged 16 %, and in cage housed chicken it was 7.6 %, the infection rate of 50 feces samples taken from the animals of piedmont geographical zone was 11.6 % and 4.9 % respectively, while the contamination of 45 feces samples taken from the chickens of mountainous climatic zone was 6.9 % and 1.7 %, respectively.

The mentioned indicators resulted per the zoning and housing characteristics are evidently due to the effect of temperature, moisture and direct solar radiation, as well as the contact of the chickens imposed upon the housing type of the poultry.

It is noteworthy that in all poultry farms the feeding conditions were at high level: the feed ration of the animals was rich, contained fresh-cut grass and hay, anyhow, the unfavorable zoo-hygienic conditions, for example, fouled cell floors/bottom nets of the cages and anti-sanitary state of troughs and water tanks and, what is most important, the high relative air humidity in the livestock houses were likely to promote the spread of eimeriosis. In the aforementioned farms the ventilation facilities were missing, while ventilation was provided via the entrance doors.

Chickens with eimeriosis are depressed, gather in heaps, lose their appetite, lag behind in growth and development and significant losses are recorded among the young chickens (Figure 3).



Figure 3. 5-month-old chickens infected with eimeriosis.

The main source of the disease spread is the infected chicken who contaminate the external medium through the excrement.

Conclusion

1. The poultry infection with eimeriosis is mainly observed in the chickens aging from two weeks up to 45 years old and the disease is associated with clearly pronounced clinical signs leading the animals to death.
2. The infection rate determined per zoning and housing forms is closely related to the temperature, humidity, direct sun radiation effects and the contacts between the chickens as a result of housing conditions.
3. The floor housing of the poultry promotes the quick transmission of the eimeriosis pathogen, which takes place only via alimentary tract.
4. Cage housing prevents both the dissemination of eimeriosis biological agent and the further development of Eimeria.

References

1. Abuladze, K.I. (1975). Parasitology and Invasion Diseases of Farm Animals. - M., 1975, - 472 p. (in Russian).
2. Bakulin, V.A. (2006). Poultry Diseases. - St. Petersburg, - 686 p. (in Russian).
3. Bolotnikov, I.A. (1979). Coccidiosis: Coccidiosis of Chickens and Measures to Combat them / I.A. Bolotnikov, V.F. Krylov // Petrozavodsk, - p. 49 (in Russian).
4. Braunies, W.W. (1984). Epidemiology of Eimeria in Broiler Fowls and the Effect of Anticoccidial Drugs on the Econom Performance / W.W. Braunies // Zootech. Journ. - V. 6, - pp.48-53.
5. Chernukha, V.K., Gostev, D.I. Some Questions of the Epizootology of Porcine Coccidiosis // Modern Problems of Protozoology: Abstracts of Reports 1 at the Congress of the All-Union Society of Protozoologists. Leningrad, - p. 163 (in Russian).
6. Jadhav, B.N., Nikam, S.V., Bhamre, S.N., Jaid, E.L. (2011). Study of Eimeria Necatrix in Broiler Chicken from Aurangabad District of Maharashtra State India // Intern. Multidis. Res. - V. 1, - pp. 11-12.
7. Khovanskikh, A.E., Ilyushechkin, Yu.P., Kirillov, A.I. (1999). Coccidiosis of Poultry. - L.: Agropromizdat, - 151 p. (in Russian).
8. Lazareva, O.F., Perepelkina, O.V. (1999). All-Russian Conference with International Participation: Ecology and Distribution of Corvids in Russia and Neighboring Countries. Conference of Ornithologists of the CIS Countries, Stavropol (in Russian).
9. Mkrtchyan, M. E. (1995). Epizootology and Therapy of Mixed Ascaridiosis-Coccidiosis Invasion of Chickens in Armenia: Ph.D. Cand. Biol. Sciences: 03.00.19 Yerevan, - 117 p. RSL OD, 61:06-3/956.
10. Naghashyan, O.Z., Shcherbakov, O.V., Hakobyan, A.R., Grigoryan, L.G. (2017). Parasitic Associations of Chickens in Small Poultry Farms in Armenia. Proceedings of the International Scientific Conference "Biological Diversity and Problems of Fauna Protection - 3". September 27-29, Yerevan, Armenia, - pp. 222-224 (in Russian).
11. Nematollahi, A., Moghaddam, G.H., Niyazpour, F. (2008). Prevalence of Eimeria spp. among Broiler Chicks in Tabriz (Northwest of Iran) // Res. J. Poult. Sci. - V. 2, - pp. 72-74.
12. Novikov, P. V., Safullin, R.T. (2015). Methodical Guidelines for the Struggle against Chicken Eimeriosis in Farms and Private Subsidiary Holdings // Russian Journal of Parasitology, - V.4, - pp. 109-113 (in Russian). <https://doi.org/10.12737/17818>.
13. Rakhimzhanov, B.A. (1988). Eimeriosis of Chickens (Prevention and Immunogenesis) / B.A. Rakhimzhanov // Abstract, Ph.D. Candidate of Veterinary Sciences, L., - 16 p. (in Russian).

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Epidemiological Peculiarities and Economic Efficiency of Veterinary Measures in Case of Diplococcal Infection of Pigs

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ABSTRACT

The article presents epizootological and clinicomorphological data on the course of diplococcus septicus infection of piglets in private pig-growing farms of Kotayk Region, Republic of Armenia. According to the results of the studies, the main reasons for the appearance of the mentioned infection among piglets is the failure in observing zoohygienic and veterinary-sanitary rules throughout housing of animals, as well as the lack of immunoprophylactic measures. Timely vaccination of gestating sows provides natural lactogenic immunity in piglets, preventing significant economic losses resulted from the death of sick animals and the expenses spent for therapeutic measures.

Introduction

The main principle in practical struggle against infectious diseases is the severance of epidemic chain in any of its loops or prevention of epidemic process transformation into other infection forms.

Immunoprevention changes the relationship between protective forces of animal body and pathogenesis of microorganisms and is considered to be one of the measures to prevent all forms of an epidemic and contribute to the interruption of the epidemic chain in a specific flock. Contagious diseases are endowed with high propagation rate and ability to cause mass animal infection. Hence, they are very dangerous and exert negative socio-economic effect, whereby affecting common state interests.

Immunoprevention is the integral part of the total strategic and tactical measures against infectious diseases, and in case of its correct implementation the hazards, though not completely eliminated, significantly get declined. The purpose of immunization is not to eradicate infectious diseases, but to timely prevent the disease of animals in the given area (Annikov, et al., 2010, Kislenko, 2012, Kolyakov, 1991, Petrov, 1984).

In pig breeding, when there is a great number of animal units, immunoprophylaxy is considered to be the crucial component for infectious disease prevention; so, it should be included in the production process and fit with the technological procedures, so that animals could be provided with full immune protection.

Pig breeding safety can be violated by a number of microbial diseases, which are characterized by high infectivity and propagation rate for a rather short time, which leads to considerable financial losses; Pasteurellosis, Salmonellosis, Streptococcosis, etc., are among these diseases. So, for the target research we have chosen pig farms, where no preventive measures against the infection diseases have been implemented.

Materials and methods

The research work was carried out in 2021 in a private pig breeding farms of Kotayk region. The livestock, not exceeding 140-160 animals, included 18-20 sows, 80-100 units of 1-4 months old piglets, and 30-40 units of above-6-month-old fattened pigs.

Epizootological, clinical and post-mortem diagnosis of the fallen animals per pathoanatomical examination was carried out in these pig farms. The calculation of economic losses, as well as estimation of the effectiveness of veterinary measures was carried in line with the formulae set out in the textbook on veterinary economics (Grigoryan, 2005).

Studies have been conducted in the laboratory of the department of Epidemiology and Parasitology of Armenian National Agrarian University. Blood taken from the heart of the animals died of clinically pronounced diplococcal infection or those subjected to forced slaughter but not having been treated with antibiotics, their liver, spleen, tubular bones, pieces of lungs taken at the borders of healthy and affected tissues and lymph nodes served as a pathological material for laboratory investigations. Smear-prints were prepared from the pathological material and sowing from the same material was carried out into the universal nutrient media: meat-peptone agar and meat-peptone broth at a concentration of 7.2 hydrogen ions, followed by incubation in a thermostat at the temperature of 37-38 °C for 24-48 hours. Bacterial smears prepared from both pathological material and colonies grown on nutrient media were stained using the Gram method (Antonov, et al., 1986, Baryshnikov, 2019, Gosmanov, 2014, Zykin, 2006). Microscopic examination of the stained smears identified oval and lanceolate cocci measuring 0.6-1.0 microns, arranged in pairs and in the form of chains (Figure 5).

Results and discussions

In order to identify the epizootological conditions in the pig farms of Kotayk region, relevant monitoring was

carried out, which is a specially organized sequential control, implying ongoing data collection on a specific infectious disease.

In the investigated farm, animals affected with different forms of diplococcal infection were detected. In piglets aged from one to three months, the superacute (infectious-toxic) and acute forms of the disease prevailed. Sick piglets refused feeding, were motionless, from time to time muscular tremor was observed and body temperature fluctuated within 40-42 °C. Breathing was rapid and heavy, sometimes prior to falling, asphyxia was observed due to pulmonary edema, manifested by wheezing, foamy discharge from the nostrils, bluishness of visible mucous membranes, thread-like arrhythmic pulse. The acute form of the disease was characterized by general weakness, lack of reaction to external stimuli, redness of the conjunctiva and lacrimation. In parallel with septic changes, diarrhea was observed, feces were liquid with traces of mucus and blood. As a result of diarrhea, animals were rapidly emaciated and weakened.

In young animals aged from two to four months, a subacute and chronic course of infection with articular, pulmonary and mixed forms of the disease was observed. The affected joints were pain-sensitive, swollen, with an increased local temperature, which was manifested by the lameness of sick animals (Figures 1, 4). Sometimes signs of inflammation in the area of the affected joint disappeared with subsequent occurrence in other joints of the same or other limb. The pulmonary form was manifested by catarrhal pneumonia, seromucous discharge was observed from the nostrils at first, later transforming into purulent discharge. The cough, initially dry and rare, subsequently became moist, frequent and painful. The fever was not constant, the appetite was fickle.

Very often, purulent mastitis and metritis were observed in sows after parturition.

In the case of superacute course of the disease, only massive hemorrhages in the gastrointestinal tract, in the peritoneum and the outer and inner membranes of the heart were observed in the animals that fell and were subjected to forced slaughter. In the acute intestinal form of infection, the disease was manifested by the presence of hemorrhagic exudate in the abdominal cavity, hemorrhages on the mucous membranes of the stomach and intestines. The liver was somewhat enlarged, clay-colored. The spleen was swollen and enlarged, sometimes dark cherry-colored with a tense capsule, rounded edges and a rubber-like consistency. In the pulmonary form of the acute course of the disease, foci of hemorrhagic and serous inflammation were observed, the mucous membranes of the trachea and



Figure 1. Joint damage.



Figure 2. Lung abscess.



Figure 3. Hemorrhagic pneumonia.



Figure 4. Autopsy picture.

bronchus were hyperemic and covered with mucopurulent exudate. Mediastinal lymph nodes were enlarged, hyperemic. The surface of the pulmonary and costal pleura was covered with fibrin membranes and adhesive pleurisy and pericarditis were observed.

Pathological changes in the subacute and chronic course of infection were observed both in the respiratory organs and in the digestive system and in the joints. Granular necrotic and purulent foci of inflammation, abscesses with the size of a pea to a chicken egg were found in the lungs (Figures 2, 3).

Sporadic forms of the disease manifest themselves throughout the year, however, depending on predisposing factors, it can occur in the form of epizootic outbreaks, the intensity of which depends on the number of susceptible animals, as well as on keeping and feeding conditions.

According to the literature, the lethality/mortality of animals in case of diplococcal infection reaches 30.9 %; however, in the case of epizootic outbreaks, 30-50 % of piglets are infected, and accordingly, the mortality ranges from 70 % to 90 % (Grigoryan, 2002, Aliyev, 2020, Lapytov, 2019, Pleshakova, 2019, Chepurov and Cherkasova, 1963).

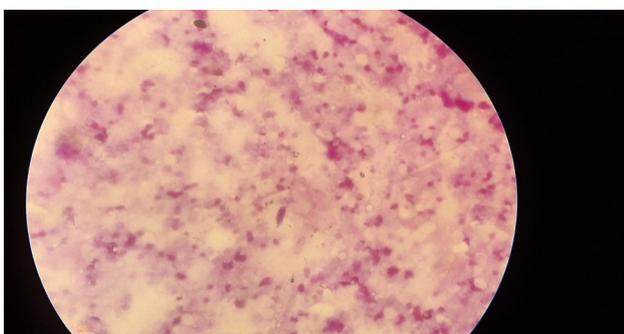


Figure 5. The causative agent of diplococcal infection under a microscope.

The actual economic damage is caused by the death and forced slaughter of the animals, as well as due to the expenses spent for therapeutic and preventive measures. On the example of one of the pig farms subjected to epizootic monitoring, we calculated the effectiveness of veterinary measures. The actual damage caused by the death of pigs with diplococcal infection was calculated using the following formula:

$$DI = N \times W \times C - SP.$$

In this formula, *DI* is the actual economic damage caused by the death of sick pigs, *N* is the total number of dead animals, *W* is the average live weight of dead pigs in this age group expressed in kilograms, *C* is the average cost of live weight of a healthy animal unit in conventional units, and *SP* is the profit received from the sale of slaughter products in case of forced slaughter of sick animals, expressed in drams.

The live weight of one-month-old piglets averaged 8 kg. Since the net slaughter yield of pigs is 80 %, and the market value of one kilogram of pork is on average 2900 drams, the cost of one kilogram of live weight (*C*) will be estimated as 2320 drams. A total of 10 piglets fell, the corpses of which were destroyed by incineration, which means the profit from the sale of slaughter products is zero. The actual damage caused by the piglets' death was

$$D_1 = 10 \times 8 \times 2320 - 0 = 185600 \text{ drams.}$$

Depending on the number of dead animals, the actual economic damage can be amounted to huge amounts.

Currently, monovalent and polyvalent vaccines have been proposed for the prevention of diplococcal infection of piglets, out of which the inactivated polyvalent formol vaccine against paratyph, pasteurellosis and diplococcal infection of pigs (PPD) have the greatest practical application. In vaccinated animals, immunity to the above stated infections is formed 12-12 days after the second

injection and persists for 6 months. Natural passive (dairy) immunity in piglets born from vaccinated sows persists for one month after birth.

According to the instructions, pregnant sows are vaccinated 15-40 days before parturition, and piglets can be vaccinated at 20-30 days of age. Pregnant sows are vaccinated three times: 35-40 days before parturition vaccination dose is 5 ml, 25-30 days before parturition it makes 10 ml and 15-20 days before parturition vaccination dose makes 10 ml. Piglets are vaccinated twice: the first time the vaccine is administered 7-10 days before separating piglets from their mothers /weaning/ with the dose of 3 ml, and the second time – 5-7 days after the first injection with the dose of 4 ml. 25 ml is spent for the vaccination of one pregnant sow, and 7 ml of vaccine is spent for vaccination of one piglet. One bottle of vaccine with a holding capacity of 100 ml is sold averagely for 1100 drams in veterinary pharmacies. So, let's try to estimate the economic efficiency of veterinary measures (in our case it is vaccination) via the following formula:

$$Pdl = M_n \times K_m \times K_{ed} - d,$$

where Pdl is the damage prevented as a result of a preventive measure, M_n is the number of susceptible animals subjected to preventive vaccination, K_m is the morbidity coefficient of animals with this disease (defined as the ratio of the number of sick animals to the number of animals susceptible to this infection), K_{ed} is the coefficient of economic damage in relation to one sick animal (defined as the ratio of the actual economic damage to the number of sick animals) and d is the actual economic damage, which is calculated as zero in the disease-resistant farms.

In the pig farm under study, 100 piglets were vaccinated, while in a neighboring vulnerable farm, where 30 out of 100 piglets got sick, the morbidity rate was 0.3, and the economic damage coefficient per piglet was 6187 drams, which means that the prevented economic damage due to vaccination will be:

$$Pdl = 100 \times 0.3 \times 6187 - 0 = 185610 \text{ drams.}$$

The economic efficiency of the veterinary measures carried out is determined by the formula $Ev = Pd - Cv$, as the difference between the prevented damage and veterinary costs expressed in drams (the cost of the biological product used). In the case under consideration, the effectiveness of the conducted immunoprophylaxis is:

$$Ev = 185610 - 1100 = 184510 \text{ drams.}$$

The economic efficiency of the veterinary measures per dram spent is defined as the ratio of the economic

efficiency of the measures carried out to the veterinary costs according to the formula $Ee = Ev / Cv$. In the case we are considering, this indicator will be:

$$Ee = 184510 / 1100 = 167.8 \text{ drams.}$$

As a result of preventive vaccination carried out in the pig farm, damage equal to 185610 drams was prevented, and each dram spent was reimbursed in the amount of 167.8 drams.

Conclusion

Taking into account the data of epizootological, clinical and laboratory studies, it can be concluded that diplococcal infection is a common disease in pig farms of the republic. The spread of the disease is facilitated by the poor sanitary condition of farms, poor keeping and feeding conditions of animals and, mostly by the high concentration of pigs in confined spaces and lack of immunoprophylaxis. Young pigs are susceptible to the disease, while adult pigs are bacterial carriers.

For the prevention of diplococcal infection, highly effective mono and polyvalent vaccines have been proposed, which can be used in both safe (disease-resistant) and unprotected farms.

Currently, diplococcal infection has been registered in the pig farms of Kotayk region of the Republic of Armenia. As a result of epizootological, clinical, pathoanatomic and laboratory studies, it was found out that the disease mainly occurs in the form of small epizootics among piglets aged from 1 to 4 months old. Besides, the disease is mainly registered in the pig farms, where planned immunoprophylaxis is not carried out.

Summarizing the results of the preventive measures carried out, it can be concluded that vaccination of sows and piglets in the pig farms surveyed by our research group makes it possible to prevent significant economic loss and demonstrates high efficiency in the immunoprophylactic measures carried out.

References

1. Grigoryan, S.L. (2002). Epizootology and Infectious Diseases of Farm Animals. Yerevan – “Astghik” Publishing House, - pp. 540-542 (in Armenian).
2. Grigoryan, S.L. (2005). Organization of Veterinary Activities. Yerevan, - pp. 173-196 (in Armenian).
3. Aliyev, A.S. (2020). Epizootology with Microbiology:

- Textbook / A.S. Aliyev, Yu.Yu. Danko, I.D. Eshchenko [et al.]; Edited by V.A. Kuzmin, A.V. Svyatsky. – 5th Ed., - St. Petersburg: Lan, - 432 p.
4. Annikov, V.V., Belov, L.G., Kaptyushin, V.A. (2010). Immunoprophylaxis of Infectious Diseases of Animals. Saratov, – pp. 45-49 (in Russian).
 5. Antonov, B.I., Borisova, V.V., Volkova, P.M. (1986). Laboratory Research in Veterinary Medicine. Bacterial Infections: Handbook/Comp; Edited by B. I. Antonov. – M.: Agropromizdat, - pp. 221-224 (in Russian).
 6. Baryshnikov, P.I. (2019). Laboratory Diagnostics of Bacterial Diseases in Animals: Textbook / P.I. Baryshnikov. - St. Petersburg: Lan, - 712 p. (in Russian).
 7. Gosmanov, R.G. (2014). Workshop on Veterinary Microbiology and Mycology [Text]: Textbook for Higher Education Students Specialized in Agrarian Branch Studying in the Specialty of “Veterinary Medicine” / R.G. Gosmanov, N.M. Kolychev, A.A. Barskov. - St. Petersburg; Moscow; Krasnodar: Lan, - 380 p. (in Russian).
 8. Zykin, L.F. (2006). Clinical Microbiology for Veterinarians [Text]: Textbook. Manual for the University Students Studying in the Specialty of “Veterinary Medicine” / L.F. Zykin, Z.Y. Khaptsev; International Association “Agrieducation”. - M.: Kolos, - 96 p. (in Russian).
 9. Kislenko, V.N. (2012). Veterinary Microbiology and Immunology. Workshop [Text], a Textbook for Students of Universities Studying in the Specialty of “Veterinary Medicine”: Approved by the Ministry of Agriculture of the Russian Federation / V.N. Kislenko – St. Petersburg; M.; Krasnodar: Lan, - pp. 45-49 (in Russian).
 10. Kolyakov, Ya.E. (1991). Veterinary Microbiology and Immunology (Edited by N.A. Radchuk) - M., – 5 p. (in Russian).
 11. Lapytov, D.G. (2019). Handbook of Pathoanatomic Diagnostics of Infectious Diseases of Pigs: Textbook / D.G. Lapytov - St. Petersburg: Lan, - 260 p. (in Russian).
 12. Pleshakova, V.I. (2019). Viral and Bacterial Diseases of Pigs: Textbook / V.I. Pleshakova, I.G. Alekseeva, N.A. Leshcheva - St. Petersburg: Lan, – 152 p.
 13. Petrov, R.V. (1984). Immunology. M., - 384 p. (in Russian).
 14. Chepurov, K.P., Cherkasova, A.V. (1963). Diplococcal and Streptococcal Diseases of Animals, K., - 25 p.

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Treatment of Third-Degree Thermal Burns in Dogs with Ozonated Vegetable Oil

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efficiency*

ABSTRACT

When comparing the blood indicators of the animals treated with ozonated vegetable oil with those of the animals treated with 0.2 % furacillin ointment, it becomes vivid that on all research days (3rd, 9th and 17th) the blood indicators of experimental animals recover faster than those of the control animals. Upon the experiments it has been proved that when treating the third-degree burn with ozonated vegetable oil, the burn wound is recovered 3 days earlier than in case of treating it with 0.2 % furacillin ointment. This is due to the reduction of hydration phase and active wound granulation process.

Introduction

Thermal burns are classified in four degrees. Depending on the burns degree, different rates of purulent-necrotic changes take place in tissues. In case of deep burns necrotic and sub-necrotic zones can be identified in the burned sector (Aydogan and Gurol, 2006). In the zone of necrosis all cells are devitalized, including even nerves. In the zone near necrosis the blood capillaries are obstructed/blocked with blood coagulum/clots, as a result of which the nutrition of lesion foci becomes disturbed (Alekseev, et al., 2001, Bernat, 1975, Barret and Herndon, 2003). This circumstance leads to the prolongation of burn wound granulation. Removal of the necrotic tissues from the healthy ones is retarded, which can result in the development of purulent-necrotic inflammation; the

granulated tissue growth and epidermization processes are missing causing lesions (Alekseev, et al, 1998).

Necrotic tissues gradually break down resulting in toxins generation, which getting imbibed by the organism, cause autotoxicosis, as well as violations in nerval, cardiovascular systems and pathological, blood morphological and biological modifications (Astamirov, 2001, Babakhanyan, et al., 2002). In the field of medical science, a number of antimicrobial, sulfanilamide, antiseptic, stimulant and analgesic drugs are used to treat different degrees of burns, which, anyhow, have demonstrated low treatment efficacy. By means of the afore stated medicinal drugs the treatment process is delayed, huge economic expenses are required and the quality and quantity of livestock products decline (Browne, et al., 1985).

Throughout the process of burn treatment the bacteria are getting used to the applied medicinal drugs, as a result of which the treatment efficiency is reduced. So, there is a need to frequently alter the applied drugs during the treatment process (Aydogan and Gurol, 2006, Baskaran, et al., 2001).

Materials and methods

The investigations were conducted in the operation room and laboratory of the Chair of Therapy, Surgery and Obstetrics, at the Armenian National Agrarian University, while the experimental animals were kept in the barn belonging to the mentioned chair. Ten heads of 1.5-2-year-old crossbred dogs were selected upon the similarity principle weighing 7-10 kg.

The animals were divided into two groups: control and experimental, with 5 animals in each group. The selected animals were in good health. Blood was taken from the subcutaneous vein of the forelimbs in all animals. The erythrocyte and leucocyte amounts were determined through Goryaev method, hemoglobin was determined through Sahli's Haemometer, ESR (Erythrocyte Sedimentation Rate) – with Panchenkov's apparatus and the leucocyte count/leukoformula – in blood smear. These indicators were considered as those of healthy animals and were compared with sick animals.

In the external part of the animals' thighs/elbows from both groups, burns were produced. The mentioned body parts were dehaired in advance and then anesthetized via administration of local circumferential anesthesia round the elbow sector with 0.5 % novocaine solution using 5 ml for each animal. The burn was produced through touching the skin surface with heated metal. In all animals the burning area made 12 cm² (coincided with the sizes of metal object area). The following day after getting burn, the burned parts obtained grey coloring, became senseless and turned into coagulative necrosis, while the surrounding tissues were reddened and swollen. The animals of control group were treated with 0.2 % furacillin ointment and the animals of experimental group were cured through ozonated vegetable oil with the simultaneous use of Bernard's Current. The objective was to improve the blood circulation in that body part, thereby promoting the disintegration of the necrotic tissues from the healthy ones and accelerating the growth of the granulation tissues. The burns were treated in an open way without any bandage; protective collars were put round the animals' necks. Daily clinical examination was carried out in the animals of both groups, while the hematological investigations were conducted on the 3rd (third), 9th (ninth) and 17th (seventeenth) days of treatment.

Results and discussions

Ozonated vegetable oil is a natural, activated olive oil containing carbonic acid ozonides. A goal was set up to investigate the efficiency of the ozonated vegetable oils in the treatment process of third-degree burns and to conduct result analysis.

During the clinical investigations 2 days after burn creation, swelling and redness round the produced burns in the animals of both groups, as well as increase in the local temperature, pain and necrotic tissues in the burned sector encompassing all dermal layers were observed.

The burn of the control animals was treated as follows: the injured body part was preliminarily treated with 1:1000 potassium permanganate solution, dried out with sterile cotton balls and then oiled with 0.2 % furacillin ointment. The burned body part of the experimental animals was also treated with 1:1000 potassium permanganate, again dried out with sterile cotton balls and then oiled with ozonated vegetable oil once a day.

The blood research results have indicated that after getting burn, qualitative and quantitative changes in the blood of control animals took place. When comparing the indicators of the control animals with those of healthy ones, it is marked that on the 3rd day of treatment the hemoglobin content increased by 30 g/L, erythrocyte content – by $1.7 \cdot 10^{12}/L$, leucocytes – by $3.0 \cdot 10^9/L$ and ESR – by 2 mm/hour.

Considerable changes were observed in the leukocyte count/leukoformula as well: basophils grew up by 2 %, eosinophils – by 3 %, out of neutrophils the young ones increased by 11 %, polymorphonuclear leukocytes/stick-nuclear – by 7 %, while the segmented /segmentonuclear neutrophils decreased by 3 % and lymphocytes – by 12 %, whereas monocytes grew up by 6 %.

In the experimental animals the following changes were recorded: on the 3rd day of treatment the hemoglobin amount increased by 20.0 g/L, erythrocyte content – by $1.1 \cdot 10^{12}/L$, leucocytes – by $2.0 \cdot 10^9/L$ (thousand), ESR – by 1 mm/hour and in leukocyte count/leukoformula again significant changes were recorded: basophils increased by 2 %, eosinophils – by 3 %, out of neutrophils the young ones grew up by 8 %, polymorphonuclear leukocytes – by 7 %, while the segmented neutrophils decreased by 4 %, lymphocytes – by 8 %, whereas monocytes grew up by 4 %. When comparing the blood research results of the experimental animals on the 9th day of treatment with the indicators recorded on the 3rd day of treatment, it becomes obvious that they are gradually approximating to the indices of healthy animals. Thus the content of hemoglobin decreased by 10 g/L, erythrocytes – by $0.2 \cdot 10^{12}/L$, leucocytes – by $1.0 \cdot 10^9/L$ and ESR – by 1.0 mm/hour.

Table. Blood indicators of burn-affected dogs*

M±m

Name of medicinal drug	Days	Hemoglobin, g/L	Erythrocytes 10 ¹² /L	Leukocytes 10 ⁹ /L	ESR mm/hour	Leukoformula						
						Basophils	Eosinophils	Neutrophils			Lymphocytes	Monocytes
								Young	Stick-nuclear	Seg-nuclear		
Healthy		120±2.5	5.5±0.4	8.0±0.7	2.0±0.1	4.0±0.01	1.0±0.01	-	5.0±1.0	15.0±1.8	72.0±3.4	3.0±0.2
0.2 % furacillin ointment	3	150±3.1	7.2±0.6	11.0±1.1	4.0±0.5	6.0±0.8	4.0±0.5	11.0±1.4	12.0±1.8	12.0±2.2	60.0±2.6	9.0±1.5
	9	140±2.8	7.0±1.1	9.5±1.0	3.5±0.7	5.0±0.9	3.0±0.1	9.0±1.3	11.0±1.9	8.0±2.0	65.0±3.3	5.0±1.2
	17	120±1.9	6.0±0.8	8.8±1.1	2.5±0.4	5.0±1.0	2.0±0.1	6.0±1.1	7.0±1.6	10.0±2.3	70.0±3.1	4.0±0.8
Ozonated vegetable oil	3	140±1.7	6.6±0.6	10.0±0.9	3.0±0.4	6.0±0.7	4.0±0.6	8.0±1.7	12.0±1.4	11.0±1.9	64.0±3.0	7.0±0.9
	9	130±0.9	6.4±0.7	9.0±1.0	2.0±0.5	5.0±0.8	2.0±0.3	8.0±1.8	9.0±1.2	9.0±2.0	68.0±2.4	5.0±0.7
	17	120±1.0	5.7±0.4	8.2±1.1	1.0±0.2	4.0±0.3	1.0±0.2	4.0±0.3	6.0±0.7	16.0±2.6	72.0±3.1	4.0±0.8

*Composed by the authors.

In the leukoformula the following changes were observed: basophil amounts reduced by 1 % and eosinophils – by 2 %. In the neutrophils the following changes were recorded: the amount of young neutrophils declined by 2 %, the stick-nuclear neutrophils – by 3 %, segmentonuclear neutrophils – by 3 %, lymphocytes increased by 4 % and monocytes decreased by 2 %.

Whereas, when comparing the blood indicators of the experimental animals on the 17th day of treatment with those recorded on the 9th day of treatment, it turns out that they are gradually becoming even closer to the blood indices of healthy animals with the recorded indicators of 10 g/L, 0.7·10¹²/L, 0.8·10⁹/L, 1 mm/hour, 1 %, 1 %, 4 %, 3 %, 7 %, 4 % and 1 % respectively, while compared to the blood indices of healthy animals the difference is estimated as 0 g/L, 0.2·10¹²/L, 0.2·10⁹/L, 1mm/hour and in leukoformula – 0 %, 0 %, 4 %, 1 %, 1 %, 0 %, 1 % respectively. As the table data indicate, the blood indices of the control animals, recorded on the 17th day of treatment, demonstrate considerable difference, when compared to those of healthy animals, which makes 0 g/L, 0.5·10¹²/L, 0.8·10⁹/L, 0.5 mm/hour against the respective indicators, and in leukocyte formula it makes 1 %, 1 %, 6 %, 2 %, 5 %, 2 %, 1 %, respectively. This comes to prove that when using 0.2 % furacillin ointment during the treatment process, the burn wound was not recovered completely and the treating process should be continued to full recovery.

When comparing the blood research results of the

experimental animals with those of the control animals, again significant differences are observed. Thus, on the 3rd treatment day the hemoglobin content declined by 10 g/L, erythrocytes – by 0.6·10¹²/L, leukocytes – by 1·10⁹/L and ESR – by 1 % and declining tendency in leukoformula indices is also observed: basophils – 0 %, eosinophils – 0 %, young neutrophils – by 3 %, stick nuclear neutrophils – by 0 %, segmentonuclear neutrophils – by 1 %, lymphocytes – by 4 % and monocytes – by 2 %. Comparing with the indices of the 9th day treatment the decline makes 10 g/L, 0.6·10¹²/L, 0.5 %, 1.5 mm/hour respectively and in leukoformula it is estimated as 0 %, 1 %, 1 %, 2 %, 1 %, 3 %, 0 % respectively. The comparison of the results obtained for the 17th day of treatment induced variations with the following respective indices: 0 g/L, 0.3·10¹²/L, 0.6·10⁹/L, 1.5mm/hour, 1 %, 1 %, 2 %, 1 %, 6 %, 2 %, 0 %.

Conclusion

Summing up the results obtained from the research work it can be surely stated that on the 17th day of treatment the animals of control group weren't completely recovered yet. Whilst, when comparing the results of the 17th day of treatment recorded for the experimental animals with those of healthy ones, it can be clearly registered that no considerable changes are observed: the hemoglobin contents are the same, the amounts of erythrocytes and leukocytes exceed only by 0.2 %, ESR is lower by

1 mm/hour, the content of basophils and eosinophils is recovered, young neutrophils exceed by 4 %, stick-nuclear and segmentonuclear neutrophils exceed only by 1 %, lymphocytes – by 0 % and monocytes – by 1 %. In the result of investigations, it was found out that on the 17th day of treatment the animals of experimental group completely recovered, while the granulation tissue growth and epidermization processes took place 3 days earlier than those recorded in the animals of control group.

References

1. Alekseev, A.A., Krutikov, M.G., Bobrovnikov, A.E. (1998). Antibiotic Therapy and Antibiotic Prophylaxis in Combustiology: New Approaches and Perspectives. New Treatment Methods for Burns Using Cultured Skin Cells // International Symposium, 2nd: Materials. – Saratov, - pp. 45-47 (in Russian).
2. Alekseev, A.A., Kudzoev, O.A., Sarygin, P.V. (2001). Rational Plastic Surgery of Local Deep Burns and Frostbites. Scientific Conference // Actual Problems of Traumatology and Orthopedics, Held within the Framework of the International Forum “Man and Trauma”: Thermal Trauma: Materials. - Nizhniy Novgorod. – 2, - pp. 69-70 (in Russian).
3. Astamirov, M.K. (2001). The Role of Central Hemodynamic Disorders and their Effect on Oxygen Delivery to Tissues in the Acute Period of Burn Injury in Children: Ph.D., Candidate of Medical Sciences (in Russian).
4. Aydogan, A., Gurol, M.D. (2006). Application of Gaseous Ozone for Inactivation of Bacillus Subtilis Spores. Journal of the Air & Waste Management Association. – United States. Feb; - vol. 56 (2), - pp. 179-185. <https://doi.org/10.1080/10473289.2006.10464443>.
5. Babakhanyan, O.V., Davidyan, N.R., Shamakhyan, O.M., Babakhanyan, A.G. (2002). The Results of the Use of “Iruksol” Ointment in the Treatment of Deep Burn Wounds in Elderly Patients. “Human Health”, Materials of the I National Scientific-Medical Conference. Yerevan (in Russian).
6. Barret, J.P., Herndon, D.N. (2003). Effects of Burn Wound Excision on Bacterial Colonization and Invasion. Plast Reconstr Surg; 111, - pp. 744-50. <https://doi.org/10.1097/01.prs.0000041445.76730.23>.
7. Baskaran, H., Toner, M., Yarmush, M.L., Berthiaume, F. (2001). Poloxamer - 188 Improves Capillary Blood Flow and Tissue Viability in a Cutaneous Burn Wound // J Surg Res; 101, - pp. 56-61. <https://doi.org/10.1006/jsre.2001.6262>.
8. Bernat, I. (1975). Pathogenesis of Burn Anemia (translated from Hungarian) Budapest: Publ. - A.N. Hungary, - p. 412.
9. Browne, G., Byrne, C., Brown, B., Pennock, M., Steiner, D., Roberts, R. (1985). Psychosocial Adjustment of Burn Survivors. Burns Incl Therm Inj; 12, - pp. 28-35.

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Developing and Improving the Production Technology of Canned Cold Smoked Rainbow Trout Fillet

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ARTICLE INFO

Keywords:

*rainbow trout,
cold smoking,
fillet,
canned,
HACCP system*

ABSTRACT

Fish and fish products are foods of high nutritional value. The current research aimed at improving the technology of manufacturing canned products from cold-smoked rainbow trout fillets has a certain scientific-practical significance.

Physicochemical indicators of the mentioned product were studied in the experimental and control samples. It has been revealed that energy value of the product is higher in the experimental sample than in control one, due to the content of proteins and fats.

HACCP system research has indicated that safety and biological indicators of the finished product meet the accepted standards. Therefore, the product is safe and can be offered to consumers.

Introduction

Nowadays, there are a lot of piscicultural farms, which provide the required raw materials in processing industry. Fish processing is of great importance as an alternative to irreplaceable food. It is necessary to consider natural, resource, market, economic and social factors of the environment for the sustainable development and reproduction of fish processing industry.

In-depth knowledge of fish processing technology enables to produce functional foods for different age groups of population and supply a range of high-quality food.

In the Republic of Armenia, a great number of rainbow

trout is bred and it is expedient to use pond rainbow trout in the production of canned food (Beglaryan and Aghababyan, 2021). Cold smoking is one of the canning methods.

Thus, conducting scientific research on the improvement of canning technology from cold smoked rainbow trout fillet has a certain scientific-practical significance, which confirms the relevance of the current work.

Materials and methods

Analytical methods (physicochemical, biochemical, safety, microbiological), accepted standards, technical conditions

and instructions approved by the relevant organizations were used in the work (Levanidov, 1987).

Experimental and theoretical research was carried out at the ANAU Chair of Animal-Based Food Products Processing Technology throughout 2019-2020 and the rainbow trout fillet served as a study subject.

The moisture content in the product was determined according to Gost 31448-98, fat content – through acid method with oil meter (Gost 23042-2015), the amount of minerals – through ashing method according to Gost 31727-2012, while the content of protein (water-soluble and salt-soluble) was determined via calculation method, and the presence of toxic elements was identified in accordance with Gost 26932 – 86.

One of the main quality indicators of the discussed food is its salt content, since the food is lightly brined. The amount of sodium salt was determined through Mohr's method per GOST 27207-87. The method is based on the precipitation of chlorine ions by means of silver ions in the presence of potassium chromate in the neutral medium. Metrological studies of food quality management were performed according to the method of A. Malkhasyan.

When implementing HACCP (hazard analysis and critical control points) system, the documentation content of the performed work should be reflected for each implementation stage. In the development and implementation of HACCP system, it is necessary to distinguish two main stages: the initial stage and basic stage.

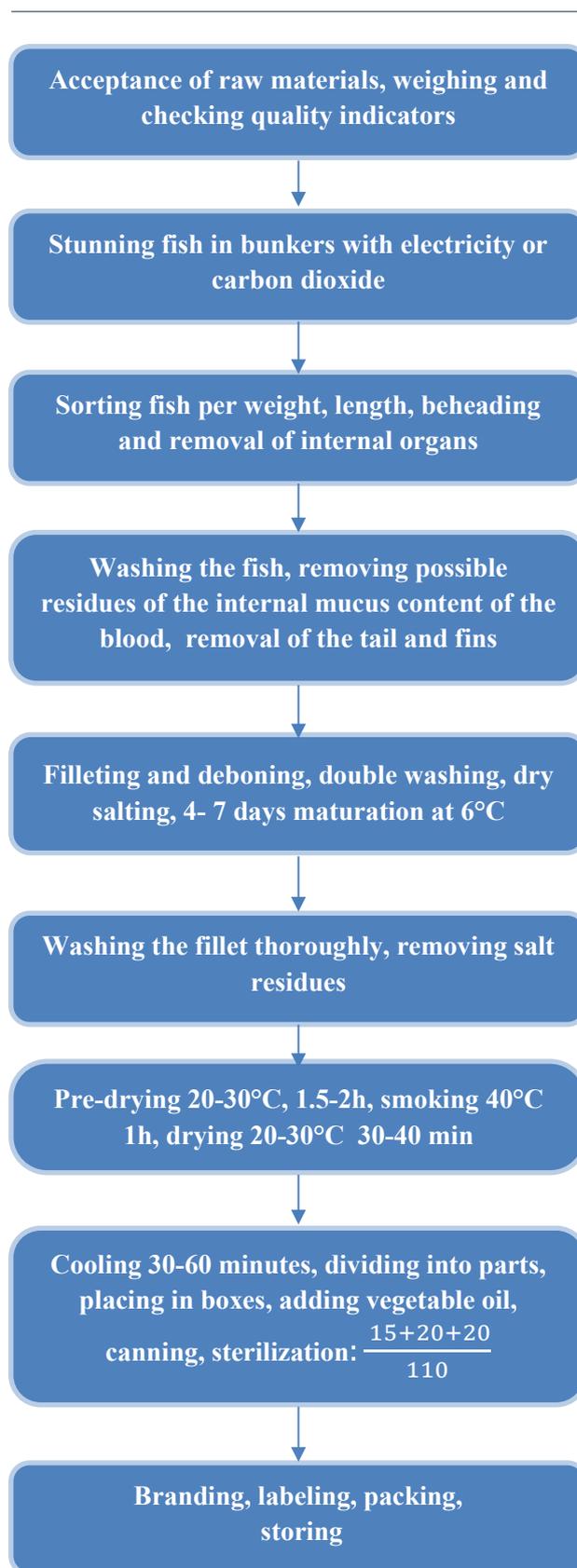
Results and discussions

The production of canned cold smoked rainbow trout fillet was implemented in line with the presented technological scheme.

The canned cold smoked rainbow trout has been produced according to the recipe described in Table 1.

The stored cans of cold smoked rainbow trout fillet were taken as a control variant (Korobeynik, 2002). Physicochemical indicators of control and experimental samples are introduced in Table 2.

The table data indicate that energy value of the product in experimental sample is higher than that of in the control sample (experimental sample – 282.06 kcal, control sample – 268.89 kcal), due to the content of proteins and fats in the product, meanwhile the summary of degustation results testified that the experimental samples had a specific pleasant taste and smell.



Scheme. Technological procedures of canned cold smoked fish production (composed by the author).

Table 1. The recipe of finished product per 100 kg raw stuff*

Main raw stuff	Spices and materials	Quantity, g
Trout fillet	Table salt	1200
	Sugar	40
	Seed pepper	400
	Aromatic pepper	400
	Laurel leaf	400
	Coriander seed	400
	Vegetable oil	1900

*Composed by the author.

Table 2. Physicochemical indicators and energy value of finished food product*

Indicators	Experimental (%)	Control (%)
The amount of minerals and salt	5.4±0.06	6.4±0.06
Moisture content	53.6±0.8	54.3±0.8
Oil content	23.0±0.5	22.0±0.5
Protein content	18.0±0.3	17.3±0.3
Energy value /kcal/	282.06	268.89
Energy value /kJ/	1118.3	1167.7

*Guidelines for Laboratory Work, 2000.

Food safety regulation is the key to the prevention of health problems ensuring that the food product is manufactured and used according to sanitary norms. The hazard analysis and critical control points system will guarantee consumers effective health protection measures throughout food production, processing and delivery cycle (Batikyan and Aghababayan, 2016). In our experiments safety indicators were studied according to the normative document and then according to the results of scientific experiments (Table 3). The obtained indicators comply with the standards stated for the given products upon the documents evidencing that they are safe and can be recommended to the consumers.

Conclusion

Based on the afore mentioned statements it can be concluded that technologies for rainbow trout canning production were thoroughly studied. The technology of manufacturing canned product from rainbow trout fillet through cold smoking was justified and improved.

Physicochemical indicators of control and experimental samples were researched. It has been confirmed that in the experimental samples the amount of minerals and salt was higher than in the control samples, while the moisture and oil contents were lower than in the control samples.

In the result of scientific experiments via implementation of HACCP system it has been proved that the recorded safety and bacteriological indicators for canned cold smoked rainbow trout fillet meet the standards of normative document. Thus, the mentioned product is safe and can be recommended to the consumers.

Table 3. Determination of safety indicators*

Indicator	Allowable level, mg/kg, no more /according to N2-III-4.9-o1-2010/	Lightly salted, smoked canned food	Compliance
Dioxins	0.000003	3-8	In compliance
Toxic elements			
Plumbum/lead	0.5	0.01	In compliance
Arsenium	0.1	Not detected	In compliance
Cadmium	0.05	Traces	In compliance
Mercury/quicksilver	0.03	Not detected	In compliance
Pesticides			
HCH (α -, β -, γ -) isomers	0.1	0.05	In compliance
DDT and its metabolites	0.1	0.03	In compliance
Radionuclides, bq/kg			
Cesium-137	160	100	In compliance
Strontium-90	50	20	In compliance

*Composed by the author.

References

1. Batikyan, H.G, Aghababyan, A.A. (2016). HACCP Food Safety Management System. Teaching Manual, Yerevan (in Armenian).
2. Beglaryan, R.A., Aghababyan, A.M. (2021). The Study of Biochemical Composition of Trout Fish Products: // "Agriscience" № 5-6, Yerevan, - pp. 361-363 (in Armenian).
3. Guidelines for Laboratory Work. Technology of Fish and Fish Products. Methods for Studying the Properties of Raw Materials and Foodstuffs. Astrakhan 2000 (in Russian).
4. Korobeynik, A.B. (2002). Processing and Commodity Research Technology of Fish and Fish Products, - 288 p. (in Russian).
5. Levanidov, I.P., Ionas, G.P., Slushnaya, T.N. (1987). Technology of Salted, Dried, Smoked Fish Products. M: Agropromizdat (in Russian).
6. Malkhasyan, A. (2001). Standardization, Metrology, Compliance Certification and Quality Management, Yerevan (in Armenian).

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Development of the First Component for The New “Yogric” Product

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ARTICLE INFO

Keywords:

*milk,
lactose-free yogurt,
lactase,
cultures,
post-acidification*

ABSTRACT

Parallel to the increase of dairy products consumption, the demand for lactose-free product ranges also grows up. The latter possess all the health benefits peculiar to milk and prevent digestive problems. Our research aims to obtain the first component of lactose-free bicomponent product Yogric, which is the mixture of yogurt and ricotta. For this purpose, we have identified the necessary starter culture, which should be used to get yogurt with the necessary properties. The dose of Ha-Lactase 5200 has been determined, which would reduce the lactose content in yogurt to less than 0.1 %, so that to consider it as a lactose-free product.

Introduction

The number of lactose-free products is growing rapidly. This is not surprising, because according to experts, 65 % of the world's population suffer from lactose intolerance. Numerous innovations are manufactured worldwide per all ranges of dairy products. The main focus is on dairy yogurt, but it is rapidly transpassing to other dairy products such as cream cheese and mozzarella. Analysts of the branch industry predict about 10 % annual growth of lactose-free cheese in the global market by 2023. Loyal consumers of lactose-free products are ready to buy them at a premium price, and in some cases pay twice as much as regular products. Thus, the development and production of lactose-free products is well justified (www.chr-hansen.com).

All over the world, a group of consumers with similar needs stands out – “Generation Millennials” or “Generation Y” – people born between 1980 and 2000. They consider yogurt

to be a natural, tasty and healthy product that serves as an excellent fast food. These are representatives of different cultures who are actively looking for new experiences. They are happy to try new dishes and foods with unfamiliar tastes, as they do not mind eating several times a day, preferring natural and healthy alternatives to sweets. Health benefits and ease of use are the prerequisites on which the consumer relies when choosing a product (www.chr-hansen.com).

Materials and methods

These research activities were carried out with the support of Innovative Agriculture Training and Learning Camp (AGRI CAMP) Program which is financed by The United States Agency for International Development (USAID) and implemented by International Center for Agribusiness Research and Education (ICARE). The contents are the responsibility of author/s and do not necessarily reflect

the views of USAID or the United States Government.

Experimental yogurts were prepared from reconstituted milk with 3.2 % fat content, fat-free dry matters – 8.2 %, density – 1027 kg/m³, titratable acidity – not higher than 21^oT. Reconstituted milk is stored for 9...12 hours at 6...8 °C for hydration, pasteurized for 3...5 minutes at 90...95 °C and cooled to a coagulation temperature of 44 °C. A freeze-dried, frozen culture and lactase enzyme was added at coagulation temperature, then mixed for 10 minutes to distribute culture and enzyme evenly. The dose of culture is 100 units per 250 liters of milk. Coagulation was carried out by the thermostatic method to obtain dense coagulation without the presence of syneresis at $pH = 4.5...4.6$. Ready yogurt was transferred to the refrigerator at a temperature of 4...5 °C. The studies were carried out 12 hours after placing the yogurt in the refrigerator (Tamime and Robinson, 2003).

Pre-selected yogurts with five bacterial cultures were produced from the Danish organization Christian Hansen. The organoleptic and physicochemical parameters of the latter were studied. Yogurt cultures consist of symbiotic combinations of strains of *Lactobacillus delbrueckii* subsp, *Bulgaricus* and *Streptococcus thermophilus*. Among these yoghurts the one, which complied with the requirements of the processed product has been singled out (Tetra Pak Processing Systems AB, 2003). Based on the latter, the technology of lactose-free products using the lactase enzyme was developed. For the preparation of lactose-free yogurt, heat-resistant lactase Ha-Lactase 5200 NLU was used as the main ingredient in the processed product. Ha-Lactase 5200 is an ultrapure standardized liquid β -galactosidase (lactase). The enzyme lactase was introduced into the experimental yogurt with the doses of 0.16; 0.32; 0.48; 0.64 and 0.80 ml/l. The lactose balance in yogurt was determined using the LACTOSENS R test (www.chr-hansen.com).

The organoleptic evaluation of the experimental yogurt was carried out according to the Chr. Hansen protocol (www.youtube.com). The rate of coagulation and post-acidification of yogurt was determined with standard methods (Aghababayan, et al., 1988).

Results and discussions

The aim of the current research is to study the technology of a new fermented milk product. Our goal is to get a superfood from yogurt and ricotta. Due to the special technology, the new product will not contain lactose

and can be useful for lactose intolerant people, as well as children and athletes. Besides, compared to lactose, the sweet taste of galactose and glucose increases the sweetness to the product.

The first component of the new Yogrik product being developed is yogurt. For the production of yogurt, we have developed 5 samples using freeze-dried and frozen cultures: YF-L811, Express 1, Speed 1, Premium 6, YC-X16. The choice of culture affects the characteristics of the final product, such as flavor, acidity, texture and appearance. The results of organoleptic evaluation of experimental yogurts, as well as the determination of the dynamics of fermentation and post-acidification are shown in Figures 1, 2.

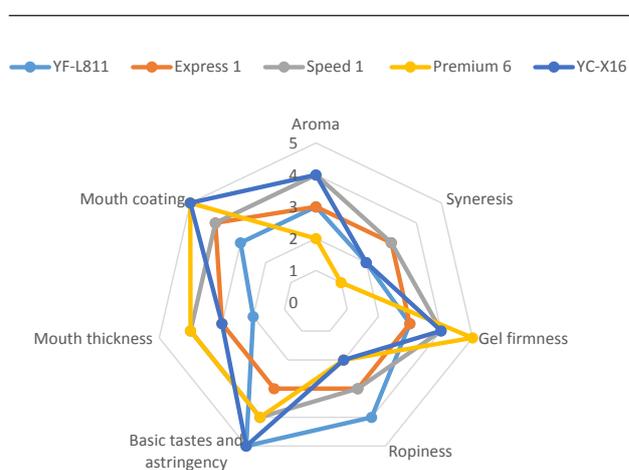


Figure 1. Sensory evaluation of the tested yogurt (composed by the authors).

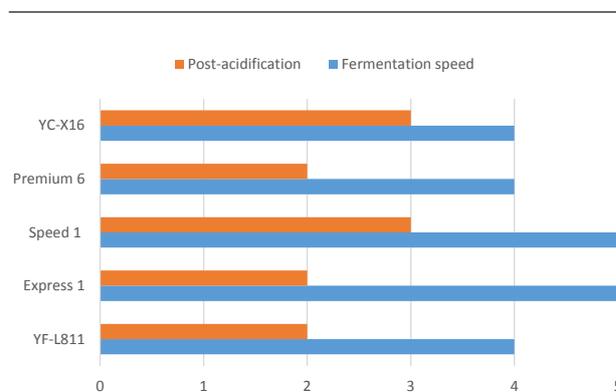


Figure 2. Technological evaluation of the tested yogurt (composed by the authors).

It is intended to get a low syneresis yogurt with a high gel firmness, low ropiness, pleasant but not sharp taste and aroma. It is very important that the experimental yogurt should have a low rate of post-acidification and a medium fermentation speed. As the results of figures 1 and 2 show, the most suitable product type under development is the yogurt, which is produced via Premium 6 culture.

For lactose-free products, the minimum residual lactose level is 0.1%. Therefore, as a result of fermentation, we should get yogurt with the similar lactose level. To this end, different doses of the lactase enzyme were added to milk, and after 24 hours the residual lactose content was determined. The results of the study are shown in Figure 3.

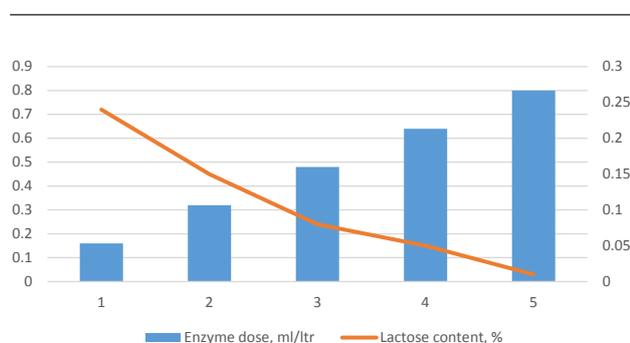


Figure 3. Lactose content in experimental yogurt in case of adding various doses of lactase enzyme to milk (composed by the authors).

According to the results of the conducted study on residual lactose content, it can be concluded that in order to reduce the lactose content in yogurt to less than 0.1%, it is necessary to add enzyme Ha-Lactase 5200 at least 0.48 ml per liter of milk (for this composition).

Conclusion

The results of the research enabled to develop a technology for the preparation of lactose-free yogurt, which should be the first component of the new Yogric product. Studies have shown that Premium 6 yogurt culture suites best for the product under development. To reduce the lactose content of yogurt to less than 0.1%, at least 0.48 ml of the lactase enzyme Ha-Lactase 5200 per liter of milk should be added.

References

1. Aghababayn, A.A., Beglaryan, R.A., Araksyants, A.A. (1988). Teaching Guide for Laboratory Classes in the Subject of "Chemistry and Physics" – Yerevan. AAA Publisher, -109 p. (in Armenian).
2. Dairy Processing Handbook Tetra Pak/ Tetra Pak Processing Systems AB, 2003, 452 p.
3. https://www.chr-hansen.com/ru/food-cultures-and-enzymes/fresh-dairy/cards/product-cards/nola-fit_2022 (accessed on 19.01.2022).
4. <https://www.chr-hansen.com/ru/food-cultures-and-enzymes/fresh-dairy/cards/article-cards/the-new-yogurt> (accessed on 28.01.2022).
5. <https://www.chr-hansen.com/ru/food-cultures-and-enzymes/test-and-equipment/cards/product-cards/lactosens> (accessed on 19.02.2022).
6. https://www.youtube.com/watch?v=i_gzFQ1MSMY_2022 (accessed on 07.02.2022).
7. Tamime, A.J., Robinson, R.K. (2003). Yogurt and Yogurt-Like Fermented Milk Products: Science and Technology (Translated from English); Publishing House: St. Petersburg: Profession, - 664 p. (in Russian).

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Developing a New Recipe for Producing Belgian Waffles with Peanut Butter

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ARTICLE INFO

Keywords:

*peanut butter,
waffle,
energy value,
recipe,
prime cost*

ABSTRACT

The issues related to children obesity and those of supplying them with daily required nutrients and energy value are becoming exacerbated year after year. The current research has been conducted within the context of developing a new recipe of Belgian waffles with peanut butter instead of the traditional one. Considering the circumstance that the mentioned product is rich in proteins, fats and carbohydrates, as well as minerals, such as manganese and copper, the relevant technology for Belgian waffle has been worked out and developed. Besides, the prime cost and chemical indicators of the new product manufactured via the store-bought and homemade peanut butter has been identified.

Introduction

Keeping to healthy diet has always been a pressing issue both throughout the world and in the Republic of Armenia. The highest rate in the habit of having breakfast is recorded in European countries both among the adults and children. Whereas, the lowest indicators for children obesity are observed in Netherlands, which is mostly due to the policy adopted by the health care institutions of the country (Louise Dye, 2017). In the countries of Eastern Europe and in Armenia, the habit of having breakfast has not been properly developed yet.

High nutrient value butter and waffles produced therewith are considered as part of breakfast foods. The process of manufacturing Belgian waffles upon the use of peanut butter hasn't been studied enough yet.

The peanut butter is considered to be an exceptionally healthy food product. It is rich not only in protein, fat and fibers, but also in vitamins and mineral matters, which are vital for the children's growth and development, as well as for metabolic functions and immunity system. People using peanut and peanut products take in more nutrients per recommended dietary allowance (RDAs) than those who don't use them. On the whole, peanut users have a healthier diet than those whose food diet lacks peanut products (Barbara Millen, 2015).

Peanut butter, as a substitute of traditional butter, promotes the reduction of high fat amount in butter and supplements the food with vitamins (E, B₃, B₆) and minerals, such as manganese and copper. The latter support the health of bones, blood vessels and immunity system. A number

of investigations have indicated that the use of sufficient amount of copper can reduce the risks for heart disease development (www.webmd.com).

Application of peanut butter, as a substitute, is also relevant from the prospect of supplementing the food diet with another primary component - Mn (manganese). Manganese is an important element, which takes part in the synthesis and activation of multiple enzymes, as well as in the regulation of human glucose and lipid metabolism. Lack of manganese can cause demineralization in children and result in their underdevelopment (Longman and Xiaobo Yang, 2018).

Materials and methods

The current research aims to develop a new recipe for waffle production by applying peanut butter with the combination of 10 % carrot extract. Based on the abovementioned, comparative analysis has been conducted both in view of qualitative properties, as well as the prime cost and economic feasibility of the new product. To this end the following objectives have been set up:

- searching out plant-based components, which will enable to manufacture Belgian waffle by substituting animal-based butter product
- developing recipe for the new product range
- producing a new food product for breakfast supplemented with proteins, fats, carbohydrates and minerals
- estimating the prime cost and justifying the economic efficiency of the product.

The peanut butter and Belgian waffle have served as the study subjects. To produce 1 kg of the new food product, the entire portion of 5 %, 15 % and 25 % ordinary butter was substituted with respective rates of peanut butter. The Belgian waffle with 15 % peanut butter has been selected as an optimal variant. This choice is conditioned by the fact that when using 5 % peanut butter, insignificant changes have been observed, while when using the option of 25 %, deterioration in organoleptic indicators have been recorded. Whereas, in case of applying 15 % peanut butter it was possible to obtain the required favorable outcomes.

The trials have been implemented in 2 variants with 2 replications:

1. *Control sample*: Belgian waffle manufactured with the store-bought peanut butter
2. *Experimental sample*: Belgian waffle manufactured with homemade peanut butter.

The research has been implemented in consistent with

the normative documents for waffles production. The content of protein mass has been determined according to the regulations set per GOST 26889-86 through Kjeldahl method, the oil mass- with extraction methods per point 8 of GOST 31902-2012 and the amount of minerals has been identified based on AOAC 974-27 and MV-01-008 methods.

These research activities were carried out with the support of Innovative Agriculture Training and Learning Camp (AGRI CAMP) Program which is financed by The United States Agency for International Development (USAID) and implemented by International Center for Agribusiness Research and Education (ICARE). The contents are the responsibility of author/s and do not necessarily reflect the views of USAID or the United States Government. The studies have been conducted in the laboratory of the Bread, Confectionery and Chocolate Manufacturing Research Center, at the Armenian National Agrarian University and in the food safety experimental research laboratory of “RVSPCLS” SNCO.

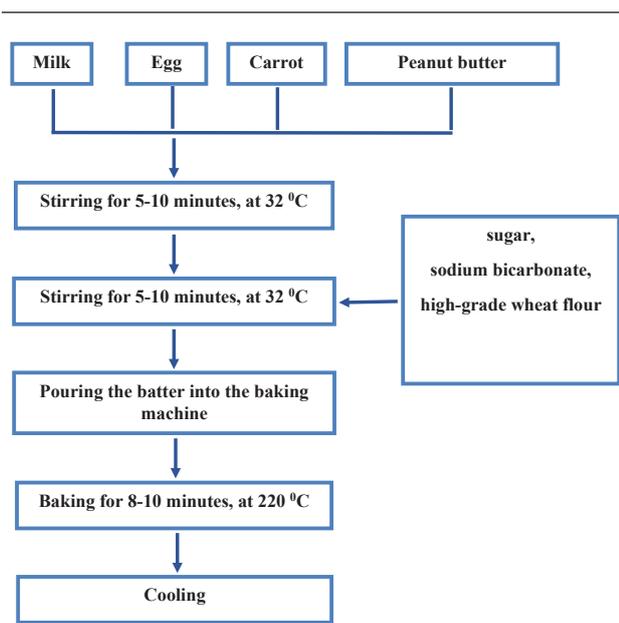
Results and discussions

The control (Belgian waffle manufactured with store-bought peanut butter) and experimental (Belgian waffle manufactured with the homemade peanut butter) samples have been subjected to investigations. The common technological methods have served as a base for the development of the new technological scheme (Koryachkina and Matveeva, 2011).

For the preparation of the first sample the following ingredients have been used: for 1 kg finished product, 600 g high-grade wheat flour, 90 g sugar, 600 ml milk, 6 eggs, 15 g soda, 150 g store-bought peanut butter and 100 g carrot was required, while for the preparation of the second sample all the ingredients stayed the same except for peanut butter, which was substituted by the homemade butter (Scheme).

The acidity degree and moisture content of the Belgian waffles prepared with store-bought and homemade peanut butters comply with the set standards (Table 1).

The protein content in the Belgian waffles produced with the use of store-bought peanut butter makes 12.3 % and the carbohydrates – 10.85 %. These indicators exceed those recorded in the Belgian waffles manufactured with homemade peanut butter by 0.35 % and 0.65 %, respectively. Anyhow, in contrast to the control sample, the fat amount in the experimental variant is higher by 1.15 % amounting to 12.75 % (Table 2).



Scheme. The technological scheme for Belgian Waffle Production (composed by the authors).

As a result, the energy value of the Belgian waffle produced with homemade peanut butter has made 203.35 kcal/g, or 848.3 kJ/g, while in the Belgian waffle prepared with the store-bought peanut butter it is 197.45 kcal/g, or 823.6 kJ/g. The latter's indices are lower than those in the Belgian waffles with homemade butter by 5.9 kcal/g or by 24.7 kJ/g (Figure 1).

Among the mineral substances manganese and copper mostly prevail in the composition of peanut butter.

According to the German Federal Institute for Risk Assessment the following doses of manganese daily intake by the body for different age groups have been identified:

- individuals aged from 4 to 7 years old: 1.5-2 mg/day
- individuals aged from 7 to 10 years old: 2-3 mg/day
- individuals aged from 10 to 15 years old: 2-5 mg/day.

For adults and even pregnant women the daily intake for manganese is estimated as 3 mg (www.bfr.bund.de).

Table 1. The physicochemical indicators of Belgian waffles*

Variants	Physicochemical indicator	
	Moisture content, %	Acidity degree, 0 N
Control sample	20.0	2.5
Experimental sample	23.0	2.1

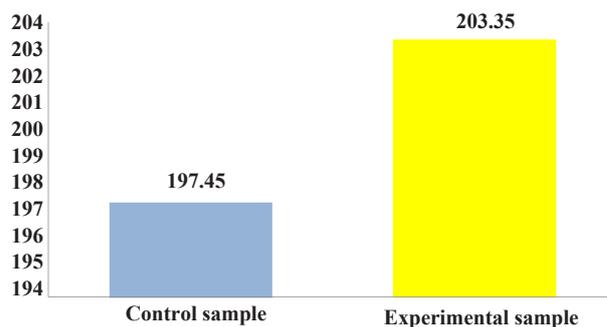


Figure 1. Energy value of Belgian waffles, kcal/g (composed by the authors).

Table 2. The chemical composition of Belgian waffles for control and experimental samples*

Variants	Protein content, %			Oil mass, %			Mass fraction of total sugars, %		
	Replication I	Replication II	Average index	Replication I	Replication II	Average index	Replication I	Replication II	Average index
Control sample	12.1	12.6	12.3	11.5	11.7	11.6	10.8	10.9	10.85
Experimental sample	11.6	12.3	11,95	12.8	12.7	12,75	10.2	10.2	10.2

* Composed by the authors.

According to the above stated indices it turns out, that a piece of waffle produced with homemade butter, averagely weighing 150 g, satisfies 21 % of the required daily manganese portion in 7-10-year-old children, while that of manufactured with store-bought peanut butter ensures 18.75 % of the required daily manganese dose (Figure 2).

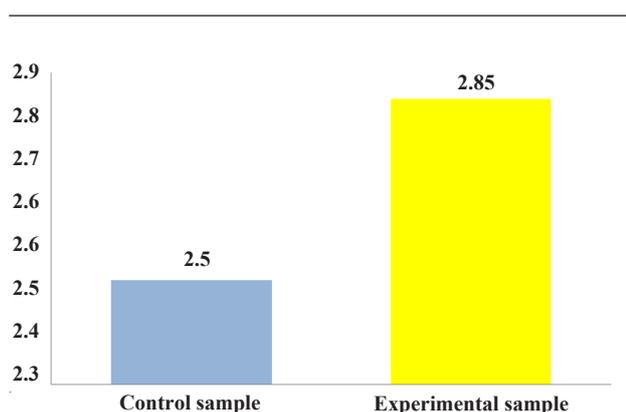


Figure 2. Manganese content in the Belgian waffles, mg/kg (composed by the authors).

Copper is another key mineral substance in the human diet. Based on the circumstance that 50 % of the body-required copper is received via drinking water and the average daily intake for 10-18-year-old individuals makes 1.2 mg (www.bfr.bund.de), it becomes clear that a piece of 150 g Belgian waffle prepared with store-bought peanut butter will provide 26.25 % copper for the human body, while 150 g Belgian waffle produced with homemade peanut butter will supply 8.75 % more copper equaling to 35 % total copper amount (Figure 3).

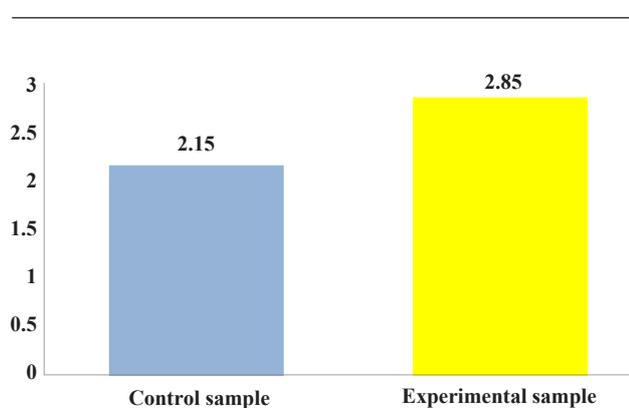


Figure 3. Copper content in the Belgian waffle, mg/kg (composed by the authors).

To estimate the prime cost of the food products, the cost calculation per a piece of waffle (150 g) for each ingredients, as prioritized per the recipe, has been conducted and then, the depreciation and electricity costs of the baking machine were added as other costs assuming AMD 100 as a fixed value for each kilogram.

The calculation per the recipe was conducted on February 2, 2022, in one of the RA supermarkets in line with the prices fixed for that period. As a result, the prime cost of 150 g Belgian waffle prepared with store-bought peanut butter has made AMD 341.2 which is higher than that of estimated for the Belgian waffle manufactured with homemade peanut butter by 120.12 drams, since the latter's prime cost has been estimated as AMD 221.08 (Figure 4).

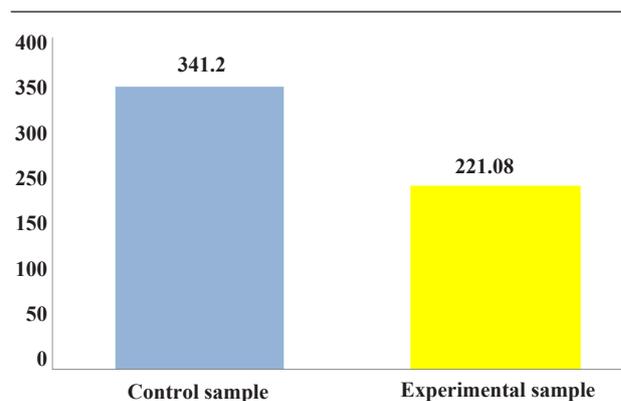


Figure 4. The prime cost of Belgian waffles per 150 g waffle piece, AMD (composed by the authors).

Conclusion

Based on the conducted scientific research experiments, the following conclusions have been inferred:

1. In the result of conducted research, a scientifically justified technology for Belgian waffle manufacture via applying peanut butter has been developed.
2. The research findings point out that the indices of energy value, manganese and copper of the Belgian waffle manufactured with homemade peanut butter exceed the same indices of Belgian waffle prepared via store-bought peanut butter by 24.7 kJ/g, 0.35 mg/kg and 0.7 mg/kg, respectively.
3. According to the economic calculations, the Belgian waffle prepared with homemade peanut butter is more cost-effective (by AMD 120.12) per 150 g Belgian waffle than that of manufactured with store-bought peanut butter.

References

1. AOAC 974-27. AOAC Official Method 974.27 Cadmium, Chromium, Copper, Iron, Lead, Magnesium, Manganese, Silver, and Zinc in Water. Atomic Absorption Spectrophotometric Method.
2. Barbara Millen (2015). U.S. Department of Health and Human Services and U.S. Department of Agriculture. 2015–2020 Dietary Guidelines for Americans, 8th Edition, - p.144, Available at: <http://health.gov/dietaryguidelines/2015/guidelines/> (accessed on 04.03.2022).
3. GOST-31902-2012. Confectionery. Methods of Determination of Fat Weight Fraction.
4. GOST-26889-86. Food-Stuffs and Food Additives. General Directions for Determination of Nitrogen Content by the Kjeldahl Method.
5. <https://www.bfr.bund.de/cm/343/hoechstmengenvorschlaege-fuer-mangan-in-lebensmitteln-inklusive-nahrungsergaenzungsmitteln.pdf> (accessed on 04.24.2022).
6. <https://www.webmd.com/diet/peanut-butter-good-for-you#:~:text=Peanut%20butter%20is%20rich%20in,sugars%2C%20oils%2C%20and%20fats> (accessed on 04.24.2022).
7. Koryachkina, S.Ya., Matveeva, T.V. (2011). Technology of Flour Confectionery Products: Textbook for Universities, St. Petersburg: Trinity Bridge, - 408 p.
8. Longman Li, Xiaobo Yang (2018). The Essential Element Manganese, Oxidative Stress, and Metabolic Diseases: Links and Interactions, Oxid Med Cell Longev. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5907490/> (accessed on 04. 03. 2022).
9. Louise Dye (2017). The Importance of Breakfast in Europe, Belgium, - p. 70, Available at: http://www.breakfastisbest.eu/docs/102017/BIB_Report_Importance_of_Breakfast_in_Europe_2017.pdf (accessed on 04.02 2022).

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The Effect of Natural Sugar Substitute on the Physicochemical Indices of Cupcake

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Keywords:

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confectionery product*

ABSTRACT

Most of the sugar substitutes differ from each other in chemical composition, ways of their production, exerted effect on the metabolism of organism, as well as in their assimilability.

The main goal of the current research is to develop a recipe for new functional food product by applying alternative natural sugar substitute. The extract produced from the licorice roots has been used as a natural substitute.

The recommended product range is a single type of food product in the domestic market of functional foods and can stimulate the development of the mentioned branch.

Introduction

Along with traditional food production technologies, new health-promoting food manufacturing technologies have started to develop. These are natural food products, the permanent use of which takes some regulatory effect both on human organism and on their individual organs or their functions (Nechaev, 2015).

Recently, the demand for therapeutic confectionery products has grown up among the population. It is first of all related to the overall deterioration of population's health. Numerous research works confirm that there is a direct relationship between the taken food and cardiovascular diseases, diabetes, obesity and atherosclerosis (Baturin, 2005, www.who.int/ru/news/).

The number of people with diabetes has increased throughout the recent years. This has resulted in the increased use of natural and artificial sweeteners instead of saccharose. Both types of sugar substitutes have the same sweetness index and can be successfully used in the food production for diabetics (Martirosyan, 2010, Nechaev, 2015).

The advantage of licorice roots is that glycyrrhizin, which is in the root's chemical composition, is sweeter than sugar in 50-100 times (Matveeva and Koryachkina, 2012). The licorice root contains glycyrrhizin, glycyrrhizic acid and salts, flavonoid glycosides (liquiritin, liquiritigenin, liquiritoside), isoflavonoids (formononetin, glabren, glabridin, glabrol, 3-hydroxyl glycerol, glycyrrhizin), steroids, essential oils (in small quantities), etc. (Matveeva and Koryachkina, 2012).

For medical purposes licorice root is usually used in combination with other medicinal herbs. The glycemic index (blood sugar rising level after food product intake) of licorice is only 20, while that of common sugar is 89 (Matveeva and Koryachkina, 2012, Nechaev, 2015).

Materials and methods

The flour confectionery product – cupcake, and the extract produced from licorice root have been used as study subjects. The samples of licorice roots have been taken from the Maralik province of Shirak region and from Gegharkunik region of the Republic of Armenia. During the extraction it was revealed that depending on the specific province, there is a considerable difference in the plants' roots regarding their taste and structural properties. Eventually, the investigations went on upon the application of the root extract, sampled from the Maralik province of Shirak region.

It has been identified that 160-200 kg sugar substitute, 10-12 kg flavonoid fraction (antioxidant), 20-40 kg lipid fraction and 500-800 kg fodder beats can be produced from one ton of licorice root (Martirosyan, 2010).

The research has been conducted in compliance with the current technical conditions and in line with the CU TR 021/2011 normative document. The consecution of technological procedures and calculation of the recipe has been implemented per the technological orders and instructions. The investigations have been conducted in the “Division of Plant-Based Raw Material and Foodstuff Processing Technology” at the ANAU Scientific Research Institute of Food Science and Biotechnology, as well as in the accredited “FDA Laboratory” LLC.

The sugar content has been determined via in-house method with the application of HPLC-refractive index detector column-nucleosil carbohydrate EC250/4 phasa device at the phase of ACN:H₂O 83:17. Since no special research method for such product types was developed yet, the research method has been developed and identified for that specific food product.

These research activities were carried out with the support of Innovative Agriculture Training and Learning Camp (AGRI CAMP) Program which is financed by The United States Agency for International Development (USAID) and implemented by International Center for Agribusiness Research and Education (ICARE). The contents are the responsibility of author/s and do not necessarily reflect the views of USAID or the United States Government.

The current research aims to develop a recipe for a new

functional food product by using alternative natural sugar substitute. The primary objectives of the research are as follows:

- to scientifically justify the functional property of the extract produced from the licorice roots, as a natural sugar substitute,
- to develop a new cupcake recipe using the optimal dosage of the extract,
- to identify the factual saccharose content in the finished product,
- to determine the energy value of the new food product.

Development of the new recipe for the mentioned functional food product upon the application of the extract manufactured from the local raw material, as a natural sugar substitute, is a scientific novelty for the branch.

Results and discussions

The investigations have been carried out based on the studies of control and experimental samples. The optimal amount of the used extract has been identified empirically. When developing the technology, the entire sugar quantity was substituted with certain dosages of the extract per grams. The following dosages have been chosen: 50 g, 100 g, 150 g per 1 kg finished product. During the experiments it has been found out that in case of using small amount of extract, sweetness is almost missing and in case of using more than 150 g extract the taste of the finished product becomes somewhat unpleasant and bitter, sometimes even burning taste is felt. The studies on organoleptic indices are presented in Table 1.

According to the preliminary organoleptic evaluation carried out via scoring system (ranging from 1 to 5 points), we'll have the data introduced in the presented Figure when calculating average indices.

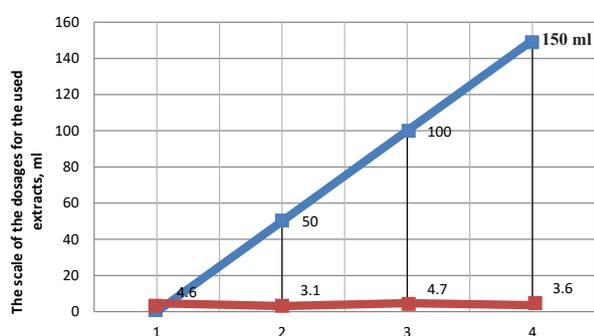
As the data of the diagram indicate, parallel with the increase of extract doses, a decline in the organoleptic scoring points is observed. In case of using 50 g extract, the sweetness almost lacks in the product and the latter obtains dark color, as a result of which this option has scored low points – 2.1. Similar points with the control sample (4.7 points) have been recorded in case of adding 100 g extract. This option ensures a rather pleasant taste and bright yellowish color. Nevertheless, with further addition of the extract, a decline in all organoleptic indices have been observed.

The recipe for the new cupcake production calculated per 1 kg finished product is introduced in Table 2.

Table 1. Evaluation of organoleptic indices of control sample and experimental sample produced with licorice extract*

Name of indicator	Control sample	Investigated options (recalculation of the substituted sugar amount per 1 kg product)		
		50 g	100 g	150 g
Appearance		Corresponding to the discussed food product		
Structure of finished product	Average porosity	Uniformly porous, with large pores	Small-sized porosity	
Color	Yellowish	Intense/pronounced yellowish	Dark yellowish	
Taste	Corresponding to the discussed food product	Unsweet	Well-pronounced pleasant sweetness	Excess sweetness with bitter tones
Smell		Corresponding to the discussed food product		

*Composed by the authors.

**Figure.** Organoleptic evaluation of the control and experimental samples (composed by the authors).**Table 2.** The recipe of cupcake for control and experimental samples (produced with licorice extract)*

Name of raw material	Control sample (per sample 1t finished product), kg	Experimental sample (per sample recalculation of 1kg finished product), g
High-grade wheat flour	360.74	360.74
Butter	180.42	180.42
Chicken egg	108.27	108.27
Licorice root extract	-	100
Edible salt	1.07	1.07
Sodium bicarbonate	3.60	3.60
Vanilla	1.0	1.0
Sugar	25.28	-
Raisin	108.27	-
Water	210.0	200
Total	998.65	955.1

*Composed by the authors.

Egg, butter and licorice extract is poured and mixed in the mixer machine for 15 minutes, after which the other ingredients, as listed in the recipe, are added. The dough is mixed up to the uniform mass and then the flour is added and mixed until the creamy mass is formed. In the experimental sample, the entire mass of sugar was substituted with licorice extract. Unlike the traditional technology, here the baking takes place at the temperature of 150-170 °C, since in case of higher temperature decomposition of glycosides is recorded, which is practically irrelevant, as it results in the production of toxic matters. Therefore, the baking temperature has been set up possibly lower and baking duration – much longer.

In the experimental sample the contents of protein, fats, carbohydrates, saccharose, glucose and fructose, as well as energy value of the product has been determined. The results of the analyses are presented in Table 3.

Table 3. Evaluation of the chemical indicators and energy value of the new cupcake product*

Name of indicator	ND, Name of document according to the experiment type	Measuring unit	Control sample	Outcomes
Protein, g	-	%	5.1	7.7
Fat, g	-	%	22	19.71
Carbohydrates, g	-	%	42.5	35.89
Glucose	IHM	%	12.0	<0.5
Fructose	IHM	%	11.2	<0.5
Saccharose	IHM	%	19.3	<0.5
Energy value	TP TC 022-2011	kcal/ 100g	388	352.03

As the laboratory results show, the index of <0.5 testifies that there is almost no sugar content in the experimental sample, which proves the feasibility of the extract application in the dietary structure of diabetics as well. The analysis has also shown that besides the absence of sugar content, the amounts of fats and carbohydrates, as well as the energy value have declined, which is again a positive tendency for the new food product. It is worthwhile to notice that the protein content has increased in the finished product, which can serve as a base for further investigations.

Conclusion

In the result of conducted research and experimental investigations, the following conclusions can be drawn:

Based on the experimental studies a scientifically justified technology for functional cupcake production has been developed by applying licorice extract.

The research has revealed that when using licorice extract in the experimental sample, almost no sugar content, particularly glucose, has been detected, which substantiates the fact, that the new cupcake product can be used in the food ration of diabetics.

It has been proved that the extract produced from licorice roots can be used in the food production as a natural sugar substitute.

The contents of carbohydrates, fats and energy value have been reduced. For a certain group of people, such as diabetics, these food indices are of vital significance for maintaining health.

The developed recipe and methods of producing a new cupcake product can be definitely involved in the dietary structure of the people affected by diabetes, since it has a functional significance and lacks glucose in its sugar content. The technology is conformed to the current productions and doesn't require any additional investments.

References

1. Baturin, A.K. (2005). Nutrition and Health: Problems of the XXI Century / A.K. Baturin, G.I. Mendelson // Food Industry, № 5. - pp. 105–107 (in Russian).
2. <https://www.who.int/ru/news/item/09-12-2020-who-reveals-leading-causes-of-death-and-disability-worldwide-2000-2019> (accessed on 10.03.2022).
3. Martirosyan, A. (2010). Encyclopedia of Medicinal Plants and Secrets of Herbal Medicine. Yerevan, - 400 p. (in Russian).
4. Matveeva, T.V., Koryachkina, S.Ya. (2012). Physiologically Functional Food Ingredients for Bakery and Confectionery Products, Orel, - 950 p. (in Russian).
5. Nechaev, A.P. (2015). Food Chemistry / A. P. Nechaev, S. E. Traubenberg, A. A. Kochetkova [and others]; - 6th Edition, - St. Petersburg: GIORD, - 672 p. (in Russian).

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Developing a New Recipe for Milk Chocolate

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vitamins*

ABSTRACT

The aim of the current research is to produce new chocolate products with some amount of vitamin content. At the same time, a more cost-effective raw material has been used as a leguminous mass, namely apricot kernel, which usually serves as a secondary raw material in the juice production. The technology of functional milk chocolate production has been developed based on the sprouted apricot kernel, which is a source for B_1 , B_2 vitamins.

The developed technology can be easily introduced in the production and will promote the development of national chocolate industry.

Introduction

Development of the technology for functional food production is of paramount significance in view of improving food production sector. The “ideology” of living healthy lifestyle is currently regaining impetus. Countries with large industries highly emphasize anything which has positive health effect. Food industry again seeks ways for health improvement and hence, for new high-quality food production (www.diabetes-ru.org/index/).

The development of functional chocolate production technology is considered as a priority task in the Republic of Armenia in prospect of two basic objectives, aimed at the stimulation of population’s healthy lifestyle, as well as economic and industrial development of the country. Processing of secondary raw material will promote enhancement of production range and reduction of the product prime cost.

Improvement of the technologies for manufacturing new products rich in useful components is the key to the confectionery market development. Recently, great number of research works have been implemented to study the functional significance and health-promoting properties of cocoa and chocolate. The investigations have indicated that cocoa constituting flavonoids can reduce the quantity of low-density lipoproteins (“bad” cholesterol) supporting the prevention of cardiovascular diseases. Besides, it has been proved, that cocoa with high content of antioxidants reduces the carcinogenic risks. In response to the mentioned positive effects, the demand for chocolate products, particularly those with high content of dark cocoa, has rather increased (Toshev and Chaika, 2004). Above all these, chocolate manufacturing has somehow provided insight into high resistance-capacitance in handling the mentioned challenges and the ability of benefiting from the new opportunities appeared in the result of consumer’s

demand changes. Traditional companies famous for their milk chocolate products present new chocolate brands with high content of dark cocoa. Currently, the world market of dark chocolate makes 5-10 % of the entire chocolate market, the other types of chocolates (common milk chocolate, common white and filled chocolate) have greater share in Europe than in the USA. Similarly, the accredited organic and special-use chocolate markets are growing at double-digit rate.

Since chocolate manufacturing process is rather complicated and requires numerous technological procedures and supplementation of a number of ingredients, conception of its scientific and technological aspects is possible only through the preliminarily specified ranges of technological parameters for getting products with proper appearance and taste in compliance with standard physical and chemical properties, which can result in the expected quality for the mentioned product.

Chocolate production and consumption forms, structural and mechanical characteristics, taste formation and sensory perception are significant for ensuring some consumer properties (Afoakw, 2010).

Materials and methods

The sprouted kernels of apricot stone, coming forth as functional ingredients, has been selected as a research subject and possibilities of their application methods have been studied. On the whole, both the sprouted and non-sprouted kernels contain vitamins, but the difference is that in the non-sprouted ones they are in passive state, while when sprouting they become activated.

The kernel of apricot stone is rich in vitamins and mineral substances. Some of the available vitamins in the apricot stone are niacin (*PP*), thiamin (B_1), riboflavin (B_2), retinol (*A*), whereas from the microelements it contains magnesium (*Mg*), potassium (*K*), phosphorus (*P*), calcium (*Ca*). The distinguishing feature of thiamin is that it is not accumulated in the organism. That is why its daily supply via food products is a prior issue. One of the advantages of vitamin B_1 is its high thermal endurance, even up to 140°C. Vitamin B_1 is also a source for energy production and is necessary for the regular functioning of nervous system. The required daily dose for an adult is 1.2-2.1 mg (Nechaev, et al., 2007). Vitamin B_2 is also rather temperature-resistant. Riboflavin in combination with other *B* group vitamins has a comprehensive effect on the human organism: it stimulates the function of nervous

system, digestion system, overall metabolism, ensures healthy skin and promotes regular hair and nail growing process. Regarding the use of riboflavin, recommendations have been developed in more than 30 countries. The approved dosage for the adults is estimated as 1.2-2.2 mg (Nechaev, et al., 2007, Kondratiev, et al., 2014).

Considering all beneficial effects of the new product range of milk chocolate on the human organism and aiming to develop the mentioned functional food production, some priority objectives have been identified:

1. to study the favorable parameters for apricot kernel sprouting methods,
2. to identify the percentage ratio of milk chocolate and sprouted kernel per their combinability,
3. to develop the technology for manufacturing the new chocolate product,
4. to examine the changes in the taste of apricot kernel and its impact on final product,
5. to study the vitamin contents in the finished product, particularly the growth in the content of vitamins B_1 and B_2 , as well as to research the moisture content and safety indicators therein.

In the result of conducted experimental research, the increased share of vitamins B_1 and B_2 in the milk chocolate is viewed as a novelty, and this is due to the sprouted kernel which was previously missing as an ingredient of milk chocolate.

Determination of moisture content in the raw material has been carried out through the gravimetric method by means of the contemporary analyzer KERN MRS with 0.95 precision. The content of vitamins has been identified through the fluorometric method which is based on the release of thiamin-binding forms through hydrolysis, then it is cleaned up from different compounds via extraction, so as not to interfere with fluorometric assay. The investigations have been conducted in line with technical conditions stated by GOST 31721-2012, CU TR 021/2011 normative documents; besides, common research methods regulated by GOSTs (GOST 31721-2012, Interstate Chocolate Standard) have been applied.

These research activities were carried out with the support of Innovative Agriculture Training and Learning Camp (AGRI CAMP) Program which is financed by The United States Agency for International Development (USAID) and implemented by International Center for Agribusiness Research and Education (ICARE). The contents are the

responsibility of author/s and do not necessarily reflect the views of USAID or the United States Government.

The investigations have been carried out in the “Division of Plant-Based Raw Material and Foodstuff Processing Technology” at the ANAU Scientific Research Institute of Food Science and Biotechnology, as well as in the food safety experimental research laboratory of “RVSPCLS” SNCO, Food Safety Inspection Body, and in the experimental laboratory of “National Body for Standards and Metrology” CJSC.

The experimental samples were prepared in three different dose ratios: 53.0 % chocolate and 47.0 % sprouted kernel, 72.0 % chocolate and 28.0 % sprouted kernel and the last one – 83.5 % chocolate and 16.5 % sprouted kernel. In the result, the third variant has been chosen as an optimal dose ratio. The sprouting duration of apricot kernel lasted 15-20 days in conditions of 35°C temperature. In the mentioned time period, the length of the sprouts made 1 cm, which is completely sufficient for the vitamin’s storage.

Results and discussions

The experiments have been conducted based on the investigations of milk chocolate control sample and empirically manufactured product types. Milk chocolate

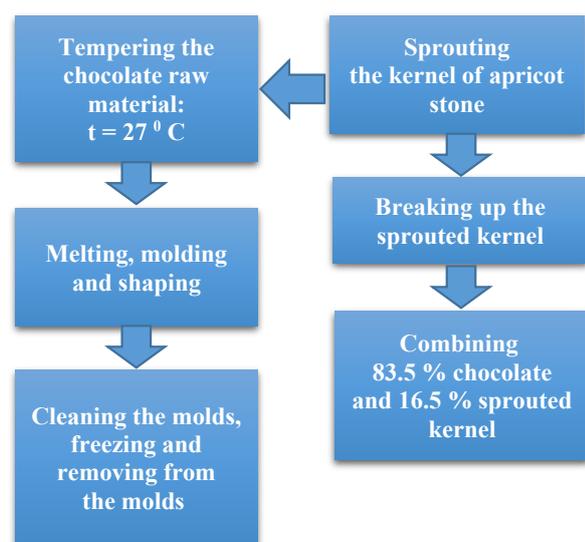


Figure 1. The sequence of technological procedures for chocolate production (composed by the authors).

has been selected as a study subject, since the combination of kernel and milk chocolate is more feasible in view of taste properties. The sequence of technological procedure is introduced in the diagram of Figure 1.

For our investigations the third variant of milk chocolate and sprouted kernel of apricot stone has been used (83.5 % chocolate and 16.5 % sprouted kernel). The choice of this option is justified by the experimental results obtained via applying the mentioned dose ratio, which testified that availability of vitamins B_1 and B_2 , safety indicators and standard-compliant moisture content can be best ensured through this combination. At the same time, the second advantage should be taken into account, which consists in the fact that when using the kernel of apricot pit as a substitute for groundnut in the form of secondary raw material (considered as such in our experiment), the used chocolate amount is reduced, which in its turn will lead to the reduction of the product’s prime cost; nevertheless, application of high kernel amount also entails to the accumulation of free fatty acids in the chocolate resulting in the appearance of whitish shades on the product surface.

In the result of conducted research, the effect of sprouted kernel on the moisture content of the finished product has been studied, which is a key indicator in the chocolate manufacturing procedure. The results are introduced in Figure 2.

The research results introduced in the diagram of Figure 2 make it clear that in case of applying the sprouted kernel, the moisture content of finished products has been reduced, which is a positive tendency in view of ensuring proper appearance for the final product. The organoleptic evaluation of the new product range was conducted on 27.01. 2022 via the tasting panel score (Table 1).

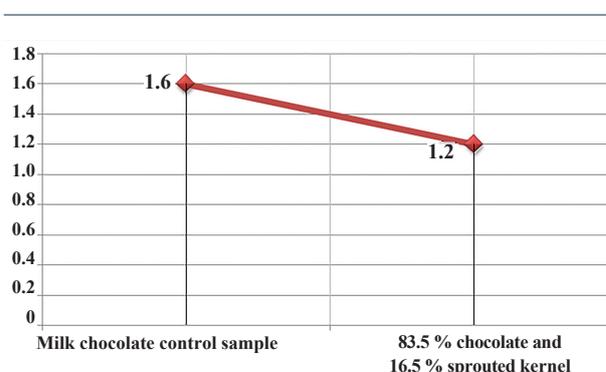


Figure 2. Moisture content of chocolate samples, % (composed by the authors).

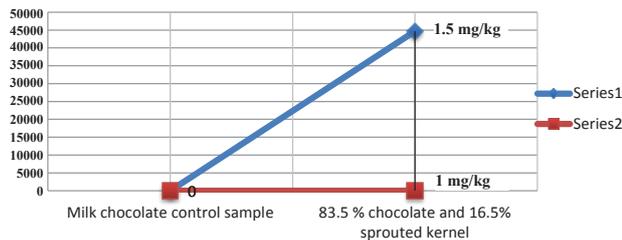


Figure 3. The content of B_1 and B_2 vitamins in the chocolate, mg/kg (composed by the authors).

Table 1. Organoleptic evaluation of the new milk chocolate product*

Name of indicator	Characteristics	
	Control sample of milk chocolate	83.5 % chocolate and 16.5 % sprouted kernel of apricot pit
Taste and flavor	Peculiar to the discussed product, without off-taste and off-flavor	Without off-taste and off-flavor, with delicate apricot taste
Appearance	Bar form, without cracks and streaks	
Consistency	Solid	
Texture	Homogeneous, wholly with the content of milled groundnut, raisin, candied fruits	Homogeneous, with the content of grinded kernel of crushed apricot stone

The results of laboratory experiments for the vitamins B_1 and B_2 are introduced in Figure 3.

Research on the safety indicators of the new chocolate product has been also carried out, the results of which are introduced in Table 2.

Conclusion

Based on the conducted scientific research experiments the following conclusions can be drawn:

- The sprouted apricot kernel is possible to apply as an alternative raw material in chocolate manufacturing industry.
- The reasonable methods of applying sprouted apricot kernel, sprouting conditions, its optimal doses and application ways have been justified and substantiated.
- In the result of laboratorial trials the moisture content, organoleptic indicators, as well as safety and microbiological indices of the finished product have been identified.
- It has been proved that it is possible to add the contents of two most important vitamins B_1 and B_2 in the products manufactured by means of the mentioned technology and with the stated dosages.

The developed chocolate recipe is economically efficient, since the apricot stone is a product with relatively lower prime cost than groundnut, notwithstanding that the former is endowed with more useful properties. This technology can be easily introduced in the national

Table 2. Safety indices of vitaminized milk chocolate*

Name of indicator	Reference number of normative document/ ND stating the index value	Reference number of normative document/ ND stating the experimental method	Measuring unit	Index value		Conclusion per the experimental result
				According to N/D	Actual output	
Lead	CU TR 021/2011	GOST EN 14083-2013	mg/kg no more	1.0 no more	n/d (<0.02)	In compliance
Arsenic	--,--	GOST R 51766-2001	mg/kg no more	1.0 no more	n/d (<0.01)	In compliance
Cadmium	--,--	GOST EN 14083-2013	mg/kg no more	0.5 no more	n/d (<0.01)	In compliance
Mercury	--,--	GOST R 53183-08	mg/kg no more	0.1 no more	n/d (<0.02)	In compliance
E. coli bacteria	CU TR 021/2011	GOST 31747-2012	g.	n/p 0.1	n/d	In compliance
MAFAnM	--,--	GOST 10444.15	CFU/g	1x10 ⁴	1x10 ³	In compliance

*Composed by the authors.

chocolate production industry as a means of manufacturing functional food product with curative and health-promoting properties.

References

1. Afoakw, E. O. (2010). Chocolate Science and Technology // University of Ghana Legon – Accra Ghana, - pp.10-25.
2. GOST 31721-2012. Interstate Chocolate Standards. General Specifications (in Russian).
3. <http://www.diabetes-ru.org/index/prodavtsu-proizvoditelju/professor-isaev-vjacheslav-artashesovich-v-den-svoego-vosmidesjatiletija-rasskazyvaet-o-funktsionalnom-pitanii> (accessed on 20.03.2022).
4. Kondratiev, N.B., Rudenko, O.S., Borodina, O.S. (2014). Changes in the Regularities of the Vitamin Content in the Process of Confectionery Production and Storage // Storage and Processing of Agricultural Raw Materials, - N 1, - pp. 32-36 (in Russian).
5. Nechaev, A.P. Trauberg, S.E., Kochetkova, A.A. (2007). Food Chemistry / under the Editorship of A.P. Nechaev, 4th Ed., Revised and Corrected. St. Petersburg: GIORD, - 640 p. (in Russian).
6. Toshev, A.D., Chaika, O.V. (2004). More Attention to the Development of Functional Food Products // Confectionery Production - № 4, - p. 38 (in Russian).

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Investigating the Effect of Yeasts and their Derivatives on the Qualitative Indices of Red Wine

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ABSTRACT

The study on the influence of yeast and yeast derivative autolyzes on the wine qualitative and quantitative characteristics has been conducted upon the first article of the series. Red grapes contain more than 1500 components, which are forming the taste and aroma of red wines, as well as the biological value of the product. One of the main technological operations in the production of red wines, which is related to the creation of favorable conditions for extracting phenolic and coloring compounds from the solid parts of the grape berry that are responsible for the color, taste, and aroma preserving them at the different stages of the wine formation and maturation, has been researched and analyzed.

Introduction

Red wines are macerated wines (Ribereau-Gayon, et al., 2006). Crushed grape is forming pomace (the mixture of skin, seeds, and grape juice and pulp) from which the coloring and aromatic phenolic compounds are released as a result of extraction (Busse-Valverde, et al., 2011, Kazumov, et al., 2013). For this purpose, red grapes are crushed in crusher comb separators, and the pomace is sent to the fermentation tanks. Extraction processes in the pomace depend on fermentation temperature, while maceration of the skin cells and seeds occurs with the extraction of color and phenolic substances. Many phenolic compounds in grape berries have antimicrobial and antiviral properties (Edi Maleti, et al., 2009). Even in ancient times, it was practiced to mix water with wine to disinfect water contaminated with bacteria. The beneficial effects of red wines on human

health has recently raised significant interest in oenotherapy.

Materials and methods

Grape variety is the base of the future wine (Cabezas, et al., 2003). A large supply of technologically important components and hygienic indicators of grapes are the main factors that determine the appropriateness of choosing a variety. Actual research in the field of development and production of additional materials for winemaking has made it possible to create effective preparations for fermentation of pomace and must. Among those materials active dry yeasts (Tikhonova, et al., 2011), natural fermentation activators, color stabilizing agents for increasing the color intensity and stability of the polyphenolic complex of the wine are involved (Ageeva, 2007).

Our studies in this field aim to investigate the characteristics of new yeast strains and yeast derivatives used in winemaking to significantly improve the wine's quality. For the first time in the field of winemaking in Armenia, an investigation of the impact of Fermentis products (by Lesaffre Group) provided by "LabCare&Consulting" LLC – the official distributor of Fermentis in Armenia, on the quality of the red wines has been carried out. The following yeast strains have been applied:

1. SafOeno™ NDA 21: a new active dry yeast strain. Alcohol resistance – up to 16 % by vol., sugar to alcohol ratio: 17.6 g/1% vol.
2. SpringFerm™ Xtrem: activator of alcoholic fermentation, consisting of 100 % fully autolyzed yeast, containing 9 times more soluble nitrogen than basic inactivated yeast.
3. SpringGel I™ Color G2: color stabilizer. Based on pure inactivated yeast from *Saccharomyces cerevisiae* particularly rich in polysaccharides, it improves the action on the intensity and the stability of the polyphenolic profile of red wines.

For the study the following Armenian grape varieties have been used: Tigrani, Karmrahyut and Charentsi (red-colored pulp), which are widespread in the Armavir region of the Republic of Armenia. The selection of these grape varieties is not occasional because wines made therefrom sometimes have problems, such as unstable color and sediment of coloring matter (Jacobson Jean, 2006).

The process of wine samples preparation has been done in the Jraghatspanyan Winery during the 2020 grape harvest season. Jraghatspanyan Winery is located in the Bambakashat village, Armavir region, Armenia.

The OIV and EAEU GOST methods were used to assess the physicochemical indicators of wines. The sugar content in grapes was determined by refractometry and densitometry methods. Alcohol content was measured by the OIV-MA-AS312-01A method, total acidity – through OIV-MA-AS313-01, volatile acidity – through OIV-MA-AS13-02, free and total sulfur dioxide – by OIV-MA-F1-07, chromatic characteristics – by means of OIV-MA-AS2-07B, Folin-Ciocalteu Index – via OIV-MA-AS2-10 (Hrazdina, et al., 1970, International Organization of Vine and Wine, 2021). Organic acids were determined by HPLC (system: Agilent 1100 Series, detector: Agilent 1260 Infinity) (Ribereau-Gayon, et al., 2006).

Grapes were harvested at the end of September and beginning of October 2020 at the stage of full technical maturity, i.e., Tigrani sugar content making 260 g/l, Karmrahyut sugar content – 215 g/l, Charentsi – 220 g/l.

The grapes were crushed in a crusher comb separator and the pomace was transferred to the tanks for fermentation and maceration for extracting coloring and phenolic substances from skin cells and seeds. Maceration of pomace is the main way of making high-quality red wines. The temperature of fermentation was + 28 °C which is the optimal one for extraction of phenolic components from the solid parts of the fermenting grape must (Ribereau-Gayon, et al., 2006).

It is well known that during the maceration of the pomace, one of the most freely isolated compounds is the seeds oenotannin, which takes part in the formation of the color and taste of the future wine (Bagaturia, et al., 2011). The floating cap of the pomace formed during alcoholic fermentation was well mixed four times per day. This process also supplies oxygen from the air in the intervals between the immersions of the cap, which ensures the occurrence of oxidative processes with the formation and accumulation of esters (substances that are responsible for the basis of the wine bouquet).

The study seeks to investigate the effect of using active dry yeast – NDA-21 on the wine quality (Tikhonova, et al., 2011) with the combination of fermentation activator: SpringFerm™ Xtrem and color stabilizing agent: G-2 during alcoholic fermentation. Yeast and yeast derivatives were introduced to the pomace according to the producer requirements: active dry yeast in the amount of 20 g/hl, SpringFerm™ Xtrem at the rate of 20 g/hl, G-2 color stabilizer – 20 g/hl.

Maceration with the pomace cap lasted 4 days, after that the pomace was pressed (separated from solid parts) and young wine was sent for further fermentation. To ensure the natural occurrence of malolactic fermentation, no sulfur dioxide was added. SpringFerm™ Xtrem has a good influence on malolactic fermentation and it can be used as an activator for malolactic fermentation too.

After the complete alcoholic fermentation, the young wines were stored on the yeast lees and periodically stirred for the enrichment of young wine with the yeast autolysis in order to enrich the taste of young wine. As the wine was clarified, it was removed from the yeast lees in December of 2020. Sulfur dioxide was added in the form of potassium metabisulfite at the rate of 60 mg/l for each sample of the wines. The wine samples were bottled in February 2021. The mentioned samples have been tested in the wine laboratory and via tasting evaluation.

Results and discussions

The results of the laboratory physicochemical tests are

shown in the presented table. Investigation of the data shows that the residual sugar content in all three samples is less than 1 g/l, the lowest amount of residual sugar is in the Karmrahyut sample – 0.16 g/l, the highest amount of sugar is in the Tigrani sample – 1 g/l. It should be noted that the concentration of sugar in the grape juices Karmrahyut was 215 g/l, Charentsi – 220 g/l, and the greatest amount of sugar was in Tigrani – 260g/l. This circumstance points out the good fermentable activity of the introduced strain of yeast SafOeno NDA 21, and SpringFerm™ Xtrem – a fermentation activator for promoting alcoholic fermentation (Kazumov, et al., 2013, Tikhonova, et al., 2011).

One of the main indicators of the wine quality is the alcohol content (Yanniotis, et al., 2007). High alcohol content gives the wine microbiological stability and improves its organoleptic characteristics. The alcohol content in the wine samples was, respectively: in Tigrani – 14.5 % vol. (17.93 g sugar consumption for 1% vol. alcohol production), Karmrahyut – 11.4 % vol. (18.86 g sugar for 1% vol. alcohol production), Charentsi – 12.1 % vol. (18.18 g sugar per 1 % vol. alcohol production). The fermentation process was most efficient in the sample of Tigrani, where the alcohol yield was closest to the indicator of 17.6 g of sugar for 1 % vol.; alcohol and the yield was over 98.6 %.

The amount of titratable or total acidity in the tested samples was at the level of 4.04 g/l for Charentsi, 3.6 g/l for Karmrahyut and Tigrani. Low total acidity and, as a result, higher level of pH in all the samples are respectively typical for wines produced in geographically southern wine regions (pH: 4.08 – Charentsi, 4.20 – Karmrahyut, and 4.33 – Tigrani). All enzymatic processes occurring at the different stages of wine production depend on the pH level of the must and wine. The level of pH of wine is responsible for its antibacterial effect and its ability to neutralize the course of undesirable microbiological processes (Ribereau-Gayon, et al., 2006), as evidenced by the low level of the obtained volatile acids: 0.46 g/l for Charentsi, 0.66 g/l for Karmrahyut, and 0.59 g/l for Tigrani.

The total concentration of sulfur dioxide in the wine samples is from 47.04 mg/l to 64.28 mg/l, which protects and provides the microbiological stability of the wine. The synergistic action of phenolic compounds with a high content of sulfur dioxide is also evidence of their joint presence in red wines which inhibits the development of cells of harmful microorganisms and their vital activity.

Organic acids play an important role in the development of wine quality. Total acidity content determines the grape's suitability for the production of the appropriate

wine type. The main acids of the grape are tartaric and malic; their content is responsible for the pH value of wine (Ribereau-Gayon, et al., 2006). Tartaric acid salts affect the organoleptic characteristics and are responsible for the tartaric stability (crystal precipitation) of wine. Potassium and calcium salts of tartaric acid are less soluble in the presence of alcohol; therefore, they can precipitate forming small crystals causing the cloudiness of wine (Ribereau-Gayon, et al., 2006). Malic acid is the most labile acid in grape berries. It can participate in the respiratory processes, in the metabolic processes and can take part as an intermediate product for the synthesis of many other compounds. The high concentration of malic acid in wine can cause the appearance of a sharp taste of wine, which is also called “green acidity” (Kazumov, et al., 2013). Spontaneous malolactic fermentation can start during or after the main alcoholic fermentation of the grape pomace or must, under favorable conditions (temperature of wine could be + 20 °C or above it). Malolactic fermentation reduces the content of malic acid increasing the level of pH, which gives the wine a soft and creamy taste and a specific aroma of the young wine (Ribereau-Gayon, et al., 2006, Schneider, et al., 1987).

Organic acid concentrations were tested in all wine samples. The result shows the presence of tartaric acid in all samples in the range of 1.46 g/l – 1.74 g/l. Malolactic fermentation was efficient. In the tested samples, malic acid presence was detected only in the Tigrani variety with a small amount (0.29 g/l). Acetic acid concentration is fixed within the range of volatile acid values. The citric acid content is in the range of 0.13-0.11 g/l. The low citric acid content can be associated with an indicator of the biological stability of the wine. In the Krebs Cycle after the addition of acetyl-coenzyme A to oxalic-acetic acid, citric acid is formed through several derivatives, which are converted into succinic acid. Succinic acid was identified in all tested samples. The highest concentration of succinic acid was identified in the Charentsi sample – 0.88 g/l, the lowest was in the Karmrahyut – 0.38 g/l and in Tigrani sample – 0.70 g/l. The Krebs Cycle ends with dehydrogenation to fumaric acid. Fumaric acid was identified only in the Tigrani sample in a very little amount – 7.77 mg/l.

Shikimic acid was detected in all the samples with fairly great amounts. So, in the sample of Charentsi the lowest amount of shikimic acid is recorded – 0.021 mg/l and the highest amount in Karmrahyut – 79.70 mg/l, while in Tigrani it was 16.31 mg/l. Grape berry contains mainly tartaric, malic and citric acids, the rest of the acids are formed as a result of alcoholic fermentation through a series of chemical transformations. Their role is important for the formation of wine taste and bouquets. Thus, the biosynthesis

of aromatic amino acids is based on an important discovery that shikimic acid is an indispensable intermediate product in the biosynthesis of aromatic compounds.

Studies on carbon 14 (C^{14}) have shown that in plants shikimic acid can be converted to phenylalanine and tyrosine. According to the existing data, the average content of aldehydes in wines is 12-220 mg/l (Gerzhikova, 2009). Aldehydes are formed as a result of a non-enzymatic process of oxidative-deamination of amino acids (alanine) and in the Cycle of Krebs. In small concentrations, they have a pleasant smell and are involved in creating a specific aroma of aged wine. Aldehydes can positively be associated not only with aromatic alcohols but also be involved in the significant reaction for red wine: polymerization of the anthocyanin-tannin complex is as a bridge between anthocyanins and tannins (Ribereau-Gayon, et al., 2006, Yakimenko, et al., 2012). The total amount of aldehydes in wine samples is low: Tigrani – 9.24 mg/l, Karmrahyut

– 8.8 mg/l, and Charentsi – 6.2 mg/l, which corresponds to the data mentioned in the literature and indicates the quality of wine, and quality of ADY (NAD-21) which is used for alcoholic fermentation.

Acetals have a direct, positively significant correlation with methanol, ethers, and aromatic acids. The increase of acetals during fermentation increases their presence in the wine. The total amount of acetals in wine samples is respectively: in Tigrani – 15.34 mg/l, Karmrahyut – 16.52 mg/l, and Charentsi – 12.98 mg/l.

Dry extract represents the concentration of the total extract (non-volatile content) by subtracting the concentration of sugars. It includes all non-volatile acids (tartaric, lactic, malic, citric, and succinic), some of them in a certain amount are allowed for addition to wine. In this case, it becomes necessary to use an additional indicator: residual extract (reduced extract-titratable acids) (Bagaturia, 2011, Yanniotis, 2007).

Table. Physicochemical analysis of red wines*

№	Parameters	Unit	Charentsi	Karmrahyut	Tigrani
Standard chemical parameters					
1.1.1	Sulfur dioxide-free	mg/l	10.98	15.68	9.40
1.1.2	Sulfur dioxide total	mg/l	61.15	64.28	47.04
1.1.2	Sulfur dioxide reductions	mg/l	4.70	4.70	4.70
1.2.1	Volatile acidity	g/l	0.46	0.66	0.59
1.2.2	Total acidity	g/l	4.04	3.60	3.60
1.2.3	pH		4.08	4.20	4.33
1.3.	Residual sugar	g/l	0.39	0.16	1.00
1.4.	Alcohol	Vol.%	12.10	11.40	14.50
1.5.1	Total aldehydes	mg/l	6.20	8.80	9.24
1.5.2	Total acetals	mg/l	12.98	16.52	15.34
1.6.1	Total extract	g/l	31.30	38.00	34.10
1.6.2	Dry extract	g/l	30.91	37.84	33.10
1.7	Density	g/ml	0.994252	0.997493	0.993292
Organic acids					
2.1.	Tartaric acid	g/l	1.46	1.50	1.74
2.2.	Malic acid	g/l	-	-	0.29
2.3.	Shikimic acid	mg/l	0.02	79.70	16.31
2.4.	Lactic acid	g/l	2.51	2.74	1.43
2.5.	Acetic acid	g/l	0.46	0.79	0.52
2.6.	Citric acid	g/l	0.13	0.11	0.12
2.7.	Succinic acid	g/l	0.88	0.38	0.70
2.8.	Fumaric acid	mg/l	-	-	7.77

*Composed by the authors.

It is known that the concentration of the dry extract is an important indicator of the wine quality. In dry white wines, it contains tartaric and malic acids, nitrogen compounds, and other substances of the grape must and non-volatile compounds formed during alcoholic fermentation. The extract of red wine compared to white additionally contains non-volatile substances extracted from the solid parts of the grape pomace (skin, seeds) (Gerzhikova, 2009). The speed of extraction of extractive substances from the skin and seeds of grapes depends on their diffusion coefficient. For example, this value for anthocyanins equals to $0.03\text{-}0.331 \times 10^{-7} \text{ m}^2/\text{s}$, for leuco-anthocyanins – $0.024\text{-}0.310 \times 10^{-7} \text{ m}^2/\text{s}$, for tannins – $0.018\text{-}0.310 \times 10^{-7} \text{ m}^2/\text{s}$. The extractive substances accumulation dynamics in red wine is maximum within 7-10 days of the pomace maceration (Ribereau-Gayon, et al., 2006). Enrichment of must with the extractive compounds of skin and seeds has a positive effect on the future wine quality up to a certain limit, and later the wine acquires rough tones. Maceration of the cap for more than 10 days (Yakimenko, et al., 2012) as a result of changing dissolving ability of the must, is caused by an increased alcohol content, as well as due to the polymerization and condensation reaction of phenolic compounds; some of them are insoluble and can precipitate, thereby reducing the extract of the wine.

Stirring the pomace cap during maceration and fermentation has a significant effect on the extract and quality of the wine. Aeration during the stirring process intensifies the multiplication and yeast metabolism, which is a positive effect on the wine quality. The aging of wine can decrease the amount of wine extract. The terroir has a significant impact on the quality of the wine, as evidenced by the amount of accumulated extract. Concentration of dry extract in wine samples ranges from 30.91 g/l to 37.84 g/l. Increased content of extracts favorably contributes to quality indicators of wine, also increasing its hygienic properties.

Conclusion

The tasting evaluation of the investigated wines showed that at this stage of production, all three samples of red wines are corresponding to the quality requirements, however, the potential for the development of quality indicators, depending on numerous factors, can reveal the character of the investigated wines in a new way, after a period of aging and the formation of wine. Therefore, repeated physicochemical analysis and wine tasting assessment will be provided in 6 months.

References

1. Ageeva, N.M. (2007). Stabilization of Grape Wines: Theoretical Aspects and Practical Recommendations, - 251 p. (in Russian).
2. Bagaturia, N. Sh., Begiashvili, N. A., Bagaturia, B.N. (2011). The Theory and Practice of Technology of the Georgian Types of Grape Wines // Winemaking and Viticulture, - N: 1, - pp. 39-42 (in Russian).
3. Busse-Valverde, N., Gómez-Plaza, E., López-Roc, J.M., Gil-Muñoz, R., Bautista-Ortín, A.B. (2011). The Extraction of Anthocyanins and Proanthocyanidins from Grapes to Wine during Fermentative Maceration is Affected by the Enological Technique. *J. Agric. Food Chem.*, 59, - pp. 5450–5455. <https://doi.org/10.1021/jf2002188>.
4. Cabezas, J.A., Cervera, M.T., Arroyo-García, R., Ibáñez, J., Rodríguez Torres, I., Borrego, J., Cabello, F., Martínez-Zapater, J.M. (2003). Garnacha and Garnacha Tintorera: Genetic Relationships and the Origin of Teinturier Varieties Cultivated in Spain. *Am. J. Enol. Vitic.* 54, - pp. 237–245.
5. Edi Maleti, Jasminka Karoglan Konti, Darko Preiner, Ana Jeromel, Claus-Dieter Patz, Helmut Dietrich (2009). Anthocyanin Profile and Antioxidative Capacity of Some Autochthonous Croatian Red Wines; *Journal of Food, Agriculture & Environment*, - Vol.7 (1), - pp. 48-51.
6. Gerzhikova, V.G. (2009). *Methods of Technochemical Control in Winemaking*, Second Edition, Simferopol, - p. 304.
7. Hrazdina, G., Borzell, A.J., Robinson, W.B. (1970). Studies on the Stability of the Anthocyanidin-3,5-Diglucosides. *Am. J. Enol. Vitic.* 21, - pp. 201–204.
8. International Organization of Vine and Wine, “Compendium of International Methods of Wine and Must Analysis”, OIV-18 RUE D’AGUESSEAU - 75008 PARIS, Edition 2021, Volume 1, - 607 p.
9. Jacobson Jean, L., (2006). *Introduction to Wine Laboratory Practices and Procedures*, United States of America, Springer Science + Business Media, Inc., - 375 p.
10. Kazumov, N. B., Kazumyan, K., N., Sukoyan, M., R. (2013). *Technology of Armenian Grape, Fruit and Berry Wines (3rd Revised Edition)*. “Ancestor”, - 340 p. (in Armenian). <https://doi.org/10.1002/0470010363>.

11. Ribereau-Gayon, P., Gloires, Y., Maujean, A., Dubourdieu, D. (2006). Handbook of Enology, Volume 2. The Microbiology of Wine and Vinifications, 2nd Edition, John Wiley & Sons, - p. 451.
12. Schneider, A., Gerbi, V., Redoglia, M., Rapid, A. (1987). HPLC Method for Separation and Determination of Major Organic Acids in Grape Musts and Wines, American Journal of Enology and Viticulture, Vol. 38, - No 2, - pp. 151-155.
13. Tikhonova, A.N., Stribizheva, L.I., Yozhov, E.V., Kachaeva, N.Y. (2011). Influence of Strains of Active Dry Yeast on Wine Organoleptic Properties // Winemaking and Viticulture, - N 2, - pp. 14-15 (in Russian).
14. Yakimenko, E.N., Guguchkina, T.I., Belyakova, E.A., Romanishin, P.E. (2012). Aroma-Forming Complex of Table and Special Wine Materials from the Don Native Grape Varieties in the Soil and Climatic Conditions of Kuban // Winemaking and Viticulture, - N 6, - pp. 28-29 (in Russian).
15. Yanniotis, S., Kotseridis, G., Orfanidou, A., Petraki, A. (2007). Effect of Ethanol, Dry Extract and Glycerol on the Viscosity of Wine, Journal of Food Engineering N: 81, - pp. 399-403. <https://doi.org/10.1016/j.jfoodeng.2006.11.014>.

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Assessing Copper Risk in Honey Sold in City of Yerevan

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ABSTRACT

Mining, including copper (*Cu*) production, is one of the primary economic activities in Armenia. Besides having an adverse environmental impact, it can lead to *Cu* accumulation in food, including honey. Considering the wide production and consumption of honey, this study aims to assess the dietary exposure of *Cu* through honey consumption in Yerevan, Armenia. Seventeen honey samples were included in the study. Food Frequency Questionnaire was used to evaluate honey consumption. While *Cu* contents exceed the Maximum Residue Level, dietary exposure estimates do not exceed the oral reference dose. Hence, the consumption of honey sold in Yerevan does not have the potential to cause adverse health effects.

Introduction

Bee farming is one of the main agricultural branches. On the one hand, this industry is highly profitable, but on the other hand bees, as major pollinators of crops, contribute to the yielding capacity and seed development of fruit trees, herbaceous plants and vegetables (Nicholls, et al., 2013). Honey is essential for the human organism due to its natural nutritious, therapeutic and preventive power. The latter is determined by chemical composition, which even in the case of the same floral origin of honey can be different depending on climatic conditions (sunlight and moisture content), chemical contents of soil, presence of diverse minerals in the soil, and so on. As a natural product used for therapeutic purposes, honey must not contain undesirable substances such as heavy metals (Eteraf-Oskouei, et al., 2013).

Honey is being consumed worldwide not only as a source of food but also for medicinal purposes, thus, it must remain pure and nutritious (Bartha, et al., 2020). However, many studies have indicated its contamination with heavy metals, pesticides, bacteria and radioactive materials (Pipoyan, et al., 2020, Mititelu, et al., 2022). These chemicals are released into the environment from both anthropogenic and natural sources and may accumulate in the soil and plant for long periods (Magna, et al., 2018).

Copper (*Cu*) has an essential part in biological systems and thus, is regarded as a necessary element (Ajibola, et al., 2012). However, high concentrations of *Cu*, as well as prolonged consumption of honey containing *Cu* can pose a risk to consumer health and cause gastrointestinal disorders (Bartha, et al., 2020).

Since environmental pollution can negatively influence

the honey quality and cause probable health risks, it is essential to assess the presence of potential toxicants (Pisani, et al., 2008). Previously, the Center for Ecological Noosphere Studies of Armenia (CENS) regularly carried out investigations regarding concentrations of heavy metals in honey and health risk assessment through honey consumption across the regions of Armenia, including mining and non-mining areas. The results of these studies indicate that in several honey samples, the concentrations of *Cu* were above the maximum allowable level, meanwhile, non-carcinogenic risk values did not exceed the acceptable level (Pipoyan, et al., 2020, Belyaeva, et al., 2011, Saghatlyan, et al., 2013). Taking into consideration the absence of similar studies in the capital city of Armenia, Yerevan, this is the first-ever attempt to evaluate *Cu* concentrations and carry out a dietary exposure assessment of honey sold in the markets of Yerevan. The work was supported by the State Budgetary Fund of the Science Committee of RA.

Materials and methods

Sampling

The study involved 17 honey samples of different floral origins. Honey sampling was done in compliance with accepted international methods. The samples were obtained from all the major supermarkets of Yerevan as well as from small-scale honey producers. The decomposition of honey was carried out in the ISO-IEC 17025 accredited laboratory of the Ecology Center at the Research Center of the National Academy of Sciences of Armenia, using methods approved by EU legal acts. For determining the content of non-volatile chemicals, honey has been exposed to high thermal degradation according to AOAC 985.01 method (Fredes, et al. 2006).

Digestion of samples

Samples were digested with nitric (HNO_3), sulfuric (H_2SO_4), and perchloric ($HClO_4$) acids. The digestion program was carried out accordingly – 500 W/5 min up to 180 °C, 0 W/2 min, and then 500 W/10 min at 180 °C. Then, the samples were cooled and filtered. Eventually, the filtrates were moved to 50 ml Erlenmeyer flasks.

Analysis of *Cu*

The levels of *Cu* were determined with an atomic absorption spectrometer (AAS, Perkin Elmer AAnalyst 800, US). Solution preparation was made with double-distilled deionized water. The glassware was cleaned with

10 % HNO_3 . The instrument was calibrated with a standard solution of the appropriate element. Blank standards from Perkin Elmer (an authorized distributor) were used. The solutions were diluted appropriately for calibration. The variation coefficients of replicate analysis were determined.

Quality assurance and quality control

Appropriate quality assurance procedures were carried out for the reliability of the results. For error minimization, the determination of contaminant level was performed with three replications. For the accuracy of the results, repeated analysis of samples against Standard Reference Materials for all trace elements was made (SRM 1570a). The obtained results were within ± 2 % of the certified values, suggesting that the results were precise.

Data collection and statistical analysis

To obtain honey consumption data, a food frequency questionnaire (FFQ) was developed and used for conducting surveys. The FFQ study was conducted in 2018 and included all the districts of Yerevan to ensure representativeness. Seven hundred people (18-65 years old) residing in Yerevan city took part in the survey. The FFQ was paper-based and interviewer-administered. The average daily consumption of honey was calculated by multiplying daily consumption frequency (portions/day) with portion size and quantity. All the statistical analyses were conducted using SPSS software (SPSS Inc., Chicago, Ill., USA, version 28). To get a normal distribution of consumption values, the K-means cluster analysis method was applied. The optimal number of clusters was determined experimentally. Clustering was carried out for several times, by varying *K* from 2 to 10 clusters. For each case, the sum of squared deviations was identified using the ANOVA table. Afterwards, three homogeneous cluster groups were revealed.

Exposure assessment

By combining *Cu*'s concentration data with consumption data, estimated daily intake (EDI) was calculated (US EPA, 1997):

$$EDI = \frac{C \times IR}{BW},$$

where *C* is the mean concentration of contaminant (mg/kg), *IR* is the rate of ingestion of food (kg/day), *BW* is the body weight (kg) (mean body weights for males and females in studied regions were 70 and 60 kg, respectively).

Non-carcinogenic health risks associated with honey

consumption by residents were assessed using the Target Hazard Quotient (THQ). THQ was calculated as the ratio of the EDI to the oral reference dose (RfD) (US EPA, 1997).

$$THQ = \frac{EDI}{RfD}$$

For the RfD of *Cu*, a dietary reference intake of 0.01 mg/kg/BW/day was used (ATSDR, 2004).

Results and discussions

Content of *Cu* in honey

The contents of *Cu* in honey samples of Yerevan are presented in Figure 1. The contents ranged from 0.26 to 1.57 mg/kg, with a mean of 0.99 mg/kg and standard deviation of 0.32 mg/kg. In Armenia there is no regulation limiting *Cu* content in honey, however, our results indicate that in several honey samples (H-1, H-2, H-5, H-10, H-11, H-14, H-15, H-17) *Cu* contents exceed the Maximum Residue Level (MRL) of 1 mg/kg set by EU (APEDA, 2008). The *Cu* concentrations assessed in the current study are comparable with the values estimated in other countries (Table). The findings are similar to those of neighboring countries of Iran and Turkey. It is noteworthy that no investigation was found regarding *Cu* content in honey in other neighboring countries of Georgia and Azerbaijan. In comparison to other countries (such as Romania, Ghana) where honey samples were collected mainly from polluted

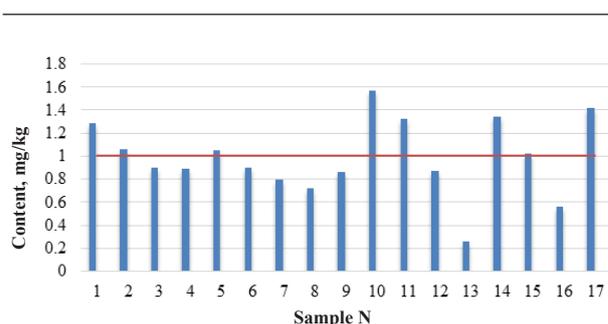


Figure 1. *Cu* contents (mg/kg) in honey samples sold in markets of Yerevan (composed by the authors).

areas, the contents of *Cu* are remarkably higher than the ones obtained in the present study.

Honey consumption

The average honey consumption for the studied population is 12.14 g/day; 60 % of consumers are female (10.16 g/day) and 40 % are male (14.80 g/day). The consumption amounts of honey for three different clusters are presented in Figure 2. For the first, second, and third clusters, the consumption amounts are equal to 6.39, 28.36, and 58.85 g/day, respectively. While the consumption amount increases from the first to the third cluster, the amount of people in each cluster decreases. Cluster 1 includes 584 people, cluster 2 includes 107 people, while cluster 3 includes only 39 people.

Table. Comparative results on honey contamination with *Cu* in different countries*

Country	Source of Honey Samples	<i>Cu</i> Concentration (mg/kg)	Literature Source
Iran, North West province, Ardabil	Multifloral honey collected from individual beekeepers	0.027-2.872	Aghamirlou, et al., 2015
Iran	Collected from different honey brands sold in markets	<0.5	Akhbari, et al., 2012
Turkey, Western Region (Budur, Antalya, Isparta)	Collected from individual beekeepers	0.24-0.54	Tutun, et al., 2019
Turkey, South and East Region	Monofloral and multifloral honey collected from local beekeepers	<0.001-0.93	Kılıç Altun, et al., 2017
Romania, Coșea Mică	Collected from private apiaries located in a polluted area	2.0-33.0	Bartha, et al., 2020
Romania	Collected from accredited beekeepers from polluted areas, multifloral honey	0.030	Mititelu, et al., 2022
Poland, Southwest region	Freshly ripened honey samples collected from a market	0.01-1.42	Stecka, et al., 2014
Ghana, Tamale Metropolis	Collected from honey harvesters from within 5 km of the industrial city	6.5-39.0	Magna, et al., 2018
Pakistan, Khyber Pakhtunkhwa	Honey samples collected from different districts	1.902	Ullah, et al., 2022

*Composed by the authors.

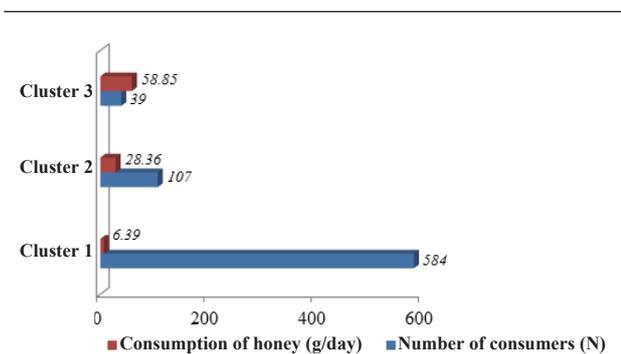


Figure 2. Honey consumption (g/day) for three clusters (composed by the authors).

EDI and THQ of Cu

The EDI values for trace elements are firmly based not only on contamination level but also on the consumption of honey (Pipoyan, et al., 2018a).

The estimated EDI values are presented in Figure 3. The amount for cluster 1 is equal to 0.0001 mg/kg BW/day, for cluster 2 – 0.0004 mg/kg BW/day, and for cluster 3 – 0.0008 mg/kg BW/day. The average EDI is equal to 0.0002 mg/kg BW/day. The EDI for both male and female consumers is equal to 0.0002 mg/kg BW/day, which does not exceed the oral reference dose of 0.0100 mg/kg BW/day (ATSDR, 2004).

The THQ values for males and females were 0.017 and 0.02, respectively. The THQ values for Cluster 1, Cluster 2 and Cluster 3 were 0.01, 0.4 and 0.08 respectively. In all cases, THQ values are less than the threshold of 1. THQ values for Cu are lower than 1 in several other countries as well, showing no health risk for consumers due to honey intake (Mititelu, et al., 2022, Ullah, et al., 2022). The intake of Cu from honey was below the provisional tolerable daily intake in Iran (Akbari, et al., 2012).

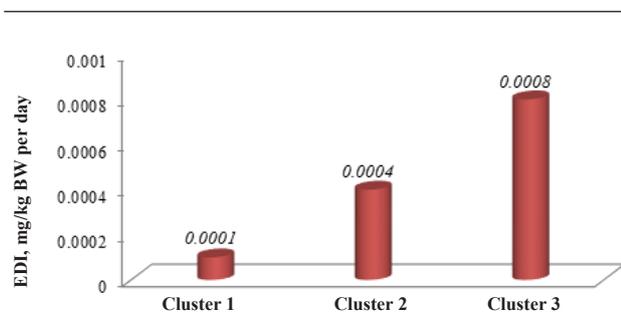


Figure 3. Estimated daily intake of Cu (mg/kg BW per day) (composed by the authors).

Conclusion

The obtained results indicate, that although in the investigated honey samples contents of Cu were higher than MRL, the consumption of honey sold in Yerevan, presented above, does not have the potential to cause adverse health effects. Due to fact that honey can contain other heavy metals, constant monitoring and risk assessment are crucial for maintaining consumer health protection (He, et al., 2013, Ru, et al., 2013). Hence, in our next investigations, we will assess the risk of other heavy metals for understanding the overall risk of honey consumed in Yerevan. Also, we plan to assess the risk of Cu in various honey samples produced in other cities and villages of Armenia to get a holistic view of Cu risk through honey consumption.

References

1. Aghamirlou, H.M., Khadem, M., Rahmani, A., Sadeghian, M., Mahvi, A. H., Akbarzadeh, A., Nazmara, S. (2015). Heavy Metals Determination in Honey Samples Using Inductively Coupled Plasma-Optical Emission Spectrometry. *Journal of Environmental Health Science and Engineering*, 13(1), - pp. 1-8. <https://doi.org/10.1186/s40201-015-0189-8>.
2. Ajibola, A., Chamunorwa, J., and Erlwanger, K.H. (2012). *Nutrition & Metabolism*. doi.org/10.1186/1743-7075-9-61. <https://doi.org/10.1186/1743-7075-9-61>.
3. Akbari, B., Gharanfoli, F., Khayyat, M. H., Khashyarmansh, Z., Rezaee, R., Karimi, G. (2012). Determination of Heavy Metals in Different Honey Brands from Iranian Markets. *Food Additives and Contaminants: Part B*, 5(2), - pp. 105-111. <https://doi.org/10.1080/19393210.2012.664173>.
4. APEDA (Agricultural and Processed Food Products Export Development Authority), 2008. Residue Monitoring Plan for 2008 for Drugs, Pesticides and Heavy Metals for Export of Honey to the European Union.
5. ATSDR (Agency for Toxic Substances and Diseases Registry), 2004. Toxicological Profile for Copper. Update. Agency for Toxic Substances and Diseases Registry, Centers for Disease Control, Atlanta, GA, USA. <https://doi.org/10.4135/9781412963855.n24>.
6. Bartha, S., Taut, I., Goji, G., Vlad, I. A., Dinulică, F. (2020). Heavy Metal Content in Poly-Floral Honey and Potential Health Risk. A Case Study of Copșa Mică, Romania. *International Journal of Environmental Research and Public Health*, 17(5), - 1507 p. <https://doi.org/10.3390/ijerph17051507>.
7. Belyaeva, O.A., Saghatelyan, A.K., Sahakyan, L.V. (2011). Studies on the Quality of Honey Produced in

- Armenia and Nagorno-Karabakh. Materials of the V International Scientific-Practical Conference “Current State and Prospects for the Development of the Food Industry and Public Catering” October 21-22, 2011, Chelyabinsk, Russia. Volume I, - pp. 54-58.
8. Eteraf-Oskouei, T., & Najafi, M. (2013). Traditional and Modern Uses of Natural Honey in Human Diseases: A Review. *Iranian Journal of Basic Medical Sciences*, 16(6), - 731p.
 9. Fredes, C., and Montenegro, G. (2006). Heavy Metals and Other Trace Elements Contents in Chilean Honey. *Ciencia e Investigación Agraria* 33:50-58. <https://doi.org/10.7764/rcia.v33i1.328>.
 10. He, J.Z., Feng, Q., & Sun, P.L. (2013). Health Risk Assessment of Six Heavy Metals in Different Sources of Honey Consumed in China. In *Advanced Materials Research* (Vol. 680, - pp. 86-93). Trans Tech Publications Ltd. <https://doi.org/10.4028/www.scientific.net/amr.680.86>.
 11. Kılıç Altun, S., Dinç, H., Paksoy, N., Temamoğulları, F. K., Savrunlu, M. (2017). Analyses of Mineral Content and Heavy Metal of Honey Samples from South and East Region of Turkey by Using ICP-MS. *International Journal of Analytical Chemistry*, 2017. <https://doi.org/10.1155/2017/6391454>.
 12. Magna, E.K., Dabi, M., Badu, E., Owusu, P. (2018). Determination of Heavy Metals and Potential Health Risk Assessment of Honey Harvested from the Tamale Metropolis of Ghana Using Atomic Absorption Spectrophotometer (AAS). *Elixir Pollut*, 121, 51522-51525.
 13. Mititelu, M., Udeanu, D.I., Nedelescu, M., Neacsu, S. M., Nicoara, A.C., Oprea, E., Ghica, M. (2022). Quality Control of Different Types of Honey and Propolis Collected from Romanian Accredited Beekeepers and Consumer’s Risk Assessment. *Crystals*, 12(1), - 87 p. <https://doi.org/10.3390/cryst12010087>.
 14. Nicholls, C.I., & Altieri, M.A. (2013). Plant Biodiversity Enhances Bees and Other Insect Pollinators in Agroecosystems. A Review. *Agronomy for Sustainable Development*, 33(2), - pp. 257-274. <https://doi.org/10.1007/s13593-012-0092-y>.
 15. Pipoyan, D., Beglaryan, M., Sireyan, L. (2018a). Exposure Assessment of Toxic Elements via Consumption of Fruit and Vegetable in Alaverdi Town. *Bulletin of National Agrarian University of Armenia*, N2, - pp.12-16.
 16. Pipoyan, D., Beglaryan, M., Sireyan, L., Merendino, N. (2018b). Exposure Assessment of Potentially Toxic Trace Elements via Consumption of Fruits and Vegetables Grown under the Impact of Alaverdi’s Mining Complex. *Human and Ecological Risk Assessment. An international Journal*, - pp. 1-16. <https://doi.org/10.1080/10807039.2018.1452604>.
 17. Pipoyan, D., Stepanyan, S., Beglaryan, M., Stepanyan, S., Asmaryan, S., Hovsepian, A., Merendino, N. (2020). Carcinogenic and Non-Carcinogenic Risk Assessment of Trace Elements and POPs in Honey from Shirak and Syunik Regions of Armenia. *Chemosphere*, 239, 124809. <https://doi.org/10.1016/j.chemosphere.2019.124809>.
 18. Pisani, A., Protano, G., Riccobono, F., (2008). Minor and Trace Elements in Different Honey Types Produced in Siena County (Italy). *Food Chem.* 107, - pp.1553–1560. <https://doi.org/10.1016/j.foodchem.2007.09.029>.
 19. Ru, Q.M., Feng, Q., He, J.Z. (2013). Risk Assessment of Heavy Metals in Honey Consumed in Zhejiang Province, Southeastern China, *Food and Chemical Toxicology* 53, -pp.256–262. <https://doi.org/10.1016/j.fct.2012.12.015>.
 20. Saghatelyan, A.K., Sahakyan, L.V., Belyava, O.A. (2013). Assessment of the Quality of Honey Produced in the Territory of the Republic of Armenia and Nagorno-Karabakh. *Environmental Problems and Identification of Risk Groups among the Population. Collection of Articles / Associate Editor: A.K. Saghatelyan. Yerevan: Gitutyun*, - pp. 171-178.
 21. Stecka, H., Jedryczko, D., Welna, M., Pohl, P. (2014). Determination of Traces of Copper and Zinc in Honeys by the Solid Phase Extraction Pre-Concentration Followed by the Flame Atomic Absorption Spectrometry Detection. *Environmental Monitoring and Assessment*, 186(10), - pp. 6145-6155. <https://doi.org/10.1007/s10661-014-3845-z>.
 22. Tutun, H., Kahraman, H.A., Aluc, Y., Avci, T., Ekici, H. (2019). Investigation of Some Metals in Honey Samples from West Mediterranean Region of Turkey. In *Veterinary Research Forum* (Vol. 10, No. 3, - p. 181). Faculty of Veterinary Medicine, Urmia University, Urmia, Iran. <https://doi.org/10.29252/jbrms.5.3.23>.
 23. Ullah, R., Jan, F.A., Gulab, H., Saleem, S., Ullah, N. (2022). Metals Contents in Honey, Beeswax and Bees and Human Health Risk Assessment Due to Consumption of Honey: A Case Study from Selected Districts in Khyber Pakhtunkhwa, Pakistan. *Archives of Environmental Contamination and Toxicology*, - pp. 1-14.
 24. US EPA, 1997. *Exposure Factors Handbook*. EPA/600/P-95/002F. Office of Research and Development, Washington.

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Target-Oriented Risk Assessment of AFB₁ in Buckwheat Consumed in Armenia

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ABSTRACT

Cereals, including buckwheat are consumed as an essential source of energy, minerals, fiber, and vitamins. However, these products are susceptible to aflatoxin B₁ (AFB₁) infection from various fungi. Considering the wide consumption of buckwheat in Armenia, this study aims to assess the dietary exposure of AFB₁ to Armenian adult population. 24-hour recall method was used to evaluate buckwheat consumption. While AFB₁ contents do not exceed the maximum residue levels, dietary exposure estimates exceed the toxicological reference value for females residing in Tavush region, as well as for consumers of cluster 2 (buckwheat consumption of 64.59 g/day). Hence, the consumption of buckwheat alone has the potential to cause adverse health effects.

Introduction

Throughout the world's healthy food market, buckwheat grains and their products are considered to have a high nutritional value and low inputs for cultivation (Kerlene, et al., 2018, Christa and Soral-Śmietana, 2008). However, many crops, including buckwheat are of concern for mycotoxin contamination, especially in the light of recent rapid changes in the weather conditions which affect all the aspects of food security (Leggieri, et al., 2012, Kerlene, et al., 2018). Mycotoxins are produced by fungi which colonize many crops and adapt to a wide range of environmental conditions (Khodaei, et al., 2021, Xiong, et al., 2021). In the food and feed industry, the most concerning mycotoxins are produced by *Aspergillus*, *Fusarium* and *Penicillium* (Das, et al., 2021).

Till now, 400 types of mycotoxins have been identified, out of which a few are dangerous to humans and animals, including aflatoxins (AFs), ochratoxins, deoxynivalenol, fumonisins, and zearalenone (Khodaei, et al., 2021). A key point of interest in relation to buckwheat are the AFs which are potent carcinogens that exist in five ways: AFB₁, AFB₂, AFG₁, AFG₂ and M₁ (EFSA, 2013, Mahapatra, 2021). The International Agency for Research on Cancer (IARC) has classified AFB₁ as a Group 1A carcinogen (carcinogenic to humans) (IARC, 1993). About 4.5 billion people worldwide are chronically exposed to low aflatoxin levels due to the daily consumption of products contaminated with it (Fan, et al., 2021, Pickova, et al., 2021). At high concentrations, the consumption can lead to serious health problems, including damage to the liver and other

organs, causing liver cancer, and death (WHO, 2020).

Considering the adverse health effects of mycotoxins on humans and animals, many countries, including the European Union (EU), set up standards for maximum levels of total aflatoxins in food products intended for both human and animal consumption. The EU established the maximum acceptable limits for AFs in nuts, dried fruits, cereals and cereal products, spices, and milk (Kortei, et al., 2021, Palumbo, et al., 2020).

To protect human health, it is essential to assess the presence of mycotoxins in cereals, including buckwheat. Previously, the Center for Ecological Noosphere Studies of Armenia (CENS) carried out investigations regarding concentrations of mycotoxins, including AFB₁ in cereals and cereal-based products and health risk assessment through cereal consumption in Yerevan, Armenia. The results of these studies indicate that contamination level of AFB₁ in cereal crops such as rice, buckwheat, maize and wheat sold in markets of the city of Yerevan range from 1.06 to 3.11 µg/kg, though the concentrations do not exceed the acceptable level (Pipoyan, et al., 2016). Meanwhile, the daily intake of AFB₁ via total consumption of cereal crops, in particular rice, buckwheat, maize and wheat, consumed by Yerevan population exceeds the toxicological reference value for AFB₁, indicating a potential health risk (Pipoyan, et al., 2017). However, individual consumption of the studied cereals didn't exceed the reference value. It is worth mentioning, that the previous investigations were carried out for the whole studied population, without taking into consideration different groups of population. Taking into consideration the absence of similar studies in the whole territory of Armenia, this is the first-ever attempt to carry out a target-oriented dietary exposure assessment of AFB₁ in buckwheat both in the capital of Armenia, as well as in other regions.

The work was supported by the Science Committee of the RA, in the frames of the research project № 21T-4A259.

Materials and methods

Data collection and statistical analysis

The data on AFB₁'s concentrations in buckwheat samples was obtained from previous studies (Pipoyan, et al., 2016, Pipoyan, et al., 2017). Detailed information regarding sample collection and analysis is presented there. The ELISA method was used to determine AFB₁ concentrations and the limit of detection (LOD) of the method has been estimated to be 0.001 mg/kg.

To obtain buckwheat consumption data, a 24-hour dietary

recall (24HR) was developed and used for conducting surveys. The survey was conducted in the frame of the research project on “Strengthening scientific and methodological capacity for assessing food security and nutrients” (20TTTCG-4A001).

The 24HR study was conducted in 2021 and included all the regions of Armenia, as well as all the districts of Yerevan to ensure national representativeness. One thousand and four hundred people (18–80 years old and over) residing in Armenia took part in the survey. The 24HR survey was paper-based and interviewer-administered. The average daily consumption of buckwheat was calculated considering the consumption frequency and the portion size. All the statistical analyses were conducted using SPSS software (version 22). Kolmogorov-Smirnov and Shapiro-Wilk tests were used to check for normality. To get a normal distribution of consumption values, the K-means cluster analysis method was applied. Two homogeneous cluster groups were revealed.

Exposure assessment

By combining AFB₁'s concentration data with consumption data, estimated daily intake (EDI) was calculated:

$$EDI = \frac{C \times IR}{BW},$$

where *EDI* is the exposure to AFB₁ (ng/kg bw/day), *C* is the mean concentration of contaminant (µg/kg), *IR* is the rate of ingestion of food (g/day), *BW* is the body weight (kg) (mean body weights for males and females in studied regions were 77 and 66 kg, respectively). Data regarding weight was self-reported through 24HR.

Results and discussions

Content of AFB₁ in buckwheat

The contents of AFB₁ in buckwheat samples ranged from 1.06 µg/kg to 1.89 µg/kg, with a mean of 1.475 µg/kg. According to the Customs Union's Technical Regulation on Food Safety (TR CU 021/2011), the content of AFB₁ in cereals do not exceed 5 µg/kg. In contrast, the European Commission Regulation No. 1881/2006 has set a maximum residue level (MRL) of 2 µg/kg of AFB₁ in all cereals and cereal products (buckwheat is included in cereals) (EC, 2006). Although the detected AFB₁ contents do not exceed the MRL, they make up 53 %-73 % of it.

The AFB₁ concentrations of the current study are comparable with the values estimated in other countries. A study towards risk assessment for aflatoxin B₁ in Japan

indicated that buckwheat is among the major contributors of AFB₁ intake. The contents of AFB₁ in buckwheat flour ranged from 0.04 – 0.08 µg/kg (Sugita-Konishi, et al., 2010). These values are substantially lower than the ones of the current study (1.06 – 1.89 µg/kg).

Buckwheat consumption

The average buckwheat consumption for the studied population is 40.52 g/day; 54 % of consumers are female (with an average buckwheat consumption of 40.5 g/day) and 46 % are male (with an average consumption of 40.4 g/day). A mean consumption data for Armenia, as well as a separate data for all 11 regions is represented in Figure 1. The amounts ranged from 36.45 g/day in Ararat region to a maximum of 52.28 g/day in Tavush region.

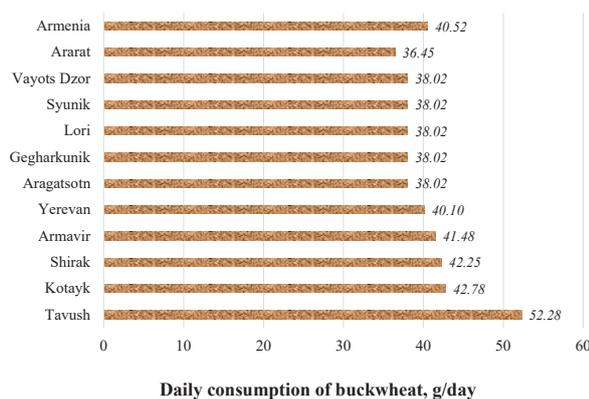


Figure 1. Buckwheat consumption (g/day) across Armenia (composed by the authors).

According to the cluster analysis 2 clusters were revealed. The consumption amounts of buckwheat for two different clusters are presented in Figure 2. For the first and second clusters, the consumption amounts are equal to 36.53 g/day and 67.59 g/day, respectively. While the consumption amount increases from the first to the second cluster, the amount of people in each cluster decreases. While cluster 1 includes most consumers (87 %), cluster 2 includes only a small portion of it (13 %).

EDI of AFB₁

The EDI values have been calculated for the whole country, each region, as well as for each cluster and gender. The amounts for cluster 1 and 2 are equal to 0.753 and

1.394 ng/kg bw/day, respectively. The average EDI obtained for the whole studied population is equal to 0.835 ng/kg bw/day. The average EDI obtained for the Yerevan population is equal to 0.827 ng/kg bw/day. Overall, the exposure to AFB₁ contamination is higher among females (0.771 ng/kg bw/day) than males (0.771 and 0.904 ng/kg bw/day). The highest daily intake of AFB₁ has been estimated in Tavush region and the lowest in Ararat region (Figure 3).

Considering the toxicological reference value of 1 ng/kg bw/day for AFB₁ defined by Scientific Committee on Food (SCF) and Expert Committee on Food Additives (JECFA), the EDI values obtained for females residing in Tavush region, as well as for consumers of cluster 2 exceed the threshold in 1.07 and 1.39 times, respectively (Leblanc, et al., 2005). It is of particular importance to state that the rest of the EDI values make up from 75 % to 88 % of the toxicological reference value. Therefore, there is a very high risk that the intake of AFB₁ through buckwheat alone can pose potential health risks for humans, particularly for the diabetic consumers who have the highest intake of buckwheat.

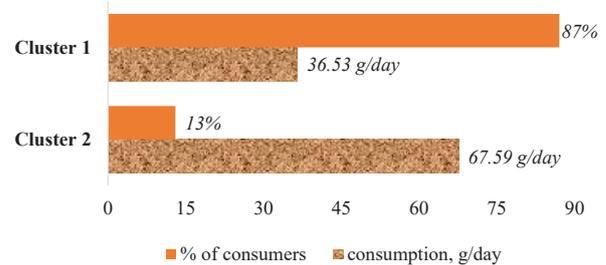


Figure 2. Buckwheat consumption (g/day) based on clusters (composed by the authors).

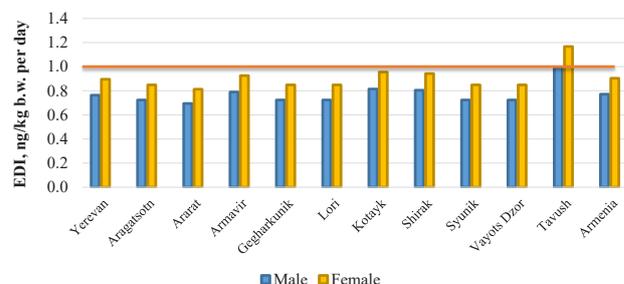


Figure 3. Estimated daily intake of AFB₁ (ng/kg bw per day) (composed by the authors).

Conclusion

The obtained results indicate, that although in the buckwheat samples contents of AFB₁ do not exceed the MRL, they make up 53 % – 73 % of it. Meanwhile, the consumption of buckwheat leads to EDI values exceeding the toxicological reference value in case of females residing in Tavush region, as well as for consumers of cluster 2 in 1.07 and 1.39 times, respectively.

Due to fact that buckwheat can contain other toxic substances, including heavy metals, constant monitoring and exposure assessment are important for protecting consumer health. It has been shown that heavy metals such as nickel, arsenic, lead, chromium, mercury, and cadmium share the main target organ, liver, with AFs, and it is therefore important to research their interactions (Renu, et al., 2021). This is particularly relevant for Armenia, since many risk assessment studies conducted in various regions of Armenia indicated the adverse effects of the above stated heavy metals for human health through the consumption of various food items (Pipoyan, et al., 2019, 2020, 2022).

Hence, in future investigations, it is recommended to assess the risk of other substances in buckwheat, as well as in other commonly consumed cereal-based products to better understand the overall risk of cereal products consumed in Armenia.

References

- Christa, K., and Soral-Śmietana, M. (2008). Buckwheat Grains and Buckwheat Products - Nutritional Fagopyrum esculentum and Selected Buckwheat Product. *Czech Journal of Food Science* 26, - pp. 153-162. <https://doi.org/10.17221/1602-cjfs>.
- Das, A., Mandal, S., Nag, S., and Mondal, B. (2021). Management of Storage Pathogens of Cereal Grains: A Review.
- EC, 2006. Commission Regulation (EC) No 1881/2006 of 19 December 2006 Setting Maximum Levels for Certain Contaminants in Foodstuffs / Official Journal of the European Union L364, - pp. 5-24.
- EFSA, 2013. Aflatoxins (Sum of B₁, B₂, G₁, G₂) in Cereals and Cereal-Derived Food Products. EFSA Supporting Publications 10: 406E. <https://efsa.onlinelibrary.wiley.com/doi/abs/10.2903/sp.efsa.2013.EN-406>.
- Fan, T., Xie, Y., and Ma, W. (2021). Research Progress on the Protection and Detoxification of Phytochemicals against Aflatoxin B₁- Induced Liver Toxicity. *Toxicol*, 195, - pp. 58-68. [https://doi.org/10.1016/0003-2670\(94\)80328-5](https://doi.org/10.1016/0003-2670(94)80328-5).
- IARC, 1993. IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. In *Some Naturally Occurring Substances: Food Items and Constituents, Heterocyclic Aromatic Amines and Mycotoxins*; World Health Organization, Ed.; IARC Press: Lyon, France. Volume 56, - pp. 445-466.
- Kerlene, I., Mankeviciene, A., and Cesnuleviciene, R. (2018). Risk Factors for Mycotoxin Contamination of Buckwheat Grain and its Products. *World Mycotoxin Journal*, 11(4), -pp. 519-529. <https://doi.org/10.3920/wmj2018.2299>.
- Khodaei, D., Javanmardi, F., and Khaneghah, A. M. (2021). The Global Overview of the Occurrence of Mycotoxins in Cereals: a Three-Year Survey. *Current Opinion in Food Science*, 39, - pp. 36-42. <https://doi.org/10.1016/j.cofs.2020.12.012>.
- Kortei, N.K., Annan, T., Kyei-Baffour, V., Essuman, E.K., Okyere, H., and Tettey, C.O. (2021). Exposure and Risk Characterizations of Ochratoxins A and Aflatoxins through Maize (*Zea mays*) Consumed in Different Agro-Ecological Zones of Ghana. *Scientific Reports*, 11(1), - pp. 1-19. <https://doi.org/10.1038/s41598-021-02822-x>.
- Leblanc, J.C, Tard, A., Volatier, J.L., Verger, P. (2005). Estimated Dietary Exposure to Principal Food Mycotoxins from the First French Total Diet Study, *Food Additives and Contaminants*, 22:(7):652-672. <https://doi.org/10.1080/02652030500159938>.
- Leggieri, M.C., Toscano, P., and Battilani, P. (2021). Predicted Aflatoxin B₁ Increase in Europe due to Climate Change: Actions and Reactions at Global Level. *Toxins*, 13(4), - 292 p. <https://doi.org/10.3390/toxins13040292>.
- Mahapatra, S.S. (2021). Antioxidants as Modulators of Plant Defense against Soilborne Fungal Pathogens upon Microbial Interaction. In *Antioxidants in Plant-Microbe Interaction*. Springer, Singapore, - pp. 305-314. https://doi.org/10.1007/978-981-16-1350-0_14.
- Palumbo, R., Crisci, A., Venâncio, A., Cortiñas Abrahantes, J., Dorne, J.L., Battilani, P., and Toscano, P. (2020). Occurrence and Co-Occurrence of Mycotoxins in Cereal-Based Feed and Food. *Microorganisms*, 8(1), - 74 p. <https://doi.org/10.3390/microorganisms8010074>.

14. Pickova, D., Ostry, V., Toman, J., and Malir, F. (2021). Aflatoxins: History, Significant Milestones, Recent Data on their Toxicity and Ways to Mitigation. *Toxins*, 13(6), - 399 p. <https://doi.org/10.3390/toxins13060399>.
15. Pipoyan, D., Hovhannisyan, A., Stepanyan, S., Ghrejyan, E. (2017). Dietary Exposure of Aflatoxin B₁ via Consumption of Cereals in Yerevan. *Bulletin of National Agrarian University of Armenia*. - Vol. 4, - pp. 143-146.
16. Pipoyan, D., Stepanyan, S., Beglaryan, M., Dorne, J.L. (2022). Risk Assessment of Uptake of Trace Elements through Consumption of Cereals: a Pilot Study in Yerevan, Armenia. *Journal of Environmental Health Science and Engineering*, - pp. 1-10.
17. Pipoyan, D., Stepanyan, S., Beglaryan, M., Stepanyan, S., Asmaryan, S., Hovsepyan, A., and Merendino, N. (2020). Carcinogenic and Non-Carcinogenic Risk Assessment of Trace Elements and POPs in Honey from Shirak and Syunik Regions of Armenia. *Chemosphere*, 239, 124809.
18. Pipoyan, D., Stepanyan, S., Stepanyan, S., Beglaryan, M., and Merendino, N. (2019). Health Risk Assessment of Potentially Toxic Trace Elements in Vegetables Grown under the Impact of Kajaran Mining Complex. *Biological Trace Element Research*, 192(2), - pp. 336-344.
19. Pipoyan, D.A., Galoyan, G.M., Hovhannisyan, A.S. (2016). Assessment of Aflatoxin B₁ Contamination Level in Cereals Sold in Yerevan, *Agroscience Scientific Journal*, 3-4, - pp. 101-103.
20. Renu, K., Chakraborty, R., Myakala, H., Koti, R., Famurewa, A.C., Madhyastha, H., Vellingiri, B., George, A., Valsala Gopalakrishnan, A. (2021). Molecular Mechanism of Heavy Metals (Lead, Chromium, Arsenic, Mercury, Nickel and Cadmium) Induced Hepatotoxicity. *Chemosphere*. 271:129735. [https://doi: 10.1016/j.Chemosphere.129735](https://doi:10.1016/j.Chemosphere.129735).
21. Sugita-Konishi, Y., Sato, T., Saito, S., Nakajima, M., Tabata, S., Tanaka, T., Norizuki, H., Itoh, Y., Kai, S., Sugiyama, K., Kamata, Y., Yoshiike, N. and Kumagai, S. (2010). Exposure to Aflatoxins in Japan: Risk Assessment for Aflatoxin B₁, Food Additives and Contaminants: Part A, 27:3, 365-372, <https://doi:10.1080/19440040903317497>.
22. TR CU 021/2011. Technical Regulations of the Customs Union “On Food Safety”. <https://docs.cntd.ru/document/902320560> (accessed on 05.03.2022).
23. WHO, 2020. Aflatoxins. Available at: <https://www.mdpi.com/2072-6651/14/5/307> (accessed on 07.03.2022).
24. Xiong, Z., Wang, Q., Xie, Y., Li, N., Yun, W., and Yang, L. (2021). Simultaneous Detection of Aflatoxin B₁ and Ochratoxin A in Food Samples by Dual DNA Tweezers Nanomachine. *Food Chemistry*, 338, 128122.

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Developing Technology for Special Beer Brewing by Using Non-Traditional Raw Materials

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ABSTRACT

The current work aims to justify special beer production technology developed through brier hips and juice. Availability of abundant species of brier hips and juice production industry in the Republic of Armenia enables to use them as non-traditional raw materials for beer brewing. The studies have shown that the most rational way of using brier juice is to add it at beer maturation stage after main fermentation. The most complete, consistent and inherent beer taste has been formed when combining 70 % young beer and 30 % brier juice. Brier hips were added 5 minutes before the end of boiling wort with hops. The best indicators have been recorded in the samples where 0.5 kg brier hips per 1 dal hopped wort has been added.

Introduction

Efficient use of raw materials is one of the prerequisites for the development of beer and non-alcoholic beverage industry. Besides saving the raw material, it is also necessary to improve the product quality and expand its range. Alcoholic beverages produced by using plant extracts not only improve in taste, but also mitigate the adverse toxic effects of ethanol (Gernet, 2009). In recent years, the direction of developing beer manufacturing technology by applying raw materials from medical plants has been actively advanced.

Non-traditional raw materials for brewing are spices, herbs, fruits, berries, medical plants, and wild yeast that can convey unusual flavor and aroma characteristics

(Danina and Ivanchenko, 2015). To produce drinks with specific properties and high nutritional value, various herbs, roots, nuts, fruits and berries are also added to the beer (Schilcher and Loew, 2013).

Honey is widely used in the production of special beers in many countries. It is added into the wort as a source of easily fermentable carbohydrates, or after fermentation into the finished beer product in amount of 1-3 % (Hahn, 2000). Beer additives can perform various functions: technological, pharmacological, nutritional. Nowadays, a technology for special beer manufacturing with addition of extracts from the Far Eastern wild plants of Araliaceae family has been developed (Palagina, et al., 2010).

Currently, significant growth in the production of low-

alcohol and soft drinks is observed, which encourages manufacturers to increase production size and range of the mentioned beverages. Manufacture of the mentioned drinks is a newly developed market branch which becomes more and more widespread among the consumers. So, the development of a technology by using non-traditional raw materials would promote the enhancement of the demanded products range. In Armenia, there is a growing interest in setting up small breweries in small towns and rural areas. Thus, the conducted research can serve as a base for the development of a new beer product manufacturing technology with innovative methodologies in Armenian breweries.

The current work is devoted to the justification of implementing special beer technology developed through brier hips and juice. Availability of great number of brier hips species (31 types), as well as production of juice in the Republic of Armenia, enables to use them as non-traditional raw materials for beer brewing. It is worth mentioning that brier hips have volatile and strong bactericidal properties. They also contain large amounts of antioxidants, but the most important thing is that brier hips come forth as a valuable multivitamin source.

Materials and methods

Throughout the research experiments traditional raw materials for the preparation of beer wort and yeast strains necessary for obtaining new type of beer has been selected. Brewing malt, brier hips, drier juice, barley, pale malt, aromatic hop pallets, brewer yeast of *Saccharomyces* race and water have been used in manufacturing the new beer product. Experimental studies were carried out in the laboratory of the Chair of Plant-Based Food Product Processing Technology, as well as at the «Beer of Yerevan» Closed Joint-Stock Company.

The technology of discussed special beer manufacture is based on the traditional beer brewing technology and consists of the following main steps:

1. *Preparation of raw material*: in this stage special attention was paid to crushing, which was implemented by means of laboratory mill.

2. *Mashing*: mashing was carried out via infusion method. The resulted mash was heated at a rate of 1°C per minute with pauses for optimal enzyme action. During pauses, the mash was stirred uninterruptedly. Termination of saccharification process was checked with an iodine test. After a positive reaction to saccharification, the beer was sent for filtration. Mashing mode is shown in the Figure 1.

3. *Wort filtration*: the first wort was returned again to the filtration to refine it maximum thoroughly. Then the grains were washed with water and the washings were mixed with the wort.

4. *Boiling the wort with hops*: when boiling the wort with hops, evaporation of excess moisture, extraction of aromatic and bitter substances of hops, coagulation of high-molecular proteins, inactivation of enzymes and sterilization of the wort is observed. Boiling duration of wort with hops ranged from 1.5 to 2 hours.

5. *Cooling and clarification of the wort*: the hot beer wort was cooled and filtered. The wort was cooled in a refrigerator to a temperature of $7 \pm 1^\circ\text{C}$. Thereinafter, yeast was added to wort.

6. *Fermentation of beer wort*: in the current research, fermentation process was carried out in closed glass vessels. The main fermentation process lasted 7 days. Fermentation was carried out according to a certain temperature schedule, planned by the technological scheme, with daily monitoring of fermentation temperatures. After reaching an extract content of 4.0-3.5 %, the fermented wort was cooled to a temperature of 3-5 °C. The decrease in temperature was carried out slowly -1°C during three hours. Thus, cooling of young beer took up to 12 hours. After reaching a temperature of 3 °C, young beer was left at this temperature for another 12 hours for better yeast settling.

7. *Maturation of beer*: The following main processes take place during maturation: saturation of beer with carbon dioxide, clarification due to the precipitation of yeast sediment and suspended particles, maturation. Maturation of beer was carried out at a temperature of 0-2 °C without oxygen. During maturation, the beer was kept in the apparatus for 21 days, after which the finished beer product was sent for filtration and bottling.

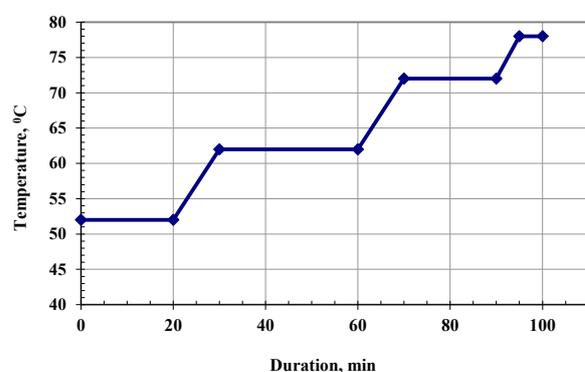


Figure 1. Mash temperature chart (composed by the author).

Results and discussions

The traditional beer manufacturing technology served as a background for the special beer production upon brier hips and juice supplementation. There are four possible options regarding the relevant time when the mentioned ingredients can be added: adding brier hips and juice to the wort at the stage of boiling wort with hops, at fermentation stage, maturation stage or adding them to the finished beer product. According to the research results and theoretical data, it is better to add brier juice after the main fermentation and at the stage of maturation. Addition of brier juice to the finished product caused turbidity, appearance of suspensions and discoloration. In such beer samples woody taste profiles were recorded. Whereas, adding brier juice at the brewing stage with hops would significantly reduce the quality of finished product, since when boiling the wort with extract and hops, a significant loss of vitamin C and other useful compounds is observed. Thus, brier juice should be added after the main fermentation parallel to the young beer maturation, which will ensure avoiding loss of juice aromatic substances, that could occur when adding juice at the stage of boiling wort with hops.

The studies have shown that the use of brier juice at the main fermentation stage again caused loss of some aromatic substances and tannins. In the result, hazy beer with opalescence was produced. Besides, it has been proved that addition of extracts at the main fermentation stage reduced yeast activity and slowed down the fermentation process. Thus, investigations have shown that the most rational way of using brier juice is to add it at the maturation stage, after main fermentation. So, the selected method for beer brewing is based on the above stated findings.

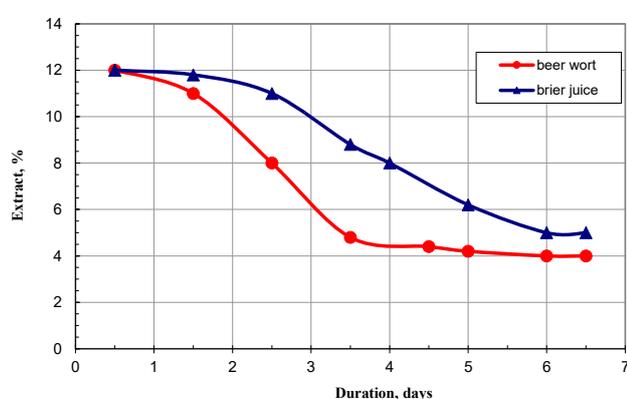


Figure 2. Fermentation dynamics of beer wort and brier juice via beer yeast (composed by the author).

Malted hopped wort with 12 % initial concentration was prepared according to the infusion method. The main fermentation and maturation took place in line with traditional technology except that before fermentation young beer was mixed with brier juice with a certain ratio. The ratio of 70 % young beer and 30 % brier juice made it possible to obtain beer drink samples with pleasant malt-brier flavor, the aroma of which is balanced with malt and brier tones. The produced special samples of beer drink are distinguished by high foam stability and foam height. The further research was related to the study of yeast fermentation dynamics of beer wort and brier juice. Fermentation dynamics of beer wort and brier juice via beer yeasts is introduced in Figure 2.

For beer production, brewer's yeasts of various races are used. The use of these yeasts is due to the fact that they convey peculiar taste and aroma to beer; besides, they are conformed to beer production conditions and composition of beer wort. Using brewer's yeast for fermenting brier juice was of particular interest, the latter being used for special beer manufacturing. In this regard, it is necessary to study the organoleptic and physicochemical indicators of fermented products. Initial concentration of dry matters in wort and juice makes 12 %. Fermentation was carried out at a temperature of 8 °C for 7 days. The values of pH, acidity and dry matters of brier juice and beer wort were the researched parameters. The research results are presented in the Table. During the beer wort fermentation pH value decreases to 3.70, which indicates that acids are formed throughout fermentation, while pH of brier juice practically does not change in fermentation process, only by the end decreasing to the level of 3.46.

Table. Physical and chemical indicators of fermented products*

Fermentation duration, day	pH		Dry matters, %		Acidity, acid value	
	Brier hips juice	Beer wort	Brier hips juice	Beer wort	Brier hips juice	Beer wort
1	3.70	5.52	12	12	4.8	2.3
2	3.62	5.50	11.6	10.6	4.9	2.4
3	3.60	5.06	11.0	8.4	5.0	2.5
4	3.58	4.80	9.2	4.9	5.3	2.6
5	3.52	3.78	7.3	4.7	5.5	2.7
6	3.50	3.75	5.3	4.6	5.7	2.8
7	3.46	3.70	5.1	4.3	5.8	2.9

*Composed by the author.

As regard to the reduction of dry matter content, it is obvious that beer wort was fermented more intensely than brier juice since fermentation was carried out with brewer's yeast. It has been revealed that with combined fermentation, brewer's yeast does not affect the organoleptic indicators of the manufactured product.

The further research activities are related to the development of technological scheme for new beer product manufacture by using brier hips. They can be applied at various stages of beverage production, such as boiling the wort with hops, main fermentation and maturation stages, but it is most relevant to add them when boiling the wort with hops for better extraction of aromatic substances available in the raw material, and to replace part of the hops with another raw materials, like brier hips.

Dry brier hips were added five minutes before the end of boiling the wort with hops and similarly aromatic hops were added so as to preserve flavoring components. Mashing was carried out through infusion method. When boiling the wort samples with dry brier hips, half of aromatic hops were added 30 minutes before the end of boiling, and then 5 min before the end of boiling aroma hops and brier hips were added. For control sample 50 % of aromatic hops was added 30 minutes before the end of wort boiling, the second half – 5 minutes before its end. After boiling the wort was cooled and hoppy wort was filtered, then the content of dry matters was investigated. Afterwards the wort was transferred into fermentation apparatus. During fermentation monitoring over the fermentation rate of the extracted substances was carried out by measuring dry matters through refractometric method.

Conclusion

Based on the research results, new non-traditional raw materials and technological scheme for special beer production has been recommended. Brier hips and juice has been selected as non-traditional raw materials. The developed technology for manufacturing new beer products by using non-traditional raw materials puts special stress on the following aspects: the wort should be prepared

through infusion method, while the initial concentration of dry matters in the hopped wort should make 12 %.

The studies have shown that the most rational way of using brier juice is to add it at the stage of maturation, after main fermentation. The physicochemical parameters and quality indicators of the finished product showed that the most complete, consistent and inherent beer taste has been recorded in the samples with the addition of 70 % young beer and 30 % brier juice.

It should be noted that in the samples with brier juice addition fermentation process was weaker than that of in the samples with brier hips. Brier hips were added at the stage of boiling wort with hops 5 minutes before the end of boiling. The best results were recorded in the samples where 0.5 kg brier fruits per 1 dal hopped wort has been added. As a result, beer drink samples with pleasant malt-brier flavor and balanced aroma of malt and brier tones have been manufactured. The use of plant-based extracts in the production of special beers will expand the market of physiologically healthy beverages.

References

1. Danina, M.M., Ivanchenko, O.B. (2015). The Use of *Brettanomyces* Yeasts in Beer Technology. Bulletin of the International Academy of Refrigeration. N 4, - pp. 27-31 (in Russian).
2. Gernet, M. V. (2009). State and Perspective Manufacture of Special Beer Varieties. Beer and Beverages. N 2, - pp. 8–10 (in Russian).
3. Hahn, P. (2000). Energy Drinks and Functional Drinks. N 4, - pp. 218-223.
4. Palagina, M.V., Zimba, A.G., Makarova, A.A. (2010). Development of Technology for New Special Beer Production via Addition of Vegetable Extracts, Innovation Technologies, N 4, - pp. 30-32 (in Russian).
5. Schilcher, H., Loew, D. (2013). Herbal Medicines Alternative to Synthetic Medicines, MMW Fortsch Med., N 16, - pp. 97-99.

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ՊԱՐԲԵՐԱԿԱՆԸ ՆԵՐԱՐՎԱԾ Է ԴՈԿՏՈՐԱԿԱՆ ԵՎ ԹԵԿՆԱԾՈՒԿԱՆ ԱՏԵՆԱԽՈՍՈՒԹՅՈՒՆՆԵՐԻ ԱՐԴՅՈՒՆՔՆԵՐԻ ԵՎ ԴՈՒՅԹՆԵՐԻ ԳՐԱՊԱՐԱԿԱՆ ՉԱՍԱՐ ՀԱՍՏԱՐ ՀԱՄԱՐ ՀԱՄԱՆ ԲՈԿ-Ի ԿՈՂՄԻՑ ԸՆԴՈՒՆԵԼԻ ԳԻՏԱԿԱՆ ՀԱՆՐԵՍՆԵՐԻ ՑԱՆԿՈՒՄ:

ИЗДАНИЕ ВКЛЮЧЕНО В ПЕРЕЧЕНЬ ВЕДУЩИХ НАУЧНЫХ ЖУРНАЛОВ ВАК МНОКС РА, В КОТОРЫХ ДОЛЖНЫ БЫТЬ ОПУБЛИКОВАНЫ ОСНОВНЫЕ РЕЗУЛЬТАТЫ И ПОЛОЖЕНИЯ ДИССЕРТАЦИЙ НА СОИСКАНИЕ УЧЕНОЙ СТЕПЕНИ ДОКТОРА И КАНДИДАТА НАУК.

THE JOURNAL IS INVOLVED IN THE LIST OF SCIENTIFIC PERIODICALS RELEVANT FOR PUBLICATIONS OF THE RESULTS AND PROVISIONS OF DOCTORAL AND PHD THESES AND APPROVED BY THE HIGHER EDUCATION QUALIFICATION COMMITTEE OF THE RA MoESCS.

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