



TECHNICAL UNIVERSITY OF MOLDOVA

JOURNAL OF ENGINEERING SCIENCE

Technical and applied scientific publication founded in 9 February 1995
Alternative title: Meridian ingineresc

2019
Vol. XXVI (3)

ISSN 2587-3474
eISSN 2587-3482

TECHNICAL UNIVERSITY OF MOLDOVA (PUBLISHING HOUSE)
„TEHNICA UTM” (PRINTING HOUSE)

Main subjects areas of the Journal of Engineering Science:

A. Industrial Engineering

- Mechanical Engineering and Technologies
- Applied Engineering Sciences and Management
- Materials Science and New Technologies
- Electrical Engineering and Power Electronics
- Energy systems
- Light Industry, New Technologies and Design
- Industrial and Applied Mathematics
- Vehicle and Transport Engineering

B. Electronics and Computer Science

- Electronics and Communication
- Microelectronics and Nanotechnologies
- Biomedical Engineering
- Computers and Information Technology
- Automation

C. Architecture, Civil and Environmental Engineering

- Architecture, Urbanism and Cadaster
- Civil Engineering and Management
- Energy Efficiency and New Building Materials
- Environmental Engineering

D. Food Engineering

- Food Technologies and Food Processes
- Food Industry and Management
- Biotechnologies, Food Chemistry and Food Safety
- Equipment for Food Industries

The structure of the journal corresponds to the classification of scientific publications: Engineering, Multidisciplinary.

How to publish a paper:

1. Send the manuscript and information about the author to the **Editorial Board address:** jes@meridian.utm.md
2. Manuscripts are accepted only in English, by e-mail, in template file (www.jes.utm.md)
3. After a review, you will be notified of the editorial board's decision.
4. After the Journal has been published, we will send it to you immediately by mail.

Editor-in-Chief

Dr. hab. prof. univ. Viorel BOSTAN

Technical University of Moldova

viorel.bostan@adm.utm.md

Editorial Board

Abdelkrim Azzouz, Dr. Ing., Professor, Quebec University of Montreal, Canada
Adrian Gheorghe, PhD, Professor Old Dominion University, Norfolk, Virginia, 23529, USA
Adrian Graur, PhD, Professor University „Ștefan cel Mare”, Suceava, Romania
Cornel Ciupan, PhD, Professor Technical University of Cluj Napoca, Romania
Cristoph Ruland, PhD, Professor, University of SIEGEN, Germany
Dimitr P. Karaivanov, Dr.Sc., PhD, Professor University of Chemical Technology and Metallurgy, Sofia, Bulgaria
Dumitru Mnerie, PhD, Professor „Politehnica” University of Timișoara, Romania
Dumitru Olaru, PhD, Professor Technical University „Gh. Asachi”, Iași, Romania
Florin Ionescu, PhD, Professor University Steinbes, Berlin, Germania
Frank Wang Professor of Future Computing, University of Kent, U.K.
Gabriel Neagu Profesor Institutul Național de Cercetare-Dezvoltare în Informatică București,
George S. Dulikravich, PhD, Florida International University, U.S.A.
Gheorghe Badea, Ph.Dr. in Engineering, Professor, Technical University of Civil Engineering Bucharest, Romania
Gheorghe Manolea, PhD, Professor University of Craiova, Romania
Grigore Marian, Dr.Sc., PhD, Professor Agrarian State University of Moldova, Chișinău, Republic of Moldova
Hai Jiang, Ph.D. Professor, Department of Computer Science, Arkansas State University, U.S.A.
Heinz Frank, PhD, Professor Reinhold Würth University. Germany
Hidenori Mimura, Professor, Research Institute of Electronics, Shizuoka University, Japan
Ion Bostan, Dr.hab., Acad. Academy of Science, Republic of Moldova
Ion Paraschivoiu, PhD, Professor Université Technologique de Montreal, Canada
Ion Rusu, Dr. hab. Professor, Technical University of Moldova
Ion Tighineanu, Dr.hab., Acad. Academy of Science, Moldova
Ion Vișa, PhD, Professor University Transilvania of Brașov, Romania
Jorj. Ciumac, Dr., Professor, Technical University of Moldova
Laurențiu Slătineanu, PhD, Professor Technical University „Gh. Asachi”, Iași, Romania
Lee Chow, PhD, Professor, University of Central Florida, USA
Leonid Culiuc, Dr.hab., Acad. ASM, Institute of Applied Physic
Livia Nistor-Lopatenco, Ph.Dr. in Engineering, Associate Professor, Technical University of Moldova
Mardar Maryna, Doctor of Technical Science, Professor, Odessa National Academy of Food Technologies, Odessa, Ukraine
Mircea Bernic, Dr. hab., Professor, Technical University of Moldova
Mitrofan Ciobanu, academic MAS, Dr.Sc., PhD, Professor Tiraspol State University, Chișinău, Republic of Moldova
Natalia Tislinschi, Dr., Ass. Professor, Technical University of Moldova
Oleg Lupan Dr.hab. Professor, Technical University of Moldova
Pavel Tatarov, Dr. hab., Professor, Technical University of Moldova
Pavel Topală, Dr.Sc., PhD, Professor, State University „Aleco Russo” from Bălți, Republic of Moldova
Peter Lorenz, PhD, Professor University of Applied Science Saar, Saarbrücken, Germania
Petru Cașcaval, PhD, Professor, ”Gheorghe Asachi” Technical University of Iasi, Romania

Petru Stoicev, Dr.Sc., PhD, Professor, Technical University of Moldova, Chişinău, Republic of Moldova
Polidor Bratu, PhD, academic RATS, president ICECON S.A. Bucureşti, Romania
Radu Munteanu, PhD, Professor Technical University of Cluj Napoca, Romania
Radu Sorin Văcăreanu, Dr. hab. Professor, Technical University of Civil Engineering Bucharest, Romania
Sergiu Zaporozhan Dr., Professor, Technical University of Moldova
Spiridon Creţu, PhD, Professor Technical University „Gh. Asachi”, Iaşi, Romania
Eden Mamut, PhD, Professor University „Ovidius” Constanţa, România
Stanislav Legutko, PhD, Professor Poznan University of Technology, Poland
Rafał Gołębski, Dr., Ass. Professor, Częstochowa University of Technology, Poland
Stefan Tvetanov, Dr., Professor, University of Food Technologies, Bulgaria
Ştefan-Gheorghe Pentiuc, Dr., Professor, University “Stefan cel Mare” of Suceava, Romania
Svetlana Albu, Dr. hab. Professor, Technical University of Moldova
Thomas Luhmann, Dr.-Ing. habil. Dr. h.c. Professor, Jade University of Applied Sciences, Germany
Tudor Ambros, Dr.Sc., PhD, Professor, Technical University of Moldova, Chişinău, Republic of Moldova
Valentin Arion, Dr.Sc., PhD, Professor, Technical University of Moldova, Chişinău, Republic of Moldova
Valentina Bulgaru, PhD, Assoc. professor, Technical University of Moldova, Chişinău, Republic of Moldova
Valeriu Dulgheru, Dr.Sc., PhD, Professor, Technical University of Moldova, Chişinău, Republic of Moldova
Vasile Tronciu Dr.hab. Professor, Technical University of Moldova
Victor Ababii, Dr. Professor, Technical University of Moldova
Victor Şontea Dr. Professor, Technical University of Moldova
Vilhelm Kappel, PhD, Institute of Research INCDIE ICPE-CA, Bucharest, Romania
Vladimir Zavialov, Dr. hab., Professor, National University of Food Technology, Ukraine
Vladislav Resitca, Dr., Ass. Professor, Technical University of Moldova
Yogendra Kumar Mishra, Dr. habil., Kiel University, Germany
Yuri Dekhtyar, Professor, Riga Technical University, Riga, Latvia

Responsible Editor:

Dr. hab. Rodica STURZA
Technical University of Moldova
rodica.sturza@chim.utm.md

Editorial Production:

Dr. Nicolae Trifan
Dr. Svetlana Caterenciuc

CONTENT

Abstracts	6
A. Industrial Engineering		
Nellu Ciobanu, Anatol Rotaru, Ilarie Gontia, Vasile Tronciu	<i>Quantum treatment of self-organization phenomena of excitons and biexcitons.....</i>	23
B. Electronics and Computer Science		
Emilian Guțuleac, Serqiu Zaporojan, Victor Moraru, Alexei Sclifos	<i>Performance modeling of network defense in breadth systems by matrix rewriting SRN with fuzzy parameters</i>	38
Titu-Marius I. Băjenescu	<i>Quo vadis robotics?.....</i>	54
C. Architecture, Civil and Environmental Engineering		
Mohammad Beykzade, Sepide Beykzade	<i>Management of investigating the effect of blasting and impact load in various structures</i>	65
Diah Octaviani Pratiwi, Febrian Hadinata, Heni Fitriani	<i>The generation rate and characteristics of municipal solid waste in slums of lawang kidul village at palembang city</i>	71
D. Food Engineering		
Anna Bocharova-Leskina, Sergii Verbytskyi	<i>Theoretic approaches to substantiate shelf life capacity of butter and spreads.....</i>	78
Aliona Ghendov-Moșanu, Rodica Sturza, Tudor Chereches, Antoanela Patras	<i>A fuzzy logic approach for mathematical modeling of the extraction process of bioactive compounds.....</i>	89
Roman Golubi	<i>Tartaric stabilization of grape juice with ionic exchange resins.....</i>	100
Elisaveta Sandulachi, Eugenia Boaghi, Pavel Tatarov, Vladislav Resitca	<i>Application of pareto principle in monitoring walnuts quality at storage.....</i>	107
Oxana Radu, Alexei Baerle, Pavel Tatarov, Liliana Popescu	<i>Factors that determine the shelf life of a butter-like spread based on walnut oil.....</i>	119
Rodica Sturza, Elisaveta Sandulachi, Daniela Cojocari, Greta Balan, Liliana Popescu Aliona Ghendov-Moșanu	<i>Antimicrobial properties of berry powders in cream cheese</i>	125
History of engineering		
Gheorghe Manolea	<i>Gheorghe Ion Duca - the reorganizer of the national school of bridges and roads of Bucharest.....</i>	137

DOI: 10.5281/zenodo.3443911
 CZU 535.01:530.1

QUANTUM TREATMENT OF SELF-ORGANIZATION PHENOMENA OF EXCITONS AND BIEXCITONS

Nellu Ciobanu¹, ORCID ID: 0000-0002-8153-8237

Anatol Rotaru, Ilarie Gontia², Vasile Tronciu^{3*}, ORCID ID: 0000-0002-9164-2249

¹State University of Medicine and Pharmacy "Nicolae Testemitanu", bd. Stefan cel Mare 165, Chisinau, Moldova

²Laboratory of Optical Process in Nanostructured Materials, National Institute of Materials Physics, Atomistilor 405A, Bucuresti Magurele, Romania

³Department of Physics, Technical University of Moldova, bd. Stefan cel Mare 168, Chisinau, Moldova

Corresponding Author: Vasile Tronciu, email: vasile.tronciu@fiz.utm.md

In memory of Anatol Rotaru

Received: June, 27, 2019

Accepted: September, 6, 2019

Abstract. We present in this paper the quantum treatment of self-organization phenomena of excitons and biexcitons in the geometry of a ring cavity. Applying the adiabatic elimination method of the exciton and biexciton variables, the Fokker-Planck equation for the transmitted field was obtained. The spectrum of transmission and second order correlation function were calculated. Thus, the spectrum of transmission describes a hysteresis cycle character, where a narrow spectral line in the end of cycle can be observed. The phenomena of optical bistability and switchings of excitons and biexcitons are investigated theoretically.

Keywords: *Optical bistability, semiconductors, Fokker-Planck Equation, self-organization, excitons, biexcitons, ring cavity.*

DOI: 10.5281/zenodo.3443911
 CZU 535.01:530.1

TRATAREA QUANTICĂ A FENOMENELOR DE AUTO-ORGANIZARE A SISTEMELELOR DE EXCITONI ȘI BIEXCITONI

Nellu Ciobanu¹, ORCID ID: 0000-0002-8153-8237

Anatol Rotaru, Ilarie Gontia², Vasile Tronciu^{3*}, ORCID ID: 0000-0002-9164-2249

¹Universitatea de Medicină și Farmacie "Nicolae Testemitanu", bd. Stefan cel Mare 165, Chisinau, Moldova

²Laboratorul Procese Optice în Materiale Nanostructurate, Institutul Național de Fizică a Materialelor, Atomistilor 405A, Bucuresti Magurele, Romania

³Departamentul de Fizică, Universitatea Tehnică a Moldovei, bd. Stefan cel Mare 168, Chisinau, Moldova

Autor corespondent: Vasile Tronciu, email: vasile.tronciu@fiz.utm.md

În memoria lui Anatol Rotaru

Recepționat: iunie, 27, 2019

Acceptat: septembrie, 6, 2019

Abstract. În această lucrare este prezentat un model cuantic de studiu al fenomenelor de auto-organizare a sistemului de excitoni și biexcitoni în cavități inelare. Aplicând metoda de eliminare adiabatică a excitonilor și biexcitonilor, s-a obținut ecuația Fokker-Planck pentru câmpul transmis. S-a calculat spectrul de transmisie și funcția de corelație de ordinul doi. După cum a fost observat, spectrul de transmisie descrie comportament de histerezis, cu apariția unei linii spectrale înguste. Sunt cercetate teoretic fenomenele de bistabilitate optică și comutări ale sistemului de excitoni și biexcitoni.

Cuvinte cheie: *Bistabilitate optică, semiconductori, Ecuația Fokker-Planck, auto-organizare, excitoni, biexcitoni, cavități inelare.*

DOI: 10.5281/zenodo.3444051
 CZU 004.056.53:519.711

PERFORMANCE MODELING OF NETWORK DEFENSE IN BREADTH SYSTEMS BY MATRIX REWRITING SRN WITH FUZZY PARAMETERS

Emilian Guțuleac*, ORCID ID: 0000-0001-6839-514X
 Sergiu Zaporozian, ORCID ID: 0000-0001-5928-4229
 Victor Moraru, ORCID ID: 0000-0002-5454-8341

Alexei Sclifos

Technical University of Moldova, 168 Stefan cel Mare bvd., MD-2004 Chisinau, Republic of Moldova

*Corresponding author: Emilian Guțuleac: emilian.gutuleac@calc.utm.md

Received: July, 04, 2019

Accepted: September, 22, 2019

Abstract. We have defined in this paper, a new kind of stochastic reward network (SRN) by introducing matrix attributes and fuzzy parameters of timed transitions and of rewriting rules, called MFRSRN, allowing the dynamic marking-dependent reconfiguration of these models. Moreover, this formalism offers a descriptive language that allows managing the compact representations the model's size through the introduction of matrix structuring and rewriting mechanisms of the compositional model's behavior. As an example of application, we show how the proposed formalism can be applied to performance modeling of network "Defense in Breadth" system which includes the combination of firewall, IDS, honeypot and moving target defense (MTD) techniques, taking into account the probabilistic and epistemic uncertainty aspects.

Keywords: *attack, cyber-security, evaluation, fuzzy number, honeypot, moving target defense, reconfiguration, stochastic reward net.*

DOI: 10.5281/zenodo.3444051
 CZU 004.056.53:519.711

MODELAREA PERFORMANȚEI SISTEMELOR DE APĂRARE ÎN LĂRGIME REȚEA PRIN RESCRIEREA MATRICEALĂ A SRN CU PARAMETRI FUZZY

Emilian Guțuleac*, ORCID ID: 0000-0001-6839-514X,
 Sergiu Zaporozian, ORCID ID: 0000-0001-5928-4229
 Victor Moraru, ORCID ID: 0000-0002-5454-8341

Alexei Sclifos

Universitatea Tehnică a Moldovei, 168 bvd. Stefan cel Mare, MD-2004 Chisinau, Republica Moldova

*Autor corespondent: Emilian Guțuleac, emilian.gutuleac@calc.utm.md

Recepționat: iulie, 04, 2019

Acceptat: septembrie, 22, 2019

Rezumat. În această lucrare este definit un nou tip de rețea Petri stocastică cu recompense (SRN) cu atribute matriceale și parametri fuzzy ai tranzițiilor temporizate și celor ai regulilor de rescriere, denumită MFRSRN, care permite reconfigurarea dinamică, dependentă de marcajul current al acestor modele. Mai mult, acest formalism oferă un limbaj descriptiv care permite de a gestiona reprezentari compacte a dimensiunii modelului prin introducerea unor mecanisme de rescriere a structurii și a matricei comportamentului modelului compozițional. Ca exemplu de aplicare, arătăm modul în care formalismul propus poate fi folosit la modelarea și evaluarea performanței „Apărare în Lărgime” al sistemului de securitate rețea, care include o combinație de firewall, sistem de detectare a intrușilor (IDS), honeypot și tehnici de mutare a țintei de apărare (MTD), ținând cont de aspecte probabilistice și a celor de incertitudine epistemică.

Cuvinte-cheie: *atac, ciber-securitate, număr fuzzy, honeypot, mutarea țintei de apărare, reconfigurare, rețea Petri stocastică cu recompense.*

DOI: 10.5281/zenodo.3444073
CZU 621.865.8:004.896

QUO VADIS ROBOTICS?

Titu-Marius I. Băjenescu, ORCID ID: 0000-0002-9371-6766

*Swiss Technology Association, Electronics Group Switzerland
tmbajenescu@gmail.com*

Received: July, 21, 2019
Accepted: September, 19, 2019

Abstract. Robotics is an extremely dynamic field with thriving advancement in its technology. The capabilities of trusted robots will grow and evolve over time. Robots will be able to explain what they do and why. This will enable people to better understand what we trust in machines and where and how we can use them, and will lead to a better understanding of the new technology and, in particular, confidence in secure use. It remains in the hands of humans how we want to use these machines and robots. The article explains what a robot is made of, where we stand with robots, robot vehicles, robot intelligence, industrial robots, aspects of legislation, legal consequences, artificial intelligence and robots, deep learning systems, the businessman's problem, and the economic model.

Keywords: *Industrial and agricultural robotics, Defence and security robotics, Service and personal robotics, sensors, software, Turing's test, artificial intelligence, legal aspects.*

DOI: 10.5281/zenodo.3444073
CZU 621.865.8:004.896

QUO VADIS ROBOTICA?

Titu-Marius I. Băjenescu, ORCID ID: 0000-0002-9371-6766

*Asociația Elvețiană de Tehnologie, Grupul Electronic Elveția
tmbajenescu@gmail.com*

Recepționat: iulie, 21, 2019
Acceptat: septembrie, 19, 2019

Rezumat. Robotica prezintă un domeniu extrem de dinamic, cu o evoluție tehnologică înfloritoare. Capacitățile roboților de încredere vor crește și vor evolua în timp. Roboții vor putea explica ce fac și de ce. Acest lucru va permite oamenilor să înțeleagă mai bine de ce avem încredere în mașini și unde și în ce mod le putem folosi și va duce la o mai bună înțelegere a noii tehnologii și, în special, la încredere în utilizarea sigură. Rămâne în mâinile oamenilor cum vrem să folosim aceste mașini și roboți. Articolul explică din ce este făcut un robot, unde stăm cu roboți, vehicule robot, inteligență robot, roboți industriali, aspecte ale legislației, consecințe legale, inteligență artificială și roboți, sisteme de învățare profundă, problema omului de afaceri și modelul economic.

Cuvinte cheie: *Robotică industrială și agricolă, robotică de apărare și securitate, robotică de service și personal, senzori, software, testul Turing, inteligență artificială, aspecte legale.*

DOI: 10.5281/zenodo.3444085
CZU 624.04:69.058.8

MANAGEMENT OF INVESTIGATING THE EFFECT OF BLASTING AND IMPACT LOAD IN VARIOUS STRUCTURES

Mohammad Beykzade^{1*}, ORCID ID: 0000-0002-5394-2363
Sepide Beykzade², ORCID ID: 0000-0003-1428-7287

¹Department of Civil Engineering, Faculty of Civil Engineering, Kharazmi University, Tehran, Iran

²Department of Management, Faculty of Management, Azad Islamic University Branch Karaj

*Corresponding author: Mohammad Beykzade, M.Beykzade@gmail.com

Received: July, 3, 2019

Accepted: September, 22, 2019

Abstract. Increasing the number of explosive threats on the structures is a warning in the direction of safety. The design of structures against the blast loads in the past has been limited to military buildings and so on. Now, with the spread of science and threats against bridges, buildings and industrial structures will require a detailed examination of the performance of these structures against the blast load. In this study, the performance of structures against explosions, the damage to the structure and the important factors in the failure of the structure were investigated and the results show that the location of the structure of the explosive factor ratio has a significant effect on stability.

Keywords: *Blast Loads, Concrete Buildings, Underground Structures, Structural Analysis.*

DOI: 10.5281/zenodo.3444085
CZU 624.04:69.058.8

MANAGEMENTUL INVESTIGĂRII EFECTULUI BLASTING ȘI AL SARCINII DE IMPACT ÎN DIVERSE STRUCTURI

Mohammad Beykzade^{1*}, ORCID ID: 0000-0002-5394-2363
Sepide Beykzade², ORCID ID: 0000-0003-1428-7287

¹Departamentul de inginerie civilă, Facultatea de Construcții Civile, Universitatea Kharazmi, Teheran, Iran

²Departamentul de Management, Facultatea de Management, Filiala Universității Islamice Azad Karaj

*Autor corespondent: Mohammad Beykzade, M.Beykzade@gmail.com

Recepționat: iulie, 3, 2019

Acceptat: septembrie, 22, 2019

Rezumat: Creșterea numărului de amenințări explozive pe diverse structuri prezintă un avertisment serios în direcția securității. Proiectarea structurilor împotriva încărcăturilor explozive din trecut s-a limitat la clădiri militare sau utilizate ca atare. Acum, odată cu răspândirea științei și amenințările împotriva podurilor, clădirilor și structurilor industriale, este necesară o examinare detaliată a performanței acestor structuri împotriva încărcăturii explozive. În acest studiu, au fost investigate performanțele structurilor împotriva exploziilor, deteriorarea structurii și factorii importanți în defecțiunea structurii, iar rezultatele arată că amplasarea structurii și raportul factorilor explozivi are un efect semnificativ asupra stabilității construcțiilor.

Cuvinte cheie: *Sarcini de explozie, clădiri din beton, structuri subterane, analiză structurală.*

DOI: 10.5281/zenodo.3444113
CZU 628.4(594)

THE GENERATION RATE AND CHARACTERISTICS OF MUNICIPAL SOLID WASTE IN SLUMS OF LAWANG KIDUL VILLAGE AT PALEMBANG CITY

Diah Octaviani Pratiwi^{1*}, ORCID ID: 0000-0003-2221-1231
Febrian Hadinata¹, Heni Fitriani¹

¹*Faculty of Engineering, University of Sriwijaya, Padang Selasa Street-30139, Palembang,
Indonesia*

*Corresponding author: Diah Octaviani Pratiwi, email: pradivia@gmail.com

Received: July, 23, 2019

Accepted: September, 24, 2019

Abstract. The problem of municipal solid waste (MSW) is closely related to slums, where houses in slums are stilt house and near the river, and making area under the house as the place of the garbage disposal place which is relatively difficult to clean. Lawang Kidul is a village that has the largest slum area among other villages and located on the edge of Musi River at Palembang City. One cause of slum is a problem of household waste that is not routinely transported to the garbage disposal place around 62,48%, causing garbage to scattered around the resident houses, even not infrequently throw garbage into rivers and waterways. The study aims to measure the generation rate and composition of MSW in slums of Lawang Kidul Village at Palembang City, and then to measure average generation rate and composition of MSW at several cities in Indonesia. Measurements were carried out for 2 days (14 March 2019 and 17 March 2019). Sampling was carried out in 2 pillars of neighbor (15 and 16) which has the highest number of heads of families among 8 other slums. There are 9 components of MSW that are measured (food waste, paper/cardboard, wood, cloth/textile products, rubber/leather, plastic, metal, glass, etc.). MSW generation rate is measured at 0,46 kg/person/day. The measured density of MSW was 244,97 kg/m³. The composition of MSW is dominated by food waste (48,81%), followed by plastic waste (33,96%), paper/cardboard waste (6,68%), and other waste components. The average of MSW generation rate in Indonesia was 0,352 kg/person/day. The average composition of MSW at several cities in Indonesia is dominated by food waste (63,63%).

Keywords: *average, composition, generation rate, Indonesia, MSW.*

DOI: 10.5281/zenodo.3444113
CZU 628.4(594)

RATA GENERĂRII ȘI CARACTERISTICILE DEȘEURILOR SOLIDE MUNICIPALE ÎN CARTIERELE SUBURBIEI KIDUL LAWANG ALE ORAȘULUI PALEMBANG

Diah Octaviani Pratiwi^{1*}, ORCID ID: 0000-0003-2221-1231

Febrian Hadinata¹, Heni Fitriani¹

¹Facultatea de Inginerie, Universitatea din Sriwijaya, str. Padang Selasa-30139, Palembang, Indonezia

*Autor corespondent: Diah Octaviani Pratiwi, e-mail: pradivia@gmail.com

Recepționat: iulie, 23, 2019

Acceptat: septembrie, 24, 2019

Rezumat: Problema deșeurilor solide municipale (MSW) este strâns legată de cartierele, în care casele sunt în stilt house și în apropierea râului, iar zona de sub casă este locul de depozitare a gunoiului, care este relativ greu de curățat. Lawang Kidul este un sat care are cea mai mare zonă de cartiere de acest tip, situat la marginea râului Musi din orașul Palembang. Problema deșeurilor menajere care nu sunt transportate în mod obișnuit la depozitul de gunoi este în proporție de 62,48%, ceea ce face ca gunoiul să se împrășteie printre casele rezidente, sau chiar să nimerească în râuri și căi navigabile. Studiul și-a propus să măsoare rata de generare și compoziția MSW în cartierele din satul Lawang Kidul din Palembang City, apoi să măsoare rata medie de generare și compoziția MSW în mai multe orașe din Indonezia. Măsurătorile au fost efectuate timp de 2 zile (14 martie 2019 și 17 martie 2019). Eșantionarea a fost efectuată pe 2 stâlpi ai vecinului (15 și 16), care are cel mai mare număr de membri ai familiei dintre alte 8 mahalale. Există 9 componente ale MSW care au fost măsurate (deșeuri alimentare, hârtie /carton, lemn, pânză /produse textile, cauciuc / piele, plastic, metal, sticlă etc.). Rata de generare a MSW a fost stabilită la 0,46 kg / persoană / zi. Densitatea măsurată a MSW a fost de 244,97 kg/m³. Compoziția MSW este dominată de deșeurile alimentare (48,81%), urmate de deșeurile de plastic (33,96%), deșeurile de hârtie/carton (6,68%) și alte componente. Media producției de MSW în Indonezia a fost de 0,352 kg /persoană /zi. Compoziția medie a MSW în mai multe orașe din Indonezia este dominată de risipa alimentară (63,63%).

Cuvinte cheie: medie, compoziție, rata de generare, Indonezia, MSW.

DOI: 10.5281/zenodo.3444117
CZU 637.2.04/.05

THEORETIC APPROACHES TO SUBSTANTIATE SHELF LIFE CAPACITY OF BUTTER AND SPREADS

Anna Bocharova-Leskina¹, ORCID ID: 0000-0002-8216-9605
Sergii Verbytskyi ^{2*}, ORCID ID: 0000-0002-4211-3789

¹Kuban State Technological University, 2, Moskovskaya Str., Krasnodar 350072, Russian Federation

²Institute of Food Resources of NAAS, Ye. Sversiyuk Str., 4a, Kyiv 02002, Ukraine

*Corresponding author: Sergii Verbytskyi, tk140@hotmail.com, <https://orcid.org/0000-0002-4211-3789>

Received: August, 22, 2019
Accepted: September, 25, 2019

Abstract. The analysis of scientific information on the theoretical aspects and practical features of long-term freezing storage of butter and spreads is carried out. Means of mathematical modeling are substantiated, allowing prediction of the storage capacity of these foods based on the study of the mechanism and kinetics of the processes that determine the deterioration of quality (the set of relevant indicators) during storage. A detailed description of the proposed method for predicting the shelf life of butter and spreads using the full factorial experiment is given, which makes it possible to evaluate their storage capacity with sufficient reliability. A comparative assessment of the known physical, chemical and sensorial indicators affecting the storage capacity is given. The titratable acidity, acidity of the fat phase, degree of dispersion and distribution of moisture, and also the peroxide number were determined as basic storage stability factors.

Keywords: *butter, spreads, shelf life, quality factors, mathematical model, regression analysis, acidity, peroxide value.*

DOI: 10.5281/zenodo.3444117
CZU 637.2.04/.05

ABORDĂRI TEORETICE PRIVIND APRECIEREA RAPIDĂ A DURATEI DE VALABILITATE A UNTULUI ȘI SPREADURILOR

Anna Bocharova-Leskina¹, ORCID ID: 0000-0002-8216-9605
Sergii Verbytskyi ^{2*}, ORCID ID: 0000-0002-4211-3789

¹Universitatea Tehnologică de Stat din Kuban, Moskovskaya 2, Krasnodar, 350072, Federația Rusă

²Institutul de resurse alimentare NAAS, Ye. Sversiyuk, 4a, Kiev, 02002, Ucraina

* Autor corespondent: Sergii Verbytskyi, tk140@hotmail.com

Recepționat: august, 22, 2019
Acceptat: septembrie, 25, 2019

Rezumat. În lucrare sunt analizate informațiile științifice cu privire la aspectele teoretice și caracteristicile practice ale depozitării pe termen lung a untului și a spreadurilor congelate. Metodele de modelare matematică sunt fundamentate, permițând predicția capacității de stocare a acestor alimente pe baza studiului mecanismului și cineticii proceselor care determină deteriorarea calității (setul de indicatori relevanți) în timpul depozitării. Este prezentată descrierea detaliată a metodei propuse pentru prezicerea duratei de valabilitate a untului și spreadurilor folosind experimentul factorial complet, care face posibilă evaluarea capacității de stocare a acestora cu o fiabilitate suficientă. Se face o evaluare comparativă a indicatorilor fizici, chimici și senzoriali care afectează capacitatea de stocare. Aciditatea titrabilă, aciditatea fazei grase, gradul de dispersie și distribuția umidității, precum și indicii de peroxid prezintă factori de bază ai stabilității untului și spreadurilor la stocare.

Cuvinte cheie: *unt, spread, durată de valabilitate, factori de calitate, model matematic, analiză de regresie, aciditate, indice de peroxid.*

DOI: 10.5281/zenodo.3444119

CZU [634.7 + 663.26]:519.6:004.8

A FUZZY LOGIC APPROACH FOR MATHEMATICAL MODELING OF THE EXTRACTION PROCESS OF BIOACTIVE COMPOUNDS

Aliona Ghendov-Moșanu^{1*}, ORCID ID: 0000-0001-5214-3562

Rodica Sturza¹, ORCID ID: 0000-0002-2412-5874

Tudor Cherecheș², ORCID ID: 0000-0002-2618-4042

Antoanela Patras³, ORCID ID: 0000-0002-4054-4884

¹Technical University of Moldova, 168, Stefan cel Mare Bd., MD-2004, Chisinau, Republic of Moldova

²UPS PILOT ARM LTD, 19 B, UNIRII Bd., Bucharest, Romania

³"Ion Ionescu de la Brad" UASVM, Iasi, Romania

*Corresponding author: Aliona Ghendov-Moșanu, aliona.mosanu@tpa.utm.md

Received: July, 18, 2019

Accepted: September, 17, 2019

Abstract. The aim of the present study was to optimize the extraction process of bioactive compounds from berries and wastes from the agro-food industry (grape marc). Mathematical models of the extraction process of biologically active compounds based on algorithms of artificial intelligence: fuzzy logic and neuro-fuzzy algorithms have been established. The mathematical models, which use the experimental average values of uncertain models, as well as of some predictive models, offer values of the sizes with a large prediction horizon. It was established, that mathematical models, which use the experimental average values of uncertain models, the experimental data, as well as of some predictive models offer values of the sizes with a large prediction horizon. The existence of various interactions between the influence factors (ethanol concentration, extraction temperature, pretreatment method) and the measured parameters (total polyphenol index, quantity of tannins extracted and antiradical activity, DPPH) was established. The great diversity of processes at different products and various parameters, as well as the existence of non-linear dependencies between sizes, allow credible extrapolations of the results only within the experimental limits.

Keywords: *fuzzy mathematical model, neuro-fuzzy mathematical model, berries, extraction, bioactive compounds.*

DOI: 10.5281/zenodo.3444119

CZU [634.7 + 663.26]:519.6:004.8

LOGICA FUZZY PENTRU MODELAREA MATEMATICĂ A PROCESULUI DE EXTRACȚIE A COMPUȘILOR BIOACTIVI

Aliona Ghendov-Moșanu^{1*}, ORCID ID: 0000-0001-5214-3562

Rodica Sturza¹, ORCID ID: 0000-0002-2412-5874

Tudor Cherecheș², ORCID ID: 0000-0002-2618-4042

Antoanela Patras³, ORCID ID: 0000-0002-4054-4884

¹Universitatea Tehnică a Moldovei, 168, Bd. Ștefan cel Mare, MD-2004, Chișinău, Republica Moldova

²UPS PILOT ARM LTD, 19 B, Bd. UNIRII, București, România

³"Ion Ionescu de la Brad" UASVM, Iași, România

* Autor corespondent: Aliona Ghendov-Moșanu, aliona.mosanu@tpa.utm.md

Recepționat: iulie, 18, 2019

Acceptat: septembrie, 17, 2019

Rezumat. Obiectivul studiului a constat în optimizarea procesului de extracție a compușilor bioactivi din fructe de pădure și deșeuri din industria agroalimentară (tescovină de struguri). Au fost stabilite modele matematice ale procesului de extracție a compușilor biologic activi, bazate pe algoritmi de inteligență artificială: logică fuzzy și algoritmi neuro-fuzzy. Modelele matematice, care folosesc valorile medii experimentale ale modelelor incerte, precum și ale unor modele predictive oferă valori ale mărimilor cu un orizont de predicție mare. S-a stabilit existența diferitelor interacții între factorii de influență (concentrația de etanol, temperatura de extracție, metoda de pretratare) și parametrii mășurați (indicele total de polifenol, cantitatea de tanin extras și activitatea antiradicalică, DPPH). Marea diversitate a proceselor la diferite produse și diverși parametri, precum și existența unor dependențe neliniare între mărimi permit extrapolări credibile ale rezultatelor doar în interiorul plajelor experimentale.

Cuvinte cheie: *model matematic fuzzy, model matematic neuro-fuzzy, extracție, fructe de pădure, compuși bioactivi.*

DOI: 10.5281/zenodo.3444127
CZU 663.257.3:678.7

TARTARIC STABILIZATION OF GRAPE JUICE WITH IONIC EXCHANGE RESINS

Roman Golubi, ORCID ID: 0000-0003-4444-9515

Scientific-Practical Institute of Horticulture and Food Technologies, 59 Vieru str., Codru, Kishinau, Moldova
Roman Golubi, rg095@yahoo.fr

Received: August, 14, 2019
Accepted: September, 27, 2019

Abstract. The limpidity of grape juice is a quality requirement asked at placing in trade networks, because consumers prefer a drink with clear transparency. A specific phenomenon is the formation of tartaric crystals during long storage or maintenance at temperatures below 0 -1°C. The traditional tartaric stabilization procedures indicates disadvantages on power consumption and duration, requirements specific to the equipment, etc. For this aim were studied the effect of five types of anionic resin to grape juice, developed a method for grape juice tartaric stabilization based on mathematic model the central rotary matrix, using the most effective resin Purolite A-400.

Keywords: *potassium bitartrate, anionic resin, duration of process, limpidity of juice, mass of formed crystals, mathematical model.*

DOI: 10.5281/zenodo.3444127
CZU CZU 663.257.3:678.7

STABILIZAREA TARTRICĂ A SUCULUI DE STRUGURI CU RĂȘINI DE SCHIMB IONIC

Roman Golubi, ORCID ID: 0000-0003-4444-9515

Institutul Științifico-Practic de Horticultură și Tehnologii Alimentare, str. Vieru 59, Codru, Chișinău, R. Moldova
Roman Golubi, rg095@yahoo.fr

Recepționat: august, 14, 2019
Acceptat: septembrie, 27, 2019

Rezumat. Limpiditatea sucului de struguri este o cerință de calitate solicitată de rețelele comerciale, deoarece consumatorii preferă o băutură cu transparență clară. Un fenomen specific este formarea de cristale tartrice în timpul depozitării îndelungate sau de întreținere la temperaturi sub 0 -1°C. Procedurile tradiționale de stabilizare tartrică prezintă o serie de dezavantaje în ceea ce privește consumul de energie și durata, cerințe specifice față de echipament, etc. În scopul limpezirii sucului de struguri a fost cercetat efectul a cinci tipuri de rășini anionice. Cercetările efectuate au permis elaborarea unei metode pentru stabilizarea tartrică a sucului de struguri, bazată pe modelul matematic matricea rotativă central, folosind cea mai eficientă rășină Purolite A-400.

Cuvinte cheie: *bitartrat de potasiu, rășină anionică, durata procesului, limpiditatea sucului, masa cristalelor formate, model matematic.*

DOI: 10.5281/zenodo.3444129
CZU 634.51

APPLICATION OF PARETO PRINCIPLE IN MONITORING WALNUTS QUALITY AT STORAGE

Elisaveta Sandulachi*, ORCID ID: 0000-0003-3017-9008

Eugenia Boaghi, ORCID ID: 0000-0003-4574-2959

Pavel Tatarov, ORCID ID: 0000-0001-9923-8200

Vladislav Resitca, ORCID ID: 0000-0002-6063-1731

*Technical University of Moldova, Faculty of Food Technology, Department of Food and Nutrition, Studentilor str. 9/9,
2045 Chişinău, Moldova*

*Corresponding author: Sandulachi Elisaveta, elisaveta.sandulachi@tpa.utm.md

Received: August, 02, 2019

Accepted: September, 23, 2019

Abstract. This paper presents two case studies of walnut quality assessment at room temperature storage of $20 \pm 2^{\circ}\text{C}$. The conformity of the *Juglans regia* L. walnuts, the Calarasi variety, (harvest 2015) and Cogalniceanu variety (harvest 2016) was analyzed by applying the *Pareto* diagram and *nP*-card. These methods present a process of risk analysis, involves obtaining, analyzing and modeling information, analyzing and adopting a decision that improves the product quality. The data were collected during storage of walnuts at room temperature $20 \pm 2^{\circ}\text{C}$ for 6 and 12 months, respectively. The external and internal defects of walnuts have been assessed and grouped by risk categories. The most widespread defects of walnuts, which diminish their quality and the weight of their use on an industrial scale have been emphasised. It has been found that temperature and humidity are critical factors when storing walnuts. It is proposed a primary scheme for the in shell walnuts processing.

Keywords: walnuts quality, diagram Pareto, *nP*-card, defects frequency.

DOI: 10.5281/zenodo.3444129

CZU 634.51

APLICAREA PRINCIPIULUI PARETO ÎN MONITORIZAREA CALITĂȚII NUCILOR LA DEPOZITARE

Elisaveta Sandulachi*, ORCID ID: 0000-0003-3017-9008

Eugenia Boaghi, ORCID ID: 0000-0003-4574-2959

Pavel Tatarov, ORCID ID: 0000-0001-9923-8200

Vladislav Resitca, ORCID ID: 0000-0002-6063-1731

Universitatea Tehnică a Moldovei, str. Studenților 9/9, 2045 Chișinău, Moldova

*Autor corespondent: Sandulachi Elisaveta, elisaveta.sandulachi@tpa.utm.md

Recepționat: august, 2, 2019

Acceptat: septembrie, 23, 2019

Rezumat. Articolul prezintă două studii de caz privind evaluarea calității nucilor la depozitarea acestora la temperatura camerei de $20 \pm 2^{\circ}\text{C}$. Conformitatea nucilor *Juglans regia* L., soiul Călărași (recolta 2015) și soiul Cogălniceanu (recolta 2016) au fost analizate prin aplicarea diagramei Pareto și a *nP* cartelei. Aceste metode prezintă un proces de analiză a riscurilor, implică obținerea, analiza și modelarea informațiilor, analiza și adoptarea unei decizii care îmbunătățește calitatea produsului. Datele au fost colectate în timpul depozitării nucilor la temperatura camerei de $20 \pm 2^{\circ}\text{C}$ timp de 6 și respectiv 12 luni. Defectele externe și interne ale nucilor au fost evaluate și grupate pe categorii de risc. Au fost accentuate cele mai răspândite defecte ale nucilor, care le diminuează calitatea și face dificilă utilizarea acestora la scară industrială. S-a constatat că temperatura și umiditatea sunt factori critici la păstrarea nucilor. Se propune o schemă primară pentru procesarea nucilor în coajă.

Cuvinte-cheie: calitatea nucilor, diagrama Pareto, *nP* cartela, frecvența defectelor.

DOI: 10.5281/zenodo.3444139

CZU 637.2:664.34

FACTORS THAT DETERMINE THE SHELF LIFE OF A BUTTER-LIKE SPREAD BASED ON WALNUT OIL

Oxana Radu*, ORCID ID: 0000-0001-9260-6314

Alexei Baerle, ORCID ID: 0000-0001-6392-9579

Pavel Tatarov, ORCID ID: 0000-0001-9923-8200

Liliana Popescu, ORCID ID: 0000-0003-3381-7511

Technical University of Moldova – MD 2004, 168, Stefan cel Mare Av., Chişinău, Republic of Moldova

**Corresponding Author: oxana.radu@sa.utm.md*

Received: 09, August, 2019

Accepted: 25, September, 2019

Abstract. The article describes the manufacturing stages for a new functional product that can enrich human diet with essential lipids – spread based on walnut oil. Due to the fact that its content of polyunsaturated fatty acids is in 3-4 times higher than in a classic milk-based butter, the problem of preserving spread biological value appeared. The analysis of product's physico-chemical, structural, organoleptic and microbiological proprieties showed that the spread is stabile 10 days at $(3 \pm 2)^{\circ}\text{C}$ and within up to one month at $-(6 \pm 3)^{\circ}\text{C}$. Polyunsaturated fatty acids in product composition were noticeably subjected to oxidative degradation only after 4 weeks of storage. It has been proven that namely microbiological stability is the determining factor, which affects the shelf life of a spread.

Keywords: *functional product, dairy and vegetable lipids, polyunsaturated fatty acids, storage period.*

DOI: 10.5281/zenodo.3444139

CZU 637.2:664.34

FACTORII CARE DETERMINĂ TERMENUL DE VALABILITATE A SPREAD-ULUI PE BAZA ULEIULUI DE NUCĂ

Oxana Radu*, ORCID ID: 0000-0001-9260-6314

Alexei Baerle, ORCID ID: 0000-0001-6392-9579

Pavel Tatarov, ORCID ID: 0000-0001-9923-8200

Liliana Popescu, ORCID ID: 0000-0003-3381-7511

Universitatea Tehnică a Moldovei, MD 2004, Bd. Ștefan cel Mare, 168, Chișinău, Republica Moldova

*Autor corespondent: *oxana.radu@sa.utm.md*

Recepționat: august, 9, 2019

Acceptat: septembrie, 25, 2019

Rezumat. În lucrare sunt analizate etapele de fabricație a unui produs funcțional nou care poate îmbogăți rația umană cu lipidele esențiale – spread pe bază de ulei de nucă. Datorită faptului, că raportul de acizi grași polinesaturați în produsul elaborat este de 3-4 ori mai mare decât în untul clasic, există problema păstrării valorii biologice a spread-ului. Analiza proprietăților fizico-chimice, structurale, organoleptice și microbiologice a demonstrat, că produsul este stabil 10 zile la temperatura (3 ± 2)°C și în termen de până la o lună la $-(6 \pm 3)$ °C. Acizii grași polinesaturați din compoziția produsului ar putea constitui obiectul degradării oxidative în mod vizibil numai după 4 săptămâni de păstrare. S-a demonstrat, că factorul determinant care influențează durata de valabilitate a spread-ului este stabilitatea microbiologică a acestuia.

Cuvintele cheie: *produs funcțional, lipide lactate și vegetale, acizii grași polinesaturați, perioadă de depozitare.*

DOI: 10.5281/zenodo.3464222

CZU 637.352:579.67

ANTIMICROBIAL PROPERTIES OF BERRY POWDERS IN CREAM CHEESE

Rodica Sturza¹, ORCID ID: 0000-0002-2412-5874

Elisaveta Sandulachi^{1*}, ORCID ID: 0000-0003-3017-9008

Daniela Cojocari^{1,2}, ORCID ID: 0000-0003-0445-2883

Greta Balan², ORCID ID: 0000-0003-3704-3584

Liliana Popescu¹, ORCID ID: 0000-0003-3381-7511

Aliona Ghendov-Moșanu¹, ORCID ID: 0000-0001-5214-3562

¹Technical University of Moldova, 168, Stefan cel Mare Bd., Chisinau, Republic of Moldova

²State University of Medicine and Pharmacy "Nicolae Testemitanu, 165,
Stefan cel Mare Bd., Chisinau, Republic of Moldova

*Corresponding author: Elisaveta Sandulachi: elisaveta.sandulachi@tpa.utm.md

Received: July, 02, 2019

Accepted: September, 15, 2019

Abstract. This study aims to evaluate the efficiency in reducing pathogens using berry powders in a cream cheese recipe, as compared to the traditional method of manufacturing. This article presents a review of the microbiological hazards of dairy products and a case study of antimicrobial properties of berry powders on pathogenic microorganisms that can accidentally colonize cream cheese. The most relevant results in the reduction of pathogenic microorganisms were obtained in cream cheese samples with the addition of rosehip and aronia powders on *Salmonella Abony* ATCC 6017; hawthorn powder on *Staphylococcus aureus* ATCC 25923. All berry powder additions had major effects on *Escherichia coli* ATCC 25922. Research has shown that powders of berries can be used for the manufacture of dairy products with natural ingredients more resistant to accidental contamination and safe for consumption.

Keywords: *reducing pathogens, thermostation period, log CFU, growth of microorganisms.*

DOI: 10.5281/zenodo.3464222

CZU 637.352:579.67

PROPRIETĂȚILE ANTIMICROBIALE ALE PULBERILOR DIN FRUCTE DE PĂDURE ÎN CREMĂ DE BRÂNZĂ

Rodica Sturza¹, ORCID ID: 0000-0002-2412-5874Elisaveta Sandulachi^{1*}, ORCID ID: 0000-0003-3017-9008Daniela Cojocari^{1,2}, ORCID ID: 0000-0003-0445-2883Greta Balan², ORCID ID: 0000-0003-3704-3584Liliana Popescu¹, ORCID ID: 0000-0003-3381-7511Aliona Ghendov-Moșanu¹, ORCID ID: 0000-0001-5214-3562¹Universitatea Tehnică a Moldovei, 168, Bd. Ștefan cel Mare, Chișinău, Republica Moldova²Universitatea de Stat de Medicină și Farmacie „Nicolae Testemițanu”,
165, Bd. Ștefan cel Mare, Chișinău, Republica Moldova*Autor corespondent: Elisaveta Sandulachi: elisaveta.sandulachi@tpa.utm.md

Recepționat: iulie, 2, 2019

Acceptat: septembrie, 15, 2019

Rezumat. În articol este evaluată eficiența pulberilor din fructe de pădure la reducerea agenților patogeni într-o rețetă de cremă de brânză, în raport cu metoda tradițională de fabricație. Este prezentată o trecere în revistă a pericolelor microbiologice afiliate produselor lactate și un studiu de caz al proprietăților antimicrobiene ale pulberilor de fructe de pădure asupra microorganismelor patogene care pot coloniza accidental crema de brânză. Cele mai relevante rezultate în reducerea microorganismelor patogene *Salmonella Abony* ATCC 6017 au fost obținute în probele de cremă de brânză cu pulbere de măceșe și aronia. Pulberea de păducel manifestă efecte marcante asupra *Staphylococcus aureus* ATCC 25923. Toate adaosurile de pulberi de fructe de pădure au avut efecte majore asupra *Escherichia coli* ATCC 25922. Cercetările efectuate au demonstrat, că pulberile din fructe de pădure pot fi folosite pentru fabricația produselor lactate cu ingrediente naturale mai rezistente la contaminări accidentale și sigure pentru consum.

Cuvinte cheie: *reducerea agenților patogeni, perioadă de termostatare, CFU log, creșterea microorganismelor.*

DOI: 10.5281/zenodo.3444009**SZU: 929:[629.7+533.69](498)**

GHEORGHE ION DUCA- THE REORGANIZER OF THE NATIONAL SCHOOL OF BRIDGES AND ROADS OF BUCHAREST

Gheorghe Manolea

*University of Craiova, 13 A. I. Cuza Street, Craiova, Romania
Gheorghe Manolea, ghmanolea@manolea.ro*

Received: July, 30, 2019

Accepted: September, 18, 2019

Abstract. School had, has and will have an important role in building the elite of a nation. The National School of Bridges and Roads played an important part in educating engineers in Romania. Here big names from the Romanian engineering were educated, and later, they made the name of this school famous worldwide. As it usually happens, in the history of an institution, there is a man who, due to his force and vision, changes its destiny for good. In the history of the National School of Bridges and Roads, this man was Gheorghe Ion Duca whose name is closely linked by the beginning of the engineering school system in our country by its reorganization and by building the headquarters at the crossroads of Polizu Street and Calea Griviței, where the Polytechnics Institute of Bucharest functioned for a long time.

Keywords: *Georghe Ion Duca, The National School of Bridges and Roads, Polytechnics Institute of Bucharest.*

DOI: 10.5281/zenodo.3444009**SZU: 929:[629.7+533.69](498)**

GHEORGHE ION DUCA - REORGANIZATORUL ȘCOLII NAȚIONALE DE PODURI ȘI DRUMURI DIN BUCUREȘTI

Gheorghe Manolea

*Universitatea din Craiova, str. A. A. Cuza nr. 13, Craiova, România
Gheorghe Manolea, ghmanolea@manolea.ro*

Recepționat: 30 iulie 2019

Acceptat: 18 septembrie 2019

Rezumat. Școala a avut, are și va avea un rol important în construirea elitei unei națiuni. Școala Națională de Poduri și Drumuri a jucat un rol important în educarea inginerilor din România. Aici s-au educat nume mari ale ingineriei românești, care mai târziu au făcut cunoscut numele acestei școli la nivel mondial. Așa cum se întâmplă de obicei, în istoria unei instituții, există un om care, datorită forței și viziunii sale, îi schimbă destinul în bine. În istoria Școlii Naționale de Poduri și Drumuri acest om a fost Gheorghe Ion Duca, al cărui nume este strâns legat de începutul sistemului școlar de inginerie din țara noastră prin reorganizarea acesteia și prin construirea sediului la intersecția străzilor Polizu și Calea Griviței, unde a funcționat mult timp Institutul Politehnic din București.

Cuvinte cheie: *Gheorghe Ion Duca, Școala Națională de Poduri și Drumuri, Institutul Politehnic din București.*

DOI: 10.5281/zenodo.3443911
CZU 535.01:530.1



QUANTUM TREATMENT OF SELF-ORGANIZATION PHENOMENA OF EXCITONS AND BIEXCITONS

Nellu Ciobanu¹, ORCID ID: 0000-0002-8153-8237

Anatol Rotaru, Ilarie Gontia², Vasile Tronciu³, ORCID ID: 0000-0002-9164-2249

¹State University of Medicine and Pharmacy "Nicolae Testemitanu", bd. Stefan cel Mare 165, Chisinau, Moldova

²Laboratory of Optical Process in Nanostructured Materials, National Institute of Materials Physics, Atomistilor 405A, Bucuresti Magurele, Romania

³Department of Physics, Technical University of Moldova, bd. Stefan cel Mare 168, Chisinau, Moldova

Corresponding Author: Vasile Tronciu, email: vasile.tronciu@fiz.utm.md

In memory of Anatol Rotaru

Received: June, 27, 2019

Accepted: September, 6, 2019

Abstract. We present in this paper the quantum treatment of self-organization phenomena of excitons and biexcitons in the geometry of a ring cavity. Applying the adiabatic elimination method of the exciton and biexciton variables, the Fokker-Planck equation for the transmitted field was obtained. The spectrum of transmission and second order correlation function were calculated. Thus, the spectrum of transmission describes a hysteresis cycle character, where a narrow spectral line in the end of cycle can be observed. The phenomena of optical bistability and switchings of excitons and biexcitons are investigated theoretically.

Keywords: *Optical bistability, semiconductors, Fokker-Planck Equation, self-organization, excitons, biexcitons, ring cavity.*

1. Introduction

During the last decade the phenomenon of optical bistability has been the subject of numerous theoretical and experimental investigations. It is one example of optical self-organisation of a system far from thermodynamic equilibrium. On the other hand, it opens up enormous opportunities for practical applications as optical logic device. A detailed classical description of optical bistability can be found in the monograph of Gibbs [1]. The first indication of optical bistability of excitons was done by Elesin and Kopaev [2]. The theoretical and experimental aspects Bose - Einstein condensation of excitons and biexcitons are reported in [3]. The theory of stationary and dynamic optical bistability and self-pulsations of excitons and biexcitons in condensed media was elaborated in [4-6] and references are cited there. The prediction of optical bimodality induced by external additive noise with a finite bandwidth in the exciton-biexciton system is reported [7]. Theoretical investigation of controlling the optical bistability and optical multistability in a GaAs quantum well inside a unidirectional ring cavity is reported in [8].

In the last decade many studies implying self-organization effects of exciton systems were published. For exemple, a method of studying the dark dipolar excitons in transition metal dichalcogenide monolayers, considering a bilayer system of two-dimensional Bose-

Einstein-condensed dipolar dark excitons was proposed in [9]. It was demonstrated that interlayer interaction leads to a mixing state between excitations from different layers. An interesting idea to generate traveling pulses from an excitonic system created in a double quantum well heterostructure by a laser illumination is suggested in [10]. The dynamics of the excitons density for various illumination conditions is explored. Other model implying the formation of the excitonic condensed phase in quantum wells with defects of macroscopic size for planar quantum wells with various thickness was proposed recently by Sugakov [11]. The appearance of different types of structures in the exciton density distribution for large size of defects studied. New effects that appear at the control of exciton and self-organization of a quasi-two-dimensional nonequilibrium Bose-Einstein condensate in an in-plane potential were studied in [12, 13].

In this paper we propose a quantum treatment of the self-organization phenomena (optical bistability) of excitons and biexcitons of a semiconductor settled in a ring cavity with high quality factor Q .

2. Hamiltonian model, Fokker- Planck and Langevin equations

Our model consists of an ensemble of photons, excitons and biexcitons coupled to the thermostat and external field [7]. We consider in our analysis only one mode of excitons, biexcitons and photons. The full Hamiltonian of the systems, in the second order quantization, is given by

$$H = H_F + H_E + H_I + H_D, \quad (1)$$

where

$$H_F = \hbar\omega_1 a^+ a + \hbar\omega_2 b^+ b + \hbar\omega c^+ c,$$

$$H_E = i\hbar \left(E c^+ e^{-i\omega_0 t} - E^* c e^{i\omega_0 t} \right),$$

$$H_I = -\hbar g \left(c^+ a + a^+ c \right) - \hbar \sigma g \left(a^+ b c^+ + c^- b^+ a \right),$$

$$H_D = \sum_{j=1}^n \left(\chi_1 a^+ \Gamma_{1j} + \chi_2 b^+ \Gamma_{2j} + \chi_3 c^+ \Gamma_{3j} \right) + c.c.$$

H_F represents the Hamiltonian of free excitons, biexcitons and photons, with $a(a^+)$, $b(b^+)$, $c(c^+)$ being the annihilation (creation) operators of excitons, biexcitons and photons, respectively. ω is the cavity mode frequency. $\hbar\omega_1$ ($\hbar\omega_2$) is the energy of exciton (biexciton) creation. H_E describes the Hamiltonian of interaction between the cavity field and external coherent field with amplitude E and frequency ω_0 . H_I is the Hamiltonian of interaction between quasiparticles (photons, excitons and biexcitons). g is the constant of coupling between exciton and photon, and σ describes the conversion of excitons into biexcitons. H_D is the Hamiltonian of interaction of excitons, biexcitons and photons with the thermostats. The annihilation (creation) operators $\Gamma_{1j}(\Gamma_{1j}^+)$, $\Gamma_{2j}(\Gamma_{2j}^+)$, $\Gamma_{3j}(\Gamma_{3j}^+)$ correspond to excitonic, biexcitonic and photonic reservoirs, respectively while χ_1 , χ_2 , χ_3 are the coupling constants between the reservoirs and quasiparticles of the system.

From eq. (1) follows that the Hamiltonian H is time dependent. In order to eliminate this dependence, we use the rotating coordinate system with the frequency ω_0 , that implies a new wave function $\psi = V\phi$. $V = e^{-i\omega_0 t N}$ is an unitary operator, and N represents the total

number of quasi-particles. Thus, we can obtain an independent time Hamiltonian, where H_F and H_E parts of (1) have the following form:

$$H'_F = \hbar \cdot \Delta_1 \cdot a^+ a + \hbar \Delta_2 b^+ b + \hbar \Delta c^+ c, \quad H'_E = i\hbar (c^+ E - c E^*). \quad (2)$$

$\Delta_1 = \omega_1 - \omega_0$ is the detuning between the incident light (external) and exciton transition frequencies. $\Delta_2 = \omega_2 - 2\omega_0$ corresponds to the detuning between frequencies of the biexciton transition and incident light. On the other hand, $\Delta = \omega - \omega_0$ is the detuning between frequency of the cavity photons and incident light.

Eliminating the reservoir variables, we obtain the following master equation

$$\frac{d\rho}{dt} = \frac{1}{i\hbar} [H'_F + H'_E + H_I, \rho] + \left(\frac{\partial \rho}{\partial t} \right)_{ex-ph} + \left(\frac{\partial \rho}{\partial t} \right)_{biex-ph} + \left(\frac{\partial \rho}{\partial t} \right)_{f-d}, \quad (3)$$

Where

$$\begin{aligned} \left(\frac{\partial \rho}{\partial t} \right)_{ex-ph} &= \gamma_1 (1 + \bar{n}_1) ([a\rho, a^+] + [a, \rho a^+]) + \gamma_1 \bar{n}_1 ([a^+ \rho, a] + [a^+, \rho a]), \\ \left(\frac{\partial \rho}{\partial t} \right)_{biex-ph} &= \gamma_2 (1 + \bar{n}_2) ([b\rho, b^+] + [b, \rho b^+]) + \gamma_2 \bar{n}_2 ([a^+ \rho, a] + [b^+, \rho b]), \\ \left(\frac{\partial \rho}{\partial t} \right)_{f-d} &= \kappa (1 + \bar{n}) ([c\rho, c^+] + [c, \rho c^+]) + \kappa \bar{n} ([c^+ \rho, c] + [c^+, \rho c]). \end{aligned}$$

The parameters γ_1 , γ_2 , κ represent the amortization rates of the excitons, biexcitons and photons, respectively ($\gamma_1 = \pi |\chi_1|^2$, $\gamma_2 = \pi |\chi_2|^2$, $\kappa = \pi |\chi_3|^2$). $\bar{n}_i = \frac{1}{\exp\left(\frac{\hbar \omega_i}{kT}\right) - 1}$ is the average

value of the thermal particles of the reservoirs at temperature T .

Using the generalized non-diagonal p representation Drummond-Gardiner [14, 15], the master equation (3) can be transformed in the Fokker-Planck equation. The complex space of representation is generated defining the correspondence between the operators and complex parts as follow: $a \rightarrow \alpha_1$, $b \rightarrow \alpha_2$, $c \rightarrow \alpha_3$; $a^+ \rightarrow \beta_1$, $b^+ \rightarrow \beta_2$, $c^+ \rightarrow \beta_3$. The statistic operator $\hat{\rho}$ can be associated with a complex distribution function p , via the relation

$$\rho(f) = \int \int_{l, l'} p(\alpha_1, \alpha_2, \alpha_3, \beta_1, \beta_2, \beta_3) \lambda(\alpha_i, \beta_i) d\mu, \quad (4)$$

where $\lambda(\alpha_i, \beta_i) = \frac{|\alpha\rangle \langle \beta^*|}{\langle \beta^* | \alpha \rangle}$ is the operator of projection and

$d\mu = d\alpha_1 d\alpha_2 d\alpha_3 d\beta_1 d\beta_2 d\beta_3$ represents the measure of integration of domain D . It worth to mention, that the contours of integration l and l' are independent. The Fokker-Planck equation can be written from master equation using the relations of the following correspondence

$$\begin{aligned}
 a\rho &\rightarrow \alpha P(\vec{\alpha}); & \rho a &\rightarrow \left(\alpha + \frac{\partial}{\partial \beta}\right) P(\vec{\alpha}); \\
 a^+\rho &\rightarrow \left(\beta + \frac{\partial}{\partial \alpha}\right) P(\vec{\alpha}); & \rho a^+ &\rightarrow \alpha P(\vec{\alpha}).
 \end{aligned} \tag{5}$$

Using expressions (5) we obtain the new form of Fokker-Planck equation

$$\begin{aligned}
 \frac{\partial P(\alpha_i, \beta_i, t)}{\partial t} = & \left\{ -\frac{\partial}{\partial \alpha_1} (-i\Delta_1 \alpha_1 + ig\alpha_3 + i\sigma g\beta_3 \alpha_2 - \gamma_1 \alpha_1) - \right. \\
 & -\frac{\partial}{\partial \alpha_2} (-i\Delta_2 \alpha_2 + i\sigma g\alpha_1 \alpha_3 - \gamma_2 \alpha_2) - \frac{\partial}{\partial \alpha_3} (-i\Delta \alpha_3 + ig\alpha_1 + \\
 & + i\sigma g\beta_1 \alpha_2 - \kappa \alpha_3 + E) - \frac{\partial}{\partial \beta_1} (i\Delta_1 \beta_1 - ig\beta_3 - i\sigma g\alpha_3 \beta_2 - \gamma_1 \beta_1) - \\
 & -\frac{\partial}{\partial \beta_2} (i\Delta_2 \beta_2 - i\sigma g\beta_1 \beta_2 - \gamma_2 \beta_2) - \frac{\partial}{\partial \beta_3} (i\Delta \beta_3 + E^* - ig\beta_1 - \\
 & - i\sigma g\alpha_1 \beta_2 - \kappa \beta_3) + \frac{\partial^2}{\partial \alpha_1 \partial \alpha_3} (i\sigma g\alpha_2) + \frac{\partial^2}{\partial \beta_1 \partial \beta_3} (-i\sigma g\beta_2) + \\
 & \left. + \frac{\partial^2}{\partial \alpha_1 \partial \beta_1} (2\gamma_2 \bar{n}_2) + \frac{\partial^2}{\partial \alpha_3 \partial \beta_3} (2\kappa \bar{n}) \right\} P.
 \end{aligned} \tag{6}$$

It is well known that each Fokker-Planck process can be associated with a system of stochastic differential equations called Langevin equations

$$\begin{aligned}
 \frac{d\alpha_1}{dt} &= -i\Delta_1 \alpha_1 + ig\alpha_3 + i\sigma g\beta_3 \alpha_2 - \gamma_1 \alpha_1 + \Gamma_{\alpha_1}(t), \\
 \frac{d\alpha_2}{dt} &= -i\Delta_2 \alpha_2 + i\sigma g\alpha_1 \alpha_3 - \gamma_2 \alpha_2 + \Gamma_{\alpha_2}(t), \\
 \frac{d\alpha_3}{dt} &= E - i\Delta \alpha_3 - \kappa \alpha_3 + ig\alpha_1 + i\sigma g\beta_1 \alpha_2 + \Gamma_{\alpha_3}(t), \\
 \frac{d\beta_1}{dt} &= i\Delta_1 \beta_1 - ig\beta_3 - i\sigma g\alpha_3 \beta_2 - \gamma_1 \beta_1 + \Gamma_{\beta_1}(t), \tag{7} \\
 \frac{d\beta_2}{dt} &= i\Delta_2 \beta_2 - i\sigma g\beta_1 \beta_3 - \gamma_2 \beta_2 + \Gamma_{\beta_2}(t), \\
 \frac{d\beta_3}{dt} &= E^* + i\Delta \beta_3 - ig\beta_1 - i\sigma g\alpha_1 \beta_3 - \kappa \beta_3 + \Gamma_{\beta_3}(t),
 \end{aligned}$$

where the stochastic Langevin forces are connected with the coefficients of diffusion of Fokker-Planck equation through the correlation relations:

$$\langle \Gamma_{\alpha_1}(t) \Gamma_{\alpha_3}(t') \rangle = i\sigma g\alpha_2 \delta(t-t'), \tag{8}$$

$$\langle \Gamma_{\beta_1}(t) \Gamma_{\beta_3}(t') \rangle = -i\sigma g \beta_2 \delta(t-t') \quad (9)$$

$$\langle \Gamma_{\alpha_1}(t) \Gamma_{\beta_1}(t') \rangle = 2\gamma_1 \bar{n}_1 \delta(t-t') \quad (10)$$

$$\langle \Gamma_{\alpha_2}(t) \Gamma_{\beta_2}(t') \rangle = 2\gamma_1 \bar{n}_2 \delta(t-t') \quad (11)$$

$$\langle \Gamma_{\alpha_3}(t) \Gamma_{\beta_3}(t') \rangle = 2\kappa \bar{n} \delta(t-t') \quad (12)$$

Considering γ_1 and γ_2 much higher than κ , so that the exciton and biexciton variables can be neglected, we obtain a system of stochastic differential equation: $\frac{\partial \alpha_1}{\partial t} = \frac{\partial \alpha_2}{\partial t} = \frac{\partial \beta_1}{\partial t} = \frac{\partial \beta_2}{\partial t} = 0$. In the exact resonance case, i.e., $\Delta_1 = \Delta_2 = \Delta = 0$, the relations for exciton and biexciton variables have the following form:

$$\alpha_1 = \frac{ig\alpha_3}{M\gamma_1} + \frac{isg\beta_3}{M\gamma_1\gamma_2} \Gamma_{\alpha_2}(t) + \frac{1}{\gamma_1 M} \Gamma_{\alpha_1}(t), \quad (13)$$

$$\alpha_2 = -\frac{\sigma g^2 \alpha_3^2}{\gamma_1 \gamma_2 M} + \frac{isg\alpha_3}{M\gamma_1\gamma_2} \Gamma_{\alpha_1}(t) - \left[\frac{\sigma^2 g^2 \alpha_3 \beta_3}{M\gamma_1 \gamma_2^2} - \frac{1}{\gamma_2} \right] \Gamma_{\alpha_2}(t), \quad (14)$$

$$\beta_1 = -\frac{ig\beta_3}{M\gamma_1} - \frac{isg\alpha_3}{M\gamma_1\gamma_2} \Gamma_{\beta_2}(t) + \frac{1}{\gamma_1 M} \Gamma_{\beta_1}(t), \quad (15)$$

$$\beta_2 = -\frac{\sigma g^2 \beta_3^2}{\gamma_1 \gamma_2 M} - \left[\frac{\sigma^2 g^2 \alpha_3 \beta_3}{M\gamma_1 \gamma_2^2} - \frac{1}{\gamma_2} \right] \Gamma_{\beta_2}(t) - \frac{isg\beta_3}{M\gamma_1\gamma_2} \Gamma_{\beta_1}(t), \quad (16)$$

$$\text{where } M = 1 + \frac{\sigma^2 g^2 \alpha_3 \beta_3}{\gamma_1 \gamma_2 M}.$$

Introducing the equations (13) – (16) into (8) – (9), one can obtain the correlation expressions that depend only on the stochastic terms. In what follows we approximate the expressions for α_2 and β_2 with the deterministic stationary relations

$$\alpha_2 \cong -\frac{\sigma g^2 \alpha_3^2}{\gamma_1 \gamma_2 M}; \quad \beta_2 \cong -\frac{\sigma g^2 \beta_3^2}{\gamma_1 \gamma_2 M}. \quad (17)$$

After elimination of the exciton and biexciton variables, the correlation relations (8)–(9) can be written in the following form

$$\langle \Gamma_{\alpha_1}(t) \Gamma_{\alpha_3}(t') \rangle = -\frac{i\sigma^2 g^3 \alpha_3^2}{\gamma_1 \gamma_2 M} \delta(t-t'), \quad (18)$$

$$\langle \Gamma_{\beta_1}(t) \Gamma_{\beta_3}(t') \rangle = \frac{i\sigma^2 g^3 \beta_3^2}{\gamma_1 \gamma_2 M} \delta(t-t'). \quad (19)$$

We calculate the drift coefficients introducing eqs. (13)–(16) into (7). Finally, we obtain the Langevin equations for the field

$$\frac{d\alpha_3}{dt} = E - \kappa\alpha_3 - \frac{g^2\alpha_3}{M\gamma_1} - \frac{g^4\sigma^2\alpha_3^2\beta_3}{\gamma_1^2\gamma_2M^2} - \frac{4\sigma^6g^8\alpha_3^3\beta_3^2}{\gamma_1^4\gamma_1^3M^4}\Gamma_\alpha(t), \quad (20)$$

$$\frac{d\beta_3}{dt} = E^* - \kappa\beta_3 - \frac{g^2\beta_3}{M\gamma_1} - \frac{g^4\sigma^2\alpha_3\beta_3^2}{\gamma_1^2\gamma_2M^2} - \frac{4\sigma^6g^8\alpha_3^2\beta_3^3}{\gamma_1^4\lambda_2^3M^4} + \Gamma_\beta(t), \quad (21)$$

where the new stochastic terms have the form

$$\Gamma_\alpha(t) = A\Gamma_{\alpha_1}(t) + B\Gamma_{\alpha_2}(t) + C\Gamma_{\beta_1}(t) + D\Gamma_{\beta_2}(t) + \Gamma_{\alpha_3}(t), \quad (22)$$

$$\Gamma_\beta(t) = C^*\Gamma_{\alpha_1}(t) + D^*\Gamma_{\alpha_1}(t) + A^*\Gamma_{\beta_1}(t) + B^*\Gamma_{\beta_2}(t) + \Gamma_{\beta_3}(t), \quad (23)$$

And

$$\begin{aligned} A &= \frac{ig}{\gamma_1 M} + \frac{i\sigma^2 g^2 \alpha_3 \beta_3}{M^2 \gamma_1^2 \gamma_2}, \\ B &= \frac{-\sigma^3 g^4 \alpha_3 \beta_3^2}{\gamma_1^2 \gamma_2^2 M^2}, \\ C &= -\frac{i\sigma^2 g^3 \alpha_3^2}{\gamma_1^2 M^2 \gamma_2}, \\ D &= -\frac{\sigma^3 g^3 \alpha_3^3}{M^2 \gamma_1^2 \gamma_2^2}. \end{aligned} \quad (24)$$

Thus, the correlations of the new stochastic terms (22) – (23) can be written in the new form

$$\langle \Gamma_\alpha(t) \Gamma_\alpha(t') \rangle = D_{\alpha\alpha} \delta(t-t') = \left[\frac{2\sigma^2 g^4 \alpha_3^2}{\gamma_1^2 \gamma_2 M^2} \left(1 + \frac{\sigma^2 g^2 \alpha_3 \beta_3}{M \gamma_1 \gamma_2} \right) \right] \delta(t-t'), \quad (25)$$

$$\langle \Gamma_\alpha(t) \Gamma_\beta(t') \rangle = D_{\alpha\beta} \delta(t-t') = \frac{2\sigma^4 g^6 \alpha_3^2 \beta_3^2}{\gamma_1^3 \gamma_2^2 M^3} \delta(t-t'). \quad (26)$$

In the case of very low temperature of reservoirs, we can neglect in expressions for stochastic correlation (14)-(15) the terms proportional to $\bar{n}_1, \bar{n}_2, \bar{n}$, being very small i.e. $\kappa T \ll \hbar \omega_i$. We are interested only in the quantum fluctuations that appear at non-linear interaction of excitons and biexcitons. Thus, the thermal fluctuations (fluctuations due to the reservoir interaction) could be neglected. Taking into account the equivalence between the Langevin and Fokker-Planck equations, a new Fokker-Planck relation for field behavior can be obtained

$$\frac{\partial P(\alpha_3, \beta_3, t)}{\partial t} = -\frac{\partial}{\partial \alpha_3} \left[\left(E - \kappa\alpha_3 - \frac{g^2\alpha_3}{M\gamma_1} - \frac{g^4\sigma^2\alpha_3^2\beta_3}{\gamma_1^2\gamma_2M^2} - \right. \right.$$

$$\begin{aligned}
& -\frac{4\sigma^6 g^8 \alpha_3^3 \beta_3^2}{\gamma_1^4 \gamma_2^3 M^4} \Big) P \Big] - \frac{\partial}{\partial \beta_3} \left[\left(E^* - \kappa \beta_3 - \frac{g^2 \beta_3}{M \gamma_1} - \frac{g^4 \sigma^2 \alpha_3 \beta_3^2}{\gamma_1^2 \gamma_2 M^2} - \right. \right. \\
& \left. \left. - \frac{4\sigma^6 g^8 \alpha_3^3 \beta_3^2}{\gamma_1^4 \gamma_2^3 M^4} \right) P \right] + \frac{1}{2} \frac{\partial^2}{\partial \alpha_3^2} \left\{ \left[\frac{2\sigma^2 g^4 \alpha_3^2}{\gamma_1^2 \gamma_2 M^2} \left(1 + \frac{\sigma^2 g^2 \alpha_3 \beta_3}{M \gamma_1 \gamma_2} \right) \right] P \right\} + \\
& + \frac{1}{2} \frac{\partial^2}{\partial \beta_3^2} \left\{ \left[\frac{2\sigma^2 g^4 \beta_3^2}{\gamma_1^2 \gamma_2 M^2} \left(1 + \frac{\sigma^2 g^2 \alpha_3 \beta_3}{M \gamma_1 \gamma_2} \right) \right] P \right\} + \frac{\partial^2}{\partial \alpha_3 \partial \beta_3} \left[\frac{2\sigma^4 g^6 \alpha_3^2 \beta_3^2}{\gamma_1^3 \gamma_2^2 M^3} P \right]. \quad (27)
\end{aligned}$$

In what follows we are interested in the behavior of transmitted light amplitude. Thus, it is more convenient to consider the polar coordinates

$$\begin{aligned}
\alpha_3 &= r e^{-i\varphi}, \quad r^2 = \alpha_3 \beta_3, \\
\beta_3 &= r e^{i\varphi}, \quad \varphi = \frac{1}{2i} \ln \frac{\beta_3}{\alpha_3}. \quad (28)
\end{aligned}$$

The general expressions of drift and diffusion coefficients of Fokker-Planck equation [16] are given by

$$\begin{aligned}
a'_i &= a'_i(a_i, t), \\
A_i &= \frac{\partial a'_i}{\partial t} + \left(\frac{\partial a'_i}{\partial a_\kappa} \right) A_\kappa + \frac{\partial^2 a'_i}{\partial a_m \partial a_n} D_{mn}, \\
D_{ij} &= \frac{\partial a'_i}{\partial a_\kappa} \frac{\partial a'_j}{\partial a_l} D_{\kappa l}. \quad (29)
\end{aligned}$$

Taking into account the equations (28) and (29) it become easy to obtain the phase and amplitude coefficients of Fokker-Planck equation

$$\begin{aligned}
A_r &= r \operatorname{Re} \left(\frac{A_{\alpha_3}}{\alpha_3} \right) - \frac{r}{2} \operatorname{Re} \left(\frac{D_{\alpha\alpha}}{\alpha_3^2} \right) + \frac{1}{2r} D_{\alpha\beta}, \\
A_\varphi &= -\operatorname{Im} \left(\frac{A_{\alpha_3}}{\alpha_3} - \frac{D_{\alpha\alpha}}{\alpha_3^2} \right), \\
D_{rr} &= \frac{r^2}{2} \operatorname{Re} \left(\frac{D_{rr}}{\alpha_3^2} \right) + \frac{1}{2} D_{\alpha\beta}, \\
D_{\varphi\varphi} &= \frac{1}{2r^2} D_{\alpha\beta} - \frac{1}{2} \operatorname{Re} \left(\frac{D_{\alpha\alpha}}{\alpha_3^2} \right), \quad (30)
\end{aligned}$$

$$D_{r\varphi} = -\frac{r}{2} \operatorname{Im} \left(\frac{D_{\alpha\alpha}}{\alpha_3^2} \right),$$

where A_{α_3} , A_{β_3} , $D_{\alpha\alpha}$, $D_{\alpha\beta}$ are the drift and diffusion terms of Fokker – Plank equation (27). Substituting these coefficients into (28) we obtain the Fokker-Planck equation as function of variable x and φ

$$\begin{aligned} \frac{\partial P(x, \varphi, t)}{\partial \tau} = & \frac{\partial}{\partial x} \left\{ x \left[1 + \frac{2c(1+2x^2)}{(1+x^2)^2} + \frac{2(1+2x^2+5x^4)}{(1+x^2)^4} \right] - y \cos \varphi \right\} P + \\ & + \frac{\partial}{\partial \varphi} \left(\frac{y}{x} \sin(\varphi) P \right) + \frac{2}{2} \frac{\partial^2}{\partial x^2} \left[\frac{x^2(1+3x^2)}{(1+x^2)^3} P \right] + \frac{2}{2} \frac{\partial^2}{\partial \varphi^2} \left[\frac{1}{(1+x^2)^3} P \right], \end{aligned} \quad (31)$$

where $x = \frac{r}{\sqrt{\pi_0}}$ and $y = \frac{E}{\kappa \sqrt{n_0}}$ describe the normalized amplitude of transmitted and incident light, respectively. $\tau = kt$ is the normalized time and $C = \frac{g^2}{2\gamma_1 \kappa}$ is a constant. $q = \frac{2C}{n_0}$ represents the parameter that describes the quantum fluctuations and $n_0 = \frac{\gamma_1 \gamma_2}{\sigma^2 g^2}$.

Neglecting the phase variation, one can obtain the Fokker-Planck equation only for amplitude:

$$\frac{\partial P}{\partial t} + \frac{\partial J}{\partial x} = 0, \quad (32)$$

where J is the density flow with the form

$$J = - \left\{ x \left[1 + \frac{2c(1+2x^2)}{(1+x^2)^2} + \frac{2(1+2x^2+5x^4)}{(1+x^2)^4} \right] - y \right\} P - \frac{q}{2} \frac{\partial}{\partial x} \left[\frac{x^2(1+3x^2)}{(1+x^2)^3} P \right]. \quad (34)$$

We have to check the balance condition at the steady state case considering

$$J = 0. \quad (35)$$

The equation (35) represents a first order differential equation, where the density of probability $P(x)$ is an unknown function and has the following solution

$$P(x) = N \exp \left[-\frac{2}{q} \phi(x) \right], \quad (36)$$

where N is the normalized constant and $\phi(x)$ describes the potential function that is given by

$$\phi(x) = \int \left\{ y - x \left[1 + \frac{2c(1+2x^2)}{(1+x^2)^2} + \frac{q(1+2x^2+5x^4)}{(1+x^2)^4} \right] \right\} \cdot \frac{(1+x^2)^3}{x^2(1+3x^2)} dx - \frac{q}{2} \ln \left[\frac{x^2(1+3x^2)}{(1+x^2)^3} \right]. \quad (37)$$

On the other hand, in the deterministic case, the steady states of a system that implies quantum fluctuations, characterize points for which the density of probability take extreme values. For function $P(x)$, the maximum of these points corresponds to the most probable states, while the minimum corresponds to less probable states. The extremes of function $\phi(n)$ coincide with those of $P(x)$, i.e. the points for which $P(x)$ is maximal correspond to the points with minimal values for $\phi(x)$, and vice-versa. It is known that the steady states of a system are given by the condition $\phi'(x) = 0$, which implies

$$y = f(x, c, q), \quad (38)$$

where

$$f(x, c, q) = x \left(1 + \frac{2c(1+2x^2)}{(1+x^2)^2} \right) + \frac{2qx(1+3x^2+x^4)}{(1+x^2)^4}.$$

Following the assumption [7], we determine the diagram q as function of new parameter C , that describes a behavior $f(x, q, C)$. The critical values of q and C can be obtained from conditions $f'_x = f''_{xx} = 0$, which are equivalent to the next system of equations

$$\begin{aligned} 1 - 2c\psi(z, k) &= 0 \\ \psi'(z, k) &= 0, \end{aligned} \quad (39)$$

$$\text{where } z \equiv x^2, \quad k = \frac{q}{C}$$

$$\psi(z, k) = \frac{2z^4 + (3k+1)z^3 + (10k-5)z^2 - (2k+5)z - (k+1)}{(1+z^5)} \quad (40)$$

$$\psi'(z, k) = -\frac{2z^4 + (6k-6)z^3 + (21k-18)z^2 - (28k+10)z - 3k}{(1+z)^6}. \quad (41)$$

From equations (39) follows the relations for parameters C and q [7]

$$\begin{aligned} C &= \frac{(1+z)^5 (6z^3 + 21z^2 - 28z - 3)}{2(6z^7 + 46z^6 + 53z^5 + 31z^4 + 84z^3 + 96z^2 + 33z + 3)} \\ q &= \frac{(1+z)^5 (-2z^4 + 6z^3 + 18z^2 + 10z)}{2(6z^7 + 46z^6 + 53z^5 + 31z^4 + 84z^3 + 96z^2 + 33z + 3)}. \end{aligned} \quad (42)$$

The system (42) represents the parametric equation of separatrix in the space (C, q) . This separatrix is plotted in the Figure 1. As one can see, the domain of parameters q and C is

separated into two regions. In the region I the system is mono-stable. The region II is characterized by bistable states. We mention that, the critical value $C = \frac{54}{17}$ corresponds to the deterministic case (see point A in Figure 1).

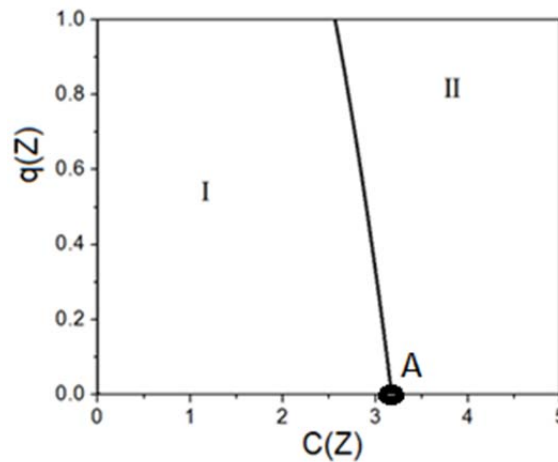


Figure 1. The separatrice line in space (q, C) .

3. Fluctuation evaluation. Optical bistability.

In what follows, we analyze the case of small fluctuations for the transmitted field through the semiconductor. The correlations and spectral line expressions of transmitted radiation can be evaluated via the linearization of stochastic differential equations around the stable steady states. This type of linearization transforms the stochastic equations in those of Ornstein-Uhlenbeck, which solutions are known and allow easy to calculate all characteristic values of fluctuations. Applying the linearization procedure of stochastic differential equations one can obtain the system:

$$\frac{\partial}{\partial t} [\delta \vec{\alpha}_\mu(t)] = - \left[\frac{\partial}{\partial \alpha_\nu} \bar{A}_\mu(\vec{\alpha}_0) \right] \delta \vec{\alpha}_\nu + [D(\vec{\alpha}_0)]_{\mu\nu}^{1/2} \xi(t), \quad (43)$$

where $A_{\mu\nu} = \frac{\partial \bar{A}_\mu(\vec{\alpha}_0)}{\partial \alpha_\nu}$ characterize the coefficients of linearization associated with the drift and $D(\vec{\alpha}_0)$ is the matrix of diffusion. Both characteristics, i.e., the diffusion and drift are evaluated in the point $\vec{\alpha}_0 [\vec{\alpha} = (\alpha_3, \beta_3)]$, and describe the solution of equation $\bar{A}_\mu(\vec{\alpha}_0) = 0$. From the system of equation $\bar{A}_\mu(\vec{\alpha}_0) = 0$ we obtain the curve of steady states plotted in Figure 2.

$$y = x_0 \left(1 + \frac{2C(1+2x_0^2)}{(1+x_0^2)^2} \right). \quad (44)$$

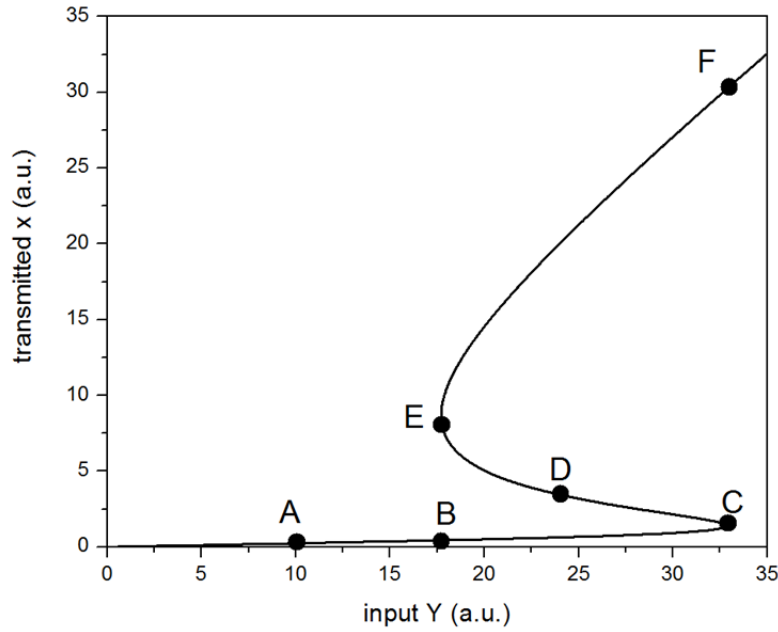


Figure 2. Stationary curve of bistability calculated from relation (44).

The drift and diffusion matrixes have the form

$$A_{\mu\nu} = \begin{pmatrix} a & b \\ b^* & a^* \end{pmatrix}, \quad D_{\mu\nu} = \begin{pmatrix} -d & \lambda \\ \lambda & -d^* \end{pmatrix}, \quad (45)$$

where a, b, d, λ are given by

$$a = k \left[1 + \frac{2c(1+3x_0^2)}{(1+x_0^2)^3} + \frac{4qx_0^4(3-x_0^2)}{(1+x_0^2)^5} \right],$$

$$b = k \left[-\frac{4x_0^2 C}{(1+x_0^2)^3} + \frac{8qx_0^2(1-x_0^2)}{(1+x_0^2)^5} \right] \eta_s^2,$$

$$d = -\frac{4Ck(1+2x_0^2)\eta_s^2}{(1+x_0^2)^3}, \quad \lambda = \frac{4Ck x_0^4}{(1+x_0^2)^3}. \quad (46)$$

The parameters $\eta_s = \frac{\alpha_{3s}}{\sqrt{n_0}}$; $x_0^2 = \eta_s \eta_s^*$, x_0 satisfy the relation (44). We consider an Ornstein-Uhlenbeck process. Thus, for the correlation matrix [6] the following expression can be used:

$$C_{\mu\nu} = \langle \delta\alpha_\mu \delta\alpha_\nu \rangle = \begin{pmatrix} \langle \delta\alpha_3 \delta\alpha_3 \rangle & \langle \delta\alpha_3 \delta\beta_3 \rangle \\ \langle \delta\beta_3 \delta\alpha_3 \rangle & \langle \delta\beta_3 \delta\beta_3 \rangle \end{pmatrix} =$$

$$= \frac{D \cdot \det A + [A - I \cdot \text{Tr}(A)] D [A^T - I \cdot \text{Tr}(A)]}{2 \cdot \text{Tr}(A) \det(A)}. \quad (47)$$

Introducing the expression (45) and (46) into (47) we obtain the following correlation matrix

$$C_{\mu\nu} = \frac{1}{4\text{Re}(a)\lambda_0} \begin{pmatrix} -d\left((a^*)^2 + \lambda_0\right) - d^*b^2 - 2a^*b\Gamma & 2\left[\lambda|a|^2 + \text{Re}(abd^*)\right] \\ 2\left[\lambda|a|^2 + \text{Re}(abd^*)\right] & -d^*(a^2 + \lambda_0) - db^{*2} - 2ab^*\Gamma \end{pmatrix}, \quad (48)$$

where $\lambda_0 = |a|^2 - |b|^2$. Using the matrix $C_{\mu\nu}$ it become possible to calculate the relative values of fluctuation intensity $\frac{\delta I}{I_{coh}}$, as well as the normalized correlation function of the second order $g^{(2)}(0)$. The relative value of intensity of fluctuations is defined as the ratio between the fluctuation intensity $\delta I_{inch} = \langle \delta\beta_3 \delta\alpha_3 \rangle$ and the intensity of coherent light $I_{coh} = n_0 x_0^2$

$$\frac{\delta I_{inch}}{I_{coh}} = \frac{\lambda|a|^2 + \text{Re}(abd^*)}{2a_R\lambda_0 n_0 x_0^2}. \quad (49)$$

We introduce (46) in (49) and obtain

$$\frac{\delta I_{inch}}{I_{coh}} = \frac{2ck^2 x_0^2}{n_0 \lambda_0 (x_0)(1+x_0^2)^3} \left[1 + \frac{2c(1+5x_0^2+4x_0^4)}{(1+x_0^2)^3} \right], \quad (50)$$

where

$$\lambda_0(x_0) = k^2 \left\{ \left[1 + \frac{2C(1+3x_0^2)}{(1+x_0^2)^3} \right]^2 - \frac{16C^2 x_0^8}{(1+x_0^2)^6} \right\}.$$

Assuming ($q \ll 1$), in coefficients a and b , the terms proportional to parameter q can be neglected. The same approximation will be considered and in the following calculations.

The second order correlation function it is calculated using the relation

$$g^{(2)}(0) = 1 + \frac{2}{I_{coh}} \left[\langle \delta\beta_3 \delta\alpha_3 \rangle + R_e \left(\frac{\beta_3}{\alpha_3} \langle \delta\alpha_3 \delta\alpha_3 \rangle \right) \right]. \quad (51)$$

Using the correlation matrix (48) we obtain

$$g^{(2)}(0) = 1 + \frac{2\lambda|a|^2 + \text{Re} \left\{ 2abd^* - \frac{\eta_s^*}{\eta_s} \left[d^2 b^* + d(a^2 + \lambda_0) + 2ab\lambda \right] \right\}}{2x_0^2 \text{Re}(a) \lambda_0(x_0) \cdot n_0}. \quad (52)$$

Finally, we replace the coefficients (46) in (52)

$$g^{(2)}(0) = 1 + \frac{4ck^2}{(1+x_0^2)^3 \lambda_0(x_0) n_0} \left[1 + 3x_0^2 + \frac{2C(1+6x_0^2+11x_0^4+6x_0^6)}{(1+x_0^2)^3} \right]. \quad (53)$$

The spectrum $S(\omega)$ of the light that cross a crystal is proportional to the Fourier transform of the autocorrelation function $\langle \beta_3(t) \alpha_3(0) \rangle$, and it is composed by the coherent and incoherent parts

$$S(\omega) = S_{coh}(\omega) + S_{incoh}(\omega). \quad (54)$$

The coherent spectral part of transmitted light $S_{coh}(\omega) = n_0 x_0^2 \delta(\omega - \omega_0)$ is just a function of the incident light frequency ω_0 , while the incoherent component of the spectrum is given by [14]

$$S_{incoh}(\omega) = \frac{1}{2\pi} \left[(A + i\omega I)^{-1} D (A^T - i\omega I)^{-1} \right]. \quad (55)$$

We are interested only in the incoherent component of the spectrum and it can be obtained by introducing (45) in (55)

$$S_{incoh}(\omega) = \frac{\gamma\lambda\omega^2 + 2\omega \text{Im}(b^*d + \lambda a) + \lambda(|a|^2 + |b|^2 + 2\text{Re}(abd^*))}{2\pi\lambda(\omega)}, \quad (56)$$

$$\text{where } \lambda(\omega) = \omega^4 + \omega^2(a^2 + a^{*2} + 2|b|^2) + (|a|^2 - |b|^2)^2.$$

Taking into account the parameters a, b, d, λ we get the next relation for the spectrum

$$S_{incoh}(\omega) = \frac{\lambda(x_0)\omega^2 + P(x_0)}{2\pi[\omega^4 + \lambda_1(x_0)\omega^2 + \lambda_2(x_0)]}, \quad (57)$$

where

$$P(x_0) = \frac{4ck^3x_0^4}{(1+x_0^2)^3} \left\{ \left[1 + \frac{2c(1+3x_0^2)}{(1+x_0^2)^3} \right] \left[1 + \frac{2c(1+7x_0^2+8x_0^4)}{(1+x_0^2)^3} \right] + \frac{16c^2x_0^8}{(1+x_0^2)^6} \right\},$$

$$\lambda_1(x_0) = 2k^2 \left\{ \left[1 + \frac{2C(1+3x_0^2)}{(1+x_0^2)^3} \right]^2 + \frac{16C^2x_0^8}{(1+x_0^2)^6} \right\},$$

$$\lambda_2(x_0) = k^4 \left\{ \left[1 + \frac{2C(1+3x_0^2)}{(1+x_0^2)^3} \right]^2 - \frac{16C^2x_0^8}{(1+x_0^2)^6} \right\}.$$

The plots of the spectral fluctuations for different values of x_0 from the optical bistability curve shown in Figure 2, are represented in Figure 3.

Each plot of Figure 3 corresponds to the marked point (A-F) of optical bistability curve shown in Figure 2. From these pictures we can observe a hysteresis cycle of spectrum, where the extreme regions are marked by two extremely narrow spectral lines for conditions of points C and E in Figure 2. These situations correspond to the jumped points from one region (branch) of the stationary curve of optical bistability to another, as shown in Figure 3 (c) and (e). On the lower branch of optical bistability curve (small values of x_0) the spectrum width is high see Figure 3 (a). When increasing parameter x_0 (see Figure 3 b) the line width become narrow, achieving a critical value at the jumped point C of Figure 2. On the upper branch of optical bistability curve, the spectrum width is narrow (see Figure 3 (d)) and continues to diminish when x_0 is moving to the next jumped point E. Thus, based on the quantum description, we demonstrated in this paper the presence of optical bistability for a system of excitons and biexcitons with a geometry of a ring resonator with high quality factor Q . Finally, it worth to mention that the obtained results are in a good agreement with those obtained by in [17, 18].

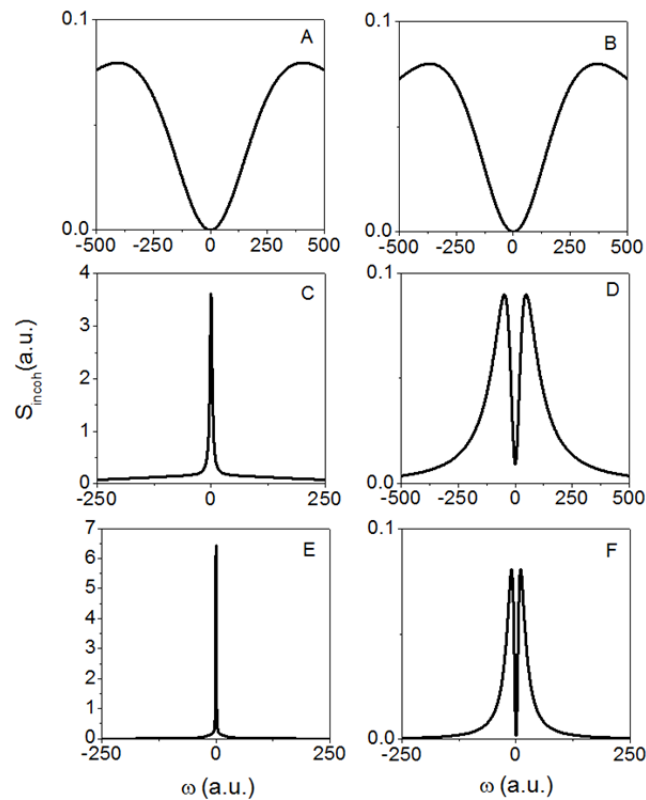


Figure 3. Spectrum of the fluctuations calculated using eq. (57) for marked points of Figure 2 with different values of x_0 : A ($x_0=0.25$), B ($x_0=0.5$), C ($x_0=1.38$), D ($x_0=5$), E ($x_0=8.5$), F ($x_0=30$).

4. Conclusions

In this paper we demonstrate that in a ring cavity the quantum treatment of optical bistability phenomena occurs for an excitons and biexcitons system. This treatment is done based on the method [14,15] and the cavity is excited via an external coherent field. The excitons, biexcitons and cavity field modes are damped due to the reservoirs interaction of the system. Following the adiabatic elimination of the exciton and biexciton variables, the Fokker-Planck equation for the transmitted field was obtained. In order to obtain this equation, we used the generalized p representation that was introduced by Drummond and Gardiner [15]. In this description only the quantum noise is considered, i.e. the fluctuations

of the nonlinear interaction between the particles (quasi-particles), the thermal fluctuations that happen due to the reservoir' interaction being neglected. It is worth to mention that quantum noise does not have any classical analogue. Thus, based on the approximation of linearization, the spectrum of transmission and second order correlation function were calculated. The spectrum of transmission describes a hysteresis cycle character, where a narrow spectral line in the end of cycle can be observed. The obtained result is similar to that of optical bistability case for two-level atom system. Finally, we believe that our work provides a good basis for future study, and, in particular, provides some pointers for more detailed experimental and theoretical investigations of optical bistability for a high Q cavity case.

References

1. H. M. Gibbs, Optical Bistability. Controlling Light with Light, Academic Press, Orlando (FL) 1985.
2. V. F. Elesin and Yu. V. Kopaev, Zh. Eksper. Teor. Fiz. 63, 1447 (1972) (Soviet Phys. J. Exper. Theor. Phys. 35, 760 (1972)).
3. S.A. Moskalenko; D W Snoke, Bose-Einstein condensation of excitons and biexcitons: and coherent nonlinear optics with excitons, New York: Cambridge University Press, 1999.
4. V.Z.Tronciu A.H. Rotaru Optical switchings, self-pulsations and dynamical chaos synchronisation in condensed matter (review). Acta Academia, vol 2, Chisinau, Evrica, 1998, p. 102-146.
5. A.H. Rotaru. and V.Z. Tronciu Optical bistability, switching, and self-pulsations in direct-gap semiconductors upon the binding of two excitons in a biexciton. Physics of the Solid State., issue 10, 1998, vol. 40, p. 1641-1645.
6. V. Zalozh, A. Rotaru. and V. Tronchu Optical hysteresis, switchover, and self-pulsation of excitons and biexcitons in condensed media, Zh.Eksp.Teor.Fiz., 1993, vol. 103, p. 994-1009 [Sov.Phys.JETP, 1993, vol. 76, p. 487-496].
7. I.I. Gontia, and A.H. Rotaru, Optical Bistability Induced By Additive Colored Noise in the Exciton-Biexciton System, Acta Physica Polonica A, 1995, 87, p. 911-917
8. Seyyed Hossein Asadpour, H. Rahimpour Soleimani, Optical bistability and multistability via biexciton coherence in semiconductor quantum well nanostructure, Optics Communications Volume 315, 15 March 2014, Pages 347-351
9. N. A. Asriyan, I. L. Kurbakov, A. K. Fedorov, and Yu. E. Lozovik, Optical probing in a bilayer dark-bright condensate system, Phys. Rev. B 99, 2019, p. 085108.
10. V. Mykhaylovsky, V. I. Sugakov, I. Goliney, Excitation of pulses of excitonic condensed phase at steady pumping, J. of Nanophotonics, 2016, 10(3), p. 033504.
11. V. I. Sugakov, Exciton condensation in quantum wells with defects of macroscopic sizes, J. Phys.: Condens. Matter 31, 2019, p. 475301.
12. Yu. E. Lozovik, New effects in and control of exciton systems in quasi-two-dimensional structures, 2019, Phys.-Usp. 61, p. 1094.
13. O. L. Berman, R. Ya. Kezerashvili, G. V. Kolmakov, and L. M. Pomirchi Spontaneous formation and nonequilibrium dynamics of a soliton-shaped Bose-Einstein condensate in a trap, Phys. Rev. E 91, 2015, p. 062901.
14. P.D.Drummond and D.F. Walls, Quantum theory of optical bistability. II. Atomic fluorescence in a high-Q cavity, Phys. Rev. A, 1981, vol. 23, p. 2563-2579.
15. P.D. Drummond and C.W. Gardiner, Generalised P - representations in quantum optics, Journal of Physics A, 1980, vol.13, p. 2353.
16. M.Lacs, Fluktuatzii i kogerentnnie yavlenia. Mir, Moskva 1987 ; Elesin V. Kopayev Yu. JETP 1972, 62, p 1447; Godiner K. Stohasticeskie metody v estestvennih naukah 1986.
17. S.A. Moskalenko, A.H. Rotaru, V.M. Shvera The Fokker-Planck equation and taking into account of quantum fluctuations in the theory of excitons and biexcitons of large density, Teor. Mat. Fiz., 1988, vol. 75, p. 295-305.
18. V.Tronciu, and A. Rotaru Quantum treatment of optical self-organization phenomena of excitons and biexcitons in ring cavity. Abstract of the 6th International Conference on Materials Science and Condensed Matter Physics Chisinau 11-14 2012, CMT-2P, p.49.

DOI: 10.5281/zenodo.3444051

CZU 004.056.53:519.711



PERFORMANCE MODELING OF NETWORK DEFENSE IN BREADTH SYSTEMS BY MATRIX REWRITING SRN WITH FUZZY PARAMETERS

Emilian Guțuleac*, ORCID ID: 0000-0001-6839-514X

Sergiu Zaprojan, ORCID ID: 0000-0001-5928-4229

Victor Moraru, ORCID ID: 0000-0002-5454-8341

Alexei Sclifos

*Technical University of Moldova, 168 Stefan cel Mare bvd., MD-2004 Chisinau, Republic of Moldova***Corresponding author: Emilian Guțuleac: emilian.gutuleac@calc.utm.md*

Received: July, 04, 2019

Accepted: September, 22, 2019

Abstract. We have defined in this paper, a new kind of stochastic reward network (SRN) by introducing matrix attributes and fuzzy parameters of timed transitions and of rewriting rules, called MFRSRN, allowing the dynamic marking-dependent reconfiguration of these models. Moreover, this formalism offers a descriptive language that allows managing the compact representations the model's size through the introduction of matrix structuring and rewriting mechanisms of the compositional model's behavior. As an example of application, we show how the proposed formalism can be applied to performance modeling of network "Defense in Breadth" system which includes the combination of firewall, IDS, honeypot and moving target defense (MTD) techniques, taking into account the probabilistic and epistemic uncertainty aspects.

Keywords: *attack, cyber-security, evaluation, fuzzy number, honeypot, moving target defense, reconfiguration, stochastic reward net.*

1. Introduction

Currently computer networks (CNs), embedded computing systems, information systems and control systems with interconnecting components and increasing interconnection have become a key infrastructure in different fields of applications, where the information security of CNs is constantly confronted with seriousness severity of challenges. Some of the major causes of these situations are that the current configurations of CN security systems are typically deterministic, static and homogeneous [1]. These features reduce attackers' difficulties in identifying specific targets by scanning CN vulnerabilities, in accessing essential information, which gives attackers asymmetrical advantages in developing, launching and spreading attacks, and defenders are always disadvantaged by their late reaction.

In order to ensure the better security and availability of the CN, a variety of defense techniques have been proposed and developed, among which the most common are: firewalls [2]; the intrusion detection systems (IDS) [3]; honeypots [4] and Moving Target Defense (MTD) [5 - 7]. As a first line of defense, the firewall protects CN against intruders. However, the firewall very rarely can identify the attacks of the allowed services [2]. Therefore, it is easy for attackers to bypass the firewall and to penetrate into the CN. IDS is

a well-known technique of security analysts in order to detect intrusions and misuse of CNs. However, it is well known that IDS-based defense has the following limitations [3]: (1) it activates a lot of false alarms; (2) it has a minor effect on the prevention or on the protection against intrusions; (3) it has a limited capacity to detect the malicious traffic in real time, thus gives to many false negative alarms.

While IDS has played a key role in cyber security, new proactive defense techniques, known as intrusion prevention techniques, have recently emerged that target the shortcomings of using IDS. To this end, intrusion prevention techniques (honeypot deceptive and MTD) have been introduced to control the actions of the attackers, as a proactive defense that can be implemented independently or combined with other defense techniques. Although deception techniques are used to mitigate the attacks success, they also have some limitations [6], including: they incur additional costs; it increases the likelihood that they will be detected by the attacker as he experiences them more over time, thus enhancing the knowledge of the deception detected as part of a "fraud" attack against a defender.

In order to create difficulties and increase the uncertainty of launching a successful CN attack, innovative proactive MTD defense techniques have been proposed and used which continuously change the area of the attack, resulting in increased effort (i.e. cost and time) [6] when carrying out the attack. For example, SW - a new server software variant, DPT - new properties of its processing platform, NAS - the system changed its network address [7]. The key features of MTD have been described in several existing papers [5-7]. Thus, frequent changes of the attack surface increase the attacker's uncertainty about the behavioral characteristics of the attack target and, thus, make it difficult to identify and exploit system vulnerabilities and greatly reduce the probability of an attack being successful.

Not oblivious to the fact that the MTD approach offers a wide range of techniques to mitigate a wide range of cyber-attacks of CN, some limits on their use have been mentioned and discussed in the literature [6]. Some MTD techniques are better at dislocating the attack compared to others, depending on the target of the attacker, which is often unknown. Also, the use of MTD leads to new costs associated with maintaining the performance of CN systems and may affect the availability of services or computing performance and / or network connectivity [6].

Designing a CN security system based on the above-mentioned defense techniques is a complex task, in which a large number of parameters must be taken into account. The influence of these parameters is often mutually opposite, often uncertain and weakly predictable. This situation is explained by the fact that it is necessary to organize the protection not of the network as such, but of the network with all the computer systems that work into and which contain many components. And because all of these factors affect the ability to perform certain attacks, building a CN protection system with a specified level of security and performance that fully takes them into account is a very daunting task. It should also be mentioned that, at present, the cyber security of the CN cannot be ensured or maintained through the use of only one defense technique [8-9]. Therefore, a combined collection of defense techniques is needed that can collaborate and complement each other to cope with sophisticated attacks. This type of defense, called "Defense in Breadth" [8], refers to defense based on several techniques and mechanisms to counter more sophisticated attack classes.

In this context, we need to model the behavior of the attackers; the defense strategies and we need also to evaluate some quantitative QoS (Quality of Service) characteristics of the CN security system and their ability to fulfill the mission within a set time frame and in the presence of intruder attacks [10]. When designing a model that describes the operation of a security system, it is necessary to select specific formalisms, methods and tools according to the specific requirements to this system, i.e. the objectives, risks, quality indicators of services, etc., as well as the incompleteness and uncertainty of the information regarding the behavior of the attackers.

Modeling and simulating the interaction of attackers and CN defense have been a great topic for several decades. However, the modeling, evaluation and quantitative analysis of CN information security have only recently attracted more attention of researchers. We mention here only some relevant bibliographic sources recently published, based on mathematical models that use different formalisms and approaches to evaluate the security mechanisms [11 - 22]. They can be grouped according to the similarity of the used approaches, being created based on different mathematical formalisms: continuous time Markov chains (CTMC) [17, 18]; attack tree [20]; theory of mathematical games [14, 22]; Petri net (PN) extensions [12, 15, 16, 19, 21], such as stochastic reward nets (SRN) [23] and generalized stochastic PN (GSPN) [24], which reflect their different behavioral aspects. The differences between these models consist in the parameters used as input and in which performance characteristics of the modeled system are evaluated. CTMC and mathematical games can be used only for modeling a small class of random attack and defense interaction processes with a small state space, because these kind of models can only be built manually and there are some problems with their validation.

SRN and GSPN allow describing the dynamics of the change of system states, to automate the process of building the underlying LMTC with a very large state space and to evaluate some QoS indicators.

However, in this type of models, the reconfigurability and the fuzzy epistemic uncertainties of the attacker's and defense's behavior are not taken into account. It is also easy to confirm from experience that ordinary SRNs (or GSPNs) [23, 24] are often difficult to use in practice due to the problem of rapidly increasing the graphical size of the model to describe the behavior of a real system. In this context, it is necessary to improve the SRN formalism in order to fully represent more compactly and flexibly the models that describe complex stochastic processes.

At the same time, the activities of the attackers and the defenses have to be represented by probability distributions of the possible actions and activities of attack in each state of the model based on the use of fuzzy numbers.

The uncertainty of epistemic evaluation of the attack risk is related to the imprecise and incomplete character of the information due to the lack of knowledge about the real values of the parameters of the defense mechanisms and of the attackers who dynamically change their states.

This can be achieved by defining a new fuzzy SRN extension (FSRN), based on which you can build compact graphical models with reconfigurability issues and some quantitative parameters may be fuzzy numbers.

In this paper a SRN matrix rewriting model (MFRSRN) with fuzzy parameters is developed and analyzed for the evaluation of the QoS indicators of a security system, "Defense in Breadth" [8] type, of the CN integrated with firewall, IDS and intrusions

prevention techniques (i.e., honeypot and MTD), where quantitative parameters are considered fuzzy numbers.

2. Matrix rewriting SRN with fuzzy parameters

2.1. Elements of fuzzy sets, fuzzy numbers and credibility theory

SRNs are an important formalism that describe the dynamic phenomena under random uncertainty. However, in the real world we often encounter difficult problems that cannot be addressed by using only the theory of stochastic processes. To deal with such complex problems, Liu in [25] have proposed the credibility theory (CT), which is a branch of mathematics for studying the behavior of systems with fuzzy phenomena. The measure of credibility is the degree of trust given to a certain data set, to an occurrence of events, to some fuzzy variables, etc. The purpose of the credibility theory is to efficiently combine information from various sources: previous and current data, data on individual and collective risk, rates of attacks and defenses, etc. [25].

The theory of fuzzy sets and concepts with fuzzy numbers [26 - 28] appears from the need to express quantitatively the imprecise quantities, in which range of values taken by the function of belonging is no longer limited to two values, but it is extended to the whole interval $[0, 1]$.

To facilitate the exposition of the proposed approach, in this subsection we present some basic elements of fuzzy sets, trapezoidal fuzzy numbers (TrFN) [26] and some elements of CT required defining SRNs with fuzzy parameters.

Let X be the set of discourse. Then a fuzzy subset of X is a function $\mu: X \rightarrow [0, 1]$ and it is denoted by μ_X . A fuzzy subset μ_A is called a fuzzy number if A is a subset of the set of real numbers and there exists at least one real number x such that $\mu_A(x) = 1$.

Two types of fuzzy numbers are most commonly found in real applications: trapezoidal numbers and triangular numbers. The use of these types of fuzzy numbers is more appropriate, one reason being the computing complexity.

Definition 2.1. A fuzzy number is said to be a TrFN if its membership function is given by the expression (2.1):

$$\mu_A(x) = \begin{cases} 0 & \text{if } -\infty < x \leq a \\ (x-a)/(b-a) & \text{if } a \leq x < b \\ 1 & \text{if } b \leq x \leq c \\ (x-d)/(c-d) & \text{if } c < x < d \\ 0 & \text{if } d \leq x < \infty \end{cases}$$

Definition 2.2. A TrFN $\tilde{A} = (a, b, c, d)$ is said to be zero (respectively non-negative) iff $a = 0, b = 0, c = 0, d = 0$ (iff $a \geq 0$). Also, two TrFNs $\tilde{A} = (a_1, b_1, c_1, d_1)$ and $\tilde{B} = (a_2, b_2, c_2, d_2)$ are said to be equal i.e., $\tilde{A} = \tilde{B}$ iff $a_1 = a_2, b_1 = b_2, c_1 = c_2, d_1 = d_2$.

Note that the triangular fuzzy number (TFN) $\tilde{A} = (a, b, d)$ is a particular case of TrFN $\tilde{A} = (a, b, c, d)$ if $b = c$.

Let Θ be a nonempty set, and $Bag(\Theta)$ is its description power that is the set of all subsets of Θ . Each element of $Bag(\Theta)$ is called an event. For each element $A \in Bag(\Theta)$, a credibility measure $Cr\{A\}$ is defined that expresses the chance of occurrence a fuzzy event

A [25]. The triplet (Θ, Bag, Cr) is called the credibility space, and a fuzzy variable ξ is defined as a function (measurable) at this space on the set of real numbers IR . According to [25], the membership function $\mu_\xi(x)$ of a measurable fuzzy variable ξ at space (Θ, Bag, Cr) , is derived from the credibility measure as follows:

$$\mu_\xi(x) = (2Cr\{\xi = x\}) \wedge 1, \quad x \in IR,$$

and for any set $B \in IR$ of real numbers we have:

$$Cr\{\xi \in B\} = (\sup_{x \in B} \mu_\xi(x) + 1 - \sup_{x \in B^c} \mu_\xi(x)) / 2.$$

The average value $\bar{\xi} = E[\xi]$ of ξ is determined by the following relation [25]:

$$E[\xi] = \int_0^{+\infty} Cr\{\xi \geq x\} dx - \int_{-\infty}^0 Cr\{\xi \leq x\} dx.$$

According to [25], based on this expression and the membership function $\mu_\xi(x)$ of a trapezoidal fuzzy variable ξ at $[a, b, c, d]$ on $0 \leq a < b < c < d$ which determines a fuzzy number $\tilde{A} = (a, b, c, d)$, we obtain the relation: $\bar{\xi} = E[\xi] = (a + b + c + d) / 4$.

This expression will further to be used to determine the parameters of the credible parameters of an FSRN or MFRSRN model.

2.2. Definition and behavior of matrix rewriting SRN with fuzzy parameters

In order to model more realistically the uncertainty of the attackers' behavior and the defense reaction of the security system, it is necessary to consider both probabilistic and fuzzy aspects [28]. As already mentioned, this fact can be achieved by defining a new extension of SRN in which some quantitative attributes may have fuzzy values. This enhancement allows the compact modeling of high complexity discrete event systems (SED) through MFRSRN, without the risk of having a very complicated graphical FRSRN model, too difficult to represent and difficult to understand.

Let IN_+ and IR_+ are sets of nonnegative natural and nonnegative real numbers, respectively. The definition of an MFRSRN is derived according to [29 -31] and inherits most of the SRN [23] and GSPN [24] characteristics. In a MFRSRN model, the matrix attributes of objects (arcs, places capacities, guard functions and transition priorities, rewriting rules, firing rates of transitions etc.) of the specified type z , depending on the current state of the network, are defined by a set of matrix $A^z = [a_{ij}^z(s)]_{k \times n} \in \mathbf{A}$. The values of the network attributes may be constant, variable, or functions of the specified type and may depend on the current state of the MFRSRN networks.

The size $k \times n$ and location of the current element $a_{ij}^z(s)$ of the matrix A^z is specified by a set $P_A^z \subset P$ of net control places. For example, for the matrix specifications A^z and the current location of its elements, two control locations should be set. Therefore, the current number of tokens $i = m_l = M(p_l)$ and $j = m_v = M(p_v)$ in control places p_l and p_v shows the position of the respective element of matrix A^z , and its values must be imported and taken into account when executing and analyzing the model. Furthermore, the capacity of the control places $p_l \in P_A^z$ and place $p_v \in P_A^z$ should be specified respectively.

Definition 2.3. The MFRSRN, denoted $M\Gamma$, is specified as a 13-tuple system such that $M\Gamma = \langle P, T, R, \phi, A_{rcs}, Pri, G^E, G^R, M_0, \tilde{\Lambda}, \tilde{W}, \tilde{\rho}, Lsp \rangle$, where:

- P is the finite set of places, $|P| = n \neq 0$. A place $p_i \in P$ is drawn with a circle and can contain a number of tokens $m_i = M(p_i) \in IN_+$ (local state). The current marking (global state) M of the $M\Gamma$ is a vector-column, describing the contents value of each place, respectively;
- T is a finite set of transitions, $|T| = k \neq 0, P \cap T = \emptyset$, which is partitioned into $T = T_0 \cup T_\tau$, $T_0 \cap T_\tau = \emptyset$ so that: T_τ is a set of timed transitions (drawn as black rectangles) and T_0 is a set of immediate transitions (drawn as tin bar);
- R is a finite set of rewriting rules, $|R| = k_R \neq 0$ which is partitioned into $R = R_0 \cup R_\tau$, $R_0 \cap R_\tau = \emptyset$ so that: R_τ is a set of timed rewriting rules (drawn as embedded empty rectangles) and R_0 is a set of immediate rewriting rules (drawn as embedded empty tin rectangles) about the runtime structural change (reconfiguration) of net, so that $P \cap T \cap R = \emptyset$. We let $E = T \cup R$ denote the set of events of the net; $\phi: E \rightarrow \{T, R\}$ is the function that indicates for every rewriting rule the type of event can occur;
- $A_{rcs} = \langle Pre, Post, Test, Inh \rangle$ is a set of forward, backward, test and inhibition functions, that describes the respectively arcs with matrix marking-dependent weight cardinalities;
- Pri defines the dynamic matrix marking-dependent priority function for the firing of each event $e \in E$. The firing of an event with higher priority potentially disables all event $e \in E$ with the lower priority. By default, the $Pri(E_0) > Pri(E_\tau)$;
- $G^E: E \times IN_+^{|P|} \rightarrow \{True, False\}$ is the set of matrix guard function associated with all event $e \in E$ and $G^R: R \times IN_+^{|P|} \rightarrow \{True, False\}$ is the set of matrix guard function associated with all rewriting rule $r \in R$. For $\forall r \in R$, the $g^E(M) \in G^E$ and $g^R(M) \in G^R$ will be evaluated in each current marking and if they are evaluated to *True*, the rewriting rule r is *enabled*, otherwise it is *disabled*. Default value of $g^E(M)$ is *True* and for $g^R(M)$ it is *False*;
- M_0 is the initial marking of net. Graphically, the initial marking is represented by writing the value of $m_i^0 = M(p_i)$ inside the corresponding place p_i . If the number m_i^0 is small it is common to draw m_i^0 tokens inside the place p_i , represented by black dots. A missing value indicates zero tokens;
- $K^P: P_D \times IN_+^{|P|} \rightarrow IN_+ \cup \{\infty\}$ is the matrix capacity bound $0 < K_i^P < +\infty$ of each place $p_i \in P$, which can contain an integer finite number of tokens. By default and K_i^P it is unlimited;
- $\tilde{\Lambda}: E_\tau \times IN_+^{|P|} \rightarrow IR^+$ is the function that determines the matrix fuzzy firing rate $0 < \tilde{\lambda}(e, M) < +\infty$ (the parameters of exponential-negative law) of timed event $e \in E_\tau$, that is enabled by current marking M ;
- $W: E_0 \times IN_+^{|P|} \rightarrow IR^+$ is the matrix fuzzy weight function $0 \leq w(e, M) < +\infty$ which determines the firing probability $q(t, M)$ of immediate event $e \in E_0$, enabled by current marking M , therein describes an probabilistic selector;
- $\tilde{\rho}: P \cup E \rightarrow IR^+$ is a matrix reward rates (real numbers) assigned to each current marking M and to each firing event $e \in E$;

• L_{sp} is the set of MRI_{ν} , $\nu=1, 2, \dots, n_{\nu}$ subnet pattern class library involved in structural reconfiguration of the current MRI configuration by firing of an enabled rewriting rule $r \in R$.

Figure 1 summarizes the graphical representation of all MRI primitives.

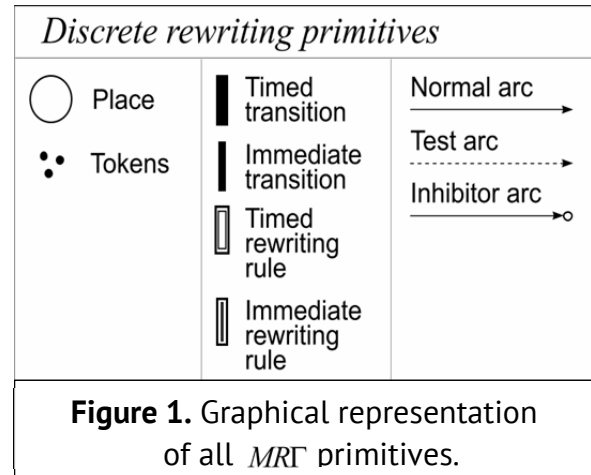
Let be $RN = \langle R\Gamma, M \rangle$ is the current configuration of MRI , where $R\Gamma = \langle P, T, R, A_{rcs}, Pri, G^E, G^R, \tilde{\Lambda}, \tilde{W}, \tilde{\rho} \rangle$ and M is the current marking of MRI .

A dynamic reconfiguration of RN by the firing of enabled rewriting rule $r \in R$ is a map $r: RN_L \triangleright RN_W$, where $RN_L \in L_{sp}$ subnet and $RN_W \in L_{sp}$ subnet are the left-hand side and the right-hand side of the rewriting operator \triangleright assigned to rewriting rule r , respectively. The rewriting operator, \triangleright , represents a binary operation which produces a *structure change* in RN by replacing (rewriting) the fixed current subnet $RN_L \subseteq RN$ (RN_L are dissolved with $P_L \subseteq P$, $E_L \subseteq E$ and subset of arcs $A_L \subseteq A$) and a new $RN_W \in L_{sp}$ subnet (with $P_W \subseteq P$, $E_W \subseteq E$ and set of arcs A_W) belongs to the new modified resulting underlying net $RN' = (RN \setminus RN_L) \cup RN_W$ with $P' = (P \setminus P_L) \cup P_W$ and $E' = (E \setminus E_L) \cup E_W$, $A' = (A - A_L) + A_W$ where the meaning of \setminus (and \cup) is operation of removing (adding) RN_L from (RN_W to) RN .

In this new RN' net, obtained by the execution of the enabled $r \in R$, the places and the events with the same attributes which belong to RN' are fused. By default, the rewriting rules $r: RN_L \triangleright \emptyset$ or $r: \emptyset \triangleright RN_W$ describe the rewriting rule which maintains $RN' = (RN \setminus RN_L)$ or $RN' = (RN \cup RN_W)$. So, a current state configuration of a RN net is the pair $(R\Gamma, M)$, i.e. the current structure configuration $R\Gamma$ of the net together with a current marking M . Also, the pair $(R\Gamma_0, M_0)$ with $P_0 \subseteq P$, $E_0 \subseteq E$ is the initial configuration. *Enabling and firing of events and rewriting rules* are the same as for reconfigurable GSPN presented in [31].

Let the $T(M)$ and $R(M)$, $T(M) \cap R(M) = \emptyset$, be the set of enabled transitions and rewriting rules in current marking M , respectively. Let the $E(M) = T(M) \cup R(M)$, be the set of enabled events in a current marking M . The event $e_j \in E(M)$ fires if no other event $e_k \in E(M)$ with higher priority has been enabled. Hence, for e_j event **if** $((\phi_j = t_j) \vee (\phi_j = r_j) \wedge (g^R(r_j, M) = False))$ **then** the firing of $t_j \in T(M)$ or of $r_j \in R(M)$ changes only the current marking: $(R\Gamma, M) \xrightarrow{e_j} (R\Gamma, M') \Leftrightarrow (R\Gamma = R\Gamma \text{ and } M[e_j > M' \text{ in } R\Gamma])$.

Also, for the every event $e_j \in E$ **if** $((\phi_j = r_j) \wedge (g^R(r_j, M) = True))$ **then** the event e_j occurs at firing of the rewriting rule r_j and it changes the configuration and marking of the current net, such that: $(R\Gamma, M) \xrightarrow{r_j} (R\Gamma', M')$, $M[r_j > M']$.



The accessible state graph configuration of a net $RN = \langle R\Gamma, M \rangle$ is the labeled directed graph whose nodes are states and whose arcs, which are labeled with events or rewriting rules of RN , are of two kinds:

a) *firing* of an enabled event $e_j \in E(M)$: arcs from state $(R\Gamma, M)$ to state $(R\Gamma', M')$ labeled with event e_j , so that this event can fire in the configuration $R\Gamma$ at marking M and leads to a new marking:

$$M': (R\Gamma, M) \xrightarrow{e_j} (R\Gamma', M') \Leftrightarrow (R\Gamma = R\Gamma' \text{ and } [M[e_j] > M' \text{ in } R\Gamma];$$

b) *change configuration*: arcs from state $(R\Gamma, M)$ to state $(R\Gamma', M')$ labeled with the rewriting rule $r_j \in R$, $r_j: (R\Gamma_L, M_L) \triangleright R\Gamma_W, M_W$ which represent the change configuration of current RN net: $(R\Gamma, M) \xrightarrow{r_j} (R\Gamma', M')$ with $M[r_j] > M'$.

The operating rules of the network models and the method of analyzing their behavioral properties are similar to those of the GSPN or SRN models, described in [23, 24]. The difference refers to identifying the firing rates of enabled events.

Thus, we first identify the firing rates (resp. weights) of the enabled timed (resp. immediate) events, which are represented as TrFN and / or TFN. Using the respective fuzzy values of these rates (resp. weights), the model is analyzed by running it in a flat SRN model, for which the Markov chain is equivalent to the fuzzy Markov chain of the original model. In this paper we will consider only models in which all the structural attributes have implicit sizes, and the capacity of all places is equal to 1.

3. MRF-based performance modeling of network defense in breadth systems

In this paper, we assume that if a single CN node is compromised and exploited by an attacker, the entire security system fails. This harsh security condition is used to evaluate the level of integrated defense of the security system equipped with honeypot, IDS and MTD techniques. To model through **MRF** the process of serving the packets, the attacks and the defense of a CN node we will adopt the following assumptions [4, 8, 12]:

- The attacker has a finite set of exploits of the vulnerabilities depending on the interaction between the attacker and the software stack of the security system of the CN target nodes;
- An attacker can detect with imperfect knowledge whether a CN node of interest has a vulnerability or not. That is, he knows with some degree of certainty whether the accessed node can be exploited to affect the security system, which can lead to system compromise. He may also, with a certain probability, detect the frauds committed;
- An attacker can learn from his past experience, including from his failure experiences. Thus, the attacker becomes more intelligent on the basis of this learning, which reduces the time to compromise the security system;
- RC has a firewall, honeypot and IDS mechanisms, used by a distributed security system in which each node must detect malicious intruder activities. The IDS is triggered adaptively at a certain time in proportion of the detected attacks, the IDS also learn from past attacks;
- The MTD mechanisms are applied according to periodic rules of modification and displacement of the attack area only in the process of serving the requests and the occurrence of the time-out expiry event or when a security alert appears. Different types of MTD mechanisms can be chosen in different rounds of service, but only one can be used in each round.

The construction of *MRN* model, which describes the behavior of the attacker interaction, exploiting the vulnerabilities of a given CN and the defense of this network through "Defense in Breadth" mechanisms, based on the integrated combination of the techniques presented above, is performed using the method described in [8].

In order to show the advantage of using the approach described in this paper, we will first present a FSRN1 model, built in the traditional form [23], which describes the behavior of the attacker interaction exploiting the vulnerabilities of a given CN node and of the defense of this node through "Defense in Breadth" mechanisms [8], based on the integrated combination of firewall, honeypot, IDS and MTD techniques. Then we will show how to build a *MRN* model based on FSRN1.

Figure 2 shows such a FSRN1 model in which, in order to give graphic visibility to this type of model, only 3 firewall rules and 3 MTD techniques are considered, namely: SW, DPT and NAS. In order to describe in the GSPN1 model the on-line switching of the MTD security mechanisms, 2 timed transitions t_{18}, t_{19} are used to reproduce the time-out times of change (modification) and use of the proactive MTD security techniques.

In this model the places (resp. transitions) correspond to the locale states (resp. events, actions, activities) of the attacker and of the CN security system.

The meanings of the places, transitions and rewriting rules of the model FSRN1 are:

- **Places:** p_1 - normal state of the CN, it is not attacked; p_2 - an CN node is attacked, the firewall is activated; p_3 - IDS has triggered a security alert; p_4 - the arrived packet is malicious; p_5, p_6, p_7 - the intruder packet bypass the firewall (with k_{r1} specified rules); p_8 - IDS activates the verification of the legitimacy of the packet data; p_9 - IDS did not trigger a security alert, the honeypot trap is activated; p_{10} - the intruder is trapped in the honeypot trap; p_{11} - the intruder bypassed the honeypot trap; p_{12} - CN is available to provide services; p_{13} - the user accesses the node resources; p_{14} - activation of the timer that measures the time-out; p_{15} - the time-out period has expired (control place for the application of the MTD mechanisms); p_{16} - the CN node server is free; p_{17} - selecting the activation of one of the type of TMD defense mechanisms; p_{18}, p_{19}, p_{20} - the respective MTD mechanism is selected, changed and activated: SW - a new variant of server software, DPT - new dynamic properties of its processing platform, NAS - the system has changed its network address; p_{21}, p_{22} - processing end of the node request in which the respective SW, DPT and NAS mechanism is used; p_{23} - requesting to be served normally; p_{24} - initiating the release of computing resources and testing the server; p_{25} - reconnecting the user to the server; p_{26} - initiation of isolation of the intruder when switching TMD; p_{27} - the intruder packet is removed when changing a current TMD mechanism.

- **Timed transitions:** t_1 - the occurrence of an attack; t_4 - the intruder bypasses the honeypot trap; t_6 - restoring the normal operating regime; t_7 - the activity of processing and rejecting the malicious package by the firewall; t_8, t_9, t_{10} - the respective activities for executing firewall rules as a result of which the intruder bypasses the firewall; t_{11} - detection of the intruder by the IDS; t_{12} - the intruder bypasses the IDS; t_{13} - the intruder falls into the trap of honeypot; t_{14} - recovery of the normal CN regime as a result of the intruder falling into the honeypot trap; t_{15} - the intruder bypasses the honeypot trap; t_{16} - access of

users by RC; t_{18}, t_{19} - the time-out of change (modification) and use of proactive MTD security mechanisms; t_{23}, t_{24}, t_{25} - the time delay of the respective MTD mechanisms established in the RC: SW - a new variant of server software, DPT - new dynamic properties of its processing platform, NAS - the system has changed its

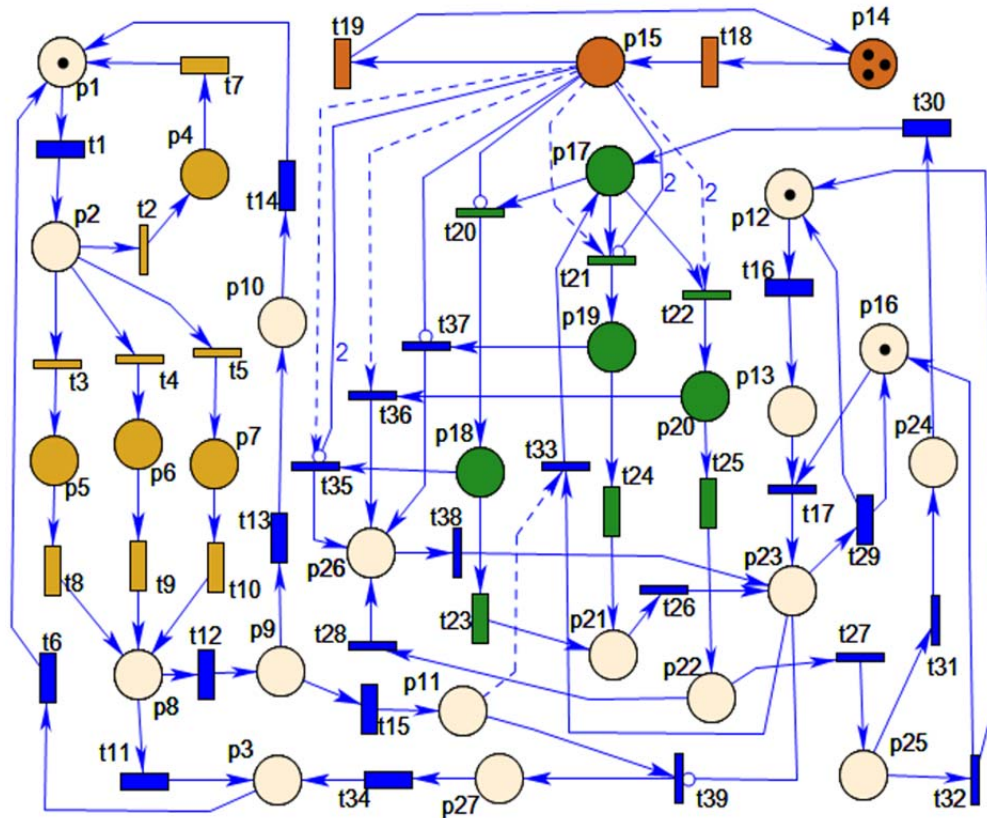


Figure 2. SRN1 model with 3 security firewall rules, honeypot, IDS and 3 MTD techniques.

network address; t_{29} - processing of the current application; t_{30} - CN provides the requested service; t_{34} - removing the intruder from the network.

- **Immediate transitions:** t_2 - determines the probability that the malicious package was detected by the firewall; t_3, t_4, t_5 - probabilistic selector that determines the probability that the malicious package will bypass the respective firewall rule; t_{20}, t_{21}, t_{22} - selecting and activating the respective MTD security mechanism: SW - a new variant of server software, DPT - new dynamic properties of its processing platform, NAS - the system changes its network address; t_{26}, t_{27}, t_{31} - reactivating the processing of the user's request by the server; t_{32} - reset the server release; t_{33} - initialization of the MTD defense activation and triggering the elimination of the intruder; t_{34} - reset the selection and change of a MTD mechanism; t_{35}, t_{36}, t_{37} - elimination of the intruder when changing the current MTD mechanism; t_{38} - switching demand service normally with the current MTD mechanism; t_{39} - eliminating the intruder when switching MTD.

It can be demonstrated that any FSRN or FGSPN model can be folded in a MRT model type with the same attributes and behavioral properties. Figure 3 shows the MRT model obtained by the respective folding of the model FSRN1. It can also be demonstrated that any model or GSPN can be wrapped in a model of the type with the same attributes

and behavioral properties. Figure 3 shows the model obtained by the respective folding of the FSRN1 model.

The timed rewriting rules of $MRT1$ are: $r1 = [r1_i]$, $i = 0, 1, \dots, k_{r1} - 1$ ($r3 = [r3_j]$, $j = 0, 1, \dots, k_{r3} - 1$ and $r4 = [r4_l]$, $l = 1, 2, \dots, k_{r4} - 1$, respectively)) are timed matrix rules for rewriting subnets that describe the activation of firewall rules (time-out changing of MTD mechanisms, respectively) for which the control place is p_{28} (p_{15} and p_{14} , respectively).

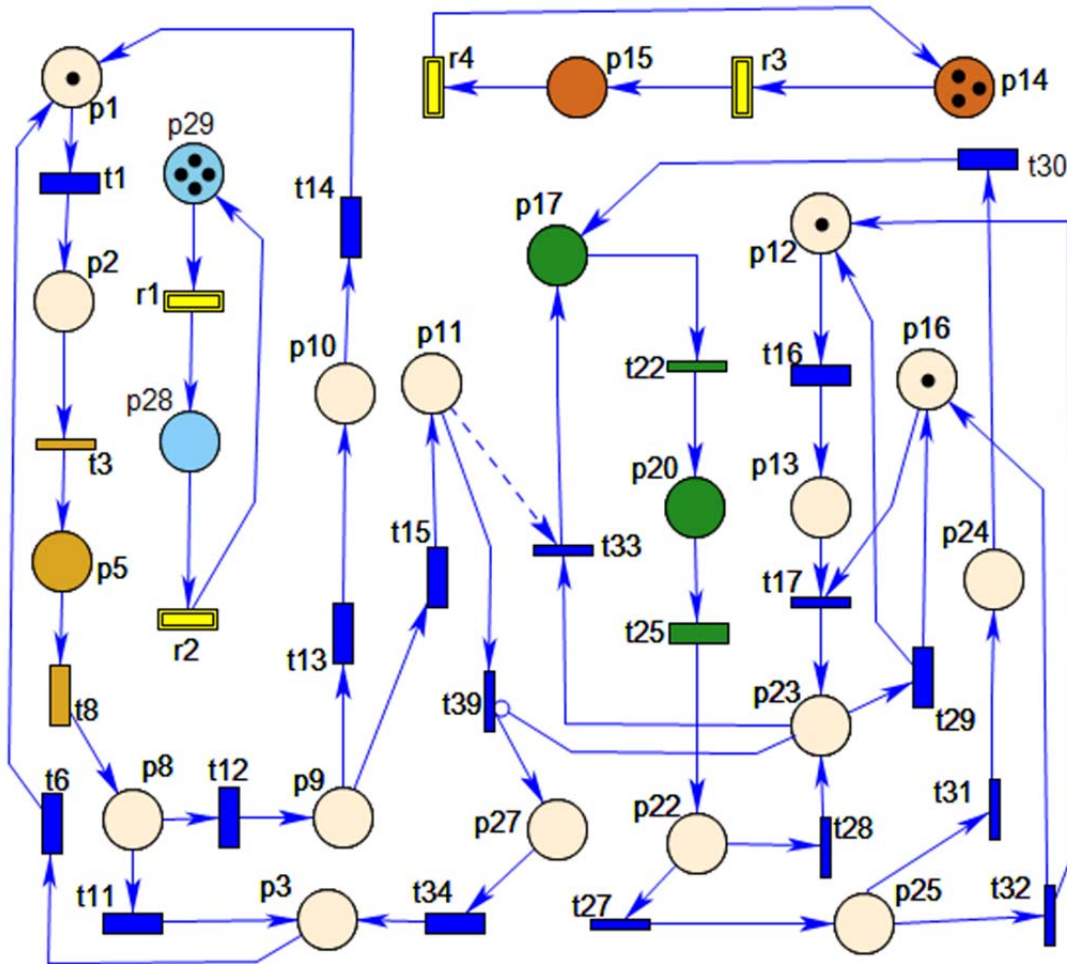


Figure 3. The $MRT1$ model obtained by folding the SRN1 model **RN1**.

$r2$ is a rewriting rule for which its guard function is $g_l^{r2}(m_{28}) = \text{"False"}$ and thus it is enabled and fired as an ordinary timed transition. The selection of a $r1_i$ (respectively $r3_j$ or $r4_l$) is made by the current marking of the place p_{28} (p_{15} and p_{14} , respectively), that $i = m_{28} = M(p_{28})$ ($j = m_{15} = M(p_{15})$ and $l = m_{15} = M(p_{15})$, respectively).

The libraries Lsp^{r1} , Lsp^{r3} and Lsp^{r4} contain subnets FSRN templates of the RN type with respective attributes, associated respectively with $r1$, $r3$ and $r4$ of the $MRT1$ model:

$$Lsp^{r1} = \{RN1_i, RN1_i^*, i = 0, 1, \dots, k_{r1} - 1\}, Lsp^{r3} = \{RN3_j, RN3_j^*, j = 0, 1, \dots, k_{r3} - 1\} \text{ and} \\ Lsp^{r4} = \{RN4_l, RN4_l^*, l = 1, 2, \dots, k_{r4} - 1\}.$$

The guard function of the application $r1_i$ is $g_i^{r1}(M) = \bigvee_{i=0}^{k_{r1}-1} (m_{i+4} = 0)$, and of the application $r3_j$ and $r4_l$ are respectively: $g_j^{r3}(M) = \bigvee_{i=0}^{k_{r3}-1} (m_{j+18} = 0)$ and $g_l^{r4}(M) = \bigvee_{i=0}^{k_{r4}-1} (m_{l+18} = 1)$.

When a rule $r1_i$ or $r3_j$ or $r4_l$ is fired the changing of current structure $MRT\Gamma$ model, with the respective attributes, is performed as follows:

$$r1_i : RN1_i \triangleright RN1_{i+1}^*, \quad r1_v : RN1_v \triangleright RN1_0^*, \quad i = 0, 1, \dots, k_{r1} - 1, v = k_{r1};$$

$$r3_j : RN3_j \triangleright RN3_{j+1}^*, \quad r3_s : RN3_s \triangleright RN3_0^* \quad j = 0, 1, \dots, k_{r3} - 1, s = k_{r3};$$

$$r4_l : RN4_l \triangleright RN4_{l+1}^*, \quad r4_e : RN_e \triangleright RN4_0^* \quad l = 0, 1, \dots, k_{r4} - 1, e = k_{r4},$$

descriptive expressions whose [29] are:

$$\begin{aligned} RN1_i &= |_{t_{i+3}} p_{i+5} |_{t_{i+8}}, \quad RN1_v = |_{t_2} p_4 |_{t_7}, \quad RN1_{i+1}^* = p_2 |_{t_{i+3}} p_{i+5} |_{t_{i+8}} p_8, \quad RN1_v^* = p_2 |_{t_2} p_4 |_{t_7} p_8, \\ i &= 0, 1, \dots, k_{r1} - 1, \quad v = k_{r1} = 3; \quad RN3_j = |_{t_{j+20}} p_{j+18} |_{t_{j+23}} p_{21} |_{t_{26}}, \quad RN3_j^* = p_{17} |_{t_{j+20}} p_{j+18} |_{t_{j+23}} p_{21} |_{t_{26}} p_{23}, \\ RN3_s &= |_{t_{s+20}} p_{s+18} |_{t_{s+23}} p_{22} |_{t_{27}} p_{25} |_{t_{31}} p_{24} |_{t_{30}} \tilde{\vee} p_{22} |_{t_{28}} \tilde{\vee} p_{25} |_{t_{32}}; \\ RN3_s^* &= p_{17} |_{t_{s+20}} p_{s+18} |_{t_{s+23}} p_{22} |_{t_{27}} p_{25} |_{t_{31}} p_{24} |_{t_{30}} p_{17} \tilde{\vee} p_{22} |_{t_{28}} p_{23} \tilde{\vee} p_{25} |_{t_{32}} (p_{12} \diamond p_{16}); \\ RN4_j &= |_{t_{j+20}} 1 p_{j+18} |_{t_{j+23}} p_{21} |_{t_{26}}, \quad RN4_j^* = p_{17} |_{t_{j+20}} p_{j+18} |_{t_{j+23}} p_{21} |_{t_{26}} 1 p_{23}, \\ RN4_s &= |_{t_{s+20}} 1 p_{s+18} |_{t_{s+23}} p_{22} |_{t_{27}} p_{25} |_{t_{31}} p_{24} |_{t_{30}} \tilde{\vee} p_{22} |_{t_{28}} \tilde{\vee} p_{25} |_{t_{32}}; \\ RN4_s^* &= p_{17} |_{t_{s+20}} p_{s+18} |_{t_{s+23}} p_{22} |_{t_{27}} p_{25} |_{t_{31}} p_{24} |_{t_{30}} p_{17} \tilde{\vee} 1 p_{22} |_{t_{28}} p_{23} \tilde{\vee} p_{25} |_{t_{32}} (p_{12} \diamond p_{16}), \\ j &= 0, 1, \dots, k_{r3} - 1, \quad s = k_{r3} = k_{r4} = 2. \end{aligned}$$

The meaning of a descriptive expression (DE) of the structure of a Petri net is [29, 31]: $DE ::= DE_i \otimes DE_j | \circ DE$, where \otimes represents the operator of a *binary compositional operation*, and \circ is the operator of a *unary operation*. By default, when applying these operations, the locations, transitions and rewriting rules that have the same name are merged, respectively. In a DE, any symbol-place, symbol-transition or symbol-rewriting rule can be used in any order multiple times. When one of these symbols is removed, all of its incident arcs will also be removed.

In [29, 31] it is shown how one can perform the mapping of a DE in graphical representation of RP and vice versa, the graphical representation of this RP mapped in DE.

We briefly explain only the significance of the compositional operations used in this work. For more details the reader can consult the works [29, 31]: The *binary Fork operation*, rendered by the operator " \diamond ", describes the fact that at the occurrence of a specified event e_j two or more post-conditions will occur simultaneously. This operation is commutative, associative and reflective; The *Sequential operation*, rendered by the operator " $|_{e_j}$ ", is a binary operation that determines the "cause-consequence" logic of the relationship between two local states p_i (pre-condition) and p_k (post-condition), determined by the event. This operation is associative, reflexive and transitive, but non-commutative;

The operation *Competitive Parallelism*, rendered by the operator " $\tilde{\vee}$ ", describes the logical relations of the competitive parallelism of the conditions and events between two or more competing processes. It is applied to perform the model composition of several sub-modules of the PN subnets, which describe the functioning of the respective subsystems in a resulting model of the considered system.

Let two subnets RN_A and RN_B . They are rendered by the $DE_A = A$ and $DE_B = B$ expressions, respectively then composing them by applying the " $\tilde{\vee}$ " operator, relative to these two DE , we obtain the resultant RN_R net, rendered by $DE_R = C = A \tilde{\vee} B$ where the places and transitions having the same name will be merged respectively. The merged nodes will

retain the attributes and incidence of the arcs in each subnet. This operation is commutative, associative and reflexive.

When evaluating DE, the following priorities for the use of compositional operations will be taken into consideration: a unary operation links more strongly than the binary ones; “ \diamond ” is superior to the operation “ $|_{t_j}$ ”, which, in turn, is superior to the operation “ ∇ ”.

In turn, the $MRT\Gamma$ model can be unfolded in a FSRN1 model with the same attributes and behavioral properties, which allows using some of the specialized PetriNetTool [32] instrumental platforms to simulate and analyze these types of models, for example, VPNP [33], PIPE 4.3 [32].

In the case of a large number of firewall rules and / or MTD techniques, the size of the graphical presentation of a model similar to FSRN1 increases considerably. Thus, we can see the advantage of compact representation of $MRT\Gamma$ type models.

The FSRN1 model, underlying to $MRT\Gamma$, has BLR behavioral properties, so the fuzzy CTMC1 (FCTMC1) describing the functioning of this model is ergodic [18, 23, 24] and it has 211 vanishing markings and 140 tangible markings.

Case Study. Next we will present a case study to show the use of the approach presented in this paper. The numerical analysis of some QoS characteristics of CN security system is based on the FSRN1 model, using the knowledge of the experts in the field [1, 4, 8, 18]. As an example for the fuzzy rates of fired transitions and timed rewriting rules, we establish the following TrNFs values: $\tilde{\lambda}_1 = (0.005, 0.0075, 0.01, 0.0125)$, $\tilde{\lambda}_6 = (0.5, 1.0, 1.5, 2.0)$,

$$\tilde{\lambda}_7 = (2.0, 2.5, 3.0, 3.5),$$

$$\tilde{\lambda}_8 = (1.75, 2.0, 2.25, 3.0), \tilde{\lambda}_1 = (0.005, 0.0075, 0.01, 0.0125), \tilde{\lambda}_6 = (0.5, 1.0, 1.5, 2.0), \tilde{\lambda}_7 = (2.0, 2.5, 3.0, 3.5),$$

$$\tilde{\lambda}_8 = (1.75, 2.0, 2.25, 3.0), \tilde{\lambda}_9 = (2.5, 2.75, 3.25, 3.50), \tilde{\lambda}_{10} = (2.25, 3.0, 3.25, 3.75),$$

$$\tilde{\lambda}_{11} = \tilde{\lambda}_{12} = (1.5, 2.0, 2.25, 2.75), \tilde{\lambda}_{13} = (2.0, 2.5, 3.0, 3.5), \tilde{\lambda}_{14} = (5.0, 5.5, 6.0, 6.5), \tilde{\lambda}_{15} = (2.0, 2.5, 3.0, 3.5),$$

$$\tilde{\lambda}_{16} = (0.5, 1.0, 1.5, 2.0), \lambda_{18} = \lambda_{19} = r3 = r4 = 0.5, \tilde{r}1 = \tilde{r}2 = 2.0,$$

$$\tilde{\lambda}_{23} = (3.5, 4.0, 4.5, 5.0), \tilde{\lambda}_{24} = (4.5, 5.0, 5.5, 6.0), \tilde{\lambda}_{25} = (3.5, 4.0, 4.5, 5.0),$$

$$\tilde{\lambda}_{29} = (3.0, 4.0, 4.25, 4.5), \tilde{\lambda}_{30} = (10, 18, 22, 25), \tilde{\lambda}_{34} = (2.0, 2.75, 3.0, 3.25).$$

Similarly, we determine the weights $w_k = 100$, associated with all the immediate transitions, based on which their firing probabilities q_k are determined [24].

The credible values of the fuzzy firing rates $\tilde{\lambda}_j = (a_j, b_j, c_j, d_j)$ of the timed transitions are calculated according to the expression:

$$\bar{\xi} = E[\xi] = (a_j + b_j + c_j + d_j) / 4 \quad [25].$$

In order to evaluate the QoS characteristics of the CN based on the FSRN1 model, with the credible fuzzy parameters of this case study, the VPNP instrumental software platform was used [33]. For example, the probability that the security system successfully countered the intruder attacks is the probability $\pi_{\text{sec}} = \Pr(M(p_1)=1)$ that FSRN1 is in the state $M_k(p_1)=1$, $M_k \in \text{Acc}(\text{FSRN1})$, where $\text{Acc}(\text{FSRN1})$ is the set of accessible markings of FSRN1 from M_0 . Figure 4 shows the graphs evolution of the state-steady probability $\pi_{\text{sec}} = \Pr(M(p_1)=1)$ and the $\pi_{\text{sva}} = \Pr(M(p_{23})=1)$, respectively that the server processes the user request, function on $\bar{\lambda}_{18} \in [0.5, 1.5]$, $\Delta\bar{\lambda}_{18} = 0.1$ and $\bar{\lambda}_{13} \in [1, 4]$, $\Delta\bar{\lambda}_{13} = 1$.

Thus, each evaluator can build his own type *MRTI* and/or *GSPN1* model, using various combinations of CN security techniques and respective fuzzy parameters to evaluate the specified performance characteristics. In other words, it can assign a weight for each chosen performance feature based on the specified requirements. For each security technique (firewall, honeypot, MTD, etc.), the evaluator can specify the values of each fuzzy parameter and then obtain based on this type of model final results of quantitative values of performance characteristics with different combinations of types of security techniques and their associated weight to perform a comparative analysis of their efficiency.

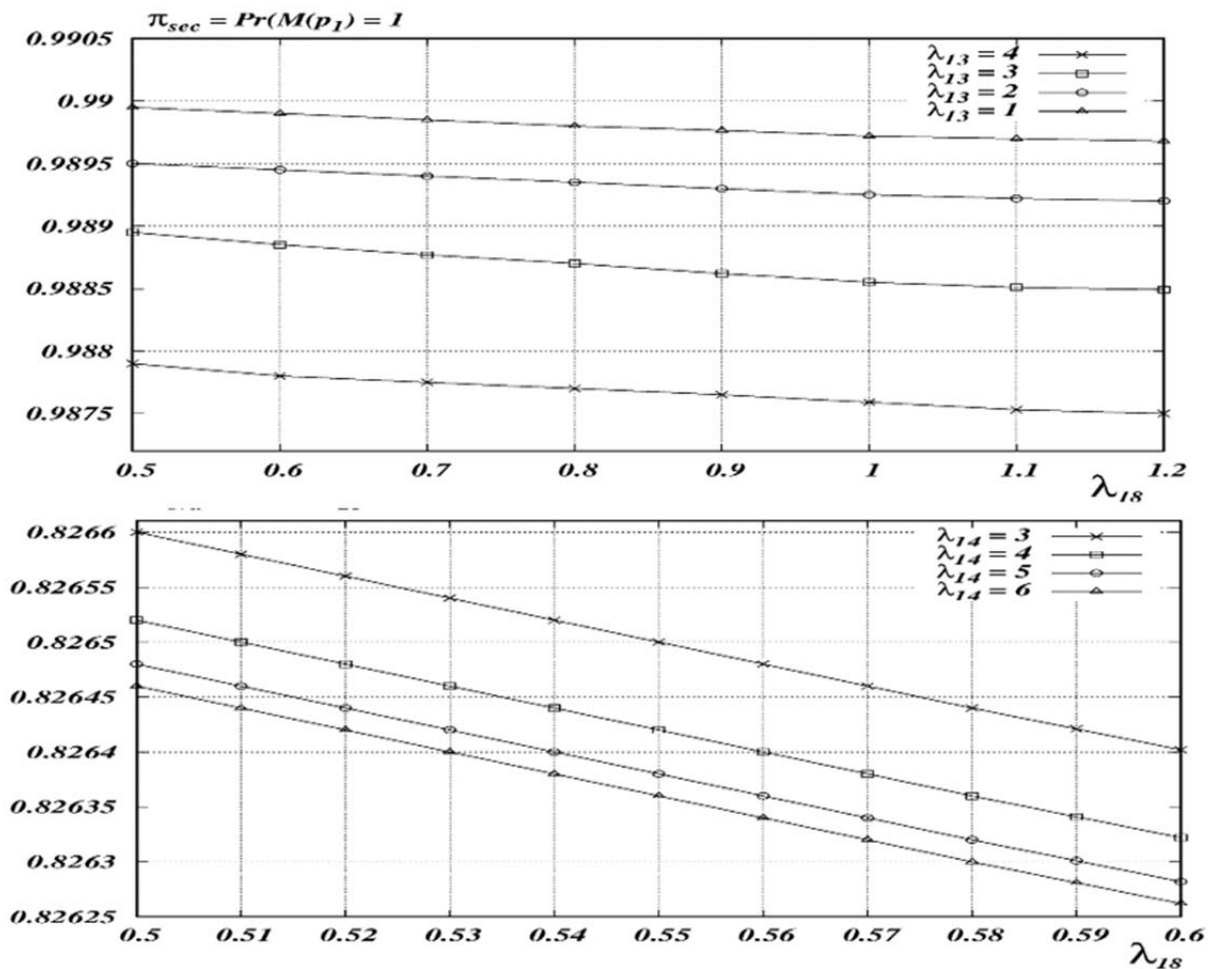


Figure 4. The graphs evolution of the state-steady probability π_{sec} and π_{sva} .

Conclusion

In this paper a new type of reward stochastic network (FSRN) is defined by introducing matrix attributes and dynamically rewriting them and its structure, called MFRSRN, which allows the dynamic reconfiguration, dependent on the current marking, of these types of models. Moreover, this formalism offers a descriptive language that allows the management of the compact representation of the model size by introducing the matrix structuring and rewriting mechanisms of the compositional behavior of the model.

As an example of an application, we show how the proposed formalism can be applied to the performance modeling of a CN “Defense in Breadth” security system, which incorporates a combination of firewall, IDS, honeypot and MTD techniques, taking into account the probabilistic uncertainty issues and the epistemic one.

In the future we intend to carry out the following researches: (1) to validate the proposed model based on different scenarios through a comprehensive analysis taking into account the fact that the timing distributions of the transitions and the timed rewriting rules are random variables with phase distributions [10] (for example, Elang, Cox, Hyperexponential etc.), and their parameters are intuitionistic fuzzy numbers [34]; (2) to integrate in the VPNP tool a software subsystem that will allow to solve by means of the Mehar method [35] the Chapman-Kolmogorov differential equations of the fuzzy CTMC, generated by a model type FGSPN; (3) to elaborate and develop a similar software product VPNP tool for visual simulation and analysis of models of the type that describe the evolution of discrete event systems with reconfigurable matrix applications.

This work was carried out within the national project of applied scientific research 14.820.18.02.03 / U.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Kumar, U. et al. Analysis of Network Security Issue and Its Attack and Defence. [online]. In: *International Journal of Computer Science and Information Technologies*, Vol. 7 (3), 2016, pp. 1029-1031. [accesat 14.03.2019]. available at: <https://www.researchgate.net/publication/301802858>
2. Kashefi, I., Kassiri, M., Shahidinejad, A. A Survey on security issues in firewalls: a new approach for classifying firewall vulnerabilities. [ONLINE]. In: *International Journal Of Engineering Research And Applications*, VOL. 3, ISSUE 2, MARCH -APRIL 2013, PP.585-591. [ACCESS DATE 16.02.2019]. Available at: <https://www.researchgate.net/publication/262116695>
3. Harale, N., Meshram, B.B. *Network Based Intrusion Detection and Prevention Systems: Attack Classification , Methodologies and Tools*. [online]. In: *International Journal of Engineering And Science* Vol.6, Issue 5, 2016, pp. 1-12. [access date 14.03.2019]. available at: <http://www.researchinventy.com/papers/v6i5/A60501012.pdf>
4. Shi, L., Li, Y., Feng, H. *Performance Analysis of Honeypot with Petri Nets*. [online]. In: *Information*, 9, 245, 2018, pp. 2-19. [access date 25.01.2019]. available at: <https://www.mdpi.com/2078-2489/9/10/245>
5. Carvalho, M., Ford, R. Moving-target defenses for computer networks. In: *IEEE Security & Privacy*, 12(2), Mar.-Apr. 2014, pp. 73-76.
6. Cai, G., Wang, B., Hu, W., Wang, T. *Moving target defense: state of the art and characteristics* [online]. *Frontiers of Information Technology & Electronic Engineering*, November 2016, 17(11), pp.1122-1153 [access date 17.01.2019]. available at: <https://link.springer.com/article/10.1631/FITEE.1601321>
7. Zheng, J., Namin A.S. A survey on the moving target defense strategies: An architectural perspective. In: *Journal of Computer Science and Technology*, 34(1), 2019, pp. 207–233.
8. Cho, J.H., Ben-Asher, N. Cyber defense in breadth: Modeling and analysis of integrated defense systems. In: *Journal of Defense Modeling and Simulation: Applications, Methodology, Technology*, Vol. 15(2), 2018, pp. 147–160.
9. Kure, H. I., Islam, S., Razzaque, M. A. *An Integrated Cyber Security Risk Management Approach for a Cyber-Physical System*. [online]. In: *Applied Sciences*. 8, 898, 2018, pp. 1-29. [access date 11.05.2019]. available at: <https://www.mdpi.com/2076-3417/8/6/898/pdf>
10. Trivedi, K. S., Kim, D.S., Roy A., Medhi D. Dependability and security models. In: *Proceedings of 7th International Workshop on the Design of Reliable Communication Networks*, Oct. 2009. pp. 11-20.
11. Cherdantseva, Y. A review of cyber security risk assessment methods for SCADA systems. [online]. In: *Computers & Security*, 56, 2016, pp.1–27. [access date 18.03.2019]. available at: <https://www.sciencedirect.com/science/article/pii/S0167404815001388>
12. Cai G., Wang B., Luo Y., Hu W. A Model for Evaluating and Comparing Moving Target Defense Techniques Based on Generalized Stochastic Petri Net. In: *Wu J., Li L. (eds) Advanced Computer Architecture. ACA 2016. Communications in Computer and Information Science*, vol 626. Springer, Singapore, 2016, pp. 184–197.
13. Connell, W., Menasce, D. A., Albanese M. *Performance Modeling of Moving Target Defenses* [online]. In: *MTD Models and Evaluation, MTD'17*, October 30, 2017, pp. 53-63, Dallas, TX, USA. [access date 16.01.2015]. available at: <https://www.academia.edu/36284557>

14. Ibdunmoye, E. O., Alese, B. K., Ogundele, O.S. A Game-theoretic Scenario for Modeling the Attacker-Defender Interaction. In: J. Comput. Eng. Inf. Technol., Vol. 2, No. 1, 2013, pp. 1-8.
15. Lin, C., Wang, Y. Z., Wang, Y. A Stochastic Game Nets Based Approach for Network Security Analysis. In: *Proceedings of the 29th International Conference on Application and Theory of Petri Nets and other Models of Concurrency, Concurrency Methods: Issues and Applications Workshop*, 2008, pp. 21-33.
16. Li, Y., Sun, J., Cao, Q. *Analysis for Ad Hoc Network Attack-Defense Based on Stochastic Game Model*. [online]. In: *Sensors & Transducers*, Vol. 173, Issue 6, June 2014, pp. 256-262. [access date 14.03.2019]. available at: <https://www.researchgate.net/publication/289241903>
17. Maleki, H. ET.AL. *Markov modeling of moving target defense games* [online]. In: proceedings of the 3rd ACM workshop on moving target defense (MTD 2016). ACM, VIENNA, 2016. AUSTRIA, 81-92. [Access date 21.01.2019]. Available at: <HTTPS://www.researchgate.net/publication/310821430>.
18. Sallhammar, K., Helvik, B. E., Knapskog, S. J. On stochastic modelling for integrated security and dependability evaluation. In: *Journal of Networks*, Vol. 1, Issue 5, 2006, pp. 31 - 42.
19. Shi, L., Li, Y., Feng, H. *Performance Analysis of Honeypot with Petri Nets*. [online]. In: *Information* 9, 245, 2018, pp. 1-19. [access date 11.05.2019]. available at: <https://www.mdpi.com/2078-2489/9/10/245/pdf>
20. Tao, M., Shan, H. An improved method of the attack tree model for mobile Ad Hoc networks. In: *Computer Applications and Software*, Vol. 26, Issue 4, 2009, pp. 271 - 273.
21. Zhang, G. et.al. *Attack Simulation based Software Protection Assessment Method with Petri Net*. [online]. In: *Intl. Journal on Cyber Situational Awareness*, Vol. 1, No. 1, 2016, pp. 152-181. [access date 11.05.2019]. available at: <https://www.c-mric.com/wp-content/uploads/2017/10/article8.pdf>
22. Zhuo, W., Lin, C., Chen, X. Quantitative analysis method of network attack and defense based on stochastic game model. In: *Journal of Computers*, Vol. 9, 2010, pp. 1748 - 1762.
23. Han K, Nguyen T.A, Min D, Choi E.M. An evaluation of availability, reliability and power consumption for a SDN infrastructure using stochastic reward net. In: *Advances in Computer Science and Ubiquitous Computing: CSACUTE 2016*, Singapore: Springer Singapore, 2017, pp. 637-648.
24. Chiola, G., Ajmone- Marsan, M., Balbo, G., Conte, G. Generalized stochastic Petri nets: A definition at the net level and its implications. In: *IEEE Transactions on Software Engineering*, 1993, 19 (2), pp. 89-107.
25. Li, X., Liu, B. Foundation of credibilistic logic. In: *Fuzzy Optimization and Decision Making*, vol. 8, no. 1, 2009, pp. 91-102.
26. Abbasbandy, S., Viranloo, T. *Numerical solution of fuzzy differential equation*. [online]. *Mathematical & Computational Applications*, 7, 2002, pp. 41-52. [access date 11.12.2018]. available at: <http://dx.doi.org/10.3390/mca7010041>
27. Ding, Z., Shen, H. Applying Fuzzy Differential Equations to the Performance Analysis of Service Composition. In: *Advanced Intelligent Computing Theories and Applications, ICIC 2010*, D.-S. Huang et al. (Eds.): LNCS 6215, Springer-Verlag, pp. 2010, pp. 118-125.
28. Tüysüz, F., Kahraman, C. *Modeling a flexible manufacturing cell using stochastic petri nets with fuzzy parameters*. [ONLINE]. IN: *EXPERT SYSTEMS WITH APPLICATIONS* 37, 2010, PP. 3910-3920. [Access date 11.05.2018]. Available at: <HTTPS://www.researchgate.net/publication/287993951>
29. Guțuleac, E. Descriptive compositional HSPN modeling of computer systems. In: *Annals of the Craiova University, România*, 2006, Vol. 3 (30), no. 2, pp. 82-87.
30. Guțuleac, E.; Zaporojan, S.; Gîrleanu, I.; Cărbune, V. Hybrid stochastic Petri nets with matrix attributes for modelling of discrete-continuous process. In: *Meridian Ingineresc*, 2, 2016, pp. 34-40.
31. Guțuleac, E., Mocanu M. L. Descriptive Dynamic Rewriting GSPN-based Performance Modeling of Computer Systems. In: *Proceedings of the 15th International Conference on Control Systems and Computer Science*, 25-27 May 2005, București, România, 2005, pp. 62-66.
32. Petri Nets Tools Database Quick Overview. [online]. [access date 11.01.2019]. available at: <https://www.informatik.uni-hamburg.de/TGI/PetriNets/tools/quick.html>.
33. Guțuleac, E., Boșneaga, C., Reilean A. VPNP-Software tool for modeling and performance evaluation using generalized stochastic Petri nets. In: *Proceedings of 6-th International Conference on D&AS-2002*, Suceava, România, 2002, pp. 243-248.
34. Atanassov, K. T. Intuitionistic fuzzy sets. In: *Fuzzy Sets and Systems*, vol. 20, 1986, pp. 87-96.
35. Lata, S., Kumar, A. *Mehar's method for analyzing the fuzzy reliability of piston manufacturing system*. [Online]. In: *Eksplotacja niezawodność - maintenance and reliability*, 51, NR. 3, 2011, PP. 26-39. [Access Date 11.01.2019]. Available at: <http://www.Ein.Org.PL/Sites/Default/Files/2011-03-04.Pdf>

DOI: 10.5281/zenodo.3444073
CZU 621.865.8:004.896



QUO VADIS ROBOTICS?

Titu-Marius I. Băjenescu, ORCID ID: 0000-0002-9371-6766

Swiss Technology Association, Electronics Group Switzerland
tmbajenescu@gmail.com

Received: July, 21, 2019

Accepted: September, 19, 2019

Abstract. Robotics is an extremely dynamic field with thriving advancement in its technology. The capabilities of trusted robots will grow and evolve over time. Robots will be able to explain what they do and why. This will enable people to better understand what we trust in machines and where and how we can use them, and will lead to a better understanding of the new technology and, in particular, confidence in secure use. It remains in the hands of humans how we want to use these machines and robots. The article explains what a robot is made of, where we stand with robots, robot vehicles, robot intelligence, industrial robots, aspects of legislation, legal consequences, artificial intelligence and robots, deep learning systems, the businessman's problem, and the economic model.

Keywords: *Industrial and agricultural robotics, Defence and security robotics, Service and personal robotics, sensors, software, Turing's test, artificial intelligence, legal aspects.*

Introduction

Robot comes from the Czech *robota*, which means "forced labour". It was first used by the author Karel Čapek in his theatre play R. U. R. (Rossum's Universal Robots) in 1920.

A succinct definition of robotics is given in *The Chamber's Dictionary* [1]: "The branch of technology dealing with the design, construction and use of robots". The full scope of robotics lies at the intersection of mechanics, electronics, signal processing, control engineering, computing and mathematical modelling.

Robotics is a vast and composite technological field. It has been undergoing extraordinary development for several decades; it has revolutionized our industry and is called upon to do the same with our society. Robotics is often presented as one of the main developments in our society for the 21st century.

The robot can be defined as an intelligent, autonomous, mobile and communicating system. Each of these qualifiers induces a set of technological bricks, often of a high level [2].

The robotics sector can be divided into 3 markets very distinct:

- (1) Industrial and agricultural robotics;
- (2) Defence and security robotics;
- (3) Service and personal robotics.

These three markets have reached very high levels of maturity different and are operated by companies with different profiles very far away.

Robots produce cars and other goods, play in films and appear almost daily in the news. Robots and automation form the basis of effective production facilities and thus make a significant contribution to the entire value chain. And yet robots are still subject to a flaw of the opaque, even dangerous or even uncontrollable, whereas in Japan things and machines are animated and cause astonishment as soon as they do something themselves, speak or move [3].

Since the drones (UAVs) are often equipped with autonomous piloting systems and artificial intelligence, they are one of the first examples of these robots from the defence world. Today, they constitute a specific market, initially military and increasingly aimed at civilians. Today there is a wide variety of these devices, ranging from the size of an aircraft to that of insects. Today, drones are able to operate at very high altitudes, as well as at ground level, on the ground or in water. Their applications range from observation in combat, to dropping missions or reconnaissance of dangerous environments (radiation, toxic gases, etc.). UAVs are the first assets to evolve in the public space and enjoying an autonomy (however very limited) to have been the subject of a framework specific legal. Their connectivity, their capacity interaction and, in the long run, their autonomy could lead to their being described as flying robots or robots airborne [4]. Japan, South Korea and the United States are major players in robotics. Japan and South Korea lead in technology for robot mobility, humanoid robots, and some aspects of service and personal robots including entertainment. Japan has the largest population of humanoid systems. The only question is: when will these future humanoids become viable. There is a second reason for the inevitability of humanoids: they encompass a large set of robotics domains. The United States leads in such areas as robot navigation in outdoor environments, robot architectures, and in applications to space, defence, underwater systems, and some aspects of service and personal robots. Europe leads in mobility for structured environments, including urban transportation. Europe also has significant programs in eldercare and home service robotics.

What is a robot made of?

The robot is equipped with sensors that collect information in its environment: cameras filming people, roads, landscapes; microphones that capture voices and perceive noises; lasers that measure the distance at which possible obstacles are located. Unlike data that an Internet search engine retrieves from computer files, data extracted from the real world are "noisy". This term, which is well understood for an acoustic signal, actually applies to all sensor signals. Just as a voice recorded in the street may be covered by the sound of cars passing by, the wind blowing or the barking of dogs, an image taken by a robot's camera in a daily environment may be "noisy" by a back-light, a shadow cast on a face, a blurred motion. Before starting to analyze the information it has retrieved, the robot must clean it up to extract what will be useful for its reasoning.

Where are we with the robots?

With the advent of electronics, robots - as we see them today - are really making their appearance. Thanks to it, then to computer technology, it is possible to "intelligently" move a mechanism. Joseph Engelberger¹, the father of robotics, said: "I don't know what a

¹ American engineer (July 26, 1925 - December 1, 2015); in 1956, he met George Devol, who had designed and patented the ancestor of the industrial robot; together they founded Unimation, the first robotics company, which produced the Unimate robot, the first of which was installed in 1961 in a General Motors plant. Soon, Chrysler and Ford also equipped themselves with Unimates robots. In 1982, Engelberger sold Unimation to Westinghouse for \$107 million and focused on

robot is, but I recognize one when I see it." To go beyond this joke, it is possible to consider that a robot is a mechanism whose movements take into account information from sensors. This mechanism can include wheels, tracks, legs, arms and even hands. Its motors can be electric, pneumatic, hydraulic, and piezoelectric. However, to be more than an automaton, the robot must also be equipped with sensors that provide it with information not only about its own state (the position of its joints, its inclination) but also about that of the world around it (cameras, microphones, rangefinders). Finally, it must have a computer that determines the movement of each joint.

In addition to these robots, there are also robots that are not (software used by search engines that explore in the same way as robots sent to distant planets); they explore the web to record information collected on the sites they visit. This review is carried out automatically: the programs define rules that allow these programs to locate words, sentences, expressions and carefully arrange them by noting the address at which they were found. Engelberger does not recognize them as robots since they do not have a physical incarnation. This is why these purely computer-based robots are sometimes called "bots" to distinguish them from "real" robots, characterized by their physical presence in a world of digital intelligence.

Robots are everywhere: in factories and fields, at the bottom of the sea and in space, in gardens and living rooms. They are of growing economic importance, and some predict that they will be in the 21st century what the car was in the 20th century. In addition, they have not only penetrated the industrial world, they are also penetrating our daily lives and culture, and some of them are participating nowadays to the renewal of the vision we have of ourselves (see Figure 1).

While classical and industrial robotics was articulated around the three D's, "dull, dirty, and dumb" characterizing boring work and dirty for which robots had to replace men, a new robotics system is developing around the three E's, "education, entertainment, every day" in which robots are present to accompany us on a daily basis to help us, to stimulate us, and have fun. That's why we're talking about company robotics and of personal robotics.

When you look at it carefully, the robot combines, in the same object, four main faculties: versatility, interaction capacity, decision-making autonomy, and learning ability. Each of them can be found individually in other objects [5]. But their combination makes the robot unique and justifies society's questions about the consequences of its arrival in our daily lives.

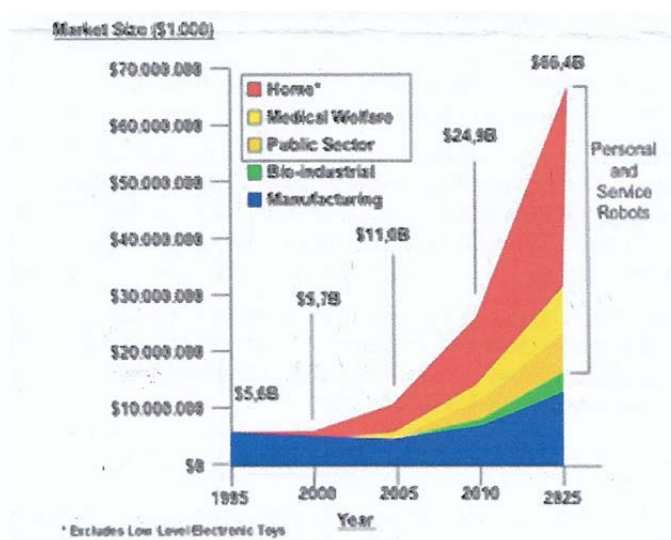


Figure 1. Projection of the evolution of the robotics market

(source: Japan Robotics Association).

mobile robotics. In 1984 he founded the Transistion Research Corporation where he created HelpMate - a mobile wheeled robot for the distribution of drugs in hospitals. In ten years, about a hundred hospitals bought the robots from his company, which he renamed HelpMate Robotics Inc. At the age of 80, he left his company but remained an ardent defender of the robotics cause, particularly for the assistance of the elderly.

Robot vehicles

The most distinctive characteristic of the last century or so might seem to be the enormous amount of change that has occurred. Dozens, if not hundreds, of advances are said to have revolutionized our lives. The list includes automobiles, air travel, television, the personal computer, the Internet, and cell phones. Change is everywhere. We have harnessed the atom, flown into space, invented antibiotics, eliminated smallpox, and sequenced the genome.

Soon our cars will be robots. Already, like planes controlled by automatic pilots, driverless buses are appearing in some cities in Europe and Asia on circuits reserved for them. Autonomous baggage and equipment transport cars are also present in airports. How can an automated car detect, perceive, understand and anticipate human behaviour on the roadside? Interactions between cars (semi-automated) and those that are fully controlled by a human being are also problematic.

Would it be worth it if the roads were systematically "increased" for automated cars? How to operate the transition, i.e. to be able to continue to integrate cars" in an environment designed for smart cars? Localisation is a fundamental aspect of any autonomous mobile robot. Without an accurate estimate of where it is, a robot cannot successfully navigate in its environment and is thus by definition not mobile, at least not in any controlled sense [6].

Given the progress of satellite wave location/wifi/gprs, advances in satellite imagery, and the development of connections high bandwidth mobile internet, one could imagine by these means of providing each car with the information it has without resorting to physical transformations of our networks truck drivers?

The intelligence of robots

The classic experiment proposed for determining whether a machine possesses intelligence on a human level is known as *Turing's test*² (Figure 2). This experiment has yet to be performed seriously, since no machine yet displays enough intelligent behaviour to be able to do well in the test.

Turing's test consists of presenting a human being, *A*, with a typewriter-like or TV-like terminal, which he can use to converse with two unknown (to him) sources, *B* and *C* (see Figure 2). The interrogator *A* is told that one terminal is controlled by a machine and that the other terminal is controlled by a human being whom *A* has never met. *A* is to guess which of *B* and *C* is the machine and which is the person. If *A* cannot distinguish one from the other with significantly better than 50% accuracy, and if this result continues to hold no matter what people are involved in the experiment, the machine is said to *simulate* human intelligence.

Alan Turing, proposed a test called "The Imitation Game" (1951) that might finally settle the issue of machine intelligence [7]. Robots are often referred to as autonomous: it is the ability of a machine to modify its movements on its own according to the data transmitted by its sensors that makes it a robot.

So much so that, formally, the remotely operated robots used by deminers to inspect a trapped package usurp the name of robot. They are only a few sophisticated remote-controlled cars, which have robots only in appearance.

² After A. M. Turing, who pioneered research in computer logic, undecidability theory, and artificial intelligence

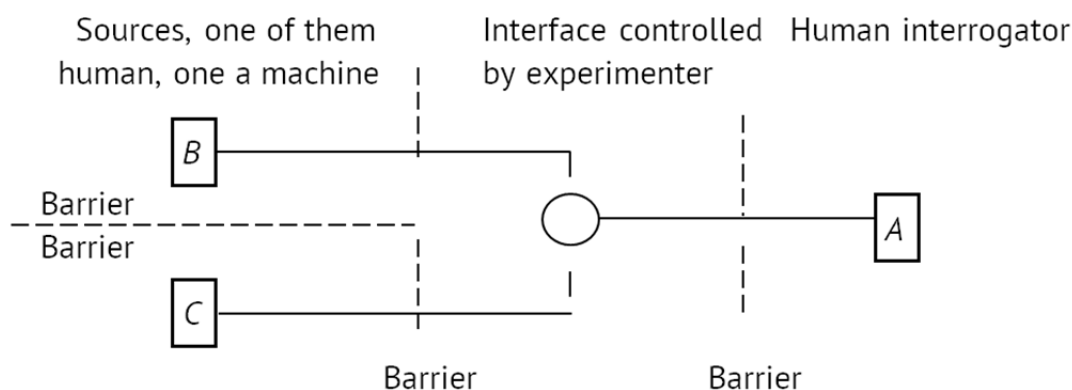


Figure 2. A diagram of Turing's test.

However, even these remote-controlled machines can have some autonomy: some automatically stop in front of a hole or obstacle that the pilot did not see; others are able to automatically retrace their steps when they have lost the radio link to their control station. Still others, such as space exploration robots sent to Mars, are more independent: engineers assign them, from Earth, a territory to explore and they perform, defining their trajectory, avoiding obstacles, managing the energy of their battery. The robot performs its task without continuous control of a pilot. He is therefore autonomous but this does not mean that he is "without a master" for all that.

Industrial robots (IR)

In the last decade the industrial robot (IR) has developed from concept to reality [8], and robots are now used in factories throughout the world. In lay terms, the industrial robot would be called a mechanical arm. This definition, however, includes almost all factory automation devices that have a moving lever. The *Robot Institute of America* (RIA) has adopted the following working definition: A robot is a programmable multifunction device designed to move material, parts, tools, or specialized devices through variable programmed motions for the performance of a variety of tasks. It is generally agreed that the three main components of an industrial robot are the mechanical manipulator, the actuation mechanism, and the controller.

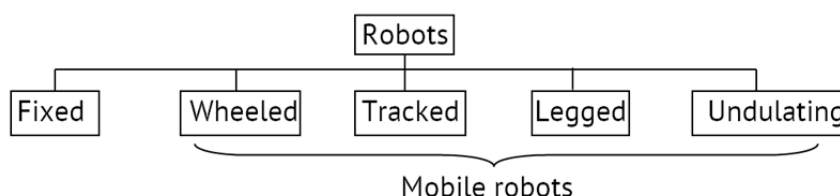


Figure 3. The robots family.

As it can be seen from the figure 3, robots cover a wide variety of types and a unified approach to robotics focusing on the two leading classes of robots, the fixed and the wheeled types. The full scope of robotics lies at the intersection of mechanics, electronics, signal processing, control engineering, computing and mathematical modelling, and the fundamental aspects concern modelling, planning and control.

The largest class of robots exists today is that of the fixed robot which does repetitive but often precise mechanical and physical tasks. These robots pervade many areas of modern industrial automation and are mainly concerned with tasks performed in a

structured environment. It seems highly likely that as the technology develops, the number of mobile robots will significantly increase and become far more visible as more applications and tasks in an unstructured environment are serviced by robotic technology. However, industrial robots still do not have the sensing, control, and decision-making capabilities that are required to operate in unstructured, 3D environments.

Legislation aspects [9-11]

Yesterday the drones, today the autonomous vehicles..... All of them, because of their particularities and the uses envisaged, have pushed our legal system to adapt. But should a new standard be adopted for each new robotic product, at the risk of quickly making our legislation look like a patchwork of technical regulations? Would it not be appropriate to embrace robotics as a whole and propose a global approach in order to avoid putting the work back on the legislative profession each time a new robot appears?

This leaves the liability regime for things. It applies only in a residual manner in relation to the product liability regime defective, already mentioned. Schematically, in this system, if damage is caused, the person responsible is the guardian of the robot. The responsibility of the producer can be brought into play every time that there is a manufacturing defect, for example. The owner, in the event that it is different from the guardian, may be held liable if he has not properly maintained the robot, if it has not made the necessary updates or, why not, if the learning provided to the robot is at the origin of the damage.

Legal consequences [12]

The robot's extraordinary ability to adapt over the course of its experience will not be without legal consequences: the multiplication of interactions proportionally increasing the risks of potential damage. This raises the question of liability. Should the producer's use of the robot evolve, knowing that it is almost unpredictable, almost unlimited? If a robot is able to perform any task at the request of its owner, should the owner himself have the knowledge and skills to supervise the requested task? Should certain functions or actions be prohibited, supervised? Should a "user license" be introduced for certain robot models or for the use of certain features? If so, this probably justifies legal reflection and the eventual adoption of certain rules. What are the existing possibilities? What legal system could capture the unique nature of robots? But legal issues also raise ethical and social questions about the appropriateness of entrusting machines with increasingly sophisticated tasks that have hitherto only been possible by human beings. In complex situations, how can the robot have a notion of good and evil, in order to evaluate the actions it is asked to perform?

Artificial intelligence and robots [13-15]

In the 1980s, research in artificial intelligence aimed to enable computers to recognize elements in an image (for example, a red ball), or even to have certain human reasoning skills, by implementing a system of rules. We imagined then that it would be possible for them to formulate a diagnosis, like doctors do: "if the patient coughs, if he has a runny nose and no fever, then he has a cold"; "if he is tired and if he has a fever, then he has the flu"... The great advance of the time was that the computer no longer dealt only with numerical values but also abstract ones: "have a fever", "be tired"... A first level of rules allowed the passage from the first to the second: "if the temperature is higher than

38°C, then the patient has a fever.” However, what should be considered when assessing patient fatigue? Of course, the computer can ask the patient if he is tired, as a doctor would do; but the answer can be very subjective. The doctor will rely on the patient's general attitude, his way of responding, the energy with which he gets up and sits down to form his own opinion. This is where true intelligence comes into play: how to extract meaningful information from a set of signals that are difficult to measure explicitly? Applying rules once you have the right information is not the most complicated. It is the very retrieval of relevant information that is often the main obstacle to truly intelligent thinking.

Not only are robotics and AI changing the world of work and education, they are also capable of providing new insights into the nature of human activity as well. The challenges related to understanding how AI and robotics can be integrated successfully into our society have raised several profound questions, ranging from the practical (*Will robots replace humans in the workplace? Could inhaling nanoparticles cause humans to become sick?*) to the profound (*What would it take to make a machine capable of human reasoning? Will “grey goo” destroy mankind?*).

Thanks to planning algorithms, he is able to analyze every conceivable move to the end of all possible parties. All he has to do is choose those who take him to victory. Is it really true-proof of intelligence?

The experts on various topics make predictions about the future that are not just a little different, but that are dramatically different and diametrically opposed to each other. So, why do Elon Musk, Stephen Hawking, and Bill Gates fear artificial intelligence (AI) and express concern that it may be a threat to humanity's survival in the near future? Each group's members are as confident in their position as they are scornful of the other side. With respect to robots and automation, the situation is the same. The experts couldn't be further apart. Some say that all jobs will be lost to automation, or at the very least that we are about to enter a permanent Great Depression in which one part of the workforce will be unable to compete with robotic labour while the other part will live lavish lives of plenty with their high-tech futuristic jobs. Others roll their eyes at these concerns and point to automation's long track record of raising workers' productivity and wages, and speculate that a bigger problem will be a shortage of human labourers [1].

Inspired by how the brain works and how babies become aware of their environment, computer scientists have sought to reproduce the activity of a neural network. The systems model the interpretation of a sensor signal and the corresponding decision making using a combination of very simple operations. The neurons are spread over different layers. Each neuron in the first layer picks up part of the signal, transforms it and transmits the result to the neurons in the second layer. Each of them retrieves the results of several neurons from the first layer, combines them through a simple operation and transmits unique information to the neurons of the third layer, etc. Such a system can identify a sound, for example. The sound signal is transmitted to the neurons of the first layer... and on the last layer, one neuron is activated if the initial sound is a telephone ringing tone, another one if it is a fire alarm, yet another one for an applause... When the network has just been created, the operations performed by each layer are arbitrary and the output neurons are therefore activated in a completely random way. Training is necessary to ensure that the operations of each neuron and the connections between the different levels lead to the expected outputs. This adaptation of neural connections through learning is a bit like what happens in the brains of babies who discover the world around them. This has helped to give the

artificial intelligence modelled by these neural networks a less artificial dimension and, at the same time, probably a little more worrying. It would be legitimate to ask the following question: "Now that computers have neurons like our brains, what's stopping them to be as smart as we are?"

A legal personality can no longer be granted to the robot as a whole, but to its artificial intelligence (AI). This presupposes that the AI can migrate from one robotic "body" to another. Some companies are working on the development of operating systems where artificial intelligence could be adapted to many robots. The physical part would only be a vehicle, a container, intended to receive - for a given time - a logical system.

The legal personality would be linked to this AI, and no longer to the body of the robot. This approach would make it possible to understand the case of the announced development of vocal assistants but also that of "robot swarms", these sets of machines acting and reacting together in order to achieve the same objective, and driven by a single artificial intelligence. It would seem justified here to recognize the legal personality not to each mechatronic object but to the AI that binds them. To legally distinguish the physical and logical aspect of the robot would also offer another advantage in terms of liability, as each party could be subject to a different regime.

Since, on the one hand, AI is at the origin of the robot's decision-making autonomy, versatility and some of its interaction capabilities and, on the other hand, the user can be involved in its learning, a differentiated approach could be appropriate. The producer responsible for the physical appearance and mechatronics of the robot would remain liable in the event of a defect related, for example, to the manufacture of a sensor, a battery, etc. The role of the robot user appears obvious and does not require any further development: he must be responsible for the orders given to the robot but also for the knowledge bricks he has been able to teach him and which could be at the origin of certain comments or actions. However, things are more complex with regard to AI, which is not currently specifically regulated by law. Everything is to be built.

Deep learning systems [16]

This new technology is now giving quite fascinating results. For example, in the case of image processing, neurons will be responsible for finding characteristic patterns in the images submitted to them. But we no longer tell them what these patterns are that they should look for (we don't say, as in the approaches mentioned above, that we should identify eyes, edges, points of interest characterized by shapes or changes in colour in a packet of pixels). The system simply has to identify repeating pixel patterns. The software identifies combinations of pixels on an image fragment and then searches them in the millions of visuals at its disposal to learn. After this first pass, he chooses the 100 most frequent combinations. Of course, he finds edges (which delimit two surfaces of different colours), patterns that resemble the points of interest of classical methods and other combinations. Then, he looks at how these first-level patterns most often aggregate to form pattern patterns. To do this, a new pass is made through the database to identify, say, the 100 most common patterns of patterns. And so on: we find a third level of patterns, then a fourth...

While the first neural networks had only three or four layers, advances in computing have made it possible to increase the number of neural networks and to obtain so-called *deep learning*³ systems.

Just as a baby discovers that the red ball in front of his eyes moves when his hand touches it, artificial intelligence will learn to evaluate the consequences of the movements of the motors it controls, so that it can then trigger the right actions and achieve the desired objectives. If a baby finally gets there, why wouldn't a robot with the same learning mechanisms do it? This is one of the fundamental questions that concerns roboticists, but also neurologists and physiologists: if the robot has the same "mechanisms" of perception, decision and action as a human being, will we obtain an equally effective being (we avoid the word "intelligent" on purpose)? And if not, will it be because robotics has not succeeded in reproducing these mechanisms accurately enough? Or because the scientists who study man have not yet grasped the full subtlety of his functioning? Is there a transcendental ingredient in man that physiology cannot identify? Physiologists and roboticists have come together in recent years to try to answer these questions.

Finally, we would like to mention the widespread idea that robots will never be as intelligent as humans because they cannot perceive and express emotions. By this we mean that they will always lack an emotional dimension, and that true intelligence is not that of calculation but that of the heart. Different techniques, such as neurolinguistic programming for example, have proposed to model all this and, with a fairly efficient ability to perceive, the robot that uses them will be able to almost read the emotions of its interlocutor in an open book. They will be added to the programs that, from today, are able to detect joy, sadness, anger, even sarcasm, in the speaker's voice. The perception of emotions is therefore not what will long differentiate man from the robot. As the robot has no personal emotion, it is even easier for him to express the emotion that his interlocutor expects. The main advantage of emotion recognition is that it allows the robot to adapt to the user's state of mind. The more robots identify emotions and respond to them in a relevant way, the more fluid they will interact, and the more accepted they will be in our daily lives.

The businessman's problem

"How am I going to succeed in making and selling this item without losing of money?" [3]. For now, the price of a robot enough evolved to be placed in a family is still too high, especially when compared to the services it can actually provide. Before to consider a generalized marketing to the general public, it is necessary to reduce the design and manufacturing costs and, most importantly, to increase the services provided. When the balance between the two will be reached, our businessman can hope to get an answer.

However, what makes the value of the robot is not only its manufacturing cost but also the service it provides and to whom it is provided. A robot may be sold with a service and it is the price of this service over time that will make it possible to support a possible selling price of the robot deliberately lower than its material value. Insurance companies, who would like robots to be able to look after their insureds that are losing their autonomy,

³ The beauty of the deep learning lies in the fact that artificial intelligence understands by itself what it takes and how to find it, such as a child who would discover the world. We don't teach him how to recognize a cat; we tell him that this being he sees regularly is called a cat. Of the same way, it is necessary to indicate to the artificial intelligence that this bundle of pixels that it locates in a large number of pixels of photos is a cat, so that she can then to propose us pictures of cats when we propose it to him request, or that the robot is able to identify it one in front of his cameras and to act accordingly.

are willing to imagine this kind of business model [16-18]. An individual could thus subscribe to a warranty contract that would ensure access to a quick repair service and software updates. This contract, over time, would allow the robot vendor to offer lower purchase prices.

Economic model

Consumer society has already shown extraordinary inventiveness in ensuring that everyone can access new technologies at a cost they consider reasonable. The business models used are not new. The robot seller will be able to invent new ones. But the robot buyer, who has learned from his experiences, may well be more demanding and more attentive to the consequences of the economic model he will subscribe to at the time of purchase. After all, the field has potential to bring great economic impact.

Conclusions

AI's motivation for dealing with robotics is clear: it provides a useful test bed for computational models of agents that include perception, reasoning, and action, as robots allow them to be examined in full integration. This is similar to AI's long-term perspective for robotics: to develop methods and tools that will contribute to closed-loop controllers for smart autonomous robots.

It is clear that technology is progressing towards the construction of intelligent sensors, actuators, and systems on small scales. These will serve as both the tools to be used for fabricating future micro/nanorobots as well as the components from which these robots may be developed. Shrinking device size to these dimensions presents many fascinating opportunities such as manipulating nano-objects with nanotools, measuring mass in femtogram ranges, sensing forces at piconewton scales, and inducing GHz motion, among other new possibilities waiting to be discovered. The 21st century will see humanoids leave the pages of fiction and step, roll or run into our world. The current generation of robots is only able to operate in two-dimensional, even, indoor environments. However, we still lack the fundamental theory and algorithms for manipulation in unstructured environments and industrial robots currently lack dexterity in their end effectors and hands.

References

1. Brooks, Ian, The Chambers Dictionary, 1825 pages, Available at: www.chambers.co.uk, 2003.
2. Rees, B., The Fourth Age. Atria Books, New York, 2018.
3. Gelin, R., Guilhem, O., Le robot est-il l'avenir de l'homme? La documentation française, Paris, 2016.
4. Gonzales, C., The Future of Collaborative Robots, Available at: www.machinedesign.com.
5. Wulfmaier, M., Efficient Supervision for Robot Learning via Imitation, Simulation and Adaptation. Ph. D. Dissertation, University of Oxford, 2018.
6. Maddern, Will, et al., Illumination Invariant Imaging: Applications in robust Vision-based Localisation, Mapping and Classification for Autonomous Vehicles. In Proceedings of the Visual Place Recognition in Changing Environments Workshop, IEEE International Conference on Robotics and Automation (ICRA), Hong Kong, China, volume 2, page 3, 2014.
7. Alan Turing and the Imitation Game. Available at: <http://www.psych.utoronto.ca/users/reingold/courses/ai/turing.html>.
8. What are Industrial Robots ? Available at: <https://niryo.com/2016/11/what-are-industrial-robots/>.
9. European Civil Law Rules in Robotics. Available at: [http://www.europarl.europa.eu/RegData/etudes/STUD/2016/571379/IPOL_STU\(2016\)571379_EN.pdf](http://www.europarl.europa.eu/RegData/etudes/STUD/2016/571379/IPOL_STU(2016)571379_EN.pdf)
10. Delvaux, Mady. Draft Report with recommendations to the Commission on Civil Law Rules on Robotics, Mai 2016. Available at: <http://bit.ly/285CBjM>.

11. Kritikos, Mihalios. Legal and ethical reflections concerning robotics. STOA Policy Briefing. June 2016. Available at: <http://bit.ly/2m3zQ2R>
12. Holder C., et al., Robotics and Law: Key Legal and Regulatory Implications of the Robotics Age, Computer Law & Security Review. Volume 32, Issue 3, June 2016, pp. 383-402.
13. Bekey George, et al., Robotics – State of the Art and Future Challenges, World Scientific, Singapore, 2008.
14. Artificial Intelligence, Robotics, Privacy and Data Protection, Room document for the 38th International Conference of Data Protection and Privacy Commissioners, October 2016. Available at: <http://bit.ly/2eB8Xkx>
15. Preparing for the Future of Artificial Intelligence. Executive Office of the President, National Science and Technology Council Committee on Technology. October 2016. Available at: <http://bit.ly/2j3XA4k>
16. LeCun Yann, et al., Deep Learning. Available at: https://creativecoding.soe.ucsc.edu/courses/cs523/slides/week3/DeepLearning_LeCun.pdf.
17. Latombe, J. C. Robot Motion Planning, Kluwer, Boston, 1991.
18. Schwartz, J. T., Sharir, M., A survey of motion planning and related geometric algorithms, Artif. Intell. J. 37, 157–169, 1988.

DOI: 10.5281/zenodo.3444085

CZU 624.04:69.058.8



MANAGEMENT OF INVESTIGATING THE EFFECT OF BLASTING AND IMPACT LOAD IN VARIOUS STRUCTURES

Mohammad Beykzade^{1*}, ORCID ID: 0000-0002-5394-2363Sepide Beykzade², ORCID ID: 0000-0003-1428-7287¹Department of Civil Engineering, Faculty of Civil Engineering, Kharazmi University, Tehran, Iran²Department of Management, Faculty of Management, Azad Islamic University Branch Karaj

*Corresponding author: Mohammad Beykzade, M.Beykzade@gmail.com

Received: July, 3, 2019

Accepted: September, 22, 2019

Abstract. Increasing the number of explosive threats on the structures is a warning in the direction of safety. The design of structures against the blast loads in the past has been limited to military buildings and so on. Now, with the spread of science and threats against bridges, buildings and industrial structures will require a detailed examination of the performance of these structures against the blast load. In this study, the performance of structures against explosions, the damage to the structure and the important factors in the failure of the structure were investigated and the results show that the location of the structure of the explosive factor ratio has a significant effect on stability.

Keywords: *Blast Loads, Concrete Buildings, Underground Structures, Structural Analysis.*

Introduction

Determining the effect and amount of damage caused by various phenomena on the structure is one of the most important human goals to prevent damage and in case of necessity, it should be prevented by considering appropriate solutions. One of the patterns of damage to the structure is the impact of blast loads on it.

The study of bomb blasts in general can be classified into the following fields. Parametric research, investigating the dynamic characteristics of the soil, investigating the effects of the input driver's amplitude on response, investigating the types of defensive structures, the investigation of surface explosions, the explosion inside the soil, and the explosion inside the underground table, all of the types of research in the field of explosion.

Surface structures are more vulnerable to dynamic structures compared with underground structures. So, the structures and underground corridors have a significant role in protecting the defense installations of countries. Since many strategic structures are built underground, the behavior of these structures is to be investigated in the face of such shocks.

As a result of the war, there is a heavy human and physical damage to the bombing of cities, which reduces vulnerabilities by employing non-operating defensive methods before the war. Failure to take non-operating defenses will cause heavy costs and irreparable damage. Hence, many researchers have tried to reduce the damage caused by

the explosion by providing solutions for construction. In order to achieve this goal, the structures can be designed and executed according to the dynamic forces due to the explosion with the required strength and stiffness. Also, it is possible to prevent the part of the explosion energy from reaching the structure by appropriate methods and elements. The study of the effect of aerial bomb on underground structures is an applied research in the field of non-operating defense, which results from dynamic analysis has an important and effective effect in this area [1].

The importance of building corridors in ancient times to this day is such that experts have considered the construction of corridors in those civilizations as an indication of the growth of culture and the technical and economic progress of that community. The early civilizations discovered the corridors for access to minerals and natural materials such as flint and its significance for life. It was also used to transport water from the corridors. Military usage has been used in the early civilizations, in particular to raise the escape power or ways to attack the sites and forts of the enemy. Underground structures and facilities form the basis of a new urban settlement and include a large number of applications such as underground railways and intercity railways, highways, fuel storage facilities, depots, stockpiles of weapons [2].

Some installations have been built in places where there is a strong seismic event, [3] Therefore, these structures must be resistant to static and dynamic load. Experimentally, underground structures face significant risks of explosion threats [4].

The first studies on the seismic behavior of underground structures were carried out to analyze the dynamics of the ammunition depot in the 19th century. The response of the soil to seismic energy is scattered in the form of waves. These waves make a strain in dealing with the underground structures in them. These waves are four types, which cutting wave has the highest impact on the structure. These waves change the sinusoidal position along the perpendicular to the axis of distribution of the waves in the ground. To model the behavior of structures and concrete bridges, including the deck and column against the explosion load, a damaged model was applied to the materials and showed that the structural response to the explosive loads has reliable results [5-7].

Traditional methods of strengthening structures against explosions are usually carried out in state and military structures. But recently engineers have become more and more interested in the massive design of the structures against improvised explosive loads to counter anti - terrorism targets. Meanwhile, bridges are a major component of transport infrastructure because of special circumstances and damage to them has a significant impact on the economy. The strengthening of the bridge in front of the blast requires special arrangements. Therefore, it is very important to obtain bridges responses to blast loads.

The necessity of research

Over the past decades, there has been considerable emphasis on explosion and earthquake issues. The problems associated with the quake are more aging, but the majority of the data collected in this area have been over the past 50 years. The blast issues are roughly new and due to different events or intentional events, the behavior of structural members under the blast load has been the subject of many research projects in recent years. Common structures, especially those built on the ground, are not usually designed to withstand explosion forces. Since the magnitude of the design force is considerably less

than the strength of the blast, the usual structures are exposed to damage caused by the blast. Considering this, researchers are increasingly looking for a solution to protect residents and construction structures. Therefore, one of the basic steps to maintain national capital and reduce risk is to study and understand the behavior of buildings under the influence of impact and explosion loads.

A review of past research

The analysis of the effect of loading the bombardment on the structure began in the 1960s. In 1959, the US Army published a publication entitled "Resistant structures against the effects of accidental explosions." The edited version of the publication, which was used in 1990, was widely used by military and non - military organizations to design structures in order to prevent the spread of explosions and protect the equipment and military personnel. Existing methods for estimating the effects of blast on construction structures are divided into different categories that are discussed below [1].

In order to determine the dynamic response of different hardening plates and to consider the effects of Mesh density sensitivity, duration of the explosion and strain rate, the hardened plates were studied under the influence of blast loads. They used the finite element method and central difference method to analyze the structures investigated [8].

In 2006, research by Pandey et al about the effect of an external explosion on a concrete crust of a structure was studied. The analysis was carried out using non - linear models to the final stages, the analysis method presented to analyze the shell structures with regard to the above models led to the production of a finite element software called DYNAIB [9].

Remennikov considered methods for estimating the effect of a bomb on the building. Simplified analytical techniques were used to determine the conservative estimates of the effects of explosion on buildings [10].

Shope studied the response of wingspan steel columns under the influence of constant axial loads and the lateral bursts of explosions. The ABAQUS Limited Components Program was used to model columns with varying weight ratios and different boundary conditions. Changes in the history of displacement and plastic hinge formation due to axial load differences were tested.[11]

Borvik et al studied the response of a steel tank as a closed structure under the influence of explosive loads. They used decreasing methods based on the Lagrange formula to reduce the number of meshes [12].

Yalciner In his research analyzed the design and analysis of structures under the influence of blast loads to understand the burst loading and the dynamic response of various structural components [13].

Explosion

The explosion is a phenomenon that has a great deal of function today and is widely used in civil projects. In addition to the benefits that this phenomenon has, it also has deficiencies and failure, which sometimes challenges its selection as an applied methodology. The shortcomings of this method can be called noise pollution and pollution in the environment surrounding the explosion. Nowadays, the explosion is known as a threat to humanity, researchers seek to achieve and develop methods to face this phenomenon. In recent years, the design of structures based on the principles of non-operating defense is such as to make the structure safer for rocket attacks, and this design

has been highly regarded by engineers. Hence, the behavior of structures constructed inside the earth is under investigation.

Explosion wave

The explosion is equivalent to a very rapid release of energy in light, heat, sound and Shock wave. When an explosion occurs, energy is suddenly released in a very short time and the effect of this energy release is seen in the form of thermal radiation and propagation of waves in space. One of the important factors in the destruction of structures is the result of the blast. The waves move faster than the speed of sound, forming a wave front. When a body is equal to this wave, the pressure at its surface has increased, and at a very short moment this pressure reaches the peak of its size. This increase in the pressure caused by the explosion wave can bring loads that are much larger than the loads for which the structure was designed and cause a great structural damage [14].

Aligning with other loads entering the building, such as wind, earthquake, flood. The load caused by the explosion has the features to be seen in the design. The magnitude of the load due to the explosion wave and how the pressure on the structure is distributed depends on factors such as: geometry and shape of the structure, explosives location relative to the structure, explosive attributes (material, weight, released energy size, wave resonance rate due to collision with the earth) [15].

Types of modeling

There are various methods for determining these effects, such as physical modeling in large scale dimensions, physical modeling in small scale dimensions, and numerical modeling. Each stated method has its own advantages and disadvantages. In order to determine the effect of the explosive phenomenon, large-scale physical modeling, despite high-precision results, costs a lot and requires a proper background. Therefore, numerical modeling is one of the most common methods in determining the effect of explosive phenomenon. In numerical modeling, by examining the model and environmental conditions and loading, we can predict the results accurately, and the research costs in the modeling method will be much less than physical modeling. The experimental method is mainly related to experimental data. Most of these methods are limited by experimental limitation. The analysis methods are based on simplified models of physical phenomena.

Discussion

As mentioned, the study of the response of the structure under the explosive charge is examined by numerical and laboratory simulation. But making a real-scale laboratory model is very costly and difficult. Moreover, the assessment of important parameters and the observation of the rupture process in the near explosions is very difficult and almost impossible because of the loss of measurement equipment. Therefore, numerical simulations are a very convenient and efficient method for assessing the behavior of structures under the influence of blast loads.

Numerical simulation of surface explosion is performed on non-sticky, dry soil, which is simulated in a tunnel through a suitable method of deformation and strain on a substructure [16].

In the numerical modeling, considering the blast wave, the large strain on the soil and the change in the amplitude response range is expected that the results of the analysis are reliable and important [17].

Dynamic Rupture of the concrete using the model in the bridge analysis, is that the model can exhibit concrete under extreme dynamic loads and extreme deformations, Comparison between laboratory testing and numerical simulation has good alignment.[18]

Xu & LU studied the general behavior of concrete plates under blast loading using a numerical method and especially focusing on destruction, damage, and they proposed the experimental criteria for concrete erosion, which takes into account the three dimensional response of concrete [19].

The researchers used the dynamic analysis of the first-degree SDOF-system to determine the response of the bridges under the explosion load. In this research, pre-tied concrete was analyzed in multi-opening bridges. The geometry of the bridge, the distance of the explosion from the target to the location of the explosion has an important effect on the bridge response [20-21].

The research conducted for an effective method of analysis of the main bridge with different sizes and the location of explosives led by BAYLOT ET AL, resulted in a review and evaluation the amount and distribution of the load [22].

Conclusion

The results of the survey show that any amount of explosives is higher and the location is closer, the history of failure and pressure is greater.

In the studies, it was found that the comparison between laboratory testing and numerical simulation is in good agreement.

The concrete components are easily broken out regardless of the compressive strength of the concrete, while the reinforcement bar is not broken and can tolerate much displacement against the explosion load. The structural components must be designed to change the large plastic deformation and high deformability.

The cable system in the bridge can be designed for a varying loading route to maintain the structure under a high explosive load. Integrated performance in the pre-tied cable system, if extended across the bridge, can reduce the local damage that may occur on the bridge deck. This system also prevents the progressive destruction and expansion of degradation to adjacent openings.

The analysis of the detonation and the progressive breakdown shows a remarkable decrease in the overall loss of destruction for schemes with the improved flexural frame system than the complex system.

It can be well concluded that soil is one of the material that reduces the intensity and pressure of the blast effect on the structure, so the underground structures are more robust than those on earth.

Due to the complex environments in which the explosion phenomenon has been investigated, such as concrete and soil, and the limitation of the study, researchers have not reached the complete and comprehensive equations with high precision.

References

1. TM 5-1300 Unified facilities criteria (UFC 3- 340-02),. Structures to Resist The Effect of Accidental Explosions, US Department of Defense, Washington DC. 2008
2. Hashash,. Y.M.A. Hook,. J.J. Schmidt,. B. Yao,. J.I.C. Seismic design and analysis of underground structures. Tunneling and Underground Space Technology. 2001. 16(4). pp.247-293
3. Beykzade,. M. Moinodini,. M.A. Baghchesaraei,. O.R. An Evaluation of Isolated Structures with Seismic Isolators, The Bulletin of the Polytechnic Institute of Jassy, Construction. Architecture Section, 2019. 65(69), pp. 157-168

4. Luccioni, B.M. Ambrosini, R.D. R.F. Danesi, R.F. Analysis of building collapse under blast loads, *Engineering Structures*, 2004. 26(1), pp. 63-71
5. Li, J. Hao, H. Influence of brittle shear damage on accuracy of the two-step method in prediction of structural response to blast loads, *International Journal of Impact Engineering*, 2013, 54, pp 217-231
6. Li, J. Hao, H. Numerical study of structural progressive collapse using substructure technique, *Engineering Structures*, 2013, 52, pp. 101-113
7. Bi, K. Hao, H. Numerical simulation of pounding damage to bridge structures under spatially varying ground motions, *Engineering Structures*, 2013. 46, pp. 62-76
8. Kadid, A. Stiffened plates subjected to uniform blast loading. *Journal of Civil Engineering and Management*, 2008. 14(3), pp. 155-161
9. Pandey, A.K. Kumar, R. Paul, D.K. Trikha, D.N. Non-linear response of reinforced concrete containment structure under blast loading, *Nuclear Engineering and Design*, 2006. 236(9) , pp. 993-1002
10. Remennikov, A.M. A review of methods for predicting bomb blast effects on buildings, *Journal of Battlefield Technology*, 2003. 6(3). pp 5-10.
11. Shope, R.L. Response of Wide Flange Steel Columns Subjected to Constant Axial Load and Lateral Blast Load, Civil engineering department, Blacksburg, Virginia, 2006
12. Tore Børvik, T. Hanssen, A.G. Langseth, M. Olovsson, L. Response of structures to planar blast loads – A finite element engineering approach, *Computers & Structures*, 2009. 87(9-10). pp .507-520
13. Yalciner, H. Structural Response to Blast Loading: The Effects of Corrosion on Reinforced Concrete Structure, *Shock and Vibration*, 2014. pp1-8
14. Itasca Consulting Group, Inc. UDEC (Universal Distinct Element Code) Manual, User's Manual, 2005
15. Krehl, P.O.K. History of Shock Waves, Explosions and Impact. A Chronological and Biographical Reference. Springer. 2009
16. Areias, P. Belytschko, T. Analysis of three-dimensional crack initiation and propagation using the extended finite element method, *International Journal for Numerical Methods in Engineering*. 2005. 63(5). Pp.760 - 788
17. Siddharthan, R. Zafir, Z. Norris, G. Moving Load Response of Layered Soil. I: Formulation, *Journal of Engineering Mechanics*, 1993. 119(10),
18. Rabczuk, T. Eibl, J. Modelling dynamic failure of concrete with meshfree methods, *International Journal of Impact Engineering* Volume 32(11), 2006, Pp. 1878-1897
19. Xu, K. Lu, Y. Numerical simulation study of spallation in reinforced concrete plates subjected to blast loading. *Computers & Structures*, 2006. 84(5-6), pp. 431-438.
20. Williamson, E.B. Winget, D.G. Risk Management and Design of Critical Bridges for Terrorist Attacks, *Journal of Bridge Engineering*. 2005. 10(1), PP.96-106
21. Winget, D.G. Marchand, K.A. Williamson, E.B. Analysis and Design of Critical Bridges Subjected to Blast Loads, *Journal of Structural Engineering*. 2005. 131(8), PP 1243-1255
22. Baylot, J.T. Ray, J.C. Hall, R.H. Prediction Method for Response of Steel Bridge Beams and Girders to Blast and Fragment Loads, *Transportation Research Record*, 2003. 1827 (1), page(s): 69-74

DOI: 10.5281/zenodo.3444113

CZU 628.4(594)



THE GENERATION RATE AND CHARACTERISTICS OF MUNICIPAL SOLID WASTE IN SLUMS OF LAWANG KIDUL VILLAGE AT PALEMBANG CITY

Diah Octaviani Pratiwi^{1*}, ORCID ID: 0000-0003-2221-1231Febrian Hadinata¹, Heni Fitriani¹

¹Faculty of Engineering, University of Sriwijaya, Padang Selasa Street-30139, Palembang, Indonesia

*Corresponding author: Diah Octaviani Pratiwi, email: pradivia@gmail.com

Received: July, 23, 2019

Accepted: September, 24, 2019

Abstract. The problem of municipal solid waste (MSW) is closely related to slums, where houses in slums are stilt house and near the river, and making area under the house as the place of the garbage disposal place which is relatively difficult to clean. Lawang Kidul is a village that has the largest slum area among other villages and located on the edge of Musi River at Palembang City. One cause of slum is a problem of household waste that is not routinely transported to the garbage disposal place around 62,48%, causing garbage to scattered around the resident houses, even not infrequently throw garbage into rivers and waterways. The study aims to measure the generation rate and composition of MSW in slums of Lawang Kidul Village at Palembang City, and then to measure average generation rate and composition of MSW at several cities in Indonesia. Measurements were carried out for 2 days (14 March 2019 and 17 March 2019). Sampling was carried out in 2 pillars of neighbor (15 and 16) which has the highest number of heads of families among 8 other slums. There are 9 components of MSW that are measured (food waste, paper/cardboard, wood, cloth/textile products, rubber/leather, plastic, metal, glass, etc.). MSW generation rate is measured at 0,46 kg/person/day. The measured density of MSW was 244,97 kg/m³. The composition of MSW is dominated by food waste (48,81%), followed by plastic waste (33,96%), paper/cardboard waste (6,68%), and other waste components. The average of MSW generation rate in Indonesia was 0,352 kg/person/day. The average composition of MSW at several cities in Indonesia is dominated by food waste (63,63%).

Keywords: *average, composition, generation rate, Indonesia, MSW.*

Introduction

Urban population growth from year to year continues to increase, as well as improved life levels. The rapid development in urban areas become the attraction of urbanization because it provides a lot of ease and also better facilities, but this is not accompanied by the provision of basic infrastructure for society. If basic infrastructure is not fulfilled, it will cause the growth of slums [1]. Slums is a poor quality environment, where the conditions of housing are not clean and unworthy, vulnerable to crime, synonymous

with poor people, and densely population [2]. The problem of MSW is closely related to slums, where houses in slums are stilt house and near the river, and making area under the house as the place of the garbage disposal place which is relatively difficult to clean, even not infrequently throw garbage into rivers and waterways. It is often done by the society because unavailability of household-generated bins, unavailability of communal waste transportation facilities, and unavailability of communal waste collection facilities [3].

Lawang Kidul is a village that has the largest slum area among other villages and is located on the edge of Musi River at Palembang City [4]. One cause of slum is a problem of household waste that is not routinely transported to the garbage disposal place around 62,48%, causing garbage to scattered around the resident houses, even not infrequently throw garbage into rivers and waterways [5]. The slums that exist today are in leave from accumulation of waste everywhere. As long as people continue to do activities, waste will continue to be produced and will continue to increase because the volume of waste will be directly proportional to the population [6].

Each city produces a different number of generation rate of MSW, for urban waste dominated by household waste and generation rate of MSW in Nassiriya City is measured at 0,68 kg/capita and the composition of MSW is dominated by food waste around 70,18%. In Sangamner City of India, organic waste from market is dominant around 61% and inorganic waste around 39% is dominated by stone and sand. The generation rate of MSW in Mosul City, Irak, is measured at 0,68 kg/person and the composition of MSW is dominated by organic waste and food waste. The average generation rate of MSW in Sultanate of Oman is 0,97 kg/day/person with total organic waste of 71,20% and 65,80% collected during winter and summer, and dominated by food waste. The generation rate of MSW in Tuz Khurmatu, Irak, is measured at 0,574 kg/capita/day [7-11].

Research on accumulation and MSW composition has also been conducted in several cities in Indonesia from 2012 to 2019. Based on Table 1, the generation rate of MSW in several cities was different and dominated by food waste.

Table 1

Generation Rate and Composition of MSW in Indonesia [12-18]

Location	MSW Generation Rate	Dominant Waste (%)
Kenjeran Coastal Settlement, Surabaya	0,23 kg/person/day	Food waste (76,21%)
Padang Panjang City	0,44 kg/person/day	Food waste (71,23%)
Tanah Datar Regency	0,23 kg/person/day	Food waste (79,4%)
Tampan Sub-district, Pekanbaru	0,19 kg/person/day	Food waste (56,06%)
Sukolilo Sub-district, Surabaya	0,38 kg/person/day	Food waste (75%)
Rungkut Sub-district, Surabaya	0,486 kg/person/day	Food waste (68%)
Pahandut Village, Palangka Raya	0,40 kg/person/day	Food waste (34,31%)

MSW can be grouped into organic waste (wet waste from kitchen activities) and inorganic waste (dry waste such as bottles, paper and plastic), with the density of MSW at sources ranging from 0,01-0,2 tons/m³ [19]. The study aims to measure the generation rate and composition of MSW in slums of Lawang Kidul Village at Palembang City, and then to measure average generation rate and composition of MSW at several cities in Indonesia.

Methodology

In order to calculate the volume of MSW, the generation rate survey is done by a saturated sampling method which is all populations are samples [20]. Measurements were carried out for 2 days, weekday and weekend. Measurements of the generation rate and composition of MSW were carried out by directly measuring the volume of MSW in 2 pillars of neighbor (15 and 16) (Figure 1). There are 9 components of MSW that are measured (food waste, paper/cardboard, wood, cloth/textile products, rubber/leather, plastic, metal, glass, etc.) [19].

The weight and volume of MSW are recorded, so the generation and density of MSW were measured based on the dimensions and volume of the MSW container. Then, waste composition was expressed as a percentage of wet weight. The sorting of MSW was carried out based on the types of MSW that have been determined (food waste, paper/cardboard, wood, cloth/textile products, rubber/leather, plastic, metal, glass, etc.) in every waste container. Sorted MSW is weighed and recorded according to the type of waste. The MSW fraction (% of wet weight) for each components was calculated by dividing the total wet weight of each MSW component with total weight of MSW [21].



Figure 1. Map of Lawang Kidul Village.

Result and Discussion

1. MSW Generation Rate

Sampling was carried out for 2 days (14 March 2019 and 17 March 2019) and sampling was carried out in 2 pillars of neighbor (15 and 16). The calculated waste is household waste. The rate of waste generation was obtained from the weight of the waste divided the number of people in sampling location.

Table 2

Household Waste Generation Rates				
No.	Day and Date of Measurement	Total Weight of MSW (kg)	Total Number of People (person)	MSW Generation Rate (kg/person/day)
1	Thursday, 14/03/2019	254,4	574	0,44
2	Sunday, 17/03/2019	270,4	574	0,47
Total		524,8	1.148	0,46

From the results of measurements, the highest MSW generation rate is found on Sunday (0,47 kg/person/day) and the lowest MSW generation rate is found on Thursday (0,44 kg/person/day). The average rate of MSW generation for 2 days was 0,46 kg/person/day.

The density of MSW is measured by taking 3x (three times) samples in measuring containers and calculated by dividing the weight of waste by the volume of waste in garbage container [21]. The average of MSW density on Thursday was 282,19 kg/m³ and The average of MSW density on Sunday was 207,74 kg/m³. If MSW density for 2 days combined, the MSW density was 244,97 kg/m³

Table 3

MSW Density								
Component of Measurements	Thursday, 14/03/2019				Sunday, 17/03/2019			
	1st test	2nd test	3rd test	Average	1st test	2nd test	3rd test	Average
Weight of MSW Sample (kg)	9,8	10,2	10	-	7,4	6,6	8,9	-
Volume of MSW Sample (m ³)	0,03	0,04	0,04	-	0,04	0,04	0,04	-
Density of MSW (kg/m ³)	284,70	285,16	276,72	282,19	191,77	182,64	248,81	207,74

2. MSW Composition

There are 9 components of MSW that are measured (food waste, paper/cardboard, wood, cloth/textile products, rubber/leather, plastic, metal, glass, etc.). The measurement of waste composition was carried out for 2 days, indicates that food waste is greater than other waste components.

Table 4

MSW Composition					
No.	Components of MSW	Thursday, 14/03/2019		Sunday, 17/03/2019	
		Weight of MSW (kg)	MSW Fraction (%)	Weight of MSW (kg)	MSW Fraction (%)
1	Food waste	131,3	51,61	124,4	46,01
2	Paper/cardboard	18,2	7,15	16,8	6,21
3	Wood	2,5	0,98	1,1	0,41

Continuation Table 4

4	Cloth/textile products	10,6	4,17	16,5	6,10
5	Rubber/leather	5,6	2,20	2,1	0,78
6	Plastic	78,6	30,90	100,1	37,02
7	Metal	1,4	0,55	3,6	1,33
8	Glass	4,4	1,73	5,8	2,14
9	Etc.	1,8	0,71	0	0
Total		254,4	100	270,4	100

If the weight of waste per component is combined, it can be seen that MSW in Lawang Kidul Village was dominated by food waste (48,81%), followed by plastic waste (33,96%), paper/cardboard waste (6,68%), and other waste components, see Figure 2.

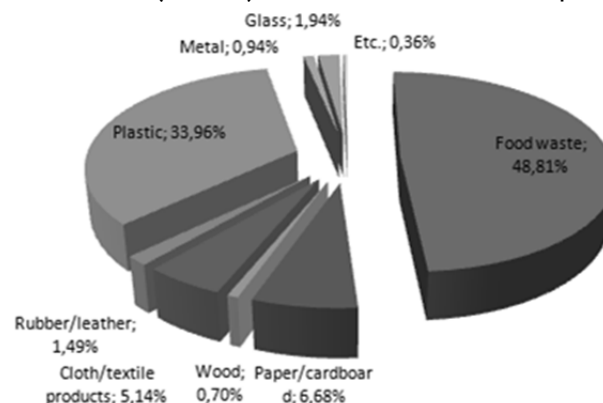


Figure 2. MSW Composition in Lawang Kidul Village.

3. The Average of MSW Generation Rate and Composition

The average of MSW generation rate is calculated by collecting data from several cities in Indonesia from 2012 to 2019. There were 7 cities in Indonesia, including Lawang Kidul Village in Palembang City, which is used to calculate the average of MSW generation rate in Indonesia. The average of MSW generation rate in Indonesia was 0,352 kg/person/day, meanwhile the average of MSW composition in Indonesia was dominated by food waste (63,63%).

Table 5

The Average of MSW Generation Rate	
Location	MSW Generation Rate (kg/person/day)
Lawang Kidul Village, Palembang	0,46
Kenjeran Coastal Settlement, Surabaya	0,23
Padang Panjang City	0,44
Tanah Datar Regency	0,23
Tampan Sub-district, Pekanbaru	0,19
Sukolilo Sub-district, Surabaya	0,38
Rungkut Sub-district, Surabaya	0,486
Pahandut Village, Palangka Raya	0,40
Average	0,352

Table 6

The Average of MSW Composition

No	Components of MSW	MSW Composition (%)								
		X ₁	X ₂	X ₃	X ₄	X ₅	X ₆	X ₇	X ₈	\bar{X}
1	Food waste	48,81	76,21	71,23	79,4	56,06	75	68	34,31	63,6 ₃
2	Paper/cardboard	6,68	5,33	4,44	3,31	11,21	7	10,8	21,93	8,84
3	Wood	0,70	1,21	15,14	0,21	0	1	3,7	2,36	3,04
4	Cloth/textile products	5,14	2,27	0	1,43	8,05	1	0,4	3,44	2,72
5	Rubber/leather	1,49	0,23	0	0	0,21	0	0,1	0	0,25
6	Plastic	33,96	10,83	7,18	15,3	19,75	11	12,6	22,64	16,6 ₆
7	Metal	0,94	0,44	0,51	0,12	0,46	1	1	0,25	0,59
8	Glass	1,94	0,82	0	0,22	4,25	1	0,3	2,31	1,36
9	Etc.	0,36	2,58	1,50	0	0	1	0,4	11,88	2,22

Note :

X₁ = Lawang Kidul Village, Palembang

X₂ = Kenjeran Coastal Settlement, Surabaya

X₃ = Padang Panjang City

X₄ = Tanah Datar Regency

X₅ = Tampan Sub-district, Pekanbaru

X₆ = Sukolilo Sub-district, Surabaya

X₇ = Rungkut Sub-district, Surabaya

X₈ = Pahandut Village, Palangka Raya

Conclusion

Based on the results, MSW generation rate is measured at 0,46 kg/person/day. The measured density of MSW was 244,97 kg/m³. The composition of MSW is dominated by food waste (48,81%), followed by plastic waste (33,96%), paper/cardboard waste (6,68%), and other waste components. The average of MSW generation rate in Indonesia was 0,352 kg/person/day, meanwhile the average composition is dominated by food waste (63,63%). Several cities in Indonesia that are shown in this research are not enough to represent the entire city in Indonesia. The average results of MSW generation rate and composition will be different when the whole city has calculated the same way. Further research is necessary to calculate the MSW generation rate and composition in each city so that the average results of MSW generation rate and composition in Indonesia can be more accurate than now.

References

1. Marx, B., Stoker, T. and Suri, T. The Economics of Slums in The Developing World. In : *Journal of Economic Perspectives*, 2013, 27(4), pp.187-210.
2. Nuissl, H. and Heinrichs, D. Slums : Perspectives on The Definition, The Appraisal and The Management of an Urban Phenomenon. In : *Journal of The Geographical Society of Berlin*, 2013, 144(2), pp.105-116.
3. Wibowo, H.E. *Community Behavior in Managing Waste Settlements in The Cambodian Village of Pontianak* : Magister. Thesis. Semarang (Indonesia) : University of Diponegoro, 2010.
4. Palembang Mayor Decree number 488 year 2014 about Location Determination of Slum Area.

5. Document of Environment Plan for Settlement of Lawang Kidul Village, Palembang, 2016.
6. Martinawati. *Community of Participation Rate Analysis in Implementing Household Waste Management (A Study in The Village of Sukodadi Sukarami District of Palembang)* : Magister. Thesis. Palembang (Indonesia) : University of Sriwijaya, 2015.
7. Yasir, R.A. and Abudi, Z.N. Characteristics and Compositions of Solid Waste in Nassiriya City. In : *Al-Qadisiya Journal For Engineering Sciences*, 2009, 2(2), pp.136-148.
8. Thitame, S.N., Pondhe, G.M., and Meshram, D.C. Characterisation and Composition of Municipal Solid Waste (MSW) Generated in Sangamner City, District Ahmednagar, Maharashtra, India. In : *Environ Monit Assess*, 2010, 170, pp.1-5.
9. Al-Rawi, S. and Al-Tayyar, T. 2013. A Study on Solid Waste Composition and Characteristics of Mosul City/Iraq. In : *Journal of University of Zakho*, 2013, 1(2), pp.496-507.
10. Palanivel, T.M., and Sulaiman, H. 2014. Generation and Composition of Municipal Solid Waste (MSW) in Muscat, Sultanate of Oman. In : *APCBEE Procedia*, 2014, 10(2014), pp.96-102.
11. Ali, S.M., Ali, Y.M., dan Faris, M.R. 2017. Characterictics of Domestic Solid Wastes in the Judiciary of Tuz Khurmatu/Iraq. In : *Eurasian Journal of Science & Engineering*, 2017, 3(2), pp.224-229.
12. Citrasari, N., Oktavetri, N.I., and Aniwindira, N.A. Generation Rate and Waste Composition Analysis at Kenjeran Surabaya Coastal Settlement. In : *Berk. Penel. Hayati*, 2012, 18, pp.83-85.
13. Komala, P.S., Aziz, R., and Wahyudi, B. Study of Generation Rate and Characteristics of Padang Panjang City. In : *Jurnal TeknikA*, 2013, 20(1), pp.23-32.
14. Dewilda, Y., Darnas, Y., and Zulfa, I. Generation Rate and Domestic Waste Composition of Tanah Datar Regency. In : *Jurnal Teknik Lingkungan UNAND*, 2014, 11(1), pp.28-33.
15. Jaspi, K., Yenie, E., and Elystia, S. Study of Generation Rate, Composition, and Characteristic of Waste in Tampan Subdistrict Pekanbaru City. In : *Jom FTEKNIK*, 2015, 2(1), pp.1-6.
16. Hapsari, D.S.A. and Herumurti, W. Generation Rate and Household Waste Composition in Sukolilo Subdistrict Surabaya. In : *Jurnal Teknik ITS*, 2017, 6(2), pp.421-424.
17. Ratya, H. and Herumurti, W. Generation Rate and Household Waste Composition in Rungkut Subdistrict Surabaya. In : *Jurnal Teknik ITS*, 2017, 6(2), pp.451-453.
18. Apriyani, N. and Lesmana, R.Y. Generation Rate and Waste Composition in Pahandut Village Palangka Raya City and Its Impact on Lindi Water Quality. In : *Jurnal Media Ilmiah Teknik Lingkungan*, 2019, 4(1), pp.5-9.
19. Damanhuri, E. and Padmi, T. *Integrated Waste Management*. Bandung : ITB Press, 2016.
20. Sugiyono. *Education Research Method : Quantitative, Qualitative, and R&D*. Bandung : Alfabeta Press, 2015.
21. SNI 19-3964-1994. Method for Taking and Measuring Samples for Generation and Composition of Urban Waste.

DOI: 10.5281/zenodo.3444117
CZU 637.2.04/.05



THEORETIC APPROACHES TO SUBSTANTIATE SHELF LIFE CAPACITY OF BUTTER AND SPREADS

Anna Bocharova-Leskina¹, ORCID ID: 0000-0002-8216-9605

Sergii Verbytskyi ^{2*}, ORCID ID: 0000-0002-4211-3789

¹Kuban State Technological University, 2, Moskovskaya Str., Krasnodar 350072, Russian Federation

²Institute of Food Resources of NAAS, Ye. Svershiuk Str., 4a, Kyiv 02002, Ukraine

*Corresponding author: Sergii Verbytskyi, tk140@hotmail.com, <https://orcid.org/0000-0002-4211-3789>

Received: August, 22, 2019

Accepted: September, 25, 2019

Abstract. The analysis of scientific information on the theoretical aspects and practical features of long-term freezing storage of butter and spreads is carried out. Means of mathematical modeling are substantiated, allowing prediction of the storage capacity of these foods based on the study of the mechanism and kinetics of the processes that determine the deterioration of quality (the set of relevant indicators) during storage. A detailed description of the proposed method for predicting the shelf life of butter and spreads using the full factorial experiment is given, which makes it possible to evaluate their storage capacity with sufficient reliability. A comparative assessment of the known physical, chemical and sensorial indicators affecting the storage capacity is given. The titratable acidity, acidity of the fat phase, degree of dispersion and distribution of moisture, and also the peroxide number were determined as basic storage stability factors.

Keywords: *butter, spreads, shelf life, quality factors, mathematical model, regression analysis, acidity, peroxide value.*

Introduction

The overall goal of the food industry consists in adequate providing all consumers with safe, affordable and nutritious foods. However, this problem cannot be solved only by increasing production volumes of the said products – a significant reduction in losses during the processing of food raw materials along the entire chain from field to table, a proper increase in the nutritional value of manufactured products, and an increase in their shelf life due to strict observance of safety requirements to food products and the full preservation of quality shall be also guaranteed [1, 2]. Industrial production of food products requires the correct application of scientifically based approaches to the storage of food products, that is, the possible suppression of their natural spoilage process. Of course, it is impossible to completely stop this process; however, changes in product quality during storage should occur in a predictable and controlled manner. This is facilitated by a significant improvement in the methods of preparation and processing of raw materials, packaging and distribution of food products [3]. Currently, research and development are held to create new packaging materials and food storage technologies, which are expected to positively affect compliance with food safety criteria [4] through the proper application

of technologies for the obtaining, storage and processing of food materials using advanced scientific achievements and developments [5]. At the same time, it is important not only to comply with food safety criteria regarding production volumes, but also to ensure their compliance with the basics of healthy nutrition, quality and safety requirements through proper coordination of the profile activities of agriculture and the food industry [6].

Based on the above, it is important to comprehensively assess the requirements for the storage conditions of butter and spreads within the framework of market turnover and food reservations. This will allow developing rational approaches to the possible and appropriate consideration of the fundamentals of food security in technical regulation, in particular when developing standards of different levels and other regulatory documents.

Aiming at the full coverage of all segments of the solvent demand of consumers, the dairy industry, together with natural butter, has mastered the technology of producing recombinant butter using dried milk (whole and skimmed), as well as buttermilk. Despite the skepticism of adherents of healthy nutrition, the spreads, the raw materials for which are dehydrated milk fat, vegetable fats and dry buttermilk, find their numerous consumers. Technological schemes and production methods, the equipment used to obtain butter and spreads are similar. In the production of recombinant butter, only the initial operations associated with obtaining stable secondary milk-fat dispersions are somewhat different. The use of milk fat concentrates and skimmed milk powder in a certain way smoothes out the seasonality of production of natural butter [7].

Butter, as a concentrate of milk fat, contains phosphatides and unsaturated fatty acids such as linoleic, linolenic and arachidonic. Butter on storage, as a result of oxidative and hydrolytic reactions, accumulates by-products this causing deterioration in taste – especially when the butter is stored for a long time. Therefore, to slow down chemical processes and maintain product quality indicators during long-term storage, a number of measures are taken to establish the appropriate temperature regime, use effective packaging materials, etc. [8, 9]. F. Vyshemirskii, a well-known Russian expert in the field of butter production, noted [10] that the product should be reliably isolated from any external influences: light, microbiological, chemical, etc. At the same time, the packaging material must be environmentally friendly, neutral to the product itself and safe for human health. Butter does not have such a protective layer as cheese, and therefore requires proper packaging. Vegetable parchment paper is widely used for these purposes, this being a universal grease-resistant and moisture-resistant paper made from pure cellulose of coniferous and deciduous wood without the use of chemicals and moisture-resistant resins. The main requirements for parchment paper as a packaging material: sterility, environmental friendliness, resistance to high temperatures, chemical inertness, neutrality to the surface of the material, elasticity and flexibility, abrasion resistance, suitability for all types of printing, etc.

Regulatory regimes and practical features of long-term storage of butter and spreads

According to the Interstate Standard GOST 32261-2013 [11] this being in force in Russia and a number of CIS countries, long-term storage of butter is carried out in mode III (air temperature – minus $(16 \pm 2) ^\circ \text{C}$, relative humidity – not more than 90%) for 15 months, and provided that the temperature does not exceed minus $24 ^\circ \text{C}$ – within 24 months. According to the norms of the National Standard of Ukraine in force – DSTU 4399: 2005 [12] butter shall be stored at temperatures from $0 ^\circ \text{C}$ to $-18 ^\circ \text{C}$ in freezers, the shelf

life of the said is specified in the regulatory document to be from 3 to 12 months. Specialists of the Ukrainian State Research Institute of Nanobiotechnology and Resource Saving noted that during prolonged (for 24 months) storage of butter, the temperature regime is -25 ± 3 °C. Under the indicated storage mode, the product is packaged in a tight monolith of 24 kg in cardboard boxes previously covered with parchment paper [13], which is not provided for by the applicable national standard [12]. In this regard, in order to predict the shelf life and development of new packaging materials for butter and spreads with subsequent amendments to existing national standards, it is relevant to study sensorial and biochemical parameters when the said foods are stored in industrial freezers at -25 ± 3 °C. The long-term storage of a batch of butter weighing 20 MT, packaged in a tight monolith of 24 kg in cardboard boxes, previously covered with parchment paper was investigated [14]. Storage was carried out in an industrial freezer at a temperature of -25 ± 3 °C. Sensorial evaluation of the selected oil samples was carried out collectively by a 10-point evaluation system, and biochemical parameters: titratable acidity and fatty acidity were also determined. After storage of butter for 30 months, a decrease in sensorial values was observed: taste and aroma – 0.8 times, color – 0.7 times. The results of sensorial evaluation of butter after long-term storage are shown in Figure 1.

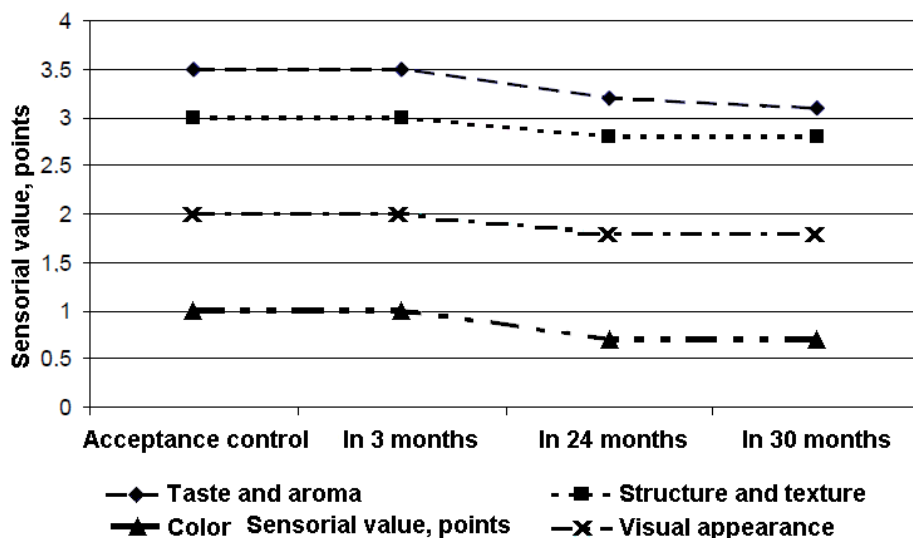


Figure 1. Results of sensorial evaluation of butter after long-term storage [14].

The study of biochemical parameters after long-term storage showed that the titratable acidity and the acidity of the fat phase increased 1.26 times and 1.32 times (Table 1). The indicated values correspond to the norms of the standard [12] in force, therefore there is every reason to assert that the temperature regime is acceptable -25 ± 3 °C in order to properly slow down biochemical processes in butter.

Table 1

Biochemical parameters of butter after long-term storage [14]

№№	Parameters	Storage duration			
		Control	3 months	24 months	30 months
1.	Acidity, °T (Degrees Turner)	15.9±0.8	15.9±0.7	16.7±0.8	20.00±0.9
2.	Acid fat phase, °K (Degrees Kettstofer)	1.79±0.08	1.80±0.09	2.00±0.1	2.37±0.1

The same long-term storage period was set for the “Gorodskoy” spread, stored at minus 25 °C. The quality of the product in transport and consumer packaging met the requirements of the regulatory documentation for it until the end of the planned shelf life (30 months). In [15] it is also indicated that experiments were started with long-term storage of spreads for 36 months.

The above information fully confirms the justification, both in terms of food safety and maintaining proper consumer properties, different temperature and humidity conditions and shelf life of butter and spreads. At the same time, full-scale studies of these foods and, accordingly, obtaining objective information about their storage capacity at present seem possible only in real time at the enterprises of the state reservation system. In this regard, substantiation of the algorithm for the numerical evaluation of food products, in particular butter and spreads, seems to be extremely expedient, based on their principal characteristics thereof.

Development of an algorithm for determining the compliance of the shelf life of a food product with regulatory requirements

In general, the shelf life of food products is the period of time during which they meet regulatory or other current requirements for sensorial, physical and chemical indicators, nutritional value, content of chemical and biological substances and their compounds, microorganisms and other biological objects. In another way, the shelf life of food products can be defined as the period of time during which the products retain the properties established in the regulatory and technical documentation. The vast majority of food products are complex multi-component biological and biochemical systems in which, as a rule, various microbiological, biochemical and physicochemical reactions take place – it is clear that their shelf life and quality retention duration depend on these and many other factors [16].

Mathematical modeling tools allow predicting the state of the object of study during storage under standard conditions, using the results obtained during storage under extreme conditions [16]. The indicated concept is based on the study of the mechanism and kinetics of processes that determine the deterioration of the quality (set of relevant indicators) of the test object during storage. Thus, for various food products, methods of mathematical modeling can be used, in particular, constructing and evaluating the quality of a regression model based on mathematical planning and processing the results of an active experiment [17, 18].

To establish a mathematical relationship between the shelf life of certain food products and factors influencing the said shelf life, a complete factor two-level experiment (CFE 2^n), including $N = 2^n$ experiments, is used [19]. In different experiments, within the framework of the experiment, all possible combinations of the levels of n factors affecting the response are fulfilled, and the response function is the value Y , which takes values y_1, y_2, y_3, \dots and determines the number of days during which the product properties do not go beyond the limits of the numerical ranges within which it can be considered usable. In other words, expiration is the acquisition by a product of such physical, chemical and sensorial characteristics that make its consumption impossible. First of all, these factors include the storage mode (under ordinary conditions, in cold room, in the frozen state) of food products and specific temperature conditions. For the proper execution of the experiment and the corresponding mathematical processing of its results, it is necessary

that the factors are controllable, operational, unambiguous, compatible, independent, and the accuracy of the measurements is sufficient. The above requirement – controllability – means that the selected value (level) of the factor can be kept constant while the experiment continues. Another requirement is that the factor's operational requirement is defined as the sequence of operations by which its specific values (levels) are established. The choice of dimension and the accuracy of fixation of this factor are also associated with this definition. The uniqueness of a factor is the directness of its influence on the response, that is, the factor should not be a function of other factors. Proper factor compatibility means that all of their combinations are workable and safe. Proper independence of factors means the absence of a correlation between them.

For example, in the course of the study it was established that for this particular product there are a combination of 4 factors corresponding to the conditions listed above. One of the prerequisites for the application of regression analysis is the distribution of the modeled value according to the normal law, for example, with a probability of 95%. Then the predicted shelf life of the food product is determined from the regression equation – an incomplete fourth order polynomial.

$$\begin{aligned}
 y = & b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_{12}X_1X_2 + b_{13}X_1X_3 + b_{14}X_1X_4 + \\
 & + b_{23}X_2X_3 + b_{24}X_2X_4 + b_{34}X_3X_4 + b_{123}X_1X_2X_3 + b_{124}X_1X_2X_4 + \\
 & + b_{134}X_1X_3X_4 + b_{234}X_2X_3X_4 + b_{1234}X_1X_2X_3X_4
 \end{aligned}
 \quad (1)$$

To determine the unknown coefficients of equation Eq.(1), a complete experiment of two factors with uniform five-fold duplication of experiments in each row of the experimental design can be implemented. The basic characteristics of this plan are given in Table 2.

Table 2

Basic characteristics of experimental plan

Characteristics	Factors X_j			
	X_1	X_2	X_3	X_4
Basic level (experimental center)	a_1	c_1	d_1	e_1
Variation interval Δ_j	a_2	c_2	d_2	e_2
Lower level	a_3	c_3	d_3	e_3
Upper level	a_4	c_4	d_4	e_4
Notations of encoded factors	x_1	x_2	d_3	e_4

Based on the conditions set, the number of experiments in this experiment is $N = 2^4 = 16$. In order to move from the actual values of factors to encoded dimensionless quantities, the formula is used:

$$x_j = \frac{X_j - X_j^0}{\Delta X_j} \quad (2)$$

where: x_j – encoded value of a factor;
 X_j – present value of a factor;

X_j^0 – value of basic level;

ΔX_i – variation interval.

Thus, for each factor, the encoded value of the lower level corresponds to (-1), and the upper level corresponds to 1. Table 6 shows the experimental design matrix.

Table 3

Experiment design matrix

i	X_1	X_2	X_3	X_4	x_1	x_2	x_3	x_4
1	a_3	c_3	e_3	d_3	-1	-1	-1	-1
2	a_3	c_3	e_3	d_4	-1	-1	-1	1
3	a_3	c_3	e_4	d_3	-1	-1	1	-1
4	a_3	c_3	e_4	d_4	-1	-1	1	-1
5	a_3	c_4	e_3	d_3	-1	1	-1	-1
6	a_3	c_4	e_3	d_4	-1	1	-1	1
7	a_3	c_4	e_4	d_3	-1	1	1	-1
8	a_3	c_4	e_4	d_4	-1	1	1	1
9	a_4	c_3	e_3	d_3	1	-1	-1	-1
10	a_4	c_3	e_3	d_4	1	-1	-1	1
11	a_4	c_3	e_4	d_3	1	-1	1	-1
12	a_4	c_3	e_4	d_4	1	-1	1	1
13	a_4	c_4	e_3	d_3	1	1	-1	-1
14	a_4	c_4	e_3	d_4	1	1	-1	1
15	a_4	c_4	e_4	d_3	1	1	1	-1
16	a_4	c_4	e_4	d_4	1	1	1	1

As the next step, coefficients of the regression equation are to be found, where the variables are encoded values of the factors:

$$\begin{aligned}
 y = & \tilde{b}_0 + \tilde{b}_1 x_1 + \tilde{b}_2 x_2 + \tilde{b}_3 x_3 + \tilde{b}_4 x_4 + \tilde{b}_{12} x_1 x_2 + \tilde{b}_{13} x_1 x_3 + \tilde{b}_{14} x_1 x_4 + \\
 & + \tilde{b}_{23} x_2 x_3 + \tilde{b}_{24} x_2 x_4 + \tilde{b}_{34} x_3 x_4 + \tilde{b}_{123} x_1 x_2 x_3 + \tilde{b}_{124} x_1 x_2 x_4 + \\
 & + \tilde{b}_{134} x_1 x_3 x_4 + \tilde{b}_{234} x_2 x_3 x_4 + \tilde{b}_{1234} x_1 x_2 x_3 x_4
 \end{aligned}
 \quad (3)$$

In Eq. (3), the coefficients of linear terms indicate the significance of the influence of factors: the larger the numerical value of the coefficient, the more this factor influences the shelf life. In the case of a positive value of the coefficient, with an increase in the value of the factor, the shelf life increases, otherwise it decreases. The coefficients available for the products x_j determine the influences of the interaction of factors. For example, if the coefficient when producing two encoded factors is positive, then to increase the shelf life of the product, it is necessary to simultaneously increase or decrease the values of these factors. Accordingly, a reduction in the shelf life of a food product is accompanied by changes in factors in different directions. If the coefficient when producing two encoded factors is negative, then in order to increase the shelf life, factors must change in different directions, and to reduce, a simultaneous increase or decrease in the values of factors is required. Similarly, the signs of higher order interaction influences are interpreted.

Unknown coefficients for the dimensionless variables x_1, x_2, x_3, x_4 are found from the formulas below.

$$\tilde{b}_0 = \frac{\sum_{i=1}^{16} \bar{y}_i}{16} \quad (4)$$

$$\tilde{b}_{ju} = \frac{\sum_{i=1}^{16} x_{ij} \cdot y_i}{16}, j=1,2,3,4 \quad (5)$$

$$\tilde{b}_{ju} = \frac{\sum_{i=1}^{16} x_{ij} \cdot x_{iu} \cdot \bar{y}_i}{16}, j < u, j, u = 1,2,3,4 \quad (6)$$

$$\tilde{b}_{juv} = \frac{\sum_{i=1}^{16} x_{ij} \cdot x_{iu} \cdot x_{iv} \cdot \bar{y}_i}{16}, j < u < v, j, u, v = 1,2,3,4 \quad (7)$$

$$\tilde{b}_{1234} = \frac{\sum_{i=1}^{16} x_{i1} \cdot x_{i2} \cdot x_{i4} \cdot \bar{y}_i}{16}, \quad (8)$$

where: \bar{y}_i – average values of shelf life calculated from the results of 5 replications of i series of experiments;

$x_{i1}, x_{i2}, x_{i3}, x_{i4}$ – encoded values of the factors not complying with i series of experiments.

If the measured random variable (expiration date) is distributed in accordance with the normal law in the entire studied range, then regardless of the average values \bar{y}_i obtained in 5 replicates of each of the 16 series of experiments, the dispersion of this quantity, called the dispersion of reproducibility, will not change its quantities. Thus, line estimates of the indicated variance in different series of experiments should be homogeneous.

In order to test the hypothesis of homogeneity of dispersions s_i^2 , the Cochran statistical test is used. If in accordance with it there is no reason to abandon the hypothesis of homogeneity of row-wise dispersion estimates, the experiments are considered reproducible.

In the case when the experiments are not reproducible, they try to achieve reproducibility by identifying and eliminating the causes of instability of the experiment, or by using more accurate methods and means of measurement. So, if among m replicates of a series of experiments there are results significantly different from other results of the same series, significant errors can be determined using the statistical r -test of the largest deviation. The result of such a check should be excluded from subsequent analysis. If there are significant errors, an additional experiment (or a series of experiments) is performed, ensuring that the experiment is carried out at $m_j = m = \text{const}$.

Considering that the determination of the shelf life of experimental samples in each experiment is carried out with a certain error, the coefficients of the regression equation will be determined in accordance with the found error. The purpose of statistical analysis of

the equation is to show with a predetermined probability that the obtained estimates of the coefficients of the equation are either greater or less than the error in their measurement. In the first case, they significantly differ from zero, in the second case – insignificantly, that is, they should be excluded from the equation.

In order to check the significance of the coefficients of the regression equation, the statistical Student's test is used. Components with negligible coefficients are excluded from the equation. The reason for obtaining an insignificant linear effect of any factor may be one of the following situations:

- a specific factor does not affect the expiration date;
- the variation interval is too small, and therefore the response change due to the change in the factor is proportional to random deviations caused by the influence of unaccounted factors;
- the value of a specific factor at the central point of the experiment (Table 3) corresponds to its optimal value; therefore, its equal increase or decrease by Δ_j will decrease the response values by approximately the same amount.

If, after checking the significance of the equation's coefficients, all N coefficients remain, then checking the adequacy of the model does not make sense, since the value of the expiration date calculated for such an equation for the conditions of any j^{th} series of experiments should coincide, within the limits of rounding accuracy, with the value accepted for calculation.

If the number of significant coefficients is at least one less than the number of series of experiments, it becomes necessary to statistically verify the adequacy of the obtained equation to experimental data. This verification is carried out using the Fisher test. The discovered inadequacy of the model can be due to both an unreasonably accurate description of the experimental data by the indicated equation, and the fact that the accuracy of the process description is significantly lower than the accuracy with which the experimental data were obtained. In the first case, the equation can serve as the basis for searching for optimal conditions, but cannot be used to test one or another hypothesis about the mechanism of the process under study.

To make it possible to determine the shelf life of a food product using the obtained regression equation in the case when the factors acquire real values, the encoded factors should be transformed according to the formula Eq. (1). In this case, the regression coefficients will change. At the same time, the interpretation of the influence of factors on the values and signs of the regression coefficients is excluded, since, due to circumstances due to the properties of the experimental design matrix, the coefficients of the equation will be determined depending on each other. However, upon receipt of the interpolation formula, this technique can be used. That is why, replacing the variables X_1, X_2, X_3, X_4 in the regression equation found, taking into account the data of Table 3, by the quantities $\frac{X_1 - a_1}{a_2}$,

$\frac{X_2 - c_1}{c_2}$, $\frac{X_3 - d_1}{d_2}$ and $\frac{X_4 - e_1}{e_2}$ accordingly, an interpolation formula is obtained that allows, for specific values of the initial storage conditions of the food product to be stored, to predict the duration of its storage without violating the normative indicators of food safety and quality.

Justification of the main characteristics of the experiment plan for predicting the storage capacity of butter and spreads

Storage issues of butter have long been the subject of interest of scientists and experts in the food industry. For example, in the well-known work [20], such criteria for the shelf life of butter after storage (without freezing) are indicated, such as the degree of oxidation of fats, bacterial contamination and sensorial characteristics. It is clear that with the widespread introduction of freezing storage of food, including dairy and milk-containing fat products, approaches to ensuring and controlling their storage capacity have changed significantly. Fresh or chilled foods usually have similar spoilage factors – primarily microbial spoilage. Therefore, it is relatively easy to simulate temperature changes in the product and present models for the development and inhibition of the growth of microorganisms at known temperatures. As a result, it is possible to predict with satisfactory accuracy when the microbial load exceeds the safe limit, thereby determining the threshold safe value of the expiration date [21]. The situation with frozen foods is not so simple, so the search for adequate approaches to determining the expiration date continues. For example, in works [22, 23] introducing a technique based on the “fingerprinting kinetics” is recommended. The said technique allows giving a realistic estimate of shelf life while using several markers that are potentially associated with quality deterioration factors. To determine the expiration date, it is necessary to check the presence of key differences in the quality of food products during storage, to determine markers in terms of their significance in relation to the dynamics of spoilage, and use multivariate analysis to link selected markers with specific processes occurring in food products. This can help in: a) determining the appropriate quality attributes by reducing the number of markers needed to effectively predict shelf life, b) understanding the combination of factors that determine, along with individual factors, the shelf life, c) understanding the general mechanics of product quality deterioration. Prediction of shelf life is based on the fundamental principles of modeling the processes of loss of quality of a food product – first of all, on the kinetic modeling of various, well-studied, deterioration mechanisms in food systems. It is the models of multivariate analysis of variance and regression analysis using the methods of mathematical design of the experiment that can simultaneously take into account microbiological, sensorial, physical and chemical indicators in determining the shelf life of food products [24].

In the case, the task of predicting the periods of freezing storage of butter and spreads at the first stage is reduced to justifying the nomenclature of factors $X_1 \dots X_4$, the most significant in the sense of determining the parameters that determine the quality of these products after specific periods of stay on the reservation.

In studies, the results of which are presented in [14], titratable acidity ($^{\circ}\text{T}$), fatty acidity ($^{\circ}\text{K}$) and sensorial indicators determined on a ten-point scale are used as criteria for the quality of butter after long-term storage: 1) taste and aroma; 2) color; 3) structure and consistency; 4) appearance. If it is entirely possible to agree with the use of the first two (objective instrumental) criteria, the appropriateness of using sensorial indicators raises certain doubts. Although there is an opinion about sensorial evaluation as an indispensable step in determining the quality of complex and variable food systems, the disadvantages inherent in sensorial methods are also well known. Firstly, serious sensorial research is quite laborious and expensive. And secondly, assessing the stability and quality of food

products is impossible without the use of numerous analytical methods for detecting signs of hydrolysis and oxidation of [25].

The authors of [26] use in some way different nomenclature of indicators of quality criteria for butter after long-term storage. In addition to the titratable acidity ($^{\circ}\text{T}$) and fatty acidity ($^{\circ}\text{K}$) mentioned above, an indicator of thermal stability (units), as well as the degree of dispersion and distribution of moisture (classes I – III) are used. In our opinion, the thermal stability index is not a determining factor in the storage capacity of butter and spreads, but the degree of dispersion and distribution of moisture is an indicator that correlates well with the physicochemical properties of fat products when they are stored, as well as with the temperature regime at which this storage is carried out.

The most important indicator of lipid oxidation of fatty products is their peroxide number (mol / kg). There are recognized international methods for determining this indicator – both in the CIS regulatory system and in the national regulatory framework of Ukraine, the relevant standards of the International Organization for Standardization ISO are harmonized, allowing determination of the peroxide number with reasonable accuracy. The use of these standard methods, to some extent, is limited by the lack of norms regarding the peroxide value in the current technical specifications for oil and spreads, however, in the conditions of voluntary application of the standards, any reliable databases obtained by scientists and practitioners of dairy production can be used.

Thus, we consider it appropriate to use the following factors when calculating the storage capacity according to the above methodology:

X_1 – titratable acidity, $^{\circ}\text{T}$;

X_2 – acidity of fat phase, $^{\circ}\text{K}$;

X_3 – degree of dispersion and distribution of moisture, classes I - III;

X_4 – peroxide number, mol/ kg.

Having determined, as a result of practical experiments, the values of these variables, we can obtain an interpolation formula with which we can reliably predict the storage time of butter and spreads without violating the threshold values of food safety and quality of these products.

Conclusion

The determination of the reliable storage capacity of butter and spreads is of great economic importance, since these products are laid for long-term freezing storage. Mathematical modeling tools allows predicting the shelf-life of food products based on the study of the mechanism and kinetics of processes that determine the deterioration in the quality (set of relevant indicators) of butter and spreads during storage. The proposed method for predicting the shelf life of these fat products on the basis of a complete factorial experiment makes it possible to evaluate their storage capacity with sufficient reliability. The titratable acidity, acidity of the fat phase, degree of dispersion and distribution of moisture, and also the peroxide number were determined as basic storage factors.

References

1. Augustin, M. A., Riley, M., Stockmann, R., Bennett, L., Kahl, A., Lockett, T., Cobiac, L. Role of food processing in food and nutrition security. In: *Trends in Food Science & Technology*, 2016, 56, pp. 115-125.
2. Kopylova, K. V., Verbytskyi, S. B., Verbova, O. V. Summarizing demands to safety and quality of foods in normative documents important for regulation of food security issues. In: *Food Resources*, 2017, 9, pp. 203-210.

3. Duarte Urbina, Y. E., Vargas, P. S. *Seguridad Alimentaria y Nutricional*. Lic. Tesis. Managua, Universidad Nacional Autónoma de Nicaragua, 2016.
4. Sun, D. W. (ed.). *Handbook of frozen food processing and packaging*. – CRC Press, 2016.
5. Bal-Prylypko, L.V. *Innovatsiini tekhnolohii yakisnykh ta bezpechnykh kharchovykh produktiv: monografiia [Innovational technologies of proper and safe meat products: monograph]*. Kyiv: NUBiP Ukrainy, 2012.
6. Garcia, A. C. Figuras, normas y protocolos de calidad como herramienta de mejora de la seguridad alimentaria. In: *Anales de la Real Academia de Ciencias Veterinarias de Andalucía*, 2004, Vol. 17 (1). pp. 229-245.
7. Vyshemirskii, F. A., Silin, V. M. Effektyvnost proizvodstva slivochnogo masla i spredov [Effectiveness of production of butter and spreads]. In: *Syrodellie i maslodellie*, 2005, 3, pp. 22-27.
8. Steele, R. *Understanding and Measuring the Shelf-Life of Food* / R. Steele – Cambridge CB1 6AH, UK: Woodhead Publishing, 2004.
9. Park, J. M., Shin, J. H., Bak, D. J., Kim, N. K., Lim, K. S., Yang, C. Y., Kim, J. M. Determination of shelf life for butter and cheese products in actual and accelerated conditions. In: *Korean journal for food science of animal resources*, 2014, 34(2), pp. 245-251.
10. Vyshemirskii, F. A. Ego velichestvo pergament [His Majesty parchment paper]. In: *Syrodellie i maslodellie*, 2006, 2, pp. 20-21.
11. *Maslo slivochnoe. Tekhnicheskie usloviia [Butter. Specifications]: GOST 32261-2013*. – [In force from: 2015-07-01]. Moscow: Standartinform, 2014.
12. *Maslo vershkove. Tekhnichni umovy [Butter. Specifications]: DSTU 4399:2005*. – [In force from 2007-07-01]. Kyiv: Derzhspozhyvstandart Ukrainy, 2005.
13. Vyshemirskii, F. A., Kaneva, E. F., Gordeeva E. Iu., Vyshemirskaia, K. V. Optimizatsiia temperaturnykh rezhimov khraneniia slivochnogo masla [Optimization of temperature regimes of butter storage]. In: *Pererabotka moloka*, 2009, 2, pp. 20–23.
14. Zaptalov, B. Y., Hrytsun, V. M., Mukovoz, V. M., Obshtat, S. V., Karpulenko, M. S., Koshovyi, V. M. Zminy yakisnykh pokaznykiv masla vershkovoho pry dovhotryvalomu zberihanni v promyslovii morozyl'nii kameri [Alterations of quality parameters of butter amid long-term storage in an industrial freezing room]. In: *Naukovo-tekhnichniy biuleten Naukovo-doslidnoho tsentru biobezpeky ta ekolohichnoho kontroliu resursiv APK*, 2015, 3, pp. 91-95.
15. Vyshemirskii, F. A., Sviridenko, Yu. A., Smirnova, O. I., Levina, N. N., Yakovlev, V. S., Kulikovskaia, T. S., Vasilkova, M. V. O dlitel'nom rezervirovanii spredov [On long-term reservation of spreads]. In: *Syrodellie i maslodellie*, 2004, 4, pp. 27-28.
16. Steele, R., ed. *Understanding and measuring the shelf-life of food*. Woodhead Publishing, 2004.
17. Adler, Iu. P., Markova, E. V., Granovskii, Iu. V. *Planirovanie eksperimenta pri poiske optimalnykh uslovii [Experiment planning while identifying optimal conditions]*. Nauka, 1976.
18. Grachev, Iu. P. Matematicheskie metody planirovaniia eksperimentov [Mathematical methods in planning experiments]. *Pishchevaia promyshlennost*, 1979.
19. Bocharova-Leskina, A. L., Ivanova, E. E., Kosenko, O. V. Prognozirovanie srokov godnosti rybnykh preservov na osnovanii polnogo faktornogo eksperimenta [Forecasting of the expiration date of fish preserves on the basis of complete factorial experiment]. In: *Nauchnyi zhurnal KubGAU*, 2013, 10 (094), pp. 691-703.
20. Schmidt, H. Ueber die Vorgänge beim Ranzigwerden und den Einfluss des Rahmpasteurisirens auf die Haltbarkeit der Butter. In: *Zeitschrift für Hygiene und Infektionskrankheiten*, 1898, 28(1), pp. 163-188.
21. Sun, D. W. *Handbook of frozen food processing and packaging*. – CRC press, 2016.
22. Corradini, M. G. Shelf life of food products: From open labeling to real-time measurements. In: *Annual review of food science and technology*, 2018, 9, pp. 251-269.
23. Grauwet, T., Vervoort, L., Colle, I., Van Loey, A., Hendrickx, M. From fingerprinting to kinetics in evaluating food quality changes. In: *Trends in Biotechnology*, 2014, 32, 125-131.
24. Bocharova-Leskina, A. L., Ivanova, E. E. Matematicheskoe modelirovanie v tekhnologii i otsenke kachestva pishchevykh produktov [Mathematical modeling in technology and quality evaluation of food products]. In: *Nauchnyi zhurnal KubGAU*, 2017, 1 (125), pp. 164-179.
25. Yang, X., Boyle, R. A. Sensory Evaluation of Oils/Fats and Oil/Fat-Based Foods. In: *Oxidative Stability and Shelf Life of Foods Containing Oils and Fats*. AOCS Press, 2016. 157-185.
26. Gaplevskaia, N. M., Serpunina, L. T. Obosnovanie uslovii rezervirovaniia slivochnogo masla [Substantiation of butter reservation technology]. In: *Izvestiia KGTU*, 2012, 27, pp. 80-97.

DOI: 10.5281/zenodo.3444119
CZU [634.7 + 663.26]:519.6:004.8



A FUZZY LOGIC APPROACH FOR MATHEMATICAL MODELING OF THE EXTRACTION PROCESS OF BIOACTIVE COMPOUNDS

Aliona Ghendov-Moșanu^{1*}, ORCID ID: 0000-0001-5214-3562

Rodica Sturza¹, ORCID ID: 0000-0002-2412-5874

Tudor Cherecheș², ORCID ID: 0000-0002-2618-4042

Antoanela Patras³, ORCID ID: 0000-0002-4054-4884

¹Technical University of Moldova, 168, Stefan cel Mare Bd., MD-2004, Chisinau, Republic of Moldova

²UPS PILOT ARM LTD, 19 B, UNIRII Bd., Bucharest, Romania

³"Ion Ionescu de la Brad" UASVM, Iasi, Romania

*Corresponding author: Aliona Ghendov-Moșanu, aliona.mosanu@tpa.utm.md

Received: July, 18, 2019

Accepted: September, 17, 2019

Abstract. The aim of the present study was to optimize the extraction process of bioactive compounds from berries and wastes from the agro-food industry (grape marc). Mathematical models of the extraction process of biologically active compounds based on algorithms of artificial intelligence: fuzzy logic and neuro-fuzzy algorithms have been established. The mathematical models, which use the experimental average values of uncertain models, as well as of some predictive models, offer values of the sizes with a large prediction horizon. It was established, that mathematical models, which use the experimental average values of uncertain models, the experimental data, as well as of some predictive models offer values of the sizes with a large prediction horizon. The existence of various interactions between the influence factors (ethanol concentration, extraction temperature, pretreatment method) and the measured parameters (total polyphenol index, quantity of tannins extracted and antiradical activity, DPPH) was established. The great diversity of processes at different products and various parameters, as well as the existence of non-linear dependencies between sizes, allow credible extrapolations of the results only within the experimental limits.

Keywords: *fuzzy mathematical model, neuro-fuzzy mathematical model, berries, extraction, bioactive compounds.*

Introduction

Classical statistics is based on the law of large numbers, which requests many experimental values. In the case of costly experiments with practical values less numerous, the formulated results can be questionable, because classical statistics offers a single prediction horizon, which is a disadvantage in terms of the conclusions credibility. Various algorithms of artificial intelligence can be applied to establish mathematical models. Thus, it is possible to call on the fuzzy sets, neural networks, neuro-fuzzy algorithms, genetic algorithms, etc. [1].

Fuzzy logic is a type of logic with a series of values specified as a degree of truth instead of true or false binary values [2]. It is considered that the most important application of fuzzy logic is in uncertainty management [3]. Fuzzy logic is a powerful and appropriate tool for managing complex problems in a position where data is incomplete or not very accurate [13]. There are many applications in the field of life sciences, for example, in the risk analysis of some diseases [4, 5], in the analysis of genetic expression data [6-8], in the modeling of enzymatic kinetics [9, 10]. The fuzzy reasoning (the fuzzy algorithm / logic) supposes the execution of rules that link the values of the factorial size (influence factors or independent variables) to those of the resultant size (experimentally measured parameters or dependent variables). These rules are usually created deductively either by man or by a calculation algorithm. Regardless of the system, there are three specific basic steps of establishing a fuzzy model. These are the fuzzification of the factorial and resultant sizes, the generation of the rules base and the convergence of the result (defuzzification) [2, 3]. It is well known that one of the trends of the modern food industry is the complex valorisation of bioactive compounds in natural products and the decrease of the synthetic additives rate [11, 12]. The aim of the present study was to optimize the extraction process of bioactive compounds from berries and wastes from the agro-food industry (grape marc). These raw materials are rich in bioactive compounds - polyphenols, carotenoids, which are of particular interest for the food and pharmaceutical industries [13-16].

The purpose of mathematical modeling consisted in establishing some predictive elements, which allow a good interpolation of the data, assures the highest credibility of the experimental results, including for the values of the influence factors on the extraction process (concentrations of ethyl alcohol), which cannot be found experimentally, as well as establishing the most accentuated and the weakest interdependencies between the measured parameters.

Materials and methods

The experimental research aimed at 3 products (extracts of bioactive compounds from berries and agro-food wastes) and a maximum number of 3 experimental parameters determined [17]. The 3 parameters, symbols and units of measurement used for them are the following:

- 1 – total polyphenols index, symbols P4;
- 2 – the antiradical activity, DPPH, in acidic medium, symbols P5 [%];
- 3 - the quantity of tannins extracted, symbols P9 [mg·3g⁻¹].

The 3 targeted products and the used symbols are:

- 1 – aronia melanocarpa, symbol "a";
- 2 – grape marc, symbol "d";
- 3 – hawthorn, symbol "p".

The experimental data represent finite discrete series, obtaining 3 values of the 3 parameters at each concentration of ethyl alcohol; in 2 products there are 5 concentrations of alcohol (20%, 40%, 50%, 60%, 80%) and in the grape marc there are 6 concentrations (20%, 40%, 50%, 60%, 80%, 96%).

Lotfi A. Zadeh introduced for the first time in 1973 the fuzzy linguistic model, which is a set of written rules in general form. Thus, for two finite discrete sizes some x and y:

$$R_i: \text{IF } x \text{ is } A_i \text{ THEN } y \text{ is } B_i, i=1, 2, \dots, k \quad (1)$$

where: x is the input linguistic variable (of the factorial size),

A_i - the linguistic term (a constant) of the input,

y - the linguistic variable of output (of the resultant size),

B_i - the linguistic term (a constant) of the output. The language terms A_i and B_i are predefined, for example by the form {small (Mc), medium (M), large (Ma)}.

Later, more advanced forms of fuzzy language models emerged. For example, in the Takagi-Sugeno model the set of rules has the general form [18]:

$$R_i: \text{IF } x \text{ is } A_i \text{ THEN } y_i = f_i(x), i = 1, 2, \dots, k \quad (2)$$

The simplest Takagi-Sugeno model is the one in which the functions f_i are straight and so the expression (2) becomes:

$$R_i: \text{IF } x \text{ is } A_i \text{ THEN } y_i = a_i x + b_i, i = 1, 2, \dots, k \quad (3)$$

Based on the above, applying the Takagi-Sugeno algorithm and using the experimental average values, nominal fuzzy models were obtained. Because the systems examined have a multitude of influence factors and many interdependencies, the combined use of neural networks and fuzzy sets was applied to establish the mathematical model (neuro-fuzzy models). For this, the ANFIS (Adaptive NeuroFuzzy Inference System) algorithm was applied using the Matlab program toolbox [19].

Results and discussions

The first step in establishing a mathematical model using fuzzy logic is the fuzzification of the factorial (independent variables) and resultant (dependent variables) sizes of the target process. This is achieved by constructing a function correlated to each from the factorial/resultant sizes. Theoretically, there is infinity of possible forms for these functions, more commonly the triangular, Gaussian or trapezoidal ones being used. Figure 1 shows the example of a triangular shape function to describe the concentration of ethyl alcohol in the 20-80% range; the purpose is to establish the model of type $P4 = f(C_a)$ at the aronia melanocarpa.

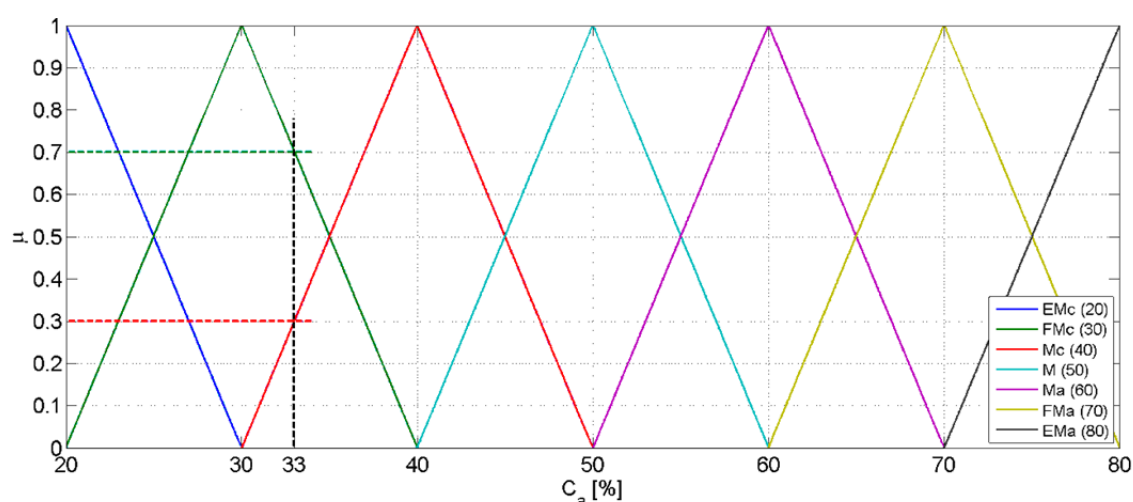


Figure 1. Triangular fuzzy sets (7) for the concentrations of ethyl alcohol (C_a) from aronia fruits in the range 20% - 80%.

The number of corresponding functions can be any number of linguistic variables. The 7 linguistic variables corresponding to the example in figure 1 are: extremely small (EMc, at

which C_a varies around 20%), very small (FMc), small (Mc), medium (M), large (Ma), very high (FMa) and extremely high (EMa), to which are appropriately assigned the values 20%, 30%, 40%, 50%, 60%, 70% and 80%; in the graph, μ represents the multiplication function. Once the correlative function is established for each size, the actual inputs/outputs are fuzzified. First, the input is read as a fixed value. It is considered, for example, that the input is introduced as 33% concentration of ethyl alcohol (figure 1). Then a vertical line is drawn on the axis of the abscissa near $C_a = 33\%$ to indicate its point of intersection with each component of the correlated function. The vertical line intersects on "Mc" to the value 0.3 and "FMc" at 0.7. In linguistic terms, an input of 33 is considered to be 30% small (Mc) and 70% very small (FMc). These are the dispersed values of the C_a input; once this process was completed for all values of the input size, the fuzzification step ended.

To generate the rule base, the correlative function P4 of the outputs must be defined in predetermined. For example, the correlative function in the form of a triangle for the total polyphenols index P4 in aronia extracts, as in Figure 2b. It was found that the linguistic variables corresponding to the output (parameter P4) are defined as: Very Small (FMc), Small (Mc), Medium (M), High (Ma), Very High (FMa) to which are associated values 7; 9.25; 11.5; 13.75 and 16. These values are shown by horizontal lines and in Figure 2a, where both the fuzzy sets for the concentrations of hydroalcoholic extracts (those in Figure 1) and the values of parameter P4 appear. Figure 2 shows the rule base sought, as a series of logical statements "IF-THEN". For example:

$$\text{IF } C_a = \text{FMc} \quad \text{THEN} \quad P4 = \text{Mc} \quad (4)$$

or, otherwise expressed: if C_a is around 30%, then parameter P4 has values around 9.25%.

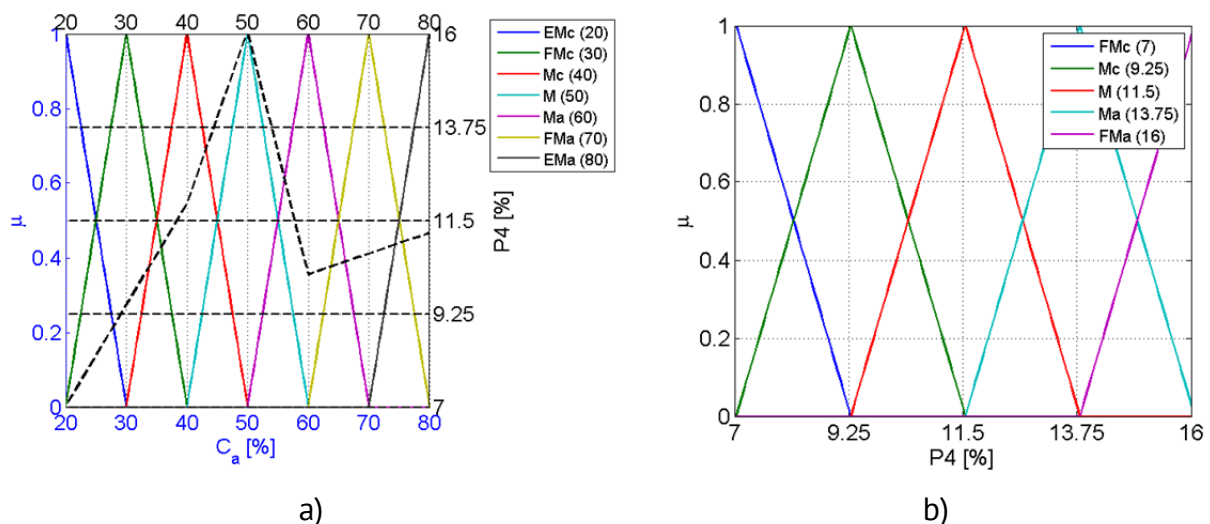


Figure 2. Triangular fuzzy sets (7) for: a) the concentrations of ethyl alcohol (C_a) from aronia fruits in the range 20% - 80%; b) the total polyphenols index P4 in aronia extracts.

Or, another example:

$$\text{IF } C_a = \text{M} \quad \text{THEN} \quad P4 = \text{FMa} \quad (5)$$

otherwise expressed: if C_a is around 50%, then parameter P4 has values around 16% (the maximum for P4 in Figure 2a).

Convergence (defuzzification) is the process of converting dispersed outputs into a single or fixed output value. This process can be accomplished by a few convergence methods. Some common methods include the principles of maximum correlation, centroid method and multiplication method. To identify the fixed value of output y^* by the multiplication method, it is calculated the sum of the multiplications of each multiplication function, μ_y , with the corresponding maximum correlation value and is divided it by the sum of the multiplication functions:

$$y^* = \frac{\sum [\mu_y(\bar{y}) \cdot \bar{y}]}{\sum \mu_y(\bar{y})} \quad (6)$$

It is now considered that the dynamics of a process / system is described on the input-output relationship by the nonlinear regressive model written in the general form [3]:

$$y(k+1) = f(y(k), y(k-1), \dots, y(k-na+1), u(k), u(k-1), \dots, u(k-nb+1)) \quad (7)$$

where: u is input size (factorial variable);

y - output size (resultant variable);

$f(\bullet)$ - nonlinear function.

Expression (7) represents the NARX model (Nonlinear AutoRegressive with eXogenous input), the correspondent of the linear model ARX (AutoRegressive with eXogenous input).

In this case the fuzzy language model has the set of form rules:

$$\begin{aligned} R_i: \quad & \text{IF } y(k) \text{ is } A_{i_1} \text{ and } y(k-1) \text{ is } A_{i_2} \text{ and } \dots y(k-n+1) \text{ is } A_{i_n} \\ & \text{and } u(k) \text{ is } B_{i_1} \text{ and } u(k-1) \text{ is } B_{i_2} \text{ and } \dots u(k-m+1) \text{ is } B_{i_m} \\ & \text{THEN } y(k+1) \text{ is } C_i \end{aligned} \quad (8)$$

For the case of the Takagi-Sugeno algorithm the mathematical model from the expression (8) becomes:

$$y^i(k+1) = \sum_{j=1}^{na} A_j^i y(k-j+1) + \sum_{j=1}^{nb} B_j^i u(k-j+1) \quad (9)$$

Consequently, the one-step prediction of the output size is:

$$y(k+1) = \sum_{i=1}^c \beta_i(u(k)) y^i(k+1) \quad (10)$$

where c represents the number of rules, and β_i the weight of rule i .

The relation (10) can be written as:

$$y(k+1)^T = \sum_{i=1}^c \beta_i(u(k)) [\Phi(k) I_{1 \times na}] \theta_i^T \quad (11)$$

in which $\Phi(k)$ represents the regression matrix (the regression matrix for the input and output sizes):

$$\Phi(k) = [y(k), \dots, y(k-na+1), u(k), \dots, u(k-nb+1)]^T \quad (12)$$

and θ_i the matrix of the parameters of the local model i (rule i):

$$\theta_i = [A_1^i, \dots, A_{na}^i, B_1^i, \dots, B_{nb}^i] \quad (13)$$

Based on the relationships presented, the values for the parameters of the fuzzy model are obtained, using for example the least squares method:

$$\theta_i = [\Phi^T \Psi_i \Phi]^{-1} \Phi^T \Psi_i Y \quad (14)$$

In the expression (14) it was noted:

$$\Phi = [\Phi(1) \quad \Phi(2) \quad \dots \quad \Phi(n)]^T; Y = [y(2) \quad y(3) \quad \dots \quad y(n+1)]^T \quad (15)$$

and respectively:

$$\Psi_i = \begin{bmatrix} \beta_i(1) & 0 & \dots & 0 \\ 0 & \beta_i(2) & \dots & 0 \\ \dots & \dots & \dots & \dots \\ 0 & 0 & \dots & \beta_i(n) \end{bmatrix} \quad (16)$$

According to the presented relations, it turns out that the values of the resulting size are calculated with a written expression in compact form as follows:

$$Y = \Psi \theta \quad (17)$$

The following is a mathematical model that offers the interdependence between parameter P4 (resultant size, total polyphenols index), concentration of ethyl alcohol C_a and parameter P5 (the antiradical activity, DPPH, in acidic medium, AAA). The analysis of the experimental data showed that there are dependencies between the various measured parameters.

Being two factorial sizes, we adopt fuzzy spatial sets, here triangular, which has on the right side the graduated scale in values and colors with μ_i values.

As shown in Figure 3, 6 fuzzy sets along the C_a axis and 6 sets along the P5 axis were adopted for the mathematical model $P4 = f(C_a, P5)$, so a total of 36 sets; as a result, the fuzzy model will have 36 coefficients θ in expressions (13) and (17).

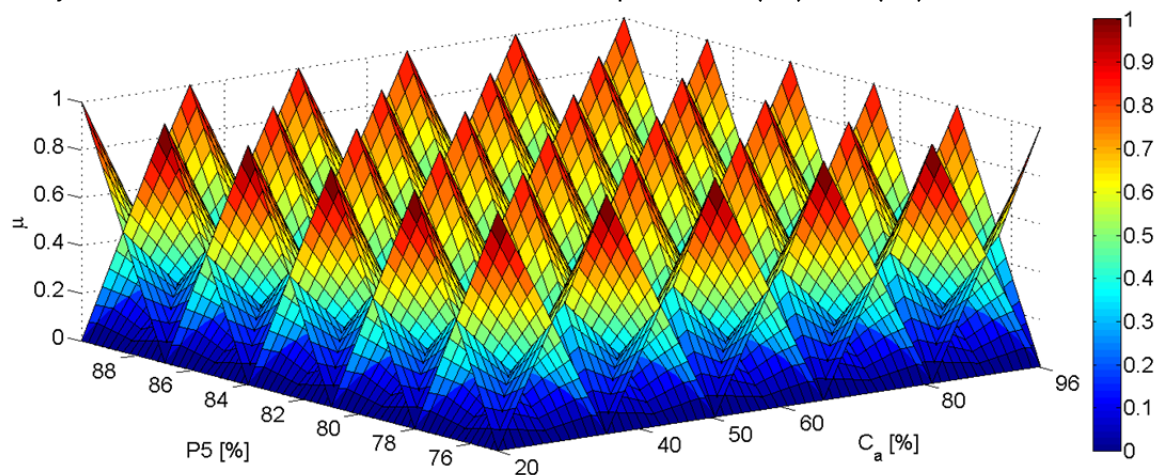


Figure 3. Fuzzy mathematical model $P4 = f(C_a, P5)$ at the grape marc, fuzzy triangular sets (6 and 6).

Figure 4 shows the fuzzy calculation surface, on which the points with the experimental values of parameter P4 are arranged.

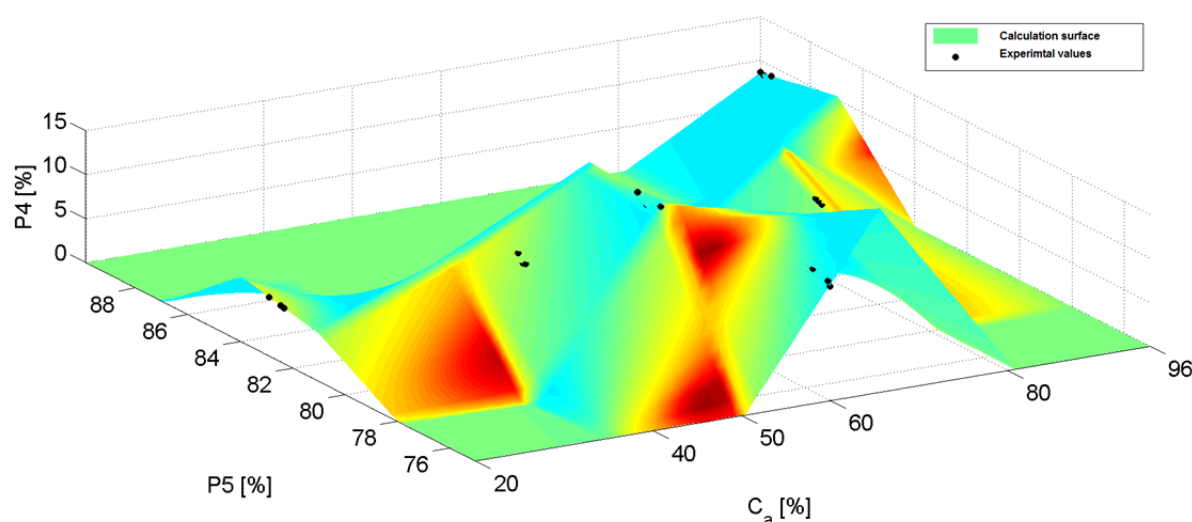


Figure 4. Fuzzy mathematical model $P4 = f(C_a, P5)$ at the grape marc, experimental values and calculation surface.

The graph in Fig. 5a contains the weights of the fuzzy sets β_i from the expression (11), which is the matrix Ψ_i from the relation (16), respectively Ψ from the general formula (17) of the mathematical model.

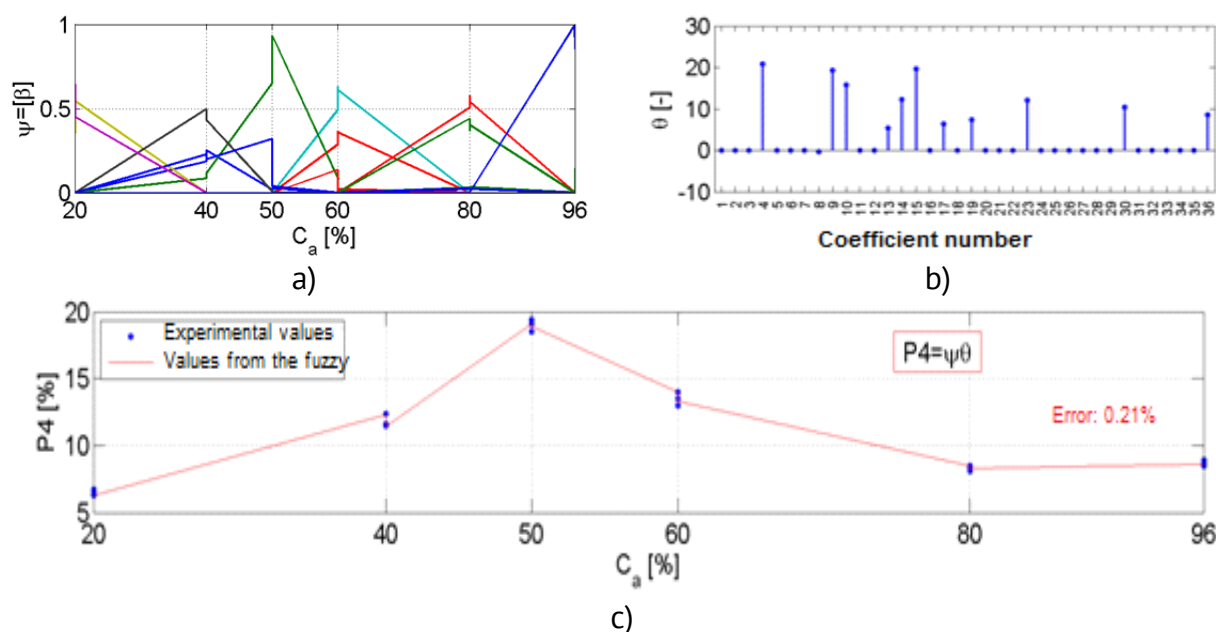


Figure 5. Fuzzy mathematical model $P4 = f(C_a, P5)$ at the grape marc, weights, coefficients, experimental values from the fuzzy model.

Figure 5b shows the values of the 36 coefficients θ_i from the expression (14) of the fuzzy model, so the vector Θ from the relation (17) that also appears on the graph in Figure 5c, where the experimental and fuzzy model values are presented, as well and modeling error, which is acceptable.

Mathematical models based on neuro-fuzzy algorithms

In this case we resort to the combined use of neural networks and fuzzy sets to establish the mathematical model (neuro-fuzzy models). For this, the ANFIS (Adaptive

NeuroFuzzy Inference System) algorithm is applied using the Matlab software toolbox; this toolbox uses the previously presented fuzzy sets (membership function) as well as others [19]. The principle diagram of the ANFIS algorithm is presented in Fig.6, where its main elements are shown.

The ANFIS algorithm applies neuro-adaptive learning techniques, which provide the needed data for modeling with the help of fuzzy sets.

Using input and output data (factorial variables and resultant sizes), a system is

constructed whose fuzzy sets adjust the coefficients of the mathematical model by a neural networks specific algorithm. For this purpose, the number of activation functions (used in neural networks - figure 7) must be equal to that of the fuzzy rules, and the algorithm is based on the fuzzy neuron. The ANFIS architecture is similar to the Takagi-Sugeno algorithm. It is considered, that the system is characterized by two input sizes u_1 and u_2 and an output size y . Consequently, if, for example, the basis of Sugeno-type rules of the first order (linear variation) is adopted, then it results:

$$\text{IF } u_1 \text{ is } A_1 \text{ and } u_2 \text{ is } B_1 \text{ THEN } y_1 = c_{11}u_1 + c_{12}u_2 + c_{10} \quad (18)$$

and respectively:

$$\text{IF } u_1 \text{ is } A_2 \text{ and } u_2 \text{ is } B_2 \text{ THEN } y_2 = c_{21}u_1 + c_{22}u_2 + c_{20} \quad (19)$$

in which c_{ij} are the coefficients of the mathematical model, i. e. the managed parameters by the fuzzy sets that adjust their values through a neural networks specific algorithm.

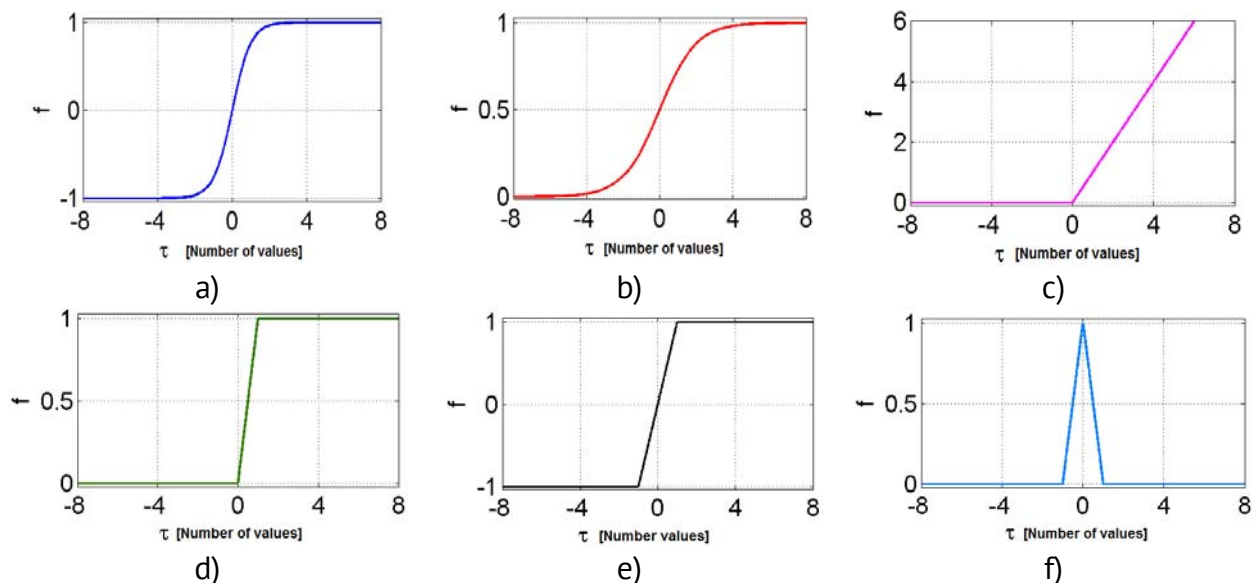


Figure 7. Discrete transfer functions used in neural networks and neuro-fuzzy algorithms: a) tansig type; b) logsig type; c) poslin type; d) satlin type; e) satlins type; f) tribas type.

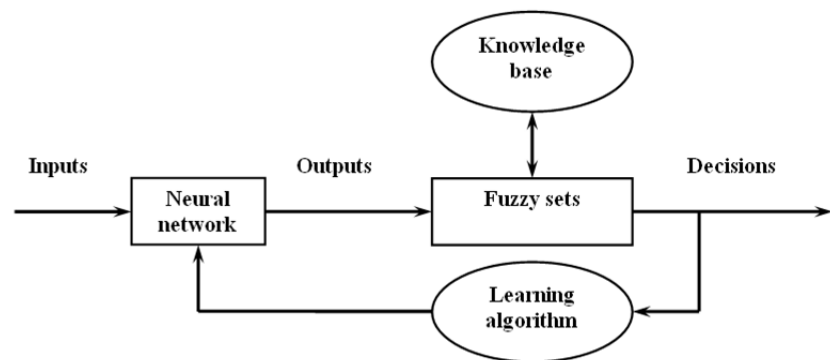


Figure 6. Principle diagram of the ANFIS algorithm.

Figure 8 presents the results of applying the ANFIS algorithm for establishing a mathematical model that offers the values of parameter P2, hawthorn, depending on the concentration of ethyl alcohol. It can be seen that in the upper graphs 13 fuzzy Gaussian sets were used, and in the lower trapezoidal ones.

In this case it followed to establish the nominal model, because it operates with the average values at each concentration of ethyl. Modeling accuracy is all the better as the number of fuzzy sets adopted is higher. The results of the mathematical modeling carried out can be presented in tabular form, for all 6 products concerned, for all the measured parameters, with a calculation step of 2 - 4% of the concentration of the ethyl alcohol with the best precision (the smallest modeling error).

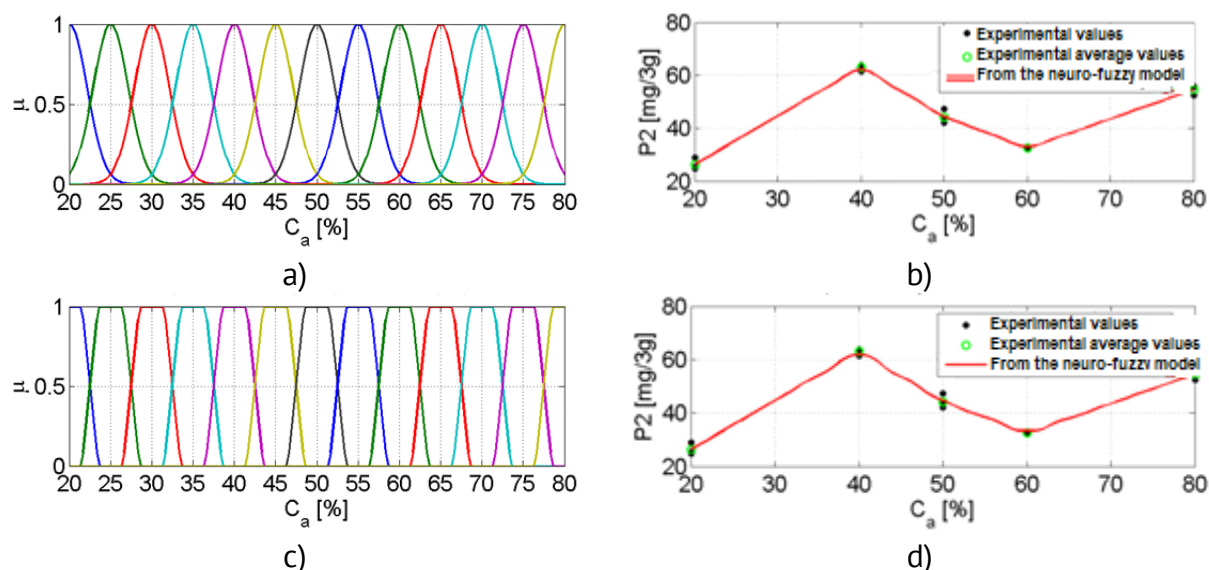


Figure 8. Neuro-fuzzy mathematical model (ANFIS algorithm), parameter P2 from hawthorn depending on the concentration of ethyl alcohol.

For example, Figure 9 shows the nominal / average values (index n) of the tannin mass $P9$, the extracted tannin mass $P9_e$ and the extracted total mass $P9_t$ depending on the number of extractions k (with $k \in Z^+$, with Z^+ the set of positive integers).

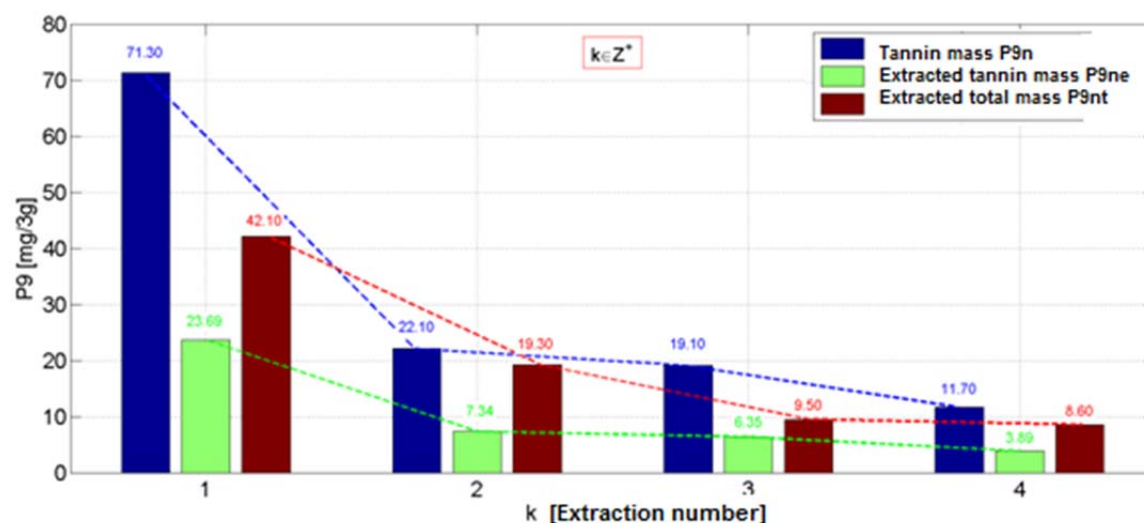


Figure 9. Nominal / average values (index n) of tannin mass $P9_n$, extracted tannin mass $P9_{ne}$ and extracted total mass $P9_{nt}$ depending on the number of extractions.

The values decrease with the order of extraction. This aspect is also confirmed in Figure 10, which shows the nominal and uncertain mathematical models, as well as the analytical expressions of the mathematical models on the 3 portions of the curve (indices 1, 2, 3), both nominal ones (index n), as well as and the uncertain upper (index s) and lower ones (index i). For example, to determine the total mass of tannins at the fourth extraction (at $k = 4$), then the expressions on the third portion are applied, where k is introduced as a difference from the left end, i. e. for $k=4-3=1$. As a result, for the nominal value: $P9_{m3}(4) = 0.151 \cdot 1^3 + 0.597 \cdot 1^2 - 1.649 \cdot 1 + 9.5 = 8.6 \text{ mg} \cdot 3\text{g}^{-1}$, so exactly the experimental value.

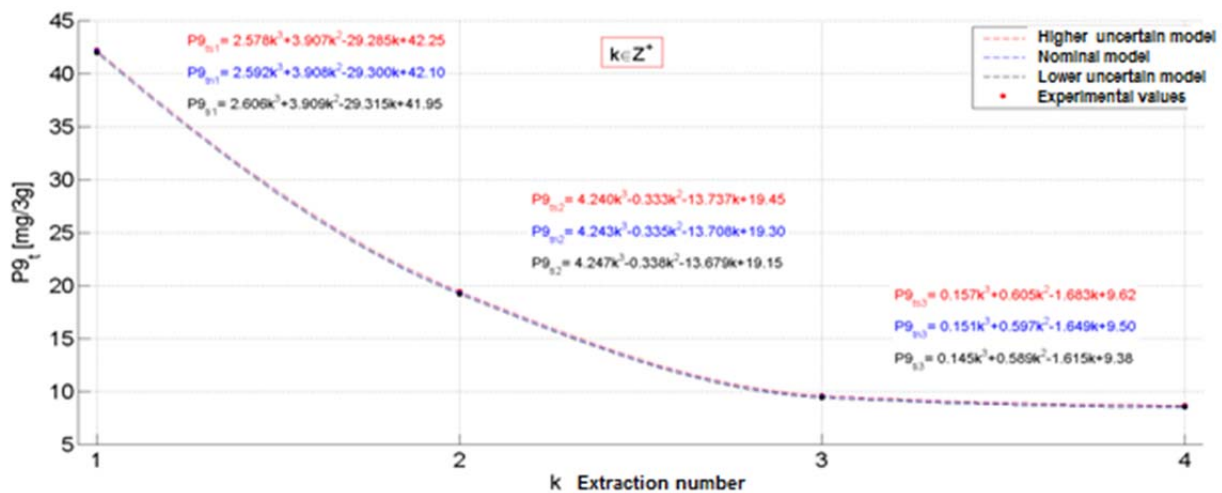


Figure 10. Mathematical modeling of the total mass of tannins according to the number of extractions.

Obviously, for the left end (at $k = 3$), in the previous expression the value $k = 0$ must be entered, where it results: $P9_{m3}(3) = 0.151 \cdot 0^3 + 0.597 \cdot 0^2 - 1.649 \cdot 0 + 9.5 = 9.5 \text{ mg} \cdot 3\text{g}^{-1}$, so exactly the experimental value. Obviously, mathematical models can be established, including through value tables for any experimental duration, and for each of them other conditions other than experimental ones are adopted.

Conclusions

Establishing mathematical models based on experimental data allowed:

- ✓ deduction of mathematical models in analytical and graphical form;
- ✓ establishing the values of the targeted parameters and of the influencing factors (concentration of ethyl alcohol) that are not experimentally found;
- ✓ deduction of mathematical models based on artificial intelligence algorithms such as fuzzy logic and neuro-fuzzy algorithm;
- ✓ establishing some mathematical models that offer the values of the measured parameters according to the influence factors, as well as models that establish the interdependencies between these parameters;
- ✓ deduction of some nominal mathematical models, which use the experimental average values of uncertain models, which use all the experimental data, as well as of some predictive models, which offer values of the sizes with a large prediction horizon.

Mathematical models that use artificial intelligence algorithms, such as fuzzy logic and neuro-fuzzy algorithm, indicate the existence of diversified phenomena between influence factors and measured parameters.

Acknowledgments

This work benefited of support within the Postdoctoral project “*Obtaining and stabilizing dyes, antioxidants and preservatives of plant origin for functional foods*”, funded by the Government of the Republic of Moldova.

References

1. Motta, S., Pappalardo, F. Mathematical modeling of biological systems. In: *Brief. Bioinform.*, 2012, 14 (4), pp. 411–422.
2. Aliwi, B.H. Mathematical Model for Fuzzy Systems. 2009. Available at: <https://www.researchgate.net/publication/309238308>.
3. Molina Mora, J.A. Fuzzy logic as a Tool for Mathematical Modeling in Life Sciences. In: *International Journal of Life Sciences Research*, 2016, 4 (3), pp: 90-95
4. Hndoosh, R.W., Kumar, S., Saroa, M.S. Fuzzy mathematical models for the analysis of fuzzy systems with application to liver disorders. 2014, DOI: 10.9790/0661-16577185. <https://www.researchgate.net/publication/269928153>.
5. Yilmaz, A., Ayan, K. Cancer risk analysis by fuzzy logic approach and performance status of the model. In: *Turkish J. Electr. Eng.*, 2013, pp. 1–27.
6. Khashei, M., Zeinal Hamadani, A., Bijari, M. A fuzzy intelligent approach to the classification problem in gene expression data analysis. In: *Knowledge-Based Syst.*, 2012, 27, pp. 465–474.
7. Zhang, S., Wang, R., Zhang, X., Chen, L. Fuzzy System Methods in Modeling Gene Expression and Analyzing Protein Networks. In: *Fuzzy Systems in Bioinformatics and Computational Biology*, 2009, 242, pp. 165–189.
8. Vineetha, S., Chandra Shekara Bhat, C., Idicula, S.M. Gene regulatory network from microarray data of colon cancer patients using TSK-type recurrent neural fuzzy network. In: *Gene*, 2012, 506 (2), pp. 408–416.
9. Aldridge, B.B., Saez-Rodriguez, J., Muhlich, J.L., Sorger, P.K., Lauffenburger, D.A. Fuzzy logic analysis of kinase pathway crosstalk in TNF/EGF/insulin-induced signaling. In: *PLoS Comput. Biol.*, 2009, 5 (4), p. e1000340.
10. Furlong, V.B., Corrêa, L.J., Giordano, R.C., Ribeiro, M.P.A. Fuzzy-Enhanced Modeling of Lignocellulosic Biomass Enzymatic Saccharification. In: *Energies*, 2019, 12 (11), pp. 2110
11. Cristea, E., Sturza, R., Jauragi, P., Niculaua, M., Ghendov-Moșanu, A., Patras, A. Influence of pH and ionic strength on the color parameters and antioxidant properties of an ethanolic red grape marc extract. In: *Journal of Food Biochemistry*, 2019, 43 (4), e12788.
12. Burri, S. C., Ekholm, A., Hakansson, A., Tornberg, E., Rumpunen, K. Antioxidant capacity and major phenol compounds of horticultural plant materials not usually used. In: *Journal of Functional Foods*, 2017, 38 (A), pp. 119-127.
13. Chaman, S., Syed, N. H. (2011). Phytochemical analysis, antioxidant and antibacterial effects of sea buckthorn berries. *Pakistan Journal of Pharmaceutical Sciences*, 24 (3), 345-351.
14. Ghendov-Moșanu, A., Cojocari, D., Balan, G., Sturza, R. Antimicrobial activity of rose hip and hawthorn powders on pathogenic bacteria. In: *Journal of Engineering Science*, 2018, 4, pp. 100-107.
15. Demir, N., Yioldiz, O., Alpaslan, M., Hayaloglu, A.A. Evaluation of volatiles, phenolic compounds and antioxidant activities of rose hip (*Rosa L.*) fruits in Turkey. In: *LWT - Food Science and Technology*, 2014, 57, pp. 126-133.
16. Ghendov-Moșanu, A., Popescu, L., Lung, I., Opriș, O.-E., Soran, M.-L., Sturza, R. Utilizarea extractului de păducel pentru fabricarea cremei de brânză funcțională [The use of hawthorn extract for manufacture of functional cheese cream]. In: *Akados*, 2018, 4 (51), pp. 45-51.
17. Cristea, E., Sturza, R., Patraș, A. The influence of temperature and time on the stability of the antioxidant activity and colour parameters of grape marc ethanolic extract. In: *The Annals of the University Dunarea de Jos of Galati, Fascicle VI – Food Technology*, 2016, 39(2), pp. 96-104.
18. Takagi, T., Sugeno, M. Fuzzy Identification of Systems in Application to Modeling and Control. In: *IEEE Trans. SMC*, 1985, 15.
19. Koivo, H. Anfis (Adaptive Neuro-Fuzzy Inference System), 2000, p. 25. Available at: <ftp.unicauca.edu.co/docs/Materias/FVAnfis2>.

DOI: 10.5281/zenodo.3444127
CZU 663.257.3:678.7



TARTARIC STABILIZATION OF GRAPE JUICE WITH IONIC EXCHANGE RESINS

Roman Golubi, ORCID ID: 0000-0003-4444-9515

Scientific-Practical Institute of Horticulture and Food Technologies, 59 Vieru str., Codru, Kishinau, Moldova
Corresponding author: Roman Golubi, rg095@yahoo.fr

Received: August, 14, 2019

Accepted: September, 27, 2019

Abstract. The limpidity of grape juice is a quality requirement asked at placing in trade networks, because consumers prefer a drink with clear transparency. A specific phenomenon is the formation of tartaric crystals during long storage or maintenance at temperatures below 0 -1°C. The traditional tartaric stabilization procedures indicates disadvantages on power consumption and duration, requirements specific to the equipment, etc. For this aim were studied the effect of five types of anionic resin to grape juice, developed a method for grape juice tartaric stabilization based on mathematic model the central rotary matrix, using the most effective resin Purolite A-400.

Keywords: *potassium bitartrate, anionic resin, duration of process, limpidity of juice, mass of formed crystals, mathematical model.*

Introduction

The limpidity of grape juice is a quality requirement asked at placing in trade networks, because consumers prefer a drink with clear transparency, this fact gives more confidence in the safety of the product. A specific phenomenon for grape products is the formation of tartaric crystals during long storage or maintenance in premises with temperatures below 0-1°C. These crystals are the consequence of the chemical reaction of potassium and calcium ions with tartaric acid [1-3]. To prevent this phenomenon, several methods [11-12 and 18] are used in the manufacturing process as: cold treatment, electrodialysis and the introduction of metatartaric acid.

Tartaric stabilization of grape juice by cold treatment provides cooling of freshly pressed juice up to the temperature of $0 \pm 1^\circ\text{C}$ and maintaining 36-48 hours for tartar precipitation and clarification, the cooled juice is decanted and isothermal filtrated [4, 6, 7]. This traditional method requires a lot of time and energy, therefore, it has been proposed a faster process [20], lasting up to 2 hours, due to the introduction of obtained tartaric crystals in the juice which is cooled to the stabilization temperature of the $0 \pm 1^\circ\text{C}$ and using centrifugation for juice clarification.

Tartaric stabilization of grape juice by electrodialysis [9-10] consists in reducing the initial concentration of potassium ions from $1200 \text{ mg}\cdot\text{dm}^{-3}$ to $1800 \text{ mg}\cdot\text{dm}^{-3}$ to values from $800 \text{ mg}\cdot\text{dm}^{-3}$ to $900 \text{ mg}\cdot\text{dm}^{-3}$, under the action of the potential difference with values from 120 V to 180 V between the working and intermediate installation block sections. Juice is

transferred in the working sections and the intermediate ones contain rinsing water. The pressure of the juice and water respectively in the installation should be more than 0.3 MPa.

The third tartaric stabilization method [4, 8] requires that the juice cooled to 25-30 °C and double filtered should be transferred to the tanks where metatartaric acid is added in the amount from 0,5 g·dm⁻³ to 6 g·dm⁻³. In advance to prepare solution of the acid metatartaric with a concentration from 250 g·dm⁻³ to 300 g·dm⁻³ in the clarified juice, then it is added to the tank to be mixed with all the juice, intended for packaging. Mixing takes 5-6 min then juice is heated since 60-70 °C and packaged. Hot filling with metatartaric acid is not allowed. The analysis of the tartaric acid stabilization methods indicates that every one of them has disadvantages on power consumption and duration, requirements specific to the equipment, etc. Therefore, there was proposed to establish a method for tartaric stabilization of the grapes juice using resins of ionic exchange [13, 16 and 17] which can provide the necessary requirement of clarity in a manner that is simple, fast and economical.

Materials and methods

For tartaric stabilization of grape juice there were selected 5 types of anionic resins: Amberlite IRA-410 [14], Amberlite IRA-67 [15], AV-17 [18], AN-31 [18] and Purolite A-400 [21]. With these resins juice samples were treated and by high performance liquid chromatography (HPLC) method [19] was determined the variation of the organic acids composition. Depending on the lowest content of tartaric acid in the juice, it was decided which resin will be used in further research. A mathematical model was developed with the factorial design of the experiments [5], where the temperature had a constant value 30 °C and 2 variable parameters were chosen: *resin quantity* (C_R) and *treatment duration* (τ). By the response factor was established *the mass of crystals* formed in cold treatment that provided at cooling of grape products samples (acidifiers and juices) up to the temperature with values of 0-1°C and maintain at this temperature for 48 hours. The separation of the tartaric sediments from the liquid part of the samples was done cold by decanting procedure. The mass of the tartaric crystals was weighed at the analytical balance.

For mathematical model elaboration the central rotary matrix was selected, where by x_1 , x_2 were encoded the variable parameters of the tartaric stabilization process: the *resin quantity* and *the treatment duration*. The minimum, centre and maximum values used were noted, see Table 1.

Table 1

The attribution matrix of influence factor values in the mathematical model				
Input factor in the mathematical model	Coding	Min. (-)	Center	Max. (+)
Ionic exchange resin quantity, g·dm ⁻³ juice	x_1	5	10	15
Duration of treatment of juice with resin, min.	x_2	5	10	15

Results and discussions

Treatment of grape juice samples with different types of anionic resins, during 20 min., had the effect of decreasing the concentrations of organic acids, established by the method of high performance liquid chromatography (see Table 3). Maximum efficiency had resin Purolite A-400, strong basic anionite, with polystyrene-divinylbenzene matrix and quaternary ammonium functional groups with a high operating capacity. This type of resin was selected for conducting the experiment of tartaric stabilization of grape juice.

Table 3

Effect of treatment of grape juice on the content of organic acids

Organic acids in grape juice	Content of organic acids after treatment with ionic exchange resins (g·dm ⁻³)					
	untreated juice	Amberlite IRA 410	Amberlite IRA 67	Purolite A-400	AV 17	AN 31
Tartaric	7.52	7.31	7.29	6.91	7.11	7.26
Malic	6.34	6.20	6.23	4.89	5.15	5.79
Citric	1.42	1.37	1.30	1.25	1.29	1.34

The juice treatment process was developed with Purolite A-400 resin, similar to the resin separation of carboxylic acids [13], based on a rotary compound central plane (see Table 4).

For the calculation of regression coefficients b the matrix with factors $\bar{y} \cdot x_{ij}$ was made and the obtained results are presented in the Tables 5 and 6.

Table 4

Rotary compound central plan for juice treatment with ionic exchange resin

C_R		T		x_0	x_1	x_2	$x_1 \cdot x_2$	$(x_1')^2$	$(x_2')^2$	y_1	y_2	\bar{y}
Z1 min	5	Z2 min	5	1	-1	-1	1	1	1	2.880	2.900	2.890
Z1 max	15	Z2 min	5	1	1	-1	-1	1	1	2.100	2.080	2.090
Z1 min	5	Z2 max	15	1	-1	1	-1	1	1	0.900	0.920	0.910
Z1 max	15	Z2 max	15	1	1	1	1	1	1	0.080	0.060	0.070
Z1 - α	3	Z2 0	10	1	-1.414	0	0	2	0	2.330	2.320	2.325
Z1 + α	17	Z2 0	10	1	1.414	0	0	2	0	0.225	0.235	0.230
Z1 0	10	Z2 - α	3	1	0	-1.414	0	0	2	2.880	2.920	2.900
Z1 0	10	Z2 + α	17	1	0	1.414	0	0	2	0.110	0.120	0.115
Z1 0	10	Z2 0	10	1	0	0	0	0	0	0.940	0.920	0.930
Z1 0	10	Z2 0	10	1	0	0	0	0	0	0.930	0.910	0.920
Z1 0	10	Z2 0	10	1	0	0	0	0	0	0.915	0.935	0.925
Z1 0	10	Z2 0	10	1	0	0	0	0	0	0.900	0.920	0.910
Z1 0	10	Z2 0	10	1	0	0	0	0	0	0.940	0.910	0.925

Table 5

Factor matrix $\bar{y} \cdot x_{ij}$ of the rotating composite central plan of experiences

Exp.	C_R	T	y_1	y_2	\bar{y}	σ^2	$\bar{y} \cdot x_0$	$\bar{y} \cdot x_1$	$\bar{y} \cdot x_2$	$\bar{y} \cdot x_{1,2}$	$\bar{y} \cdot (x_1')^2$	$\bar{y} \cdot (x_2')^2$
1	5	5	2.880	2.900	2.890	0.000200	2.890	-2.890	-2.890	2.890	2.890	2.890
2	15	5	2.100	2.080	2.090	0.000200	2.090	2.090	-2.090	-2.090	2.090	2.090
3	5	15	0.900	0.920	0.910	0.000200	0.910	-0.910	0.910	-0.910	0.910	0.910
4	15	15	0.080	0.060	0.070	0.000200	0.070	0.070	0.070	0.070	0.070	0.070
5	3	10	2.330	2.320	2.325	0.000050	2.325	-3.288	0.000	0.000	4.650	0.000
6	17	10	0.225	0.235	0.230	0.000050	0.230	0.325	0.000	0.000	0.460	0.000
7	10	3	2.880	2.920	2.900	0.000800	2.900	0.000	-4.101	0.000	0.000	5.800
8	10	17	0.110	0.120	0.115	0.000050	0.115	0.000	0.163	0.000	0.000	0.230
9	10	10	0.940	0.920	0.930	0.000200	0.930	0.000	0.000	0.000	0.000	0.000

Continuation Table 5

10	10	10	0.930	0.910	0.920	0.000200	0.920	0.000	0.000	0.000	0.000	0.000
11	10	10	0.915	0.935	0.925	0.000200	0.925	0.000	0.000	0.000	0.000	0.000
12	10	10	0.900	0.920	0.910	0.000200	0.910	0.000	0.000	0.000	0.000	0.000
13	10	10	0.940	0.910	0.925	0.000450	0.925	0.000	0.000	0.000	0.000	0.000
$\Sigma \bar{y} \cdot x_{ij}$						16.140	-4.602	-7.938	-0.040	11.070	11.990	

In order to obtain the results of the output parameter *the mass of the tartaric crystals* formed, 13 experiments were performed each in 2 repetitions, where the input parameters *the resin quantity* and *the treatment duration* had maximum, minimum and center values. The average response \bar{y} was the average of the two parallel experiments y_1 and y_2 , which represent the weighed masses of tartaric crystals formed in juice during maintenance for 48 hours at low temperature values 0...+1°C.

Table 6

Regression coefficients of the second order equation of the rotary compound central plane

b_0	b_1	b_2	$b_{1,2}$	b_{11}	b_{22}
0.9220	-0.5753	-0.9922	-0.0100	-0.0227	0.1096

The coefficients $b_{1,2}$ and b_{11} have insignificant values and were subsequently omitted the regression equation of the treatment process with ion exchange resin of grape juice, the following form was obtained:

$$y = 0.9220 - 0.5753 \cdot x_1 - 0.9922 \cdot x_2 + 0.1096 \cdot x_{22} \quad (1)$$

After decoding and transformation into real factors, the regression Eq (1) obtained the polynomial function form of a second degree, containing 2 variable factors:

$$M = f(R; T) = 4.6500 - 0.0930 \cdot R - 0.2824 \cdot T + 0.044 \cdot T^2 \quad (2)$$

where: **M** – mass of tartaric crystals formed in grape juice cooled at 0-1°C, g;

R – amount of resin used for treatment, g·dm⁻³; **T** – duration of treatment, min.

Dispersions on the periphery, in the plan center and degrees of freedom m were calculated, the obtained results are presented in Table 7:

Table 7

Dispersions on the peripheries and centre of the rotary compound central plan

$S_1^2 = \Sigma(y_j - \bar{y})^2$	$S_1^2 = \Sigma(y_{0j} - \bar{y}_{0j})^2$	$S_3 = S_1^2 - S_2^2$	n	m_1	n_0	m_2	m_3
0.001750	0.000230	0.001520	13	12	5	4	8

The Fisher criterion was calculated according to the formula:

$$F_{calculated} = \frac{0.001520/8}{0.000230/4} = 3.30$$

In order to ascertain the veracity of the hypothesis that the developed mathematic model it is true, it has been determined the number of degrees of freedom of the m_3 (for the dispersion of the non-volatile S_3), also m_2 (for the dispersion of the reductibility S_2^2).

Depending on the degrees of freedom and chosen error level $q = 0.05$ Fisher criterion value $F_{tab}(q; m_3; m_2)$ was found therefore were obtained following values:

$$q=0.05; m_3=8; m_2=4; F_{tab}(0.05;8;4) = 3.63$$

Since the condition $3.30 < 3.63$ was established, respectively $F_{calculated} < F_{tab}(0.05;8;4)$ follows that the regression Eq is true, respectively and the mathematical model developed on the basis of the rotary compound central plan is also true.

Based on the regression Eq (2) values of the mass of tartaric crystals were calculated depending on the values of the quantity of the ionic exchange resin and the treatment duration. As a consequence, it was determined what values of the mentioned variation factors in grape juice are not formed tartaric crystals, that the response function has values equal to „0”. Using the MS Excel 2007 software, the mathematical model was developed in the form of a 3D surface, see figure 1.

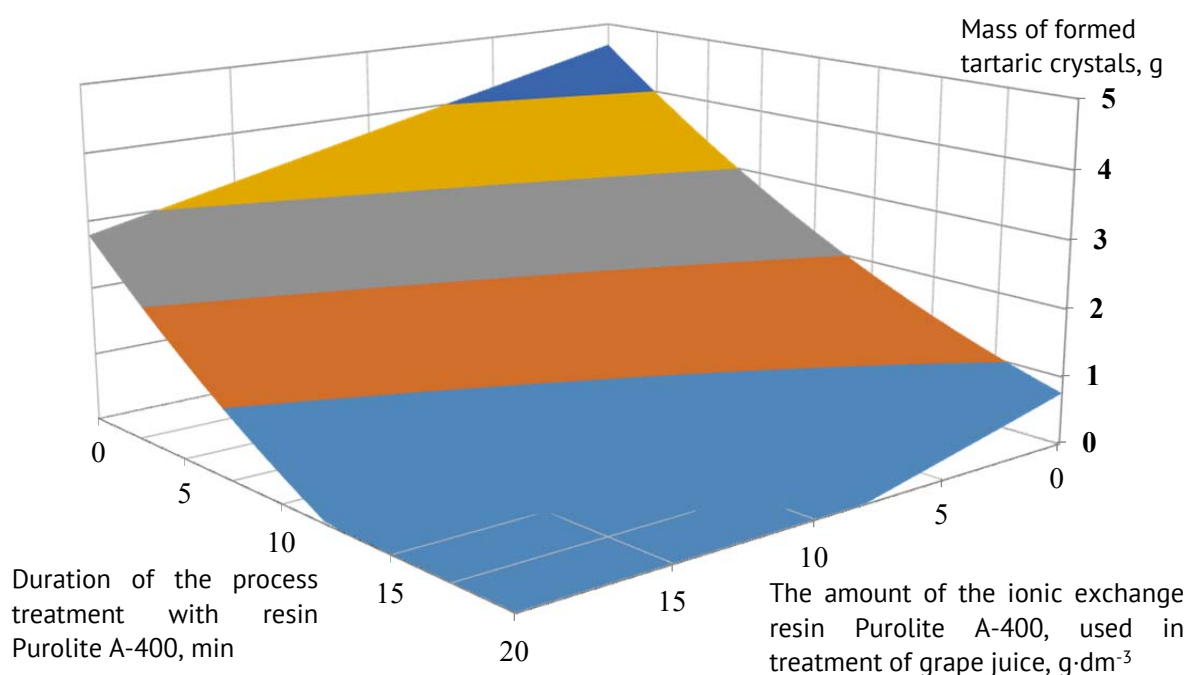


Figure 1. Graphical representation of the mathematical model of diminishing the formation of tartaric crystals in grape juice treated with ionic exchange resin.

In accordance to the values of the Eq of the applied mathematical model and the graphic representation obtained, it has been determined the optimum parameters to ensure the tartaric stability of grape juice which includes: resin Purolite A-400 has reducing effect to the crystalline tartaric sediments formation at amount since 10 g at 1 dm³ of juice and treatment duration from 12 min. Tartaric crystalline sediments were not formed in grape juice when Purolite A-400 ionic exchange resin was applied in amounts of 16-18g·dm⁻³ and the treatment time was between 15-16 min.

The process of acidity stabilization in grape juice with ionic exchange resin can be scientifically explained based on the results obtained in the quantitative analysis by the HPLC method. They show 20 % decrease of the amount of tartaric acid in Isabella variety acidifier from values of 7.7-8.0g·dm⁻³ to values of 6.0-6.1g·dm⁻³. Tartaric acid was adsorbed on the surface of the ionic exchange resin spheres and the amount of malic acid with the

value of $10.9\text{g}\cdot\text{dm}^{-3}$ (its was decrease) had buffer effect. That's why favorable conditions were not created for sedimentation of potassium acid tartrate, sodium-potassium neutral tartrate and calcium tartrate.

Conclusions

A process of grape juice tartaric stabilization with ionic exchange resins was proposed as alternative to traditional methods (cold treatment, electrodialysis and introduction of metatartaric acid). From five types of anionic resins there was selected Purolite A-400, which most effectively diminished the content of tartaric acid in juice samples, as it was demonstrated by the method of high performance liquid chromatography. The development of tartaric stabilization process was based on mathematic model, ensuring the limpidity of grape juice by adding Purolite A-400 resin in the count of $18\text{g}\cdot\text{dm}^{-3}$ during 15-16 min.

Acknowledgments

We would like to express our sincere gratitude to the Department of Technological Chemistry of the Moldova State University for the collaboration and the offer of anionic resins at developing the tartaric stabilization process in grape juice.

References

1. Odăgeriu, Gh. T. Evaluarea solubilității compușilor tartrici în vinuri [Solubility evaluation of tartaric compounds in wines]. Iași, Editura „Ion Ionescu de la Brad”, 2006.
2. Cotea V. D., Zănoagă C. V., Cotea V. V., Tratat de oenochimie [Treaty oh oenochemistry], vol. I, Editura Academiei Române, București, 2009.
3. ȚÎRDEA C., Chimia și analiza vinului [Chemistry and analysis of wine], Editura „Ion Ionescu de la Brad”, Iași, 2007.
4. Ribereau-Gayon P., Glories Y., Maujean A., Dubourdieu D. Handbook of Enology Volume 2. The Chemistry of Wine Stabilization and Treatments 2nd Edition. Original translation by Aquitrad Traduction, Bordeaux France. Revision translated by Christine Rychlewski. Ed. John Wiley & Sons, Ltd. 2006.
5. Coman Gh. Managementul cercetării [Research management]. Ed. PIM, Iași, 2009.
6. Vacarciuc L. Vinul: alte vremuri, alte dimensiuni. Compendiu oenologic [Wine: other times, other dimensions. Oenological compendium], Chișinău: S. n., 2015 (F.E.-P. „Tipografia Centrală”).
7. Sturza R., Covaci E. Tartaric stabilization of young wines and thermodynamic indices of stability. Revue Roumaine de Chimie, 2015, 60 (11-12), 1019-1024.
8. Sprenger S., Dietrich H., Hirn S., Will F. Metatartaric acid: physicochemical characterization and analytical detection in wines and grape juices. Journal European Food Research and Technology, 241(6), December 2015, DOI : 10.1007/s00217-015-2503-1.
9. Escudier J. L., Samson A., Moutounet M., Salmon J. M., Bes. M. Innovations technologique en oenologie : Quelles consequences ? [Technological innovations in oenology: What consequences ?] in *Cahier scientifique, 6^e Journee scientifique de l'IHEV 2013*, Institut des Hautes Etudes de la Vigne et du Vin, SupAgro, Montpellier, pp. 24-33.
10. Escudier J.L., Bouissou D., Caille S., Samson A., Bes M., Moutounet M. Membraned-based options to regulate pH and acidity. Internationales Oenologisches Symposium, 16, 2011, Bozen, Italie.
11. Bates R. P., Morris J. R. Crandall P. G. Principles and practices of small- and med.-scale fruit juice processing. FAO Agricultural Service Buletin 146, 2001, pp. 135-148.
12. Moutounet M., Saint Pierre B., Battle J.L., ESCUDIER J.L. Stabilisation tartrique. Détermination du degré d'instabilité des vins. Mesure de l'efficacité des inhibiteurs de cristallisation [Tartaric stabilization. Determination of wine instability degree. Effectiveness measurement of crystallization inhibitors]. *Actualités OEnologiques 1999. VI th International OEnologie Symposium*, Bordeaux 10-12 juin 1999, pp. 531-534.
13. Kazuhiko T., Hisao C., Wenzhi H., Kiyoshi H. Separation of carboxylic acids on a weakly acidic cation-exchange resin by ion-exclusion chromatography. Journal of Chromatography, 1999, volume 850, Issues 1-2, pp.187-196.

14. Xuejun C., Hyun S. Y., Yoon-Mo K. Recovery of L (+)-lactic acid by anion exchange resin Amberlite IRA-400. *Biochemical Engineering Journal*, September 2002. Vol. 11, Issues 2-3, p. 189-196.
15. Uslu H., Inci I., Bayazit S. S., DEMIR G. Comparison of solid-liquid equilibrium data for the adsorption of propionic acid and tartaric acid from aqueous solution onto Amberlite IRA-67. *Ind. Eng. Chem. Res.*, 48 (16), 2009, pp. 7767-7772.
16. Chen M. *An electrolytic method for tartrate stabilization in Chardonnay wine*: Master thesis: California Polytechnic University, 2016.
17. Membrane Applications in Grape Juice and Wine Processing. An Interim Report based on Trials Conducted at E. & J. Gallo Winery, Fresno, California. November 2000-April 2001. Sponsored by the California Energy Commission, Sacramento, California [accesat 21.11.2014].
Disponibil: <https://pdfs.semanticscholar.org/9b77/2b443b8a15997c720e31dbdad2914de1aa98.pdf>
18. Ionic exchange resin AV-17 and AN-31. [accesed 21.11.2014] Disponibil <http://www.anionit.ru>
19. Technical Regulation "Methods of analysis in the field of wine production" [Annex. 10.1 Organic acids MA-MD-AS 313-04-ACIORG] in GOVERNMENT DECISION Nr. 708 at 20.09.2011. [accesat 10.03.2012].
Disponibil :
<http://www.justice.gov.md/file/Centrul%20de%20armonizare%20a%20legislatiei/Baza%20de%20date/Materiale%202009/Acte/HG%20708%2020.09.2011.pdf>
20. Systems and technological processes from GEA Westfalia Separator for winemaking. GEA mechanical Equipment. Published number 9997-6934-060/0210 EN.
21. Ionic exchange resin Purolite A-400. Disponible: http://aquasorbent.ru/Resins_Purolite_A400.php

DOI: 10.5281/zenodo.3444129

CZU 634.51



APPLICATION OF PARETO PRINCIPLE IN MONITORING WALNUTS QUALITY AT STORAGE

Elisaveta Sandulachi*, ORCID ID: 0000-0003-3017-9008

Eugenia Boaghi, ORCID ID: 0000-0003-4574-2959

Pavel Tatarov, ORCID ID: 0000-0001-9923-8200

Vladislav Resitca, ORCID ID: 0000-0002-6063-1731

Technical University of Moldova, Faculty of Food Technology, Department of Food and Nutrition, Studentilor str. 9/9,
2045 Chişinău, Moldova

*Corresponding author: Sandulachi Elisaveta, [elisaveta.sandulachi @tpa.utm.md](mailto:elisaveta.sandulachi@tpa.utm.md)

Received: August, 02, 2019

Accepted: September, 23, 2019

Abstract. This paper presents two case studies of walnut quality assessment at room temperature storage of $20 \pm 2^{\circ}\text{C}$. The conformity of the *Juglans regia* L. walnuts, the Calarasi variety, (harvest 2015) and Cogalniceanu variety (harvest 2016) was analyzed by applying the *Pareto* diagram and *nP*-card. These methods present a process of risk analysis, involves obtaining, analyzing and modeling information, analyzing and adopting a decision that improves the product quality. The data were collected during storage of walnuts at room temperature $20 \pm 2^{\circ}\text{C}$ for 6 and 12 months, respectively. The external and internal defects of walnuts have been assessed and grouped by risk categories. The most widespread defects of walnuts, which diminish their quality and the weight of their use on an industrial scale have been emphasised. It has been found that temperature and humidity are critical factors when storing walnuts. It is proposed a primary scheme for the in shell walnuts processing.

Keywords: walnuts quality, diagram Pareto, *nP*-card, defects frequency.

Introduction

Quality in the food manufacturing industry can be defined in different ways. One definition of quality is meeting or exceeding customer expectations and requirements [3, 25]. This aspect of quality certainly applies to the food industry as customers expect nutrition, good taste and pleasing appearance in the products they purchase. Another definition of quality that is applicable to the food industry is the assurance that the product is safe to eat and that the food is sanitary and has a maintained integrity that is without physical or chemical contamination [1-3, 26]. Many consumers expect pleasing appearance and taste and that the food is safe to eat. Two parameters can be used to address quality within the food industry. The first is Failure Mode and Effects Analysis (FMEA), which is widely used within multiple industries to improve and manage overall quality. The second is more commonly used for the food safety aspects of quality, Hazard Analysis and Critical Control Points (HACCP), which identifies potential safety risks in food

products and proactively seeks to reduce or eliminate them [25]. A risk analysis process involves acquiring information, modeling, analyzing the information and the model and coming to a decision that improves the product [17, 20]. There are five approaches that can be identified in practice [4, 10]: Safety-based root cause analysis; Production-based root cause analysis; Process-based root cause analysis; Failure-based root cause analysis; Systems-based root cause analysis. The Pareto chart aims to [15, 16, 21, 22]:

- Separate important issues from potential ones so you can focus on improving them,
- Arrange information by priority or importance,
- Help determine the important issues based on information rather than opinion.

The basic process consists of a number of basic steps. These corrective measures will lead to the true cause of the problem: identifying the problem; setting the improvement target; case analysis; formulation of improvement proposals; implementing the improvement plan; evaluating the results of the improvement; ensuring that the problem is not repeated [9, 10, 27]. The Pareto diagram presents the following advantages [16, 27]:

- Graphical representation highlights the causes of defects, as support for making decisions.
- By comparing diagrams made before and after taking corrective or improvement measures, it is possible to highlight the progress made in revolving problems [15].

Methodology of the research

To carry out the research work the following methodology were used.

- **Problem Identification:** Within the project nr. 15.817.02.30A „Methodological and technical elaboration for the modernization of the walnut processing technology (*Juglans regia* L.) with use of biologically active components in functional food „NUCALIM –PROBIO” „, a walnut game was purchased, which was later used for scientific research. It was noted that during the storage period there was a mismatch in the purchase of walnuts.
- **Data Collection:** The data were collected from October 2015 to March 2016.
- **Data Analysis:** Analyzed defects in April 2016
- **Implementation of Quality Control Tools:** The tools used were sampling, *nP*-card, Pareto analysis, and flow diagram. With the help of these tools the main causes came out which were highly responsible for the walnut quality.
- **Remedies / Action Taken:** the modified and corrective actions were taken into account at the next purchase of the walnuts for the project's research nr. 15.817.02.30A.
- **Standardization:** After the implementation of the quality control tool and the actions taken, the problem was solved.

If the number of defects classified by category is noted: n_c , n_p , n_s , n_m , and the weights of the respective defects: P_c , P_p , P_s , P_m , of a sample with total number N , in this case the quality is appreciated by the index D depending on the deviations from the excellent quality indicators through the relationship:

$$D = \frac{P_c n_c + P_p n_p + P_s n_s + P_m n_m}{N} \quad (1)$$

Quality can also be assessed and fixed on the basis of standards, technical prescriptions (D_0). In this case, the index that reflects losses in the quality (I_D) of a food being examined is defined by the report:

$$I_D = \frac{D}{D_0} \quad (2)$$

I_D index values can be next:

- a) $I_D = 1$, quality is the same as the reference (D_0);
- b) $I_D < 1$, quality is superior to the reference;
- c) $I_D > 1$, quality is inferior to the reference.

The method that judges deviations from excellent quality indicators is called demerit and it is used for any control method: wholly through sampling or reception. The order of defects according to the frequency is done by *Pareto analysis (chart)*.

Pareto chart. The Pareto diagram was created by plotting the frequency of the relative frequency of the causes in descending order, after which the essential factors for analysis are graphically formatted and ordered [8, 14, 28]. The Pareto chart helps to guide interventions methodically through action plans built around the major causes of emerging issues, being a visually-oriented, instrumental tool to make the decision. It is a qualitative analysis tool because it focuses on process parameters through the frequency of occurrence. Defined parameters can be events, errors, features, etc. [2, 8, 11, 14].

nP – control chart.

This chart served the basis of the statistical method for testing and assessing the quality of the batch of Calarasi variety walnuts, the harvest year 2015 and consists in analyzing the number of damaged walnuts in the examined batch. According to the nP - chart method the number of walnuts in each sample was 20. Following the analysis of the samples, the number of defective nuts was determined on the basis of which the tolerance limits were calculated. The upper and lower tolerance bands (LTS and LTI) appreciate the permissible variation limits of the number of damaged walnuts in the test lot.

The distribution of defective walnuts relative to the average value of total walnuts is characterized by the Student distribution coefficient. Based on 3σ concept, according to the Student distribution and applying the relations (5) and (6), the LTS and LTI tolerance limits were calculated relations (Student coefficient equal to $k = 3,0$).

Experimental data: 15 selections were used and analyzed with 20 walnuts in each selection. The number of defective nuts (p) has been identified in each selection.

- n - The number of walnuts in a sampling batch;
- p_i – total number of nuts with defected kernel;
- m - total number of batches.

*** Average number of defective walnuts in a sampling batch:**

$$np = \frac{\sum p_i}{\sum m} \quad (3)$$

Tolerance Limit:

$$LA = np \pm k \sqrt{np \left(1 - \frac{np}{n}\right)} \quad (4)$$

Superior tolerance limit (**LTS**):

$$LTS = np + k \sqrt{np \left(1 - \frac{np}{n}\right)} \quad (5)$$

Inferior tolerance limit (**LTI**):

$$LTI = np - k \sqrt{np \left(1 - \frac{np}{n}\right)} \quad (6)$$

Table 1 includes defects in food products grouped by the risk they pose to consumers.

Table 1.

Classification of defects by category [27]

Defect type	Defect definition
Critic	Defect that prevents use of the product, producing rebut, risk to the health of the consumer
Primary	Reduces the possibility of using the product causing some inconvenience to the consumer. It generally produces complaints
Secondary	In principle, it does not affect the possibility of use; is perceptible to consumers but does not generate complaints
Minor	Does not reduce usage; do not pose serious inconvenience to consumers

This experimental study examined the defects of *Junglans regia* L. walnut harvested in Moldova and stored under laboratory conditions. The defects have been studied on the basis of the Government Decision, on the approval of the Technical Regulation "Nut fruit crops. Quality and marketing requirements". Table 2 shows the defects of shelled and unshelled walnuts on the basis of the regulations on fresh walnut tolerance [21]. Quality and size tolerances shall be allowed in each package for products not in conformity with the requirements of the category indicated (Table 2).

Table 2.

Walnuts defects regulated by the Technical Regulation "Nut fruit crops. Quality and marketing requirements "

The allowed defects	Allowed tolerances, %		
	Category super	Category I	Category II
a) Total tolerance for shell defects	7	10	15
b) Total tolerance for the defects of the party edible *	8	10	15
c) Of which nuts are eaten, rotted or attacked by insects	3	6	8
Including nuts moldy**	3	4	6

* For fresh nuts, tolerance of kernel defects is: Extra- 8% , 1st category -12%, 2nd category – 15%.

** Live insects or animal pests are not allowed in any category.

Determination of defects in shelled walnuts.

Defects of the shell are considered defects that alter the appearance, such as [21]:

- 1) color change: uncharacteristic stains or color, which comprise 20% of the surface of the shell of the nut, and which has a brown, brownish, gray or other color, contrasting net with the rest of the shell or most of the shells in the batch;
- 2) dirt, sticky soil comprising more than 5% of the surface of the shell;
- 3) adherent shell comprising more than 10% of the shell surface;
- 4) Traces of decay: traces pronounced on the shell, resulting from the mechanical removal of the shell.

Walnuts defects are considered to be:

- 1) defects that alter the appearance of the core, such as stains or discolored areas: a color change of more than a quarter of the core, and a hue that contrasts with the core;
- 2) Spattered cores - considerably creased, dried and hardened cores.

Results and discussion

The article presents two case studies of Junglass regia L walnuts quality change during storage at ambient temperature of $20 \pm 2^{\circ} \text{C}$:

- Variety **Calarasi**, harvest 2015, storage time 6 months;
- Variety **Cogalniceanu**, harvest 2016, storage time 12 months;

Walnuts were purchased under project no. 15.817.02.30A „Methodological and technical elaboration for the modernization of the walnut processing technology (Juglans regia L.) with use of biologically active components in functional food „NUCALIM –PROBIO”.

Table 3 presents the results of the Calarasi variety examination, 15 lots of walnuts, each containing 20 walnuts were sampled.

Table 3.

Defects found in nuts, Calarasi variety

Lot no.	Walnuts external defects			Walnuts inner defects		
	Walnuts with defects	Defect description	Frequency, %	Walnuts with defected kernel	Defect description	Frequency, %
1.	3	3 nuts with black spots on the shell. When the walnuts were broken, two had a good kernel.	15	1	Dark kernel	5
2.	-	-	-	5	3- black, 1 - dry, 2 - molds	25

Continuation Table 3

3.	5	5 nuts with black spots on the shell. When broken, a nut had a good kernel	25	3	2 – affected by larvae; 1- black with mold	15
4.	-	external defects have not been detected	-	4	1 – black kernel; 2 – inner mold; 1 – black and dry kernel.	20
5.	2	2 walnuts completely black outside	10	2	1 – black kernel; 1 - dry kernel.	10
6.	-	external defects have not been detected	-	3	2 – black kernel; 1 – kernel with mold	15
7.	-	external defects have not been detected	-	-	inner defects have not been detected	-
8.	1	black surface, partly with mold	5	4	2-black kernel; 1-partially dry; 1- black with mold.	20
9.	1	Black spots	5	3	1- black kernel; 1 – kernel with mold; 1 – dry kernel.	15
10.	-	-	-	-	-	-
11.	-	external defects have not been detected	-	6	1– black kernel; 1 – infested kernel; 2 – dry kernel.	30
12.	2	Black spots outside	10	4	2 – black kernel; 1 – infested kernel; 1 – dry kernel.	20
13.	1	Black spot outside	5	4	1 – kernel with mold; 1 – infested kernel; 1 – black and partially dry kernel.	20
14.	2	2 walnuts completely black outside	10	1	1-black kernel.	5
15.	-	external defects have not been detected	-	4	3 – black kernel; 1 – dry and infested kernel	20
Σ	17		5,67	44		14,67

According to the experimental data presented in Table 3, two categories of walnut defects were analyzed:

- 1) External defects of walnuts (walnut skin). Following analysis, the following defects were identified: black spots, completely black shell.
- 2) Inner defects of walnuts (walnut core defective). Following analysis, the following defects were identified: blackened, dry, black core with mold.

Analyzing the defects found in the 15 batches of tested walnuts, 6 types of defects were identified, which are presented in Table 4.

Table 4.

Percentage of walnuts waste Based on Their Categories				
Nr.	Walnuts Defect Type	Number of defects	Cumulative number of defects	Cumulative number of defects, %
1.	A dark core, internal defect (A)	21	21	34,43
2.	Color change, external defect (B)	12	21 + 12 = 33	54,01
3.	Core with mold (C)	12	33 + 12 = 45	73,77
4.	Dry core, internal defect (D)	11	45 + 11 = 56	91,80
5.	Traces of decay, external defect (E)	3	56 + 3 = 59	96,72
6.	Adherent shell, external defect (F)	2	59 + 2 = 61	100
	Total defects	61		

For the quantitative interpretation and hierarchy of the main defects according to the frequency of their occurrence, the Pareto analysis was performed. The Pareto principle is also called the 80/20 rule, which states that 80% of the effects (quality defects) occur as a result of only 20% of the existing causes.

According to statistical analysis of the 15 samples of tested walnuts non-compliant walnuts were found to be 15%. The upper tolerance limit of the non-conforming nuts was 8 pieces, or 3% of the total tested lot.

Analyzing the category and the percentage of defects in selected sample samples, the same results were identified by other authors. One of the important factors in the quality of nuts during storage is the way of harvesting the fruit.

In order to correctly determine the moment of in shell walnut harvesting, several factors are taken into account, considering that nuts maturing does not take place on all the trees and never on the same tree [12]. Premature harvesting of walnuts leads to considerable loss of product (25-40%) but especially to deterioration of its quality. Nuts collected before physiological maturity are dried, the kernel is wrinkled containing few albumins, fats and sugars and tastes non-specific to walnuts. Moreover, the walnuts that were harvested early are very hard to remove the green peel, which leads to the loss of their quality [18].

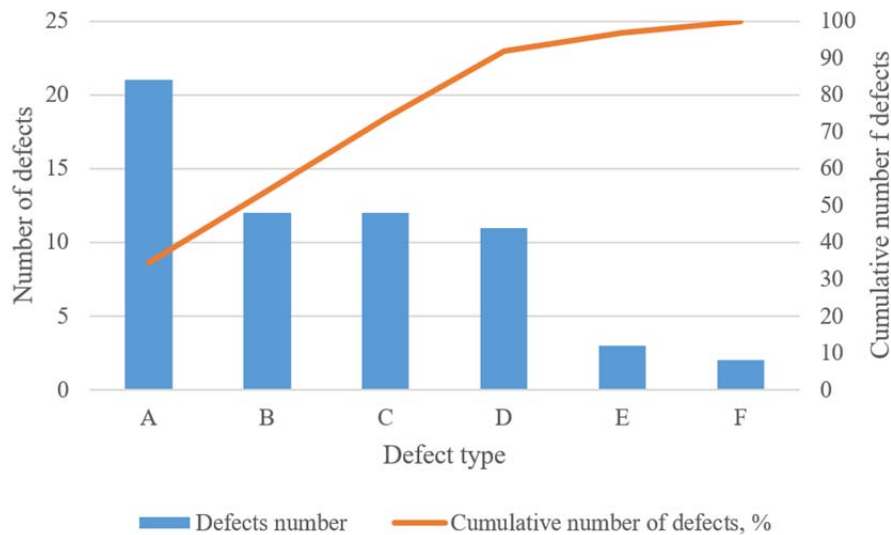


Figure 1. Pareto chart. The cumulative weight of Calarasi variety walnuts defects.

np chart analysis

Data of case study: 15 samples were selected and analyzed with 20 walnuts in each sample. The number of defective nuts (p) has been identified in each sample:

Table 5.

Characteristics of walnut samples

	Number of samples														
M	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
N	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
P	1	5	3	4	2	3	0	4	3	0	6	4	4	1	4
%	5	25	15	20	10	15	0	20	15	0	30	20	20	5	20

Where: n - walnut number in one sample, $n = 20$:

p_i - number of walnuts with defected kernel, $\Sigma p_i = 44$

m - number of samples, $m = 15$

Table 6.

Parameters of walnut batches for np chart elaboration

No.	Parameter	Calculated value	References to the calculation formula
1.	Average number of defective walnuts in a sampling batch (np)	3,0	(3)
2.	Tolerance Limit (LA)	3	(4)
3.	Superior Tolerance Limit (LTS)	0	(5)
4.	Inferior Tolerance Limit (LTI)	8	(6)

According to the 3σ conception in a batch of examined walnuts, the content of defective walnuts is determined with the accuracy of 99, 73%, i.e. the potential for error is admitted no more than 0.27%. At the same time, the number of walnuts without defects of quality is $(100 - 0,27 = 99,73\%)$.

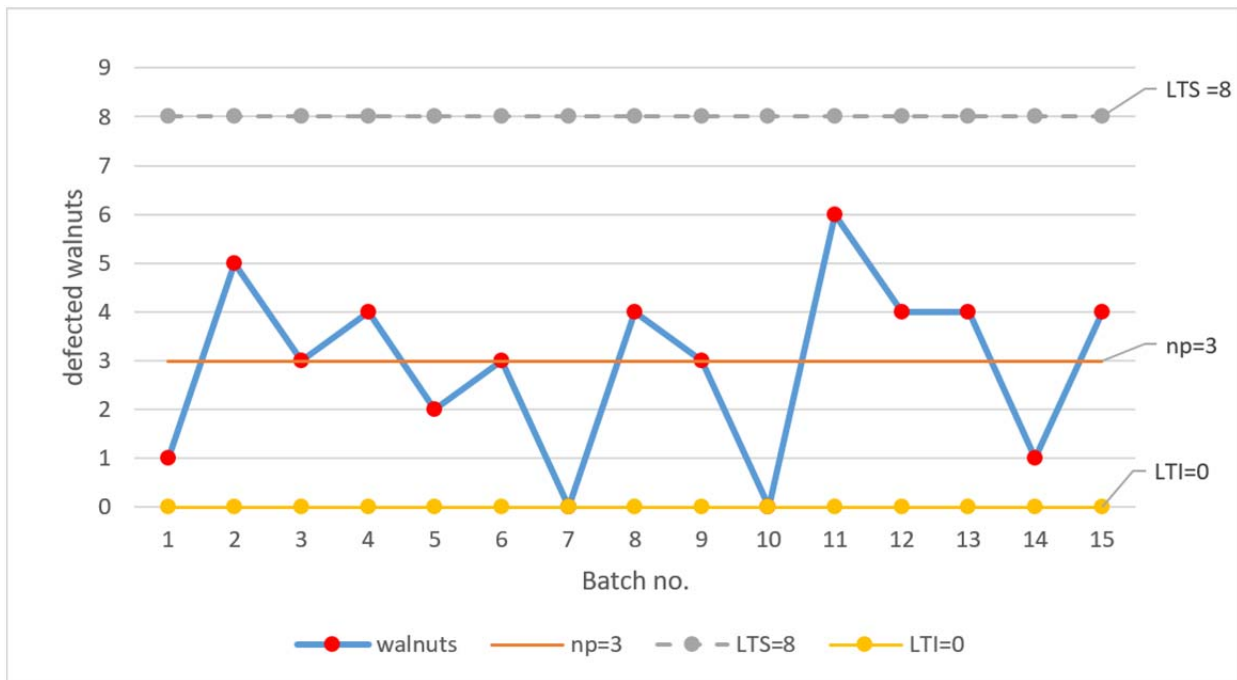


Figure 2. Graphic representation of nP - chart.
Variation of the number of damaged walnuts in the tested lot.

Knowing that walnuts are kept longer, when the intensity of their respiration is reduced, it is advisable to avoid the consequences of respiration-inducing factors: temperature and phytosanitary status [6, 12, 29]. Heat released during storage of horticultural products is proportional to the intensity of metabolic processes, which depend on the ambient temperature. In order to remove this heat, storage facilities must be equipped with ventilation systems.

If respiration heat is not readily operable, temperature rise and rapid depreciation occur [6, 18, 19]. What was also found in our tested walnuts stored at $20 \pm 2^\circ\text{C}$.

Unsuitable phytosanitary status due to the presence of parasitic microorganisms causes increased respiration [6, 12, 13, 24]. To ensure a normal sweating and respiration process of walnuts it is required that humidity does not exceed 70%. During storage, it is advisable to easily ventilate the deposit for the removal of carbon dioxide, ethylene, heat and excess moisture. It must be taken into account that excess water loss changes the taste and physical attributes of walnut [6, 7, 12].

The experimental study previously conducted has shown that *Juglans L.* can be infected by fungi, yeasts and bacteria that minimize their quality.

The rate of infection depends on climatic conditions (temperature, humidity), cultivation mode and storage conditions [13, 23, 24].

It has been found that irradiation of walnuts collected from the ground reduces the microbial storage risk by 20-90%. Proper storage ensures the quality and safety of walnuts. It is recommended to prolong the storage and maintain nutritional value of walnuts to carry out their irradiation at 4 kGy dose in 60 minutes [24].

Next, we present in Tables 7 and Figure 3 the results obtained in the testing of the nuts of the Cogalniceanu variety [5].

Table 7.

The frequency of occurrence of defects identified in a batch of nuts harvested in 2016 and kept for 12 months

No.	Defect type	Frequency of occurrence, %	Relative Frequency, %
External Defects			
1.	Imperfect nuts - cracked, broken, split	0,50	1,32
2.	Adherent Pericarp	0,00	0,00
3.	Excessive external humidity	0,00	0,00
4.	Dark color of the shell	2,50	6,54
Internal Defects			
5.	Empty Walnuts (without kernel)	1,25	3,27
6.	he presence of moldy kernel	10,50	27,50
7.	The presence of wrinkled kernel (lack of full maturity)	1,75	4,58
8.	The presence of the kernel with a tangled taste	4,00	10,46
9.	The presence of foreign smell	0,50	1,32
10.	Presence of the kernel with excessive humidity	1,00	2,61
11.	The presence of the black / stained kernel	15,60	40,83
12.	Oily appearance of the kernel	0,00	0,00
13.	The presence of insect attack	0,60	1,57
	TOTAL	38,2	100

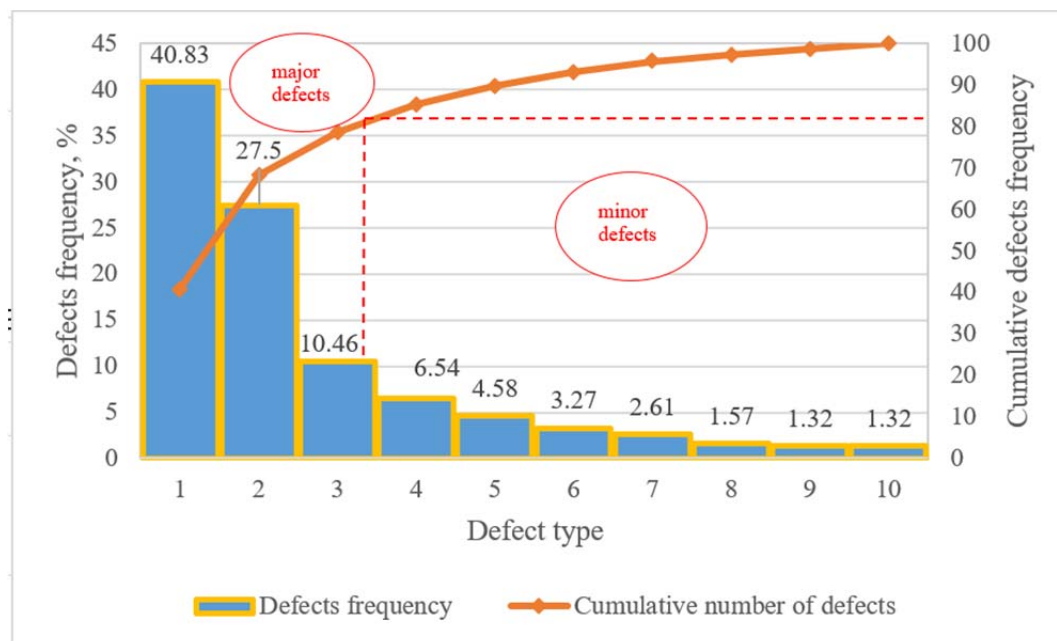


Figure 7. Pareto diagram. The share of defects identified in a walnut batch of 2016 harvest, stored for 12 months. 1 - The presence of the black / stained kernel, 2 - The presence of moldy kernel, 3 - The presence of the kernel with a tangled taste, 4 - Dark color of the shell, 5 - The presence of wrinkled kernel (lack of full maturity), 6 - Empty Walnuts (without kernel), 7 - Presence of the kernel with excessive humidity, 8 - The presence of insect attack, 9 - The presence of foreign smell, 10 - Imperfect nuts - cracked, broken, split.

The chart indicates that significant defects are the presence of black or stained kernel with a frequency of about 41% of defected walnuts, moldy kernel (27.5%), and rancid walnut kernel (10.45%). Empty walnuts, those with a dark bark, with wet and wrinkled kernel (defects 4-7 in the diagram) are about 15% and the other 6 defects only 5% of the defects [5].

Similar values were also obtained for the batch of nuts harvested in the previous years. Thus, the weight of the first three defects, representing about 23% of the total defects (13), represents about 79% of the damaged walnuts, which corresponds to the principle of functionality of the Pareto diagram. From the data presented, it is obvious that it is necessary to remove the causes that cause their alteration, namely the monitoring of the storage conditions (especially the relative humidity of the air) that would prevent the development of fungi (molds) and the raking and application of technological bleaching treatments of the shell. To store walnuts should be taken into account Code of Practice for the prevention and reduction of aflatoxin contamination in nuts [7].

Conclusion

Bibliographic and experimental study shows that walnuts *Juglans regia* L. can be infected with fungi, yeasts and bacteria, which minimize their quality. Infection rate depends on climatic parameters (temperature, relative humidity, precipitations and UV irradiation), variety nuts and storage conditions. Good storage practices should be implemented to minimize the levels of insects and fungi in storage facilities.

In order to assess the attractiveness of nuts in the shell, statistical methods based on defect classification (Pareto diagram) were tested and the tolerance limits were determined by the nP chart. It has been found that test methods can be applied to assess the attributive quality of nuts after harvest. According to this upper and lower tolerance limits of defective nuts in the tested lot range from 0 to 8 units. It is possible to improve the quality of walnuts by forming the conditions in which the upper limit must strive to zero to (LTS = 0, the number of defective nuts will be 0)

According to the 3σ conception in a batch of examined walnuts, the content of defective walnuts is determined with the accuracy of 99, 73%, i.e. the potential for error is admitted no more than 0.27%. At the same time the number of walnuts without defects of quality is $(100-0,27 = 99,73\%)$.

References

1. Andersen, B. & Fagerhaug, T. (2006). *Root cause analysis: simplified tools and techniques*. ASQ Quality Press.
2. Arthur L.J. Rapid Evolutionary Development –Requirements, Prototyping & Software Creation, John Wiley & Sons. Inc.
3. Atkins Steven, Hagen Marcia, An Integrated Approach to Food Quality and Safety: A Case Study in the Cookie Industry, FROZEN FOODS <https://www.foodsafetymagazine.com/magazine-archive1/april-may-2012/an-integrated-approach-to-food-quality-and-safety-a-case-study-in-the-cookie-industry/>
4. Barsalou, M. A. (2014). *Root Cause Analysis: A Step-By-Step Guide to Using the Right Tool at the Right Time*. Productivity Press.
5. Boaghi Eugenia. Modificări biochimice și tehnologice ale nucilor pe parcursul prelucrării și păstrării. PhD thesis. 2018.
6. Burzo I., Fiziologia și tehnologia păstrării produselor horticoale, Editura Tehnică, București, 1986, 252 p.
7. Code of Practice for the prevention and reduction of aflatoxin contamination in tree nuts (CAC/RCP 59-2005)
8. Dankovic, D. D. (2001). *Root Cause Analysis*. Technometrics, 43(3), 370-371.
9. Fulea, Gh.L., Borzan M., Bulgaru M., Dezvoltări actuale privind instrumentele clasice ale calității (i)

10. Fulea, Gh.L., *Contextul și stadiul actual al dezvoltării și aplicării instrumentelor calității în industria auto*, Referat 1, Universitatea Tehnică din Cluj Napoca, 2013.
11. George, M. L., Maxey, J., Rowlands, D. & Price, M. (2004). *The Lean Six Sigma Pocket Toolbook: A Quick Reference Guide to 100 Tools for Improving Quality and Speed*. McGraw-Hill Education.
12. Gherghi A., Iordănescu C, Burzo I. Menținerea calității legumelor și fructelor în stare proaspătă, Ed. Tehnică, București. 370 p. 27
13. Gurjui, A., Sandulachi, E., Silivestru E., *Microbiological risk estimation at walnuts long term storage*, Proceeding of conference “40 years department “Machine and apparatus of Food Industry” of University of Food Technologies” Bulgaria: Journal of FOOD and PACKAGING Science, Technique and Technologies, Plovdiv, Bulgaria, 2013, ISSN 1314-7773, pp. 93-95. Disponibil: <http://mahvp.uft-plovdiv.bg/wp-content/uploads/2012/10/2-part-1.pdf>
14. <http://blog.dataparc-solutions.com/using-pareto-charts-for-quality-control>
15. <https://www.toolshero.com/problem-solving/root-cause-analysis-rca/>
16. Iacob Sorina Daniela, Instrumentele calității - Diagrama PARETO, Universitatea Tehnică din Cluj-Napoca, Proiect cofinanțat din Fondul Social European prin Programul Operațional Sectorial pentru Dezvoltarea Resurselor Umane 2007 – 2013
17. J. Andres Vasconcellos, *Quality Assurance for the Food Industry: A Practical Approach*, Crc Press , Boca Raton London, New York Washington, D.C., 59 pag.15
18. Jamba A. Tehnologia păstrării produselor horticoale, Chișinău, 2006. p.193-198.
19. Jamba A. Carabulea B. Tehnologia păstrării și industrializării produselor horticoale. Editura „Cartea Moldovei”, Chișinău 2002, 493p.
20. Jenab, K.K. and B.S. Dhillon. 2005. Group-based failure effects analysis. *Int J Reliability Quality Safety Engineer* 12:291–307.
21. RM GUVERNUL HOTĂRÎRE Nr. 174 din 02.03.2009 cu privire la aprobarea Reglementării tehnice „Fructe de culturi nucifere. Cerințe de calitate și comercializare” Publicat : 17.03.2009 în Monitorul Oficial Nr. 55-56 art Nr : 241 Data intrării in vigoare : 17.06.2009
22. Root Cause Analysis, e-learning coourse Food Standarts Agency
23. Sandulachi, E. et al., *Microbial contamination of Juglans regia L. walnuts stored in Moldova*, Chișinău: Proceedings of International Conference MTFI-2012, Modern Technologies in the Food Industry, V.2, 2012, pp. 289-294, ISSN 978-9975-80-646-6.
24. Sandulachi, E., Rubțov, S., Costiș, V., *Микробиологическая обсемененность орехов*, International Scientific Practical Conference, Azerbaijan State Agrarian University, Ganja, Azerbaijan: 2015, pp. 139-141.
25. Schroeder, R., S. Goldstein and M. Rungtusanatham. 2011. *Operations management, contemporary concepts and cases*, 5th edition. McGraw Hill.
26. Scipioni, A., G. Saccarolla, A. Centazzo and F. Arena. 2002. FMEA methodology design, implementation and integration with HACCP system in a food company. *Food Control* 13:495–501.
27. Scot Larsen | 80/20 rule, Pareto principle, Pareto charts, process audits, layered process audits, quality culture, culture of quality, Beacon Quality
28. The Concesi Encyclopedia of Economics, Vilfredo Pareto, <http://www.econlib.org>
29. *Walnut, Agriculture-Transport Information Service*. Government of Germany, 2010 TIS. www.tis-gdv.de/tis

DOI: 10.5281/zenodo.3444139

CZU 637.2:664.34



FACTORS THAT DETERMINE THE SHELF LIFE OF A BUTTER-LIKE SPREAD BASED ON WALNUT OIL

Oxana Radu*, ORCID ID: 0000-0001-9260-6314

Alexei Baerle, ORCID ID: 0000-0001-6392-9579

Pavel Tatarov, ORCID ID: 0000-0001-9923-8200

Liliana Popescu, ORCID ID: 0000-0003-3381-7511

*Technical University of Moldova – MD 2004, 168, Stefan cel Mare Av., Chişinău, Republic of Moldova**Corresponding Author: oxana.radu@sa.utm.md

Received: 09, August, 2019

Accepted: 25, September, 2019

Abstract. The article describes the manufacturing stages for a new functional product that can enrich human diet with essential lipids – spread based on walnut oil. Due to the fact that its content of polyunsaturated fatty acids is in 3-4 times higher than in a classic milk-based butter, the problem of preserving spread biological value appeared. The analysis of product's physico-chemical, structural, organoleptic and microbiological proprieties showed that the spread is stabile 10 days at $(3 \pm 2)^{\circ}\text{C}$ and within up to one month at $-(6 \pm 3)^{\circ}\text{C}$. Polyunsaturated fatty acids in product composition were noticeably subjected to oxidative degradation only after 4 weeks of storage. It has been proven that namely microbiological stability is the determining factor, which affects the shelf life of a spread.

Keywords: *functional product, dairy and vegetable lipids, polyunsaturated fatty acids, storage period.*

Introduction

The problem of rational and healthy nutrition is far from being solved and only worsens over the years. The consumption of both animal and vegetable fats is considered one of the aspects of balanced diet. It is known that polyunsaturated fatty acids (PUFA) have antioxidant and antiradical activity, being essential for the proper functioning of human immune and nervous systems [1, 2]. At the same time, generally available food items, namely dairy products, contain a small amount of triglycerides of polyunsaturated fatty acids [3, 4]. This problem was proposed to be resolved as by saturating the diet of dairy cows with lipids rich in cis-9, trans-11 conjugated linoleic acid [5, 6], so as by the elaboration of food products – spreads, in which dairy fat is partially or completely replaced by vegetable oils [7, 8].

Spread is a fat-containing composition based on milk components and vegetable lipids, similar in physical and chemical structure to a milk-based butter. Usually, sunflower seed oil, olive oil, soybean oil and palm oil are used to produce spreads [9]. The introduction of the latter is very widespread in food industry, however, due to the saturated nature of palm oil, the optimal ratio of fatty acids with different saturation degrees is not

achieved in such kind of spreads. From this point of view, it seems extremely interesting to obtain a spread using a virgin walnut oil as a vegetable component rich in essential lipids.

The analysis of the chemical composition of walnut oil produced in France, Hungary, Italy, Spain and Moldova has shown that the content of linoleic acid (ω -6) varies in limits 53...70%, linolenic acid (ω -3) – in 10...15% , and oleic acid (ω -9), belonging to the group of monounsaturated fatty acids (MUFA), constitutes about 14...30% [10]. Due to the high content of unsaturated fatty acids, walnut oil is subjected to rapidly oxidation (rancidity), losing consumer and functional properties. We suggest that the introduction of walnut oil in spreads lipid phase will help to stabilize polyunsaturated fatty acids and will lead to the obtaining of a healthy affordable product.

Spread based on walnut oil

Methods of the elaboration of functional products with an optimal ratio between saturated (SFA) and unsaturated fatty acids are based on the obtaining of multicomponent food systems using physiologically important ingredients [11, 12]. Spreads represent a part of the food group, for which a scientific and technological base is currently developing very intensively because of the possibility to improve their nutritional properties by the increase of polyunsaturated fatty acids, macro- and microelements, vitamins, pro- and prebiotics [13].

Butter, being an emulsion of W/O type, is obtained by lipids separation from a sweet cream. The method of a new functional spread obtaining was elaborated, accompanying by the solidification of the mixture of sweet cream and O/W direct emulsion of walnut oil (vegetable lipids, water, emulsifier) [14]. The formation of a vegetable lipid emulsion before its mixing with the source of dairy fat and the subsequent mixture stirring allowed to stabilize the composition by crystallization process and to exclude the overdose of saturated fatty acids. As a result, a new food product with a butter-like texture can be obtained, which content of polyunsaturated fatty acids is 3-4 times higher than in a classic butter [15] (Table 1).

Table 1

Characteristics of spread based on walnut oil.

Analyzed characteristics	Values
Lipids, % including	72.5 ± 0.5
ω 3 and ω 6 polyunsaturated fatty acids, %	19...46
Water, %	25.0 ± 0.5
Proteins, %	<1
Carbohydrates, %	<1.5
Melting temperature, °C	30...32
Thermostability, %	85 ± 5
Taste and smell	sweet cream taste with a pleasant aftertaste of walnut oil
Consistence at 12 ± 2°C	compact, plastic, homogeneous, with a glossy surface in the section
Color	light yellow color, uniform throughout the product

Thus, walnut oil can indeed be used to obtain food compositions with functional properties; however, unresolved questions remain: what is the shelf life of obtained product and whether is its biological value preserved during storage.

Determining the shelf life of spread

To provide research, spread samples were prepared according to the elaborated method [14]. The optimal ratio of dairy and vegetable lipids in spread was determined depending on the content of saturated and unsaturated fatty acids, as well as it is based on organoleptic properties of obtained product. The thermo-stability of samples, up to 0.83, considered satisfactory [16], was obtained for the spread with 53.1% of saturated fatty acids (SFA), 25.9% of monounsaturated fatty acids (MUFA) and 21.0% of polyunsaturated fatty acids (PUFA). Because PUFA contains linolic ($\omega 3$), linolenic ($\omega 6$) and other PUFA with a priori different biological activity, it was important to estimate a $\omega 3 : \omega 6$ ratio. So, calculated $\omega 3 : \omega 6$ ratio corresponds to 1 : 6, which correlate to recommended value [1, 3]. It should be noted, that the content of saturated fatty acids in spread decreased non-essential compared to a classic milk-based butter.

The obtained samples were packaged in aluminum foil with 10 - 40 g mass in each and stored at two temperature regimes: $t = (3 \pm 2)^{\circ}\text{C}$ and $t = - (6 \pm 3)^{\circ}\text{C}$. The shelf life of spread was determined according to its physico-chemical (Figure 1), structural (Figure 2), organoleptic and microbiological (Table 2) stability.

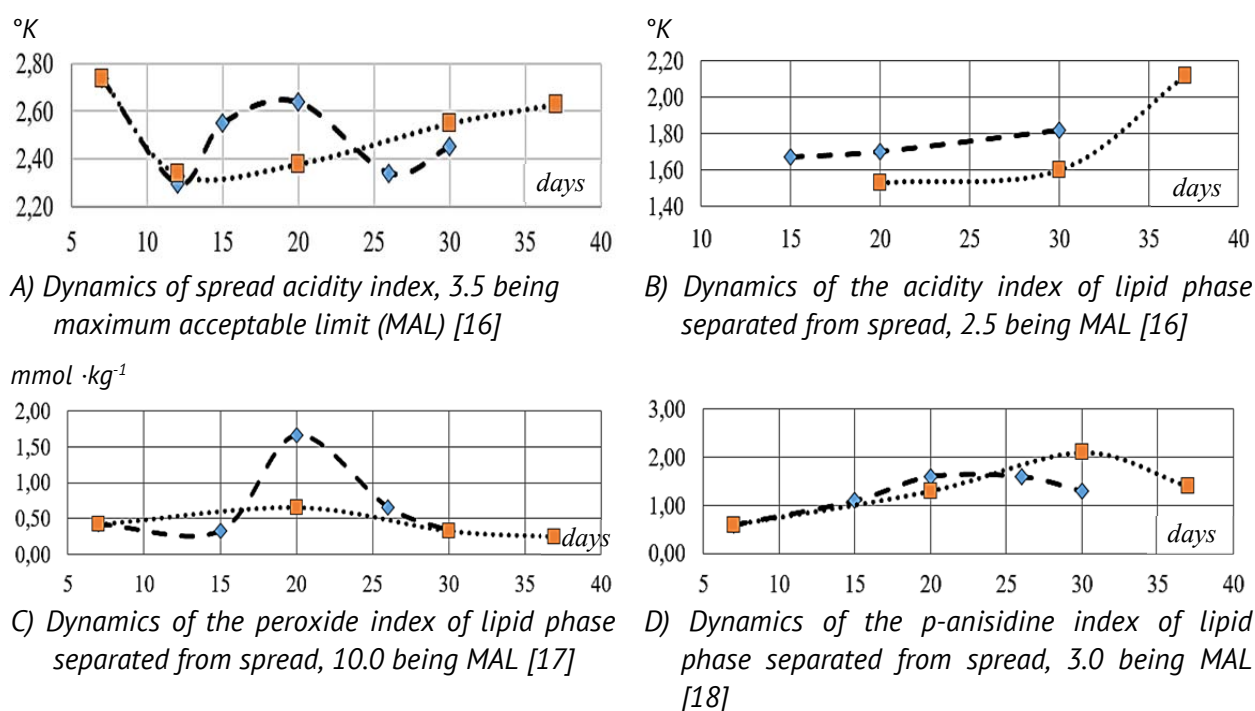


Figure 1. The evaluation of spread stability against oxidative degradation during storage:

—◆— spread, $t = (3 \pm 2)^{\circ}\text{C}$

··■·· spread, $t = - (6 \pm 3)^{\circ}\text{C}$

The analysis of Figure 1 shows that obtained spread does not undergo oxidative degradation within 40 days. Analyzed indexes do not cross maximum acceptable limits. Considering the oxidation of polyunsaturated fatty acids as an irreversible process, the simultaneously formation of primary and secondary compounds was demonstrated. It has been noticed the visible variation of hydroperoxides accumulation (Figure 1.C) and the

simultaneously growing of secondary compounds concentration during storage (Figure 1.D). Thus, the character of hydroperoxides concentration changes shows that these compounds are intermediates in PUFA oxidation reaction and represent the substrate of reactions for secondary compounds formation [10].

Generally, changes of physicochemical properties of the samples kept at $t = - (6 \pm 3)^{\circ}\text{C}$ are less pronounced, than in spread kept at $t = (3 \pm 2)^{\circ}\text{C}$. While the process of Ostwald ripening [19], accompanied by coalescence and water phase elimination, manifested in 30 days of spread storage at $t = (3 \pm 2)^{\circ}\text{C}$ (Figure 2) and in 37 days at $t = - (6 \pm 3)^{\circ}\text{C}$ (Figure 3).



Figure 2. The microstructure of spread kept 30 days at $t = (3 \pm 2)^{\circ}\text{C}$.

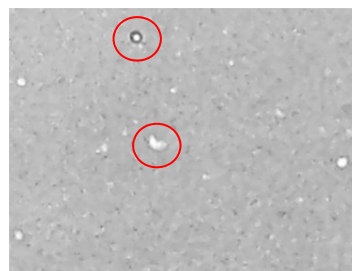


Figure 3. The microstructure of spread kept 37 days at $t = - (6 \pm 3)^{\circ}\text{C}$.

The microscopic study demonstrates substantial changes of spread texture properties, manifested organoleptically as product softening because of water micelles coalescence.

The dynamic evaluation of spread microbiological stability was performed for samples with $10.0 \pm 0.5\text{g}$ mass (Table 2).

Table 2

Dynamic evaluation of microbiota development in spread.

Microbiota, cfu·g ⁻¹ .	Maximum acceptable limits, cfu·g ⁻¹ .	Validity, days	
		$t = (3 \pm 2)^{\circ}\text{C}$	$t = - (6 \pm 3)^{\circ}\text{C}$
The total bacteria count (TBC)	$1,0 \cdot 10^5$	10	>30
Coliform bacteria	in 0,01g of sample	20	>30
Yeast	100	>30	>30
Mold	100	>30	>30

The exceed of maximum acceptable limits for TBS was determined in 10 days in spread kept at $t = (3 \pm 2)^{\circ}\text{C}$. Experimental samples kept at $t = - (6 \pm 3)^{\circ}\text{C}$ were found to be inoffensive within up to one month. Based on the fact that the analysis was performed for samples with $10.0 \pm 0.5\text{g}$ mass each, the time of spread microbiological degradation in a consumer pack (50 - 1000g) may be at least 2 times longer [20].

The dependence of spread shelf life on its rate of physical-chemical, organoleptic and microbiological degradation is presented in Figure 4.

The analysis of Figure 4 shows that the main criterion in the determination of the shelf life of elaborated spread is the speed of microbiota development in product. That is, the main risk while spread storage, despite expectations, is not its fizico-chemical instability, characteristic for walnut oil, but it is the influence of microbiological and technological factors, caused by the presence of dairy products in spread composition.

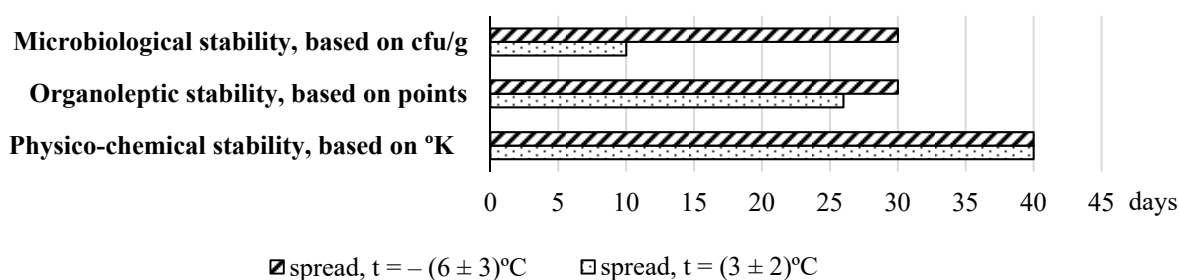


Figure 4. Factors contribution that determine spread shelf life.

Conclusions

It has been elaborated a new functional product of spread type with a more than 20% content of polyunsaturated fatty acids, which can enrich daily human diet with essential lipids. The rate of oxidative degradation of the spread falls within the recommended storage term for a classic milk-based butter [16, 20], the analysis of its microbiota development being the main principle of product shelf life estimation.

The main risk while spread storage represents not the instability of walnut oil, but the presence of dairy raw material and water phase in product composition. Spread retains its functionality and high biological value within two weeks at temperature regime up to 5°C.

Acknowledgments. Gratitude and deep appreciation are expressed to the National Scholarship Programme of the World Federation of Scientists for the support in scientific activity.

Bibliography

- Whitney, E., Rolfes, S.R. *Understanding Nutrition*. 11th Ed, California: Thomson Wadsworth, 2008.
- Spector, A., Hee-Yong Kim. Thematic review series: Living history of lipids: Discovery of essential fatty acids. In: *The Journal of Lipid Research*, 56 (1), 2015 – pp. 11-21. DOI:10.1194/jlr.R055095
- Tatarov, P. *Chimia produselor alimentare*. [Food chemistry]. Chişinău: MS Logo, 2017.
- Botta, A., Ghosh, S. Exploring the impact of n-6 PUFA-rich oilseed production on commercial butter compositions worldwide. In: *Journal of Agricultural and Food Chemistry*, 64(42), 2016. DOI: 10.1021/acs.jafc.6b03353
- O'Callaghan, T. et al. Quality characteristics, chemical composition, and sensory properties of butter from cows on pasture versus indoor feeding systems. In: *Journal of Dairy Science*, vol.99(12), 2016. – pp. 9441-9460. DOI:10.3168/jds.2016-11271
- Shingfield, K.J., Reynolds, C.K., Hervás, G., Griinari, J.M., Grandison, A.S., Beever, D.E. Examination of the persistency of milk fatty acid composition responses to fish oil and sunflower oil in the diet of dairy cows. In: *Journal of Dairy Science*, Vol. 89, Issue 2, 2006. – pp. 714-732. DOI: 10.3168/jds.S0022-0302(06)72134-8
- Nielsen, M., Olsen, P., Rokkedahl, K., Thorning, P. *A butter-like dairy spread and method for production*. EP 1688044 B1, 2012.
- Lane, R., Wiles, R. *Process for preparing a butter-like spread*. Dairy Crest Limited, EP 0106620 B2, 2002.
- Segovia G., bello A., monzó M., boix C., sanchis D.Llobell, castelló O. *Emulsified spread based on olive oil and/or other vegetable oils and method for preparing it*. WO 2010076318 A1, 2010.
- Tatarov, P. Physicochemical changes of walnut oil (*Juglans regia* L.). In: *Proceedings of International Conference "Modern Technologies, in the Food Industry – 2012"*, Chisinau, 2012. – pp.192-197
- Saveliev, I. *Razrabotka i issledovanie tehnologii funktsionalnogo slivochno-rastitelnogo spreda s ispolzovaniem emulgatorov kompleksnykh svoystv*. [Development and research of the technology of functional creamy-vegetable spread using emulsifiers with complex properties.]. Ph.D. Thesis. Kemerovo, 2010. – in Russian
- Mamontov, A. *Razrabotka molochno-zhirovnykh kompozitsiy dlya spredov iz ustoychivogo k okisleniyu v protsesse transportirovki syrya*. [The development of dairy-fat compositions for spreads resistant to oxidation during raw materials transportation.]. Ph.D. Thesis. Ulan-Ude, 2016. – in Russian

13. Doronin, A. et al. *Funktsionalnyie pischevyie produkty. Vvedenie v tehnologii* [Functional foods. Introduction to Technology]. Moscow: DeLi print, 2009. – in Russian
14. Technical University Of Moldova, MD. *Procedeu de obținere a amestecului de grăsimi tartinabile pe bază de smântână dulce*. [Process of the preparation of a spreadable fats mixture based on sweet cream]. Patent no. 1281. Inventors: Radu, O., Popescu, L., Tatarov P., Baerle, A. Publ.: BOPI, 2018-09-30.
15. STEPYPICHEVA, N., KULIKOVA, A. Time to help producers. Study of the fatty acids composition of the dairy butter and its analogues. In: *Syrodellie i maslodellie* [Cheese and butter making], vol.2, 2019. – pp.50-52. DOI: 10.31515/2073-4018-2019-2-50-52
16. Dolmatova, O., Sharshov, A. The study of the properties of sweet cream butter with flavoring components. In: *Vestnik VGUIT* [Proceedings of VSUET], vol. 80, no. 3, 2018. – pp. 220-223. DOI:10.20914/2310-1202-2018-3-220-223
17. Idoui, T, Benhamada, N, Leghouchi, E. Microbial quality, physicochemical characteristics and fatty acid composition of a TB produced from cows' milk in East Algeria. In: *GRASAS YACE/ITES*, 61 (3), 2010 – pp. 232-236.
18. Esmaeili N., Bahmaei, M., Eshratabadi, P. Comparison of physicochemical characteristics of margarine and butter in Iranian market during storage. In: *Journal of Pharmaceutical and Health Sciences* 4(3), 2016. – pp. 181-192
19. Schmitt, V. et al. Emulsions: Structure Stability and Interactions. In: *Interface Science and Technology*, 2004.
20. Pal, M., Deressa, A., Feleke, A., Demissie, K. Hygienic and microbial quality of butter. In: *Beverage and Food World*, vol.41, 2014 – pp. 37-38.

DOI: 10.5281/zenodo.3464222

CZU 637.352:579.67



ANTIMICROBIAL PROPERTIES OF BERRY POWDERS IN CREAM CHEESE

Rodica Sturza¹, ORCID ID: 0000-0002-2412-5874Elisaveta Sandulachi^{1*}, ORCID ID: 0000-0003-3017-9008Daniela Cojocari^{1,2}, ORCID ID: 0000-0003-0445-2883Greta Balan², ORCID ID: 0000-0003-3704-3584Liliana Popescu¹, ORCID ID: 0000-0003-3381-7511Aliona Ghendov-Moșanu¹, ORCID ID: 0000-0001-5214-3562¹Technical University of Moldova, 168, Stefan cel Mare Bd., Chisinau, Republic of Moldova²State University of Medicine and Pharmacy "Nicolae Testemitanu, 165,
Stefan cel Mare Bd., Chisinau, Republic of Moldova*Corresponding author: Elisaveta Sandulachi: elisaveta.sandulachi@tpa.utm.md

Received: July, 02, 2019

Accepted: September, 15, 2019

Abstract. This study aims to evaluate the efficiency in reducing pathogens using berry powders in a cream cheese recipe, as compared to the traditional method of manufacturing. This article presents a review of the microbiological hazards of dairy products and a case study of antimicrobial properties of berry powders on pathogenic microorganisms that can accidentally colonize cream cheese. The most relevant results in the reduction of pathogenic microorganisms were obtained in cream cheese samples with the addition of rosehip and aronia powders on *Salmonella Abony* ATCC 6017; hawthorn powder on *Staphylococcus aureus* ATCC 25923. All berry powder additions had major effects on *Escherichia coli* ATCC 25922. Research has shown that powders of berries can be used for the manufacture of dairy products with natural ingredients more resistant to accidental contamination and safe for consumption.

Keywords: *reducing pathogens, thermostation period, log CFU, growth of microorganisms.*

Introduction

Due to their unique composition and properties milk and other dairy products are excellent growth media for many spoilage and pathogenic microorganisms [1, 2].

Salmonella continues to be a major concern for the dairy industry because these bacteria have caused recent outbreaks of illness and have been isolated from various dairy products in the market place. *Salmonella* bacteria are generally not heat resistant and normally grow at 35 to 37 °C, but they can grow at much lower temperatures, provided that the incubation time is suitably extended. To minimize problems, foods should be kept at 2 to 5 °C or below at all times [3]. Lately several salmonellosis cases have been recorded due to consumption of raw milk (both regular and organic). It goes to prove that more of the animal origin strains have been gaining entrance and surviving in the raw milk. The

December 2016 recall of nonfat dry milk had a huge resonance regarding dairy contamination [4].

The questions to be asked are: does *Salmonella* gain entrance into raw milk from cows, and does pasteurization kill the bacteria? *Salmonella* does gain entrance into raw milk from cows, and in the majority of cases pasteurization is adequate to kill it. If some strains of *Salmonella* survive high heat treatments, how can we eliminate this problem in dairy products [4]?

Microbiological risks in foods such as milk and dairy products are addressed in several studies. Most research includes the influence of heat treatment or salt in monitoring this risk [5]. The objective proposed in State project 18.51.07.01A / PS was to investigate other methods of reducing and controlling microbiological risk in food. Previous studies [6, 7] have shown that berry powder has an inhibitory effect on pathogenic microorganisms (*S. aureus*, *Staphylococcus aureus*, *Escherichia coli*, *Klebsiella pneumonia*, *B. mesentericus*), including meat products [8].

The purpose of this study was to evaluate the effect of adding berry powders to the cream cheese recipe on pathogenic microorganisms that may accidentally infect the finished product.

Materials and methods

In the pilot laboratory of the Food Technology Department, Technical University of Moldova, cream cheese samples were prepared using various berry powders grown in the Republic of Moldova. In this study the following samples with berry powder additions were investigated microbiologically:

- ✓ Cream cheese - sample control – (S1);
- ✓ Cream cheese with 2% rose-hip powder – (S3);
- ✓ Cream cheese with 2% sea buckthorn powder – (S6);
- ✓ Cream cheese with 2% aronia powder – (S9);
- ✓ Cream cheese with 2% hawthorn powder – (S12).

Microbiological tests were carried out in the laboratory of the Microbiology and Immunology Department, “Nicolae Testemitanu” State University of Medicine and Pharmacy. For the contamination of the experimental samples of cream cheese the microbial strains (*Staphylococcus aureus* ATCC 25923, *Salmonella Abony* ATCC 6017, *Escherichia coli* ATCC 25922) were procured from the National Public Health Agency. Inoculation of microorganisms in cream cheese samples, thermostatzation and monitoring of microbial growth was performed according to the following bibliographic sources [8-10].

Results and discussions

The predominant human bacterial pathogens that can potentially be transferred to milk include mainly *Listeria monocytogenes*, *Salmonella spp.*, *Staphylococcus aureus* and *Escherichia coli*. Raw milk provides a potential growth medium for the development of these bacteria [11]. Although pasteurization destroys potential pathogenic microorganisms, post pasteurization processing can lead to the recontamination of dairy products. For hygienic reasons, most cheeses are produced from pasteurized milk; however, with a production of 700,000 tons per year, raw milk cheeses represent a significant proportion of ripened cheeses produced in Europe, particularly in Italy, France and Switzerland. Many artisan cheese makers, customers and researchers claim the benefits/advantages of raw milk cheeses, so it is important to know the consequences and possible implications of

pasteurization on the ripening process, and ultimately on the sensory characteristics of cheese [12, 13].

Efficient pasteurization of milk eliminates the risk of pathogenic organisms, but does not destroy organisms that grow slowly or produce spores. While pasteurization destroys many microorganisms in milk, improper handling after pasteurization can recontaminate it [14, 15]. Both raw and pasteurized milk can be contaminated during bottling, shipment and storage. Pasteurization only destroys the pathogens in milk at the time of processing; if unsanitary conditions allow pathogens to re-enter the milk later, it will be contaminated again [16].

Heat is lethal to microorganisms, but each species has its own particular heat tolerance. During a thermal destruction process, such as pasteurization, the rate of destruction is logarithmic, as is their rate of growth. Thus bacteria subjected to heat are killed at a rate that is proportional to the number of organisms present. The process is dependent both on the temperature of exposure and the time required at this temperature to accomplish the desired rate of destruction. Thermal calculations thus involve the necessity to know the concentration of microorganisms to be destroyed, the acceptable concentration of microorganisms that can remain after (e.g. spoilage organisms, but not pathogens), the thermal resistance of the target microorganisms (the most heat tolerant ones), and the temperature-time relationship required to destroy the target organisms [17].

Table 1 and Figures 1 and 2 include the obtained results in the evaluation of the influence of the berry powders (rose-hip, sea buckthorn, aronia and hawthorn) on *Salmonella Abony* ATCC 6017.

Table 1

Reducing the growth rate of pathogenic microorganisms in cream cheese samples with the berry powders additions.

Sample coding	Estimated values	Incubation duration, h		
		0	24	48
Salmonella Abony ATCC 6017				
S1	CFU/1g product	1.4*10 ⁴	7.12*10 ⁸	1.4*10 ⁸
	log CFU	4.146	8.85	8.15
S3	CFU/1g product	1.4*10 ⁴	1.1*10 ⁷	0
	log CFU	4.146	7.041	-∞
S6	CFU/1g product	1.4*10 ⁴	4.2*10 ⁷	5*10 ⁶
	log CFU	4.146	7.62	6.70
S9	CFU/1g product	1.4*10 ⁴	0	0
	log CFU	4.146	-∞	-∞
S12	CFU/1g product	1.4*10 ⁴	6.6*10 ⁷	10 ⁷
	log CFU	4.146	7.82	7
Staphylococcus aureus ATCC 25923				
S1	CFU/1g product	1.4*10 ⁴	1.25*10 ⁸	3.2*10 ⁷
	log CFU	4.146	8.097	7.50
S3	CFU/1g product	1.4*10 ⁴	3.8*10 ⁷	1*10 ⁶
	log CFU	4.146	7.58	6

Continuation Table 1

S6	CFU/1g product	1.4*10 ⁴	4,0*10 ⁷	2.8*10 ⁷
	log CFU	4.146	7.6	7.45
S9	CFU/1g product	1.4*10 ⁴	7.1*10 ⁷	5.1*10 ⁷
	log CFU	4.146	7.85	7.71
S12	CFU/1g product	1.4*10 ⁴	2.8*10 ⁷	0
	log CFU	4.146	7.45	-∞
<i>Escherichia coli</i> ATCC 25922				
S1	CFU/1g product	1.4*10 ⁴	1.9*10 ⁷	8*10 ⁶
	log CFU	4.146	7.28	6.90
S3	CFU/1g product	1.4*10 ⁴	1.2*10 ⁷	0
	log CFU	4.146	7.08	-∞
S6	CFU/1g product	1.4*10 ⁴	0	0
	log CFU	4.146	-∞	-∞
S9	CFU/1g product	1.4*10 ⁴	2*10 ⁶	0
	log CFU	4.146	6.30	-∞
S12	CFU/1g product	1.4*10 ⁴	6*10 ⁶	0
	log CFU	4.146	6.78	-∞

According to European legislation, raw milk must be processed within a maximum limit of 48 hours, to reduce the development of pathogens [18]. In raw-milk cheese production, checking the acidity (pH and titratable acidity) of the milk and the curd along the production chain can help minimize risk. If acidity develops rapidly (in the first 6, 8 or 12 hours since the start of processing), it means that a good part of the microorganisms dangerous to health and product quality have been limited [19].

Salmonella has long been recognized as an important human health problem of economic significance in animal and humans. A total of 108,614 confirmed cases of salmonellosis were reported in the European Union in 2009, although cases attributed to *S. enteritidis* have decreased during the last years [20]. However, *Salmonella* infections have not declined over the past 15 years in USA [21]. Dairy products along with meat and eggs are the most common causes of food-borne infection by *Salmonella*. Salmonellosis from contaminated milk and dairy products has been associated with inadequate pasteurization and post-process contamination. Most cheeses, including raw or pasteurized milk cheeses, properly manufactured and aged, appear to pose no significant health risk of *Salmonella* infection [22].

There is extensive literature describing strains of lactic acid bacteria (LAB) from traditional dairy products able to inhibit the most important cheese pathogens (*L. monocytogenes*, *S. aureus*, *Klebsiella pneumoniae*, *Salmonella typhimurium*, *Bacillus subtilis*, and *Pseudomonas aeruginosa*) in media laboratory [19, 23]. Single strains of *L. garvieae* and *Lactococcus lactis* inhibited *S. aureus* early in a cheese matrix [24, 25].

Bertrand et al. [26] investigated the effect of raw milk cheese consumption on the enteric microbiota. The study by Fstanz [27] and Podolak et al. [14] is also of interest.

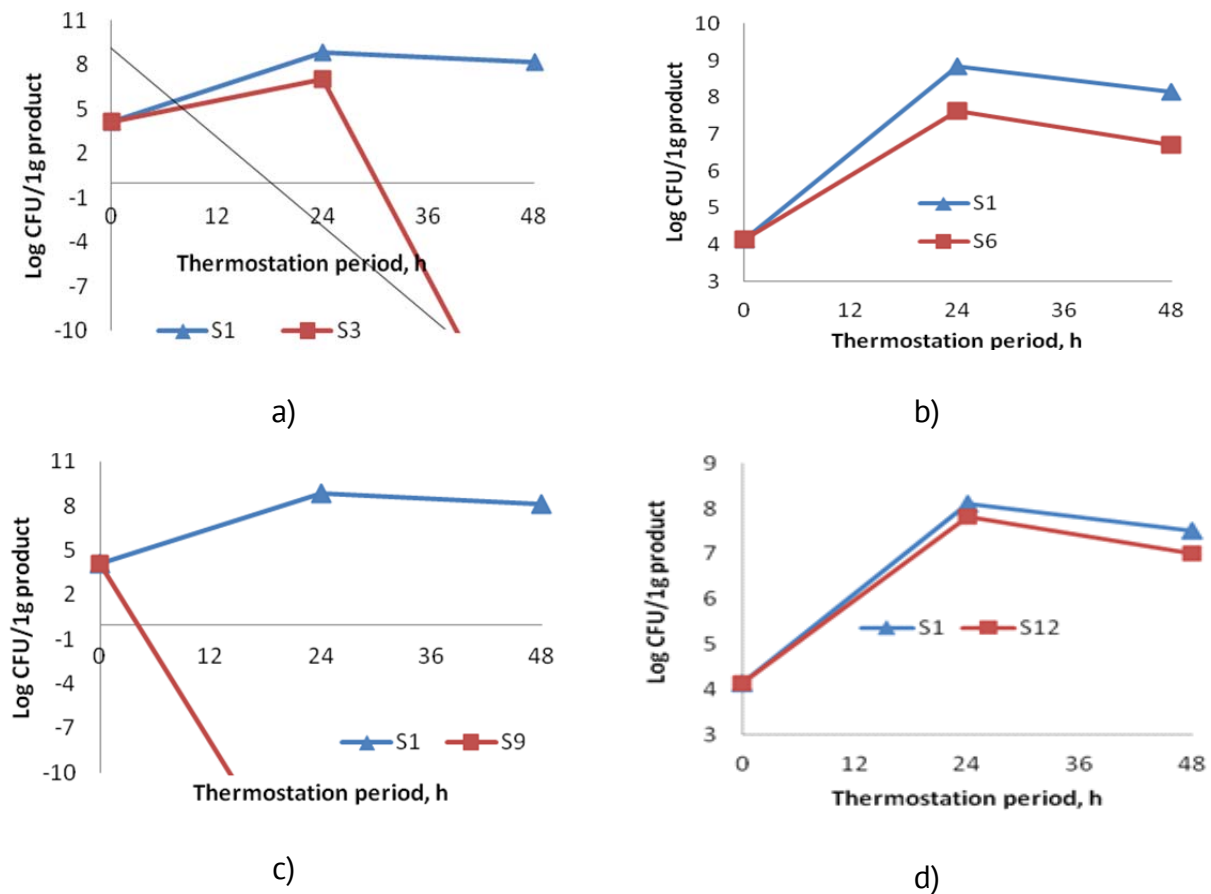


Figure 1. Comparison of the growth rate reduction of *Salmonella Abony* ATCC 6017 in the control sample and the samples with berry powders additions during 48 hours:

- a) Cream cheese: sample control – (S1) and with rose-hip powder – (S3);
- b) Cream cheese: sample control – (S1) and with sea buckthorn powder – (S6);
- c) Cream cheese: sample control – (S1) and with aronia powder – (S9);
- d) Cream cheese: sample control – (S1) and with hawthorn powder – (S12).

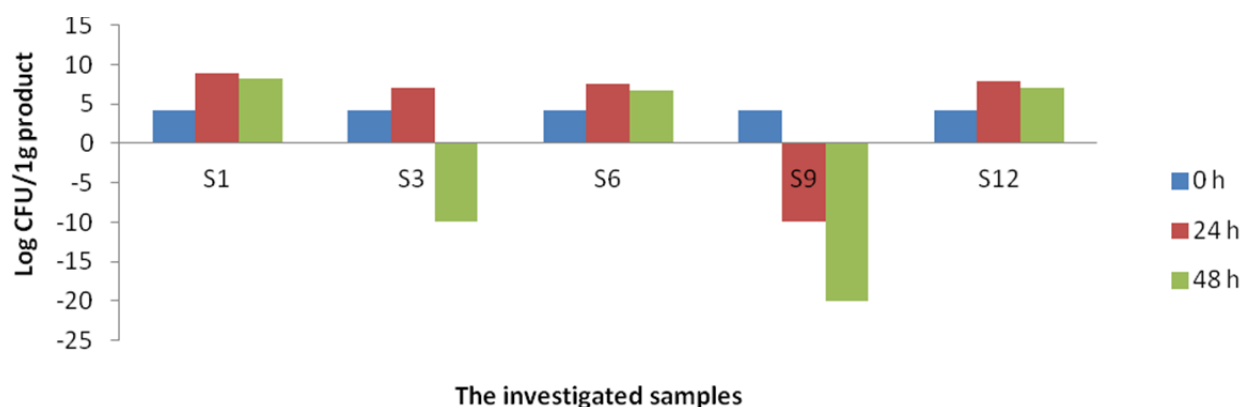


Figure 2. Modification of the content of *Salmonella Abony* ATCC 6017 inoculated in cream cheese samples at thermostat for 48 hours and temperature 37 °C.

The factors that determine the growth of *Salmonella spp.* are included in Table 2 [14, 28]. It is known that groups of grown microorganisms in food have the optimum, minimum and maximum pH. Table 2 lists the approximate pH ranges for growth in laboratory media

for selected organisms relevant to food. Generally, pH interacts with other parameters in food to inhibit growth. The pH can interact with factors such as a_w , salt, temperature, redox potential and preservatives to inhibit growth of pathogens and other organisms. The pH of food significantly impacts the lethality of heat treatment of the food. Less heat is needed to inactivate microbes as the pH is reduced [29, 30].

Table 2

Limits for growth of pathogenic microorganisms when other condition are near optimum*

Indicators	Minimum	Optimum	Maximum
<i>Salmonella ssp.</i>			
Temperature, °C (F)	5 (41)	35 - 37 (95 - 99)	45 - 47 (113 - 117)
pH	3.8	7-7.5	9.5
Water activity	0.93	0.99	>0.99
<i>Staphylococcus aureus growth</i>			
Temperature, °C (F)	7 (45)	35 - 40 (95 - 104)	48 (118)
pH	4.0	6.0-7.0	10.0
Water activity	0.83	0.98	0.99
<i>Staphylococcus aureus toxin</i>			
Temperature, °C (F)	10 (50)	40 - 45 (104 - 113)	46 (115)
pH	4.5	7.0- 8.0	9.6
Water activity	0.88	0.98	0.99
<i>Enteromorarrhagic E. coli</i>			
Temperature, °C (F)	10 (50)	40 - 45 (104 - 113)	46 (115)
pH	4.4	6.9-7.0	9.0
Water activity	0.95	0.99	

*Sources: ICMSF 1980, p 101. [<https://www.canr.msu.edu/uploads/234>]

A literature review showed that pathogenic microbes may be present in raw milk and in various types of dairy products, and these pathogenic microbes may also be present in the finished product, as they can enter industrial products during processing, packaging, distribution and storage [31, 32]. Some individuals are chronic carriers of *Salmonella* and if such an individual comes in contact with the anticaking agents (at the time of their manufacturing), especially dry blended products, the *Salmonella* can gain entrance into the anticaking agents and thus into the finished cheese. It is recommended to use low pH, high-heat spray dried anticaking agents, which are handled by workers to eliminate subdued pathogens [4]. The key factors to reduce the risk of *S. typhimurium* contamination are the implementation of appropriate hygiene measures to minimize the contamination of raw milk and proper storage of cheeses (e.g. water buffalo mozzarella cheese) at refrigeration temperature [33]. There are also alternative methods of controlling the microbiological risk in dairy products [34, 35].

Table 1 and Figures 3 and 4 include the results in evaluating the influence of berry powders (rose-hip, sea buckthorn, aronia and hawthorn) on *Staphylococcus aureus* ATCC 25923.

Staphylococcus aureus is a ubiquitous pathogen, thus, the sources of this bacteria for dairy products contamination are diverse [36]. This bacterium is commonly found in a wide

variety of mammals and birds and can be transferred to food mainly by dairy animals that have mastitis and by human carriers during food processing [37].

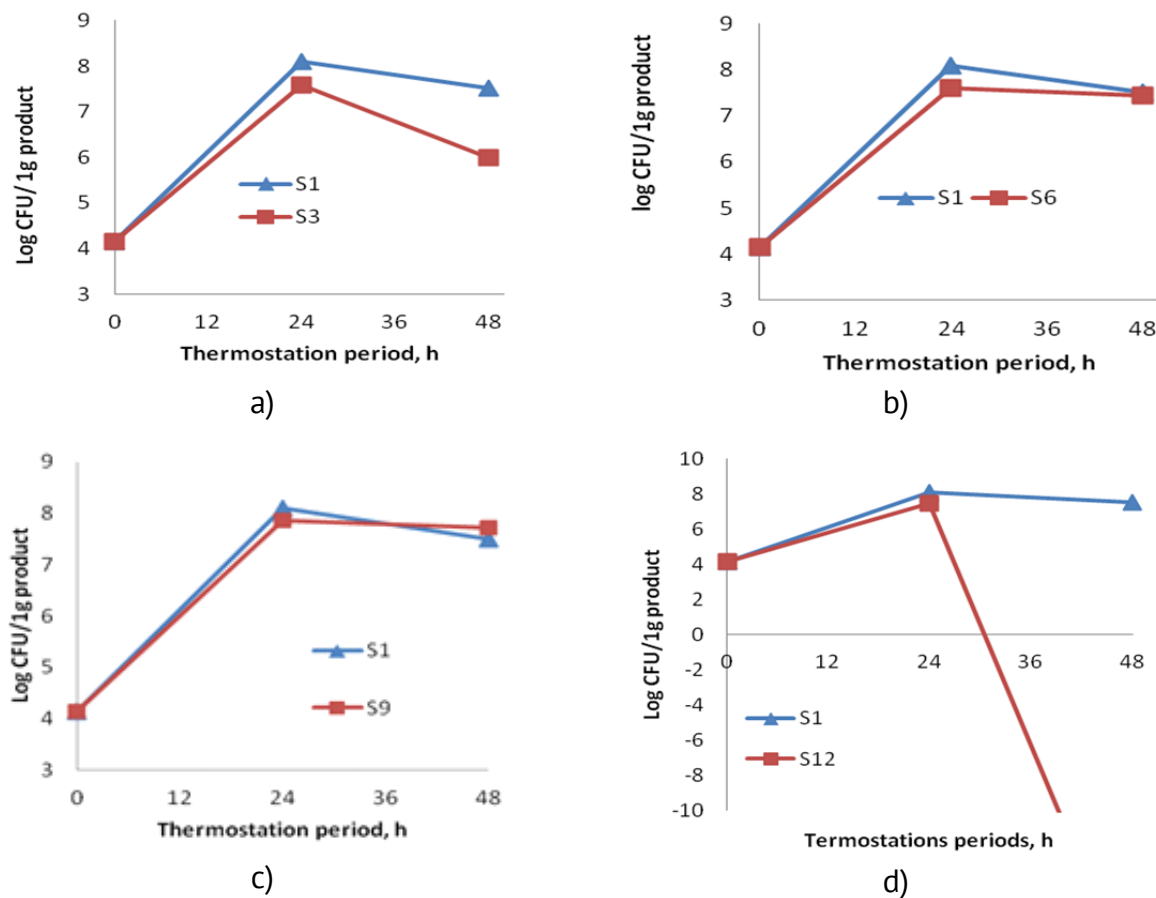


Figure 3. Comparison of the growth rate reduction of *Staphylococcus aureus* ATCC 25923 in the control sample and the samples with berry powders additions during 48 hours:

- a) Cream cheese: sample control – (S1) and with rose-hip powder – (S3);
- b) Cream cheese: sample control – (S1) and with sea buckthorn powder – (S6);
- c) Cream cheese: sample control – (S1) and with aronia powder – (S9);
- d) Cream cheese: sample control – (S1) and with hawthorn powder – (S12).

Contamination of *Staphylococcus aureus* can have a broad occurrence in raw dairy products, with frequencies between 5 and 100% in cheeses [38].

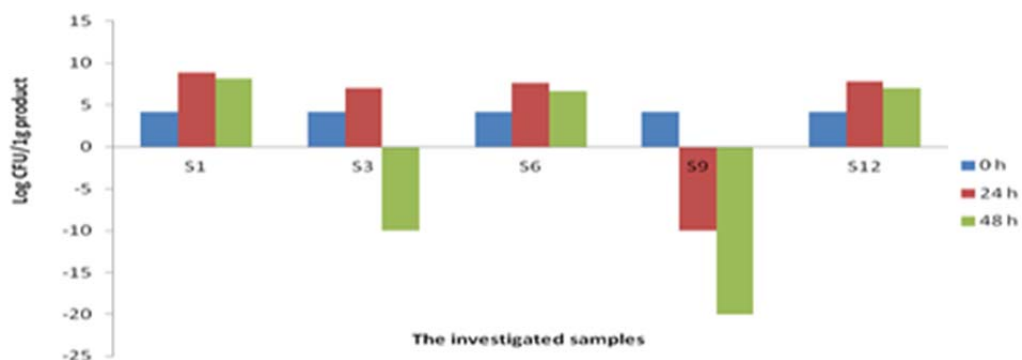


Figure 4. Modification of the content of *Staphylococcus aureus* ATCC 25923 inoculated in cream cheese samples at thermostat for 48 hours and temperature 37 °C.

The number of *Staphylococcus aureus* in raw milk or other dairy products needs to be less than 10^4 CFU g⁻¹, according to the United States Food and Drug Administration regulations [39]. Investigations indicated that *Escherichia coli* O157:H7 is an emerging cause of food borne illness and that young dairy cattle are a reservoir for it. A particularly dangerous type is referred to as enterohemorrhagic *E. coli* (EHEC).

Infection with EHEC strains is often associated with food borne outbreaks traced from milk, dairy products and other foods leading to hemorrhagic colitis (bloody diarrhea) and hemolytic uremic syndrome in humans [40]. Table 1 and Figures 5 and 6 include the results after evaluating the influence of berry powders (rose-hip, sea buckthorn, aronia and hawthorn) on *Escherichia coli* ATCC 25922.

On the other hand, the outbreaks of *Listeria monocytogenes* and *Staphylococcus aureus* (*S. aureus*) are enterotoxin producers. *Salmonella spp.* and *Escherichia coli* O157: H7 result from direct or indirect contamination of cheese. *S. aureus*, one of the pathogenic microorganisms that can be found in cheese, is a significant part of the poisonings from cheese [41].

The growth of *E. coli* can occur at temperatures between 7 – 46 °C, pH of 4.4 – 10.0 and a minimum water activity of 0.95 when other conditions are near optimum.

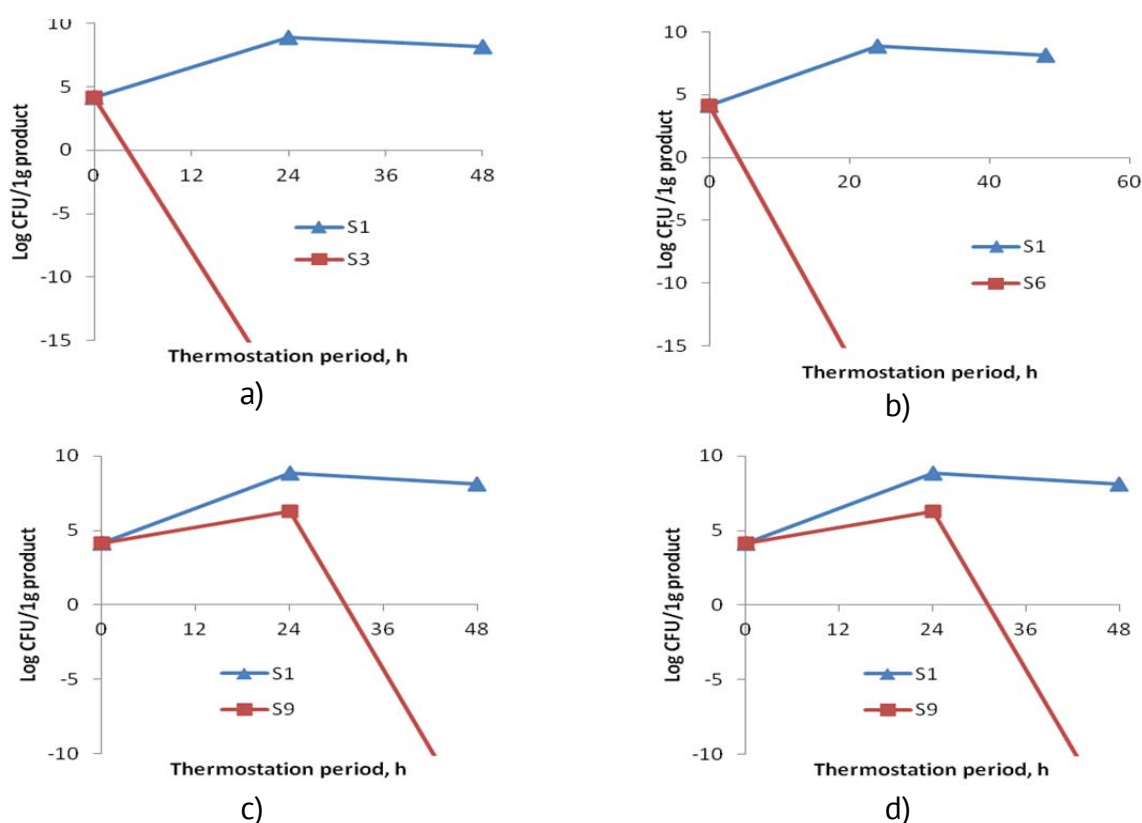


Figure 5. Comparison of the growth rate reduction of *Escherichia coli* ATCC 25922 in the control sample and the samples with berry powders additions during 48 hours:

- a) Cream cheese: sample control – (S1) and with rose-hip powder – (S3);
- b) Cream cheese: sample control – (S1) and with sea buckthorn powder – (S6);
- c) Cream cheese: sample control – (S1) and with aronia powder – (S9);
- d) Cream cheese: sample control – (S1) and with hawthorn powder – (S12).

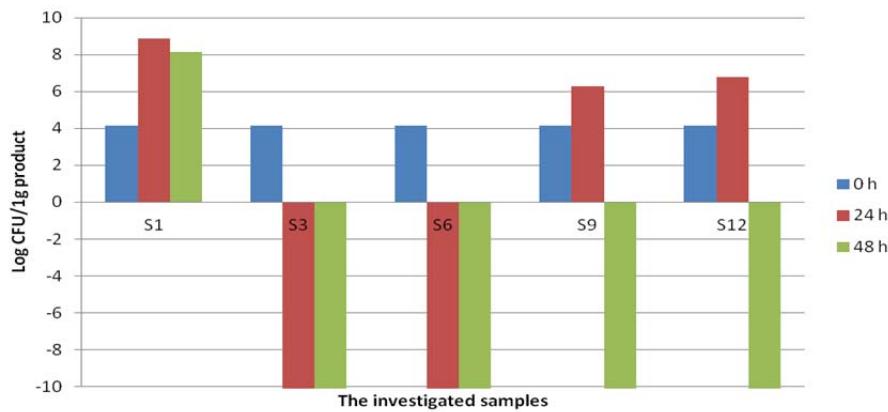


Figure 6. Modification of the content of *Escherichia coli* ATCC 25922 inoculated in cream cheese samples at thermostat for 48 hours and temperature 37 °C.

Some Shiga toxin-producing *Escherichia coli* (STEC) strains can survive at pH 2.5 – 3.0 for over 4 hours. STEC is capable to survive frozen storage at -20°C, however, it is readily inactivated by cooking [42, 43].

STEC can be a contaminant of milk sourced from infected herds. As raw milk cheese production does not include a process that reliably inactivates pathogens, the microbiological quality of raw milk is critical. Other risk factors include temperature control of the raw milk, acidification process, curd cooking, maturation/ripening, salt concentration, water activity, pH and nitrate [44, 45]. *Staphylococcus aureus*, *Salmonella* spp., *Listeria monocytogenes* and *Escherichia coli* O157:H7 are the most frequent potential pathogens associated with milk or dairy products in industrialized countries [46-48].

The food industry is looking for alternatives to satisfy consumer demand for safe foods with a long shelf-life capable of maintaining the nutritional and organoleptic quality. The application of antimicrobial compounds-producing protective cultures may provide an additional parameter of processing in order to improve the safety and ensure food quality, keeping or enhancing its sensorial characteristics. In addition, strong evidence suggests that certain probiotic strains can confer resistance against infection with enteric pathogens [49]. Thus, it is proposed to use berry powders to control the microbiological risk that can occur in cream cheese at an unconditional deviation.

Conclusions

Various published studies have shown that several food borne pathogens are present in raw milk of different dairy species, and these pathogenic microbes can also be present in manufactured products, because they can enter the manufactured products opportunistically during processing, packaging, distribution and storage processes. The factors that determine the growth of pathogenic microorganisms in dairy products are: temperature, pH, water activity and presence of antimicrobial substances. The efficiency of a certain antimicrobial solution will also depend on the type, genus, species, and strain of the target microorganism. Likewise, it will also depend on environmental factors such as pH, water activity, temperature, atmosphere composition, initial microbial load, and acidity of the food substrate. The test results evaluated the antimicrobial effect of berry powders on pathogenic microorganisms (*Salmonella* Abony ATCC 6017; *Staphylococcus aureus* ATCC 25923 and *Escherichia coli* ATCC 25922). It was determined that the addition of berry

powders (rose-hip, aronia, sea buckthorn and hawthorn) can keep the growth rate of the microorganisms, including the pathogens, under control. Most microorganisms inoculated in tested cream cheese samples with the addition of berry powders were destroyed after 48 hours of thermostation at 37 °C. The calculated CFU log was minus infinity. The most relevant antimicrobial effect was seen for berry powders on *E. coli* strains inoculated in tested cream cheese samples. The additions of rose-hip and aronia powders manifested major antimicrobial effect on *Salmonella* strains. The addition of hawthorn powder manifested major antimicrobial effect on *Staphylococcus aureus*. Therefore, the use of added berry powders in the recipe for the production of dairy products can have two meanings: improving the nutritional value of the food and increasing the product shelf-life by keeping the microbiological risk under control. The results of this study highlighted the need to improve and implement hygienic practices. Moreover, further research is needed to fully study the antimicrobial properties of berry powders in dairy production.

Acknowledgments

This work was benefited from support through the 18.51.07.01A/PS State project "Decreasing contamination of raw materials and food product with pathogenic microorganism", funded by the Government of the Republic of Moldova.

References

1. Smigic, N., Djekic, I., Tomasevic, I., Miocinovic, J., Gvozdenovic, R. 2012. Implication of food safety measures on microbiological quality of raw and pasteurized milk. In: *Food Control*, 2012, 25, pp. 728-731.
2. Claeys, W.L., Cardoen, S., Daube, G., De Block, J., Dewettinck, K., Dierick, K. et al. Raw or heated cow milk consumption: Review of risks and benefits. In: *Food Control*, 2013, 31, 251e262.
3. Gazzar, F.E., Marth, E.H. *Salmonellae, salmonellosis, and dairy foods: a review*. In: *Journal Dairy Science*. 1992, 75(9), pp. 2327-2343. Available at: <https://www.sciencedirect.com/science/article/pii/S0022030292779934>
4. Reddy, M. Prevention of Salmonella in Cheese and Other Dairy Products. In: *Market News*, 2017 <https://hartdesign.com/industry-news/prevention-salmonella-cheese-dairy-products/>
5. Alvarez-Ordóñez, A., Broussolle, V., Colin, P., Nguyen-The, C., PRIETO, M. The adaptive response of bacterial food-borne pathogens in the environment, host and food. Implication for food safety. In: *Journal Food Microbiology*, 2015, 213, pp. 99-109
6. Ghendov-Moșanu, A., Cojocari, D., Balan, G., Sturza, R. Antimicrobial activity of rose hip and hawthorn powders on pathogenic bacteria. In: *Jornal of Enineering Science*, 2018, 25 (4), pp. 100-107
7. Ghendov-Moșanu, A., Sturza, R., Sandulachi, E., Patraș, A. Diminution de la contamination des produits de panification en bactéries sporulées *Bacillus subtilis*, *Bacillus mesentericus*. In: *Actes du deuxième Colloque Franco-Roumain de Chimie Appliquée COFrRoCA*, 2018, p. 97.
8. Cojocari, D., Sturza, R., Sandulachi, E., Macari A., Balan, G., Ghendov- Mosanu, A. Inhibiting of accidental pathogenic microbiota in meat products with berry powders. In: *Journal of Engineering Science*, 2019, 26 (1), pp.114-122.
9. *Preparation of McFarland Turbidity Standards, Medical microbiology guide*, <https://microbeonline.com/preparation-mcfarland-turbidity-standards/>
10. Sandulachi, L., Rubțov, S., Popescu L. Controlul microbiologic al produselor alimentare [Microbiological control of food products]. Ed. *UTM, Tehnica*, 2017, 128p. ISBN 1978-9975-45-472-8.
11. Farrokh, C., Jordan, K., Auvray, F. et al. Review of Shiga-toxin-producing *Escherichia coli* (STEC) and their significance in dairy production. In: *International Journal of Food Microbiology*, 2013, 162 (2), pp. 190–212.
12. <http://orgprints.org/29120/1/29120.pdf>
13. Newman, K.L. Leon, J.S., Rebolledo, P.A., Scallan, E. The impact of socioeconomic status on foodborne illness in high-income countries. A systematic review. In: *Epidemiology and Infection*, 2015, 143, pp. 2473-2485.

14. Podolak, R., Enache, E., Stone, W., Black, D.G., Elliott, P.H. Sources and risk factors for contamination, survival, persistence, and heat resistance of *Salmonella* in low-moisture foods. In: *Journal of Food Protection*, 2010, 73 (10), pp. 1919–1936
15. Paulin, S., Horn, B., Hudson, J.A. Factors influencing staphylococcal enterotoxin production in dairy products. In: *Ministry for primary industries*, 2012.
16. Marler, B. Comparing the food safety record of pasteurized and raw milk products – Part 3, 2009, pp. 1–33. Available at: <http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:Comparing+the+Food+Safety+Record+of+Pasteurized+and+Raw+Milk+Products#0>
17. Thermal Destruction of Microorganisms. Available at: <https://www.uoguelph.ca/foodscience/book-page/thermal-destruction-microorganisms>
18. Council directive 92/46/EEC of 16 June 1992 laying down the health rules for the production and placing on the market of raw milk, heat-treated milk and milk-based products.
19. Diop, M.B., Dibois-Dauphin, R., Tine, E., Jacqueline, A.N., Thonart, P. Bacteriocin producers from traditional food products. In: *Biotechnology, Agronomy, Society and Environment*, 2007 11, pp. 275–281.
20. The European Union summary report on trends and sources of zoonoses, zoonotic agents and food-borne outbreaks in 2010. In: *The EFSA Journal*, 2012, 10, p. 2597.
21. Gilliss, D., Cronquist, A., Cartter, M. et al. Vital signs: incidence and trends of infection with pathogens transmitted commonly through food—food borne diseases active surveillance network, 10 U.S. sites, 1996–2010. In: *Morbidity and Mortality Weekly Report*, 2011, 60 (22), pp. 749–755.
22. Argues, J.L., Rodríguez, E., Langa, S., Landete, J.M., Medina, M. Antimicrobial Activity of Lactic Acid Bacteria in Dairy Products and Gut: Effect on Pathogens. In: *BioMed Research International*, 2015. <http://dx.doi.org/10.1155/2015/584183>
23. Ortolani, M.B.T., Moraes, P.M., Perin, L.M., Vicoso, G.N., Carvalho, K.G., Silva JR., A., Nero, L.A. Molecular identification of naturally occurring bacteriocinogenic and bacteriocinogenic-like lactic acid bacteria in raw milk and soft cheese. In: *Journal. Dairy Science*, 2010, 93, pp. 2880–2886
24. Alomar, J., Loubiere, P., Delbes, C., Nouaille, S., Montel, M.C. Effect of *Lactococcus garvieae*, *Lactococcus lactis* and *Enterococcus faecalis* on the behaviour of *Staphylococcus aureus* in microfiltered milk. In: *Food Microbiology*, 2008, 25, pp. 502–508.
25. Cretenet, M., Nouaille, S., Thouin, J., Rault, L., Stenz, L., Francois, P., Hennekinne, J.-A. et al. *Staphylococcus aureus* virulence and metabolism are dramatically affected by *Lactococcus lactis* in cheese matrix. In: *Environmental Microbiology Reports*, 2011, 3, 340–351.
26. Bertrand, X., Dufour, V., Millon, L., Beuvier, E., Gbaguidi-Haore, H., Piarroux, R., Vuitton, D.A., Talon, D. 2007. Effect of cheese consumption on emergence of antimicrobial resistance in the intestinal microflora induced by a short course of amoxicillin– clavulanic acid. in: *Journal of Applied Microbiology*, 2007, 102, pp. 1052–1059.
27. Food Standards Australia New Zealand. *Microbiological risk assessment of raw cow milk*. Canberra, 2009. Available at: <http://www.foodstandards.gov.au/code/proposals/documents/P1007%20PPPS%20for%20raw%20milk%201AR%20SD1%20Cow%20milk%20Risk%20Assessment.pdf>.
28. International Commission on Microbiological Specification for Foods. *Microorganisms in foods*. Roberts T.A., Baird-Parker A.C., Tompkin R.B., editors. Volume 5, Characteristics of microbial pathogens. London: Blackie Academic & Professional, 1996, p 513.
29. Mossel, D.A.A., Corry, J.E.L., Struijk, C.B., Baird, R.M. *Essentials of the microbiology of foods: a textbook for advanced studies*. In: Chichester (England): John Wiley and Sons, 1995, 699 p.
30. https://www.canr.msu.edu/uploads/234/48511/Safe_Practices_fo
31. Park, Y.W. *Goat milk—chemistry and nutrition*. In: Park YW, Haenlein GFW (ed.), *Handbook of Milk of Non-bovine Mammals*. Blackwell Publishing Professional, Oxford, UK/Ames, Iowa, 2006, pp: 34–58.
32. IDF Recommendations for Hygienic Manufacture of Spray Dried Milk Powders. In : *IDF Bulletin*, 1996, 267. Int Dairy Fed Brussels, Belgium.
33. Serraino, A., Giacomo, G.F et al. Behaviour of *Salmonella Typhimurium* during production and storage of artisan water buffalo *Mozzarella* cheese. In: *Italian Journal of Animal Science*, 2012, 11 (3). <https://doi.org/10.4081/ijas.2012.e53>
34. Loss, C.R., Hotchkiss, J.H. *Inhibition of microbial growth by low-pressure and ambient pressure gasses*. In: Juneja VK, Sofos JN, editors. *Control of foodborne microorganisms*. New York: Marcel Dekker, 2002, pp. 245–79.

35. Morris, J.G. *The effect of redox potential*. In: Lund BL, Baird-Parker TC, Gould GW, editors. *The microbiological safety and quality of food*. Volume 1. Gaithersburg (MD): Aspen, 2000, pp. 235–50.
36. Rosengren, Å. et al. Occurrence of food borne pathogens and characterization of *Staphylococcus aureus* in cheese produced on farm-dairies. *Int. Journal Food Microbiology*, 2010, 144, pp. 263–269.
37. Hennekinne, J., De Buyser M., Dragacci S. *Staphylococcus aureus* and its food poisoning toxins: characterization and outbreak investigation. In: *FEMS Microbiology Reviews*, 2012, 36, pp. 815–836.
38. Verraes, C., Vlaemynck, G., Van Weyenberg, S., De Zutter, L. et al. A review of the microbiological hazards of dairy products made from raw milk. In: *International Dairy Journal* 2015, 50, pp. 32–44.
39. Yu, J., Zhang, Y., Zhang, Y., Li, H., Yang, H., Wei, H. Sensitive and rapid detection of *staphylococcus aureus* in milk via cell binding domain of lysine. In: *Biosensors and Bioelectronics*, 2016, 77, pp. 366–371
40. Nguyen, Y, Sperandio, V. Enterohemorrhagic *E. coli* (EHEC) pathogenesis. In: *Frontiers in Cellular and Infection Microbiology*, 2012, 2, p. 90.
41. Baran, A., Erdoğan, A., Turgut, T., Adigüzel, M. C. A review on the presence of *Staphylococcus aureus* in cheese. In: *Journal of Turkish Nature and Science*, 2017, 6 (2).
42. Food Standards Australia New Zealand. Agents of food borne illness, Canberra, 2013, 2nd ed, http://www.foodstandards.gov.au/publications/Documents/FSANZ_Foodbornellness_2013_WEB.pdf.
43. Meng J., Le Jeune J.T., Zhao T., Doyle M.P. *Enterohemorrhagic Escherichia coli*. Ch 12 In: Doyle MP, Beuchat LR (eds) *Food microbiology: Fundamentals and frontiers*. 4th ed, ASM Press, Washington D.C., 2013, p. 287–309
44. Food Standards Australia New Zealand. Microbiological risk assessment of raw milk cheese, Canberra, 2009. Available at: <http://www.foodstandards.gov.au/code/proposals/documents>
45. <http://www.foodstandards.gov.au/consumer/importedfoods/Documents/Raw%20milk%20cheese%20and%20STEC.pdf>
46. Ostin, A., de Buyser, M. L., Guillier, F. et al. First evidence of a food poisoning outbreak due to staphylococcal enterotoxin type E, France, 2009. In: *Eurosurveillance*, 2010, 15(13), pp.10–13.
47. CDC (Centers for Disease Control and Prevention) Multistate Outbreak of *E. coli* O157:H7 Infections Associated with Cheese, 2010, Available at: <https://www.cdc.gov/ecoli/2010/bravo-farms-cheese-11-24-10.html>
48. Jakobsen, R.A., Heggebø, R., Sunde, E.B., Skjervheim, M. *Staphylococcus aureus* and *Listeria monocytogenes* in Norwegian raw milk cheese production. In: *Food Microbiology*, 2011, 28, pp. 492–496.
49. Arqués, J.L., Rodríguez, E., Langa, S., Landete, J.M., Medina, M. Antimicrobial activity of lactic acid bacteria in dairy products and gut: effect on pathogens. In: *BioMed Research International*, 2015, 1-9. <http://dx.doi.org/10.1155/2015/584183>

DOI: 10.5281/zenodo.3444009
SZU: 929:[629.7+533.69](498)



GHEORGHE ION DUCA - THE REORGANIZER OF THE NATIONAL SCHOOL OF BRIDGES AND ROADS OF BUCHAREST

Gheorghe Manolea

University of Craiova, 13 A. I. Cuza Street, Craiova, Romania
Gheorghe Manolea, ghmanolea@manolea.ro

Received: July, 30, 2019

Accepted: September, 18, 2019

Abstract. School had, has and will have an important role in building the elite of a nation. The National School of Bridges and Roads played an important part in educating engineers in Romania. Here big names from the Romanian engineering were educated, and later, they made the name of this school famous worldwide. As it usually happens, in the history of an institution, there is a man who, due to his force and vision, changes its destiny for good. In the history of the National School of Bridges and Roads, this man was Gheorghe Ion Duca whose name is closely linked by the beginning of the engineering school system in our country by its reorganization and by building the headquarters at the crossroads of Polizu Street and Calea Griviței, where the Polytechnics Institute of Bucharest functioned for a long time.

Keywords: *Georghe Ion Duca, The National School of Bridges and Roads, Polytechnics Institute of Bucharest.*

Biography

Gheorghe Duca was born on the 3rd of February 1847 at Galați. His father, Ion Duca, was a minister during Alexandru Ioan Cuza's reign. He attended Louis le Grand High School in Paris. His education and his life were supervised by Iancu Alecsandri, the poet Vasile Alecsandri's brother, who was at his time one of the close collaborators of Alexandru Ioan Cuza. He passed the baccalaureate exam in 1864, and he immediately registered at the Central School of Arts and Crafts in Paris, getting the engineer diploma in 1869.

Educational Reformer

He came back in the country in the same year and he got a job as a descriptive geometry professor at the Military High School from Iași where his organizational spirit and his teaching strictness were remarked.

As a result, he was appointed professor and manager of the School of Bridges and Roads of Bucharest on the 8th of April 1881. Following the model of the French school that he had graduated 12 years before, he improved the curricula for all disciplines and the teaching methods so that the results of the graduates would be similar to the ones got by the French students, by the European students. The new manager introduces a very severe discipline. Thus, in the Report no. 109 from the 16th of June 1881, approved by the minister,

he proposed measures which will allow the students to be declared repeaters or to be expelled if they do not study steadily or fail the general exam. Gheorghe Duca said: *"An essential condition to succeed is an absolute severity for behaviour as well as for study"*. With the Report no. 205 from the 19th of September 1881, he proposed for the 1881-1882 school year a preparatory year in order to complete the high school graduates' lack of mathematical knowledge.

Criticizing the tendency to form engineers from all branches (bridges, roads, railways, buildings, mining, industry and so on), Gheorghe Ion Duca considered that the state, which made huge money efforts, should form specialists for public works (namely bridges, roads, railways). Gheorghe Duca organized an extremely rigorous selection of the students. The number of students who managed to pass the first year was less than 15 although *"nothing would be easier than having at least 50 students in each class, but, in this case, the school would become a factory of nullities"*. *"He reorganized the school from the ground up"* was stipulated in a document of that time.

A Short Story of the National School of Bridges and Roads

On the 1st of October 1864 the engineering school was founded after a project elaborated by Mihail Kogălniceanu. This school was named The School of Roads, Mining and Architecture which had as a goal the forming of specialists in charge with more and more numerous public works. The studies lasted two years. On the 30th of October 1867, this school became the School of Bridges, Roads and Mining, five years were needed to graduate: a preparatory year, three years with common courses and the fifth specialized year with two specializations: "The Department of Bridges and Roads" and "The Department of Mining". This is considered a stabile beginning of organizing the engineering academic system in Romania, and this beginning ended in 1881 when Gheorghe Duca was appointed manager of this school.

School under Gheorghe Ion Duca's Management

On the 1st of April 1881, under Gheorghe Ion Duca's management, the institution changes its structure and name: The National School of Bridges and Roads. Its setting-up, only two years after the setting-up of the Polytechnics School in Berlin- Charlottenburg, is one of the many proofs of technical maturity of our great scientists. The National School of Bridges and Roads educated engineers in different specializations, in the domain of public works, of constructions, mining and oil exploitation and so on. The level of the theoretical knowledge was very high and helped some of the graduates approach new domains of sciences and they were even able to create new sciences. An example of such engineer is Gogu Constantinescu. He introduced compulsory practical hours in order to form artillery officers, and, together with their engineer degree, they also became the lieutenants in reserve.

Starting with 1890, the graduates of the National School of Bridges and Roads were acknowledged their diplomas at the same level as the diplomas got at foreign polytechnics schools.

Gheorghe Duca considered that a good school should have a lot of space, and this is why he moved it on the former Calea Craiovei, Calea Rahovei today, in a large building situated on Știrbei Vodă Street, where nowadays there is the "Ciprian Porumbescu" Conservatory.

Due to Gheorghe Duca's initiative, in 1884 the school started to build a new building on Polizu Street, at the crossroads with Calea Grivitei. This is Building A, ground floor and first floor, where, later, the Polytechnic Institute functioned for many years.

On the 2nd of October 1886, the new building was solemnly inaugurated. The building was designed for 100 students, with an area of 7000 m² and it contained an auditorium, many classrooms, a chemistry lab, a physics lab, a mechanic lab, as well as drawing rooms, a library and a museum which still functions.

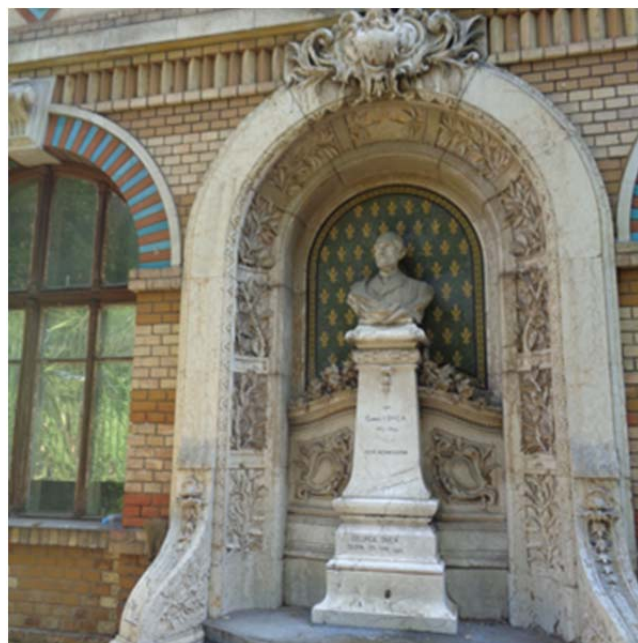
Gheorghe Duca managed the School until March 1888 when he was appointed general manager of the railway company. In fact, a great part of his activity was carried out in the railway company. In 1874 he was appointed manager of Iași – Ungheni route. Between 1876 – 1881 he worked at the Central Direction of Guillaux Company, on Ploiești – Predeal railway route. In 1897 he was appointed general manager of Romanian Railway Company. In this position, he implemented a lot of innovative solutions, he developed the railway network, he used specific devices for increasing the safety of the railway traffic and reducing the number of accidents, he reduced the ticket prices. In order to increase the professional quality of the personnel, he set up a school for traction mechanics (1890), a school for maintenance chiefs (1892) and another one for manipulators (1893).

Gheorghe Ion Duca and Professional Associations

Polytechnics Association. Gheorghe Ion Duca was one of the founding members, being vice-president from the very beginning and President in 1883 and 1890. He died too early, on the 7th of August 1899. He was only 52. His statue, made of bronze, is placed on Calea Grivitei from Bucharest, between the old building of the Polytechnics Institute and North Railway Station, two institutions which he dedicated most of his energy, and the stone statue is placed in the interior court of the building on Polizu Street.



Gheorghe Ion Duca's statue on Calea Grivitei



Gheorghe Ion Duca's statue in the interior court of Polytechnics Institute building in Bucharest, Calea Grivitei

Reference

1. Manolea Gheorghe. *Invențiile și istoriile lor. Despre inventatori*. Editura ALMA, Craiova, 2010.