Vol. 56, No.3 / 2018

e: ISSN 2068 – 2239
p: ISSN 2068 – 4215

# INMATEH – AGRICULTURAL ENGINEERING

SEPTEMBER - DECEMBER

*No liability is assumed by the editorial staff for the content of scientific papers and opinions published in this volume. They represent the author's point of view*

# Editorial

The National Institute of Research-Development for Machines and Installations designed to Agriculture and Food Industry - INMA Bucharest has the oldest and most prestigious research activity in the field of agricultural machinery and mechanizing technologies in Romania.

**Short History**

- In 1927, the first research **Center for Agricultural Machinery** in Agricultural Research Institute of Romania - ICAR (Establishing Law was published in O.D. no. 97/05.05.1927) was established;
- In 1930, was founded **The Testing Department of Agricultural Machinery and Tools** by transforming Agricultural Research Centre of ICAR - that founded the science of methodologies and experimental techniques in the field (Decision no. 2000/1930 of ICAR Manager - GHEORGHE IONESCU ŞIŞEŞTI);
- In 1952, was established the Research Institute for Mechanization and Electrification of Agriculture - ICMA Bănеasa, by transforming the Department of Agricultural Machines and Tools Testing;
- In 1979, the Research Institute of Scientific and Technological Engineering for Agricultural Machinery and Tools – ICSITMUA was founded - subordinated to Ministry of Machine Building Industry - MICM, by unifying ICMA subordinated to MAA with ICPMA subordinated to MICM;
- In 1996 the National Institute of Research-Development for Machines and Installations designed to Agriculture and Food Industry – INMA was founded – according to G.D. no.1308/25.11.1996, by reorganizing ICSITMUA, G.D no. 1308/1996 coordinated by the Ministry of Education and Research G.D. no. 823/2004;
- In 2008 INMA has been accredited to carry out research and developing activities financed from public funds under G.D. no. 551/2007, Decision of the National Authority for Scientific Research - ANCSno. 9634/2008.

As a result of widening the spectrum of communication, dissemination and implementation of scientific research results, in 2000 was founded the institute magazine, issued under the name of SCIENTIFIC PAPERS **(INMATEH)**, ISSN 1583 – 1019.

Starting with volume 30, no. 1/2010, the magazine changed its name to **INMATEH - Agricultural Engineering**, appearing both in print format (ISSN 2068 - 4215), and online (ISSN online: 2068 - 2239). The magazine is bilingual, abstract being published in native language and English, with a rhythm of three issues / year: January-April, May-August, September-December and is recognized by CNCSIS – with $B^+$ category. Published articles are from the field of AGRICULTURAL ENGINEERING: technologies and technical equipment for agriculture and food industry, renewable energy, machinery testing, environment, transport in agriculture etc. and are evaluated by specialists inside the country and abroad, in mentioned domains.

Technical level and performance processes, technology and machinery for agriculture and food industry increasing, according to national requirements and European and international regulations, as well as exploitation of renewable resources in terms of efficiency, life, health and environment protection represent referential elements for the magazine „**INMATEH - Agricultural Engineering**".

We are thankful to all readers, publishers and assessors.

Editor in chief,

Ph. D. Eng. **Vladut Nicolae-Valentin**

# Managing Editorial Board - INMA Bucharest


**Editor in Chief**
**VLADUŢ Nicolae-Valentin**
Ph.D.Eng, SR I
*E-mail:* inmatehjournal@gmail.com

**Executive Editor**
**POPA Lucreţia**
Ph.D.Eng, SR I

**Assistant Editor**
**MATACHE Mihai-Gabriel**
Ph.D.Eng, SR I

**Logistic support, database**
**MURARU Virgil,** Ph.D.Eng, SR I
**ŢICU Tania,** techn.

**Scientific Secretary**
**Cârdei Petre,** math.

**Official translators**
**RADU Daniela-Cristina,** Prof. English, French

## Editorial Board

- Acad. Prof. Ph.D. TABĂRA Valeriu - Romania, President of ASAS - Academy of Agricultural and Forestry Sciences "Gheorghe Ionescu Şişeşti";
- Ph.D. BOGOESCU Marian - Romania, Vicepresident of ASAS - Academy of Agricultural and Forestry Sciences "Gheorghe Ionescu Şişeşti";
- Hon.Prof.Ph.D.Eng. PIRNA Ion - Romania, President of the Department of Agricultural Mechanization of ASAS - Academy of Agricultural and Forestry Sciences "Gheorghe Ionescu Şişeşti";
- Ph.D. Eng. NICOLESCU C. Mihai - Romania, Scientific General Secretary of the ASAS-Academy of Agricultural and Forestry Sciences "Gheorghe Ionescu Şişeşti";
- Assoc.Prof. Ph.D. Eng. BELC Nastasia - Romania, IBA Bucharest;
- Ph.D. Eng. BUŢU Alina - Romania, INSB Bucharest;
- Prof. Ph.D. Eng. PARASCHIV Gigel - Romania, P.U. Bucharest;
- Prof. Ph.D.Eng. BIRIŞ Sorin - Romania, P.U. Bucharest;
- Prof. Ph.D. Eng. VLASE Sorin - Romania, "Transilvania" University Braşov;
- Prof. Ph.D.Eng. BURNETE Nicolae - Romania, Technical University Cluj Napoca;
- Prof. Ph.D. Eng. FILIP Nicolae - Romania, Technical University Cluj Napoca;
- Prof. PhD. Eng. VOICU Gheorghe - Romania, P.U. Bucharest;
- Prof. PhD. Eng. GERGEN Iosif -Romania,USAMVB Timişoara;
- Prof. Ph.D. Eng. ŢENU Ioan - Romania, USAMV Iaşi;
- Assoc.Prof.Ph.D.Eng. BUNGESCU Sorin - Romania, USAMVB Timişoara;
- Prof. Ph.D.Eng. FENYVESI László - Hungary, Hungarian Institute of Agricultural Engineering Godolo;
- Assist.Prof.Ph.D.Eng. BILANDZIJA Nikola - Croatia, University of Zagreb;
- Ph.D. BIOCCA Marcello - Italy Agricultural Research Council, Agricultural Engineering Research Unit;
- Prof.Ph.D.Eng. MIHAILOV Nikolay - Bulgaria, University of Rousse;
- Assoc.Prof.Ph.D.Eng. ATANASOV At. - Bulgaria, University of Rousse;
- Assoc.Prof. Ph.D. ERTEKIN Can - Turkey, Akdeniz University Antalia;
- Prof. Ph.D.Sc. Eng. VARTUKAPTEINIS Kaspars - Latvia, Latvia University of Agriculture, Institute of Agricultural Machinery;
- ir. HUYGHEBAERT Bruno - Belgium, Walloon Agricultural Research Center CRA-W;
- Prof.Ph.D. Eng. FABBRO Dal Inacio Maria - Brazil, Campinas State University;
- Prof. PhD. Eng. DE WRACHIEN Daniele - Italy, State University of Milan;
- Prof. PhD.Guanxin YAO - P.R.China, Along Agriculture R&DTechnology and Management Consulting Co., Ltd;
- Prof. PhD. Eng. GONZÁLEZ Omar - Republic of Cuba, Central University "Marta Abreu" de las Villas;
- Assist. Prof.Dr. KABAŞ Önder –Turkey, Akdeniz University.
- Asist.Prof.Dr. SELVİ Kemal Çağatay - Turkey, Ondokuz Mayıs University.



**In the present, *INMATEH - Agricultural Engineering* journal is indexed in the next international databases:**
ELSEVIER /SciVerse SCOPUS, CLARIVATE ANALYTICS' WEB OF SCIENCE- Emerging Sources Citation Index (ESCI), ULRICHS Web: Global Serials Directory, CABI, SCIPIO, Index COPERNICUS International, EBSCO Publishing, Elektronische Zeitschriftenbibliothek

**INMATEH - Agricultural Engineering**
**vol. 56, no.3 / 2018**
NATIONAL INSTITUTE OF RESEARCH-DEVELOPMENT FOR MACHINES AND INSTALLATIONS DESIGNED TO AGRICULTURE AND FOOD INDUSTRY - INMA Bucharest
6 Ion Ionescu de la Brad Blvd., sector 1, Bucharest

Three issues per year,
e-ISSN: 2068 – 2239
p ISSN: 2068 – 4215

Edited by: INMA Bucharest

**Copyright: INMA Bucharest / Romania**

# CONTENT


| | | Page(s) |
|---|---|---|
| 1. | **EXPERIMENTAL RESEARCH ON THE MOVEMENT STABILITY OF A PLOUGHING AGGREGATE, COMPOSED ACCORDING TO THE "PUSH-PULL" SCHEME /** ***PĒC «PUSH-PULL» SHĒMAS KOMPLEKTĒTA ARŠANAS AGREGĀTA KUSTĪBAS STABILITĀTES EKSPERIMENTĀLS PĒTĪJUMS*** **PhD. Ivanovs S.[1)], Prof.PhD. Bulgakov V.[2)], Prof.PhD. Adamchuk V.[3)], Prof.PhD. Kyurchev V.[4)], Prof.PhD. Kuvachov V.[4)]** [1)]Latvia University of Agriculture / Latvia; [2)]National University of Life and Environmental Sciences of Ukraine / Ukraine; [3)]National Scientific Centre "Institute for Agricultural Engineering and Electrification" / Ukraine; [4)]Tavria State Agrotechnological University / Ukraine | 9 |
| 2. | **RESEARCH ON THE VIBRATION OF MINI TILLER /** ***微耕机的振动研究*** **Ph.D. Eng. Liang X.C. *), Prof. Ph.D. Chen J., Ms.Stud. Eng. Wang Z.** Southwest University, College of Engineering and Technology, Chongqing Key Laboratory of Agricultural Equipment for Hilly and Mountainous Regions / P. R. China | 17 |
| 3. | **ANALYSIS OF THE WORKS PERFORMED BY PNEUMATIC AND MECHANICAL SEEDING DEVICE WITHOUT USING VACUUM /** ***АНАЛІЗ РОБОТИ ПНЕВМОМЕХАНІЧНОГО ВИСІВНОГО АПАРАТА БЕЗ ВИКОРИСТАННЯ ВАКУУМУ*** **Lect. Ph.D. Eng. Vasylkovska K.V., Lect. Ph.D. Eng. Vasylkovskyi O.M., Prof. Ph.D. Eng. Sviren M.O., Lect. Ph.D. Agric. Kulik G.A.** Central Ukrainian National Technical University / Ukraine | 25 |
| 4. | **PRODUCTION TESTS OF A SEED DRILL CPH 2000 FOR DIRECT SOWING /** ***ESSAIS AU CHAMP D'UN SEMOIR CPH 2000 POUR LE SEMIS DIRECT*** **Warouma Arifa*[1)], Haidenko Oleh[2)]** [1)]Dan Dicko Dan Koulodo University of Maradi, Niger Republic [2)] Institute of Steppe Agriculture of the National Academy of Agrarian Sciences of Ukraine | 31 |
| 5. | **RESEARCH ON THE RATIONAL REGIMES OF WHEAT SEEDS DRYING /** ***ДОСЛІДЖЕННЯ РАЦІОНАЛЬНИХ РЕЖИМІВ СУШІННЯ НАСІННЯ ПШЕНИЦІ*** **Assoc. Prof.Ph.D.Eng. Paziuk V.M.[1)], Assoc. Prof. Ph.D. Eng. Liubin M.V. [2)], Assoc. Prof. Ph.D. Eng. Yaropud V.M. [2)], Assoc. Prof. Ph.D. Eng. Tokarchuk O.A. [2)], Assoc. Prof. Ph.D. Eng. Tokarchuk D.M. [2)]** [1)]Institute of technical thermal physics NAS of Ukraine [2)]Vinnitsa National Agrarian University / Ukraine | 39 |
| 6. | **AN ANALYSIS OF EIGHT TILLAGE METHODS IN A SILTY-CLAY SOIL: PROPOSAL FOR FLEXIBLE TILLAGE CYCLES /** ***ANALISI DI OTTO METODI DI LAVORAZIONE DI TERRENI LIMO-ARGILLOSI: PROPOSTA DI CICLI FLESSIBILI DI LAVORAZIONE*** **Fanigliulo R., Biocca M., Pochi D.** Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria (CREA), Centro di ricerca Ingegneria e Trasformazioni agroalimentari (Research Centre for Engineering and Agro-Food Processing), Monterotondo (Rome), Italy | 49 |
| 7. | **TECHNIQUE FOR CALCULATING THE RESULTANT FORCE AND MOMENT OF SOIL RESISTANCE TO CUTTING BY BLADE OF ROTARY TILLAGE TOOL /** ***МЕТОДИКА РАСЧЕТА РЕЗУЛЬТИРУЮЩЕЙ СИЛЫ И МОМЕНТА СОПРОТИВЛЕНИЯ ПОЧВЫ РЕЗАНИЮ ЛЕЗВИЕМ ЛОПАСТНОГО РОТАЦИОННОГО РАБОЧЕГО ОРГАНА*** **Prof. PhD. Eng. Sc. Akimov A.P.*), Asst. Prof. PhD. Eng. Sc. Konstantinov Y.V., Asst. Prof. PhD. Stepanov A.V.** Chuvash State Agricultural Academy / Russia | 59 |
| 8. | **NUMERIC MODEL OF THE GRAIN MIXTURE FLOW IN A CYLINDRICAL SIEVE WHICH REVOLVES AROUND THE INCLINED AXIS /** ***ДОСЛІДЖЕННЯ РУХУ ЗЕРНОВОЇ СУМІШІ В ЦИЛІНДРИЧНОМУ РЕШЕТІ, ЩО ОБЕРТАЄТЬСЯ НАВКОЛО НАХИЛЕНОЇ ОСІ*** **Lect. Ph.D.Eng. Naumenko M., Lect. Ph.D.Eng. Sokol S., Lect. Ph.D. Eng. Filipenko D., Lect. Ph.D. Eng.Guridova V., Prof. Ph.D. Agri.Sci. Kharytonov M.** Dnipro State Agrarian and Economics University, Faculty of Agrarian Engineering / Ukraine | 67 |
| 9. | **RESEARCHES ON THE MONITORING OF AIR PRESSURE IN THE TIRES AT ROAD TRANSPORT MEANS /** ***CERCETARI PRIVIND MONITORIZAREA PRESIUNII AERULUI DIN PNEURI LA MIJLOACELE DE TRANSPORT RUTIERE*** **Ph.D. Eng. Ciupercă R., Ph.D. Stud. Eng. Persu C., Ph.D. Eng. Nedelcu A., Ph.D. Eng. Popa L., Ph.D. Stud. Eng. Zaica A., Ph.D. Stud. Eng. Ştefan V.** National Institute of Research-Development for Machines and Installations designed to Agriculture and Food Industry – INMA, Bucharest / Romania | 75 |

| | | Page(s) |
|---|---|---|
| 10. | **RESEARCHES REGARDING THE OPTIMIZATION OF IMPURITIES REMOVAL TECHNOLOGY FROM THE CEREAL AND INDUSTRIAL PLANT SEEDS FOR ESTABLISHING ECOLOGICAL CROPS /** ***CERCETĂRI PRIVIND OPTIMIZAREA TEHNOLOGIEI DE ELIMINARE A IMPURITĂȚILOR DIN MASA DE SEMINȚE DE CEREALE ŞI PLANTE TEHNICE DESTINATE ÎNFIINȚĂRII CULTURILOR ECOLOGICE*** **Ph.D. Eng. Păun A. [1)], Eng. Stroescu Gh. [1)], Ph.D. Eng. Vişan A.L. [1)], Ph.D. Eng. Olan M. [1)], Ph.D. Stud. Eng. Zaica Alexandru [1)], Lect.Ph.D.Eng. Moiceanu G.[2)]** [1)] National Institute of Research-Development for Machines and Installations designed to Agriculture and Food Industry – INMA, Bucharest / Romania; [2)] Politehnica University of Bucharest / Romania | 83 |
| 11. | **RESEARCH OF YELLOW-FEATHER CHICKEN BREEDING MODEL BASED ON SMALL CHICKEN CHAMBER /** ***基于小型鸡舍的黄羽鸡精细化养殖模式研究*** **MAE. Stud. Heyang Yao [1)], Ms. Qiyue Sun [1)], Assoc. Prof. Ph.D. Xiuguo Zou *[1)], MEE. Stud. Siyu Wang [2)], Senior Exper. Shixiu Zhang [1)], MAE. Stud. Shikai Zhang [1)], Ms. Shuyue Zhang [1)]** [1)] College of Engineering, Nanjing Agricultural University / China; [2)] School of environmental science and Engineering, Nanjing University of Information Science and Technology / China | 91 |
| 12. | **RESEARCH ON TEMPERATURE PREPARATION OF DIESEL BIOFUEL IN AN ENERGY VEHICLE FUEL TANK /** ***ДОСЛІДЖЕННЯ ТЕМПЕРАТУРНОЇ ПІДГОТОВКИ ДИЗЕЛЬНОГО БІОПАЛИВА В ПАЛИВНОМУ БАКУ ЕНЕРГОЗАСОБУ*** **Prof.D.Sc. Golub G.A.[1)], Ph.D. Eng. Chuba V.V. [1)], Ph.D. Eng. Kepko O.I*[2)]** [1)]National University of Life and Environmental Sciences of Ukraine, Kyiv / Ukraine; [2)] Uman National University of Horticulture, Uman / Ukraine | 101 |
| 13. | **NUMERICAL ANALYSES OF AIR VELOCITY AND TEMPERATURE DISTRIBUTION IN POULTRY HOUSE USING COMPUTATIONAL FLUID DYNAMICS** ***آنالیز عددی توزیع سرعت و دما در مرغداری با استفاده از دینامیک سیالات محاسباتی*** **Ph.D. Stud. Eng. Pourvosoghi N[1)], Assoc.Prof. Ph.D. Eng. Nikbakht A.M.*[1)], Assoc.Prof. Ph.D. Eng. Sharifian F.[1)], Assist.Prof. Ph.D. Eng. Najafi R [2)]** [1)]Department of Mechanical Engineering of Biosystems, Urmia University / Iran [2)]Department ofAnimal Science, Urmia University / Iran | 109 |
| 14. | **RESEARCH ON SUNFLOWER SEEDS SEPARATION BY AIRFLOW /** ***ДОСЛІДЖЕННЯ ПРОЦЕСУ СЕПАРАЦІЇ НАСІННЯ СОНЯШНИКУ ПІД ДІЄЮ ПОВІТРЯНОГО ПОТОКУ*** **Ph.D. Aliev E.B. [1)], Ph.D. Yaropud V.M.[2)], Ph.D. Dudin V.Yr. [3)], Ph.D. Pryshliak V.M.[2)], Ph.D. Pryshliak N.V.[2)], Ph.D. Ivlev V. V. [3)]** [1)]Institute of Oilseed Crops NAAS, Zaporizhzhia / Ukraine, [2)]Vinnitsa National Agrarian University / Ukraine [3)] Dnipro State Agrarian and Economic University / Ukraine | 119 |
| 15. | **DESIGN OF SHAPED-HOLE VOLUME-VARIABLE PRECISION SEEDER /** ***变容量型孔轮式排种器设计*** **Lect. Ph.D. Jiaxin Zheng[1)], M.S. Yanyu Gao[1)], Lect. Ph.D. Hongfang Yuan[2)], Lect. Ph.D. Rong Chen*[1)]** [1)] School of Mechanical and Electrical Engineering, Yunnan Agricultural University, Kunming /China; [2)] Key Laboratory of Bionics Engineering, Ministry of Education, Jilin University, Changchun / China | 129 |
| 16. | **RESEARCH AND DEVELOPMENT OF AIR-SUCTION CORN PRECISION SEED METERING DEVICE /** ***气吸式精量玉米播种器的研究与开发*** **Prof. Ph.D. Eng. Lv Xiaorong*[1)], Prof. Ph.D. Eng. Zhang Lihua[1)], Ph.D. Eng. Lv Xiaolian[2)], M.A. Stud. Eng. Tian Zhiwei[1)]** [1)] Sichuan Agricultural University, College of Machinery & Electronics / China; [2)] Chuzhou University, College of Machinery & Automotive Engineering / China | 137 |
| 17. | **DESIGN AND EXPERIMENTAL STUDY OF THE FINGER-TYPE LIFTER TEST BENCH FOR *Cerasus humilis* BRANCHES /** ***拨指式钙果扶禾试验台的设计与试验*** **As. M.S. Stud. Eng. Yongqiang He, Prof. Ph.D. Eng. Junlin He[*)], Ph.D. Stud. Eng. Xiaobin Du, M.S. Stud. Eng. Dawei Fang** College of Engineering, Shanxi Agriculture University, Taigu / China | 147 |
| 18. | **DESIGN AND TEST ON CONTROL SYSTEM OF AUTOMATIC SEEDLING FEEDING MECHANISM FOR TRANSPLANTING MACHINE /** ***移栽机自动送苗机构控制系统设计和试验*** **As. Ph.D. Stud. Eng. Yong Zhang[1,2)], A/Prof. Ph.D. Eng. KaiXing Zhang*[1)], M.S. Stud. Eng. Chao Song[1)], Prof. Ph.D. Eng. XianXi Liu.[1)], Prof. Ph.D. Eng. ZhengHe Song[3)]** [1)] College of Mechanical and Electrical Engineering, Shandong Agricultural University, Taian / China; [2)] School of Information And Electronic Engineering, Shandong Technology and Business University, Yantai / China; [3)] College of Engineering, China Agricultural University, Beijing / China | 155 |
| 19. | **THE EFFECT OF POTATOES' COMPRESSIVE MECHANICAL PROPERTIES UNDER DIFFERENT MOISTURE CONTENTS: AN EXPERIMENTAL STUDY /** ***不同含水率下马铃薯压缩力学特性影响的试验研究*** **Ph.D. Yu Fan[1,2)], A. Prof. Ph.D. Ping Zhao*[1)], Prof. Ph.D. Lichun Qiu[1)], M.S. Jizhe Zhao[1)]** [1)] Agricultural University of Shenyang, Shenyang 110886, China [2)] Heilongjiang Agricultural Economy Vocational College, Mudanjiang / China | 165 |

| | | Page(s) |
|---|---|---|
| 20. | **THE INFLUENCE OF BULK MATERIAL FLOW ON TECHNICAL AND ECONOMICAL PERFORMANCE OF A SCREW CONVEYOR / *ВПЛИВ ПОТОКУ СИПКОГО МАТЕРІАЛУ НА ТЕХНІКО-ЕКОНОМІЧНІ ПОКАЗНИКИ РОБОТИ ГВИНТВОГО КОНВЕЄРА*** **Prof. Ph.D. Eng. Hevko R.B.[1)], Prof. Ph.D. Eng. Baranovsky V.M.[2)], Prof. Ph.D. Eng. Lyashuk O.L.,[2)] Prof. Ph.D. Eng. Pohrishchuk B.V.[1)] Assoc. Prof. Ph.D. Eng. Gumeniuk Y.P.[1)] Assoc. Ph.D. Eng. Klendii O.M,[3)] Assoc. Ph.D. Eng. Dobizha N.V.[1)]** [1)]Ternopil National Economical University / Ukraine; [2)]Ternopil Ivan Puluj National Technical University [3)]Separated Subdivision of National University of Life and Environmental Sciences of Ukraine, Berezhany Agrotechnical Institute / Ukraine | 175 |
| 21. | **THE NUMERICAL SIMULATION OF HYDRODYNAMICS AND MASS TRANSFER PROCESSES FOR VENTILATING SYSTEM EFFECTIVE LOCATION / *ЧИСЕЛЬНЕ ДОСЛІДЖЕННЯ ГІДРОДИНАМІКИ І ТЕПЛОПЕРЕНОСУ У ПТАШНИКУ ДЛЯ ЕФЕКТИВНОГО РОЗМІЩЕННЯ ВЕНТИЛЯЦІЙНОГО ОБЛАДНАННЯ*** **Prof. Ph.D. Eng. Gorobets V.G.[1)], Senior lecturer Ph.D. Eng. Trokhaniak V.I.[1)], Assoc. Prof. Ph.D. Eng. Rogovskii I.L.[1)], Senior lecturer Ph.D. Eng. Titova L.L.[1)], Senior lecturer Ph.D. Eng. Lendiel T.I.[1)], Assoc. Prof. Ph.D. Eng. Dudnyk A.O.[1)], PhD student Masiuk M.Yu.[1)]** [1)] National University of Life and Environmental Sciences of Ukraine / Ukraine | 185 |
| 22. | **STUDY ON NDVI OPTIMIZATION OF CORN VARIABLE FERTILIZER APPLICATOR / *变量施肥机 NDVI 的优化研究*** **Ph.D. Hongli Liu[1)], Prof. Xi Wang*[1)], M.S. Jin Bing-kun[2)]** [1)] College of Engineering, Heilongjiang Bayi Agricultural University, Daqing/China; [2)] Western University, 1151 Richmond Street, London, Ontario / Canada | 193 |
| 23. | **EFFECT OF PRE-SOAKING AND GRAIN SHAPE ON COOKING ENERGY OF PARBOILED AND RAW RICE / *තම්බන ලද සහ කැකුළු සහල් ඇටවල හැඩය හා පිසීමට කලින් පෙඟවීම සහල් පිසීමේ ශක්ති පරිභෝජනය මත බලපෑම*** **K. G. Gunasekara [1)], D. A. N. Dharmasena [2)] and F. H. C. A. Silva [*2)]** [1)] Postgraduate Institute of Agriculture, University of Peradeniya, Peradeniya, Sri Lanka [2)] Department of Agricultural Engineering, Faculty of Agriculture, University of Peradeniya, Sri Lanka | 203 |
| 24. | **DETECTION AND CLASSIFICATION OF BRUISES IN “RED DELICIOUS” APPLE FRUITS BY APPLYING PIEZOELECTRIC TRANSDUCERS / تشخیص و طبقه‌بندی کوفتگی سیب "رد دلیشز" با استفاده از ترانسدیوسرهای پیزوالکتریک** **Ph.D. Stud. Mehrdad Foj Laley[1)], Assoc. Prof. Parviz Ahmadi Moghadam[*1)], As Prof. Ali Hasanpour[1)], As prof. Vahid Rostampour[1)]** **[1)] Department of Mechanical Engineering of Biosystems, Urmia University, Urmia / Iran** | 211 |

# RESEARCH ON THE RATIONAL REGIMES OF WHEAT SEEDS DRYING
# /
# ДОСЛІДЖЕННЯ РАЦІОНАЛЬНИХ РЕЖИМІВ СУШІННЯ НАСІННЯ ПШЕНИЦІ

**Assoc.Prof. Ph.D.Eng. Paziuk V.M. [1)], Assoc. Prof. Ph.D. Eng. Liubin M.V. [2)], Assoc. Prof. Ph.D. Eng. Yaropud V.M. [*2)],**
**Assoc. Prof. Ph.D. Eng. Tokarchuk O.A. [2)], Assoc. Prof. Ph.D. Eng. Tokarchuk D.M. [2)]**
[1)]Institute of technical thermal physics NAS of Ukraine
[2)]Vinnitsa National Agrarian University / Ukraine
*Tel: +380978399834; E-mail: yaropud77@gmail.com*

**Keywords:** *seeds, drying, regimes, germination, wheat, temperature*

**ABSTRACT**

*The value of the grain seeds is in the ability to germinate and ensure high yields. The main technological process for preserving the properties of seeds is drying. The proper carrying out and providing of rational modes of drying is a necessary condition to preserve the high ability to germinate. For the object of drying we have taken wheat seeds to determine the rational regimes. The research of the drying process kinetics is carried out on a convective drying stand in the following modes: coolant temperature in the drying chamber t = 50-80˚C, velocity V = 0.5-1.5 m/s. The highest intensity of drying occurs from an increase in the temperature of the coolant from 50 to 80°C in 3 times, but the main indicator is wheat maximum permissible temperature, which, at the coolant temperature of 50°C, is 48.6°C.*

*The biochemical indicators of wheat seeds were determined in the laboratory of the Institute of Technical Thermophysics according to the method on the 7th day of germination. The results of the researches showed that the best results of wheat germination were at 50°C at the level of 96%. Coolant temperature of 80°C has the most negative influence on wheat germination as the seeds lose their properties.*

*The analysis of the three-factors of influence, such as temperature and speed of coolant, as well as wheat initial humidity, on seed drying time and germination is done.*

*The obtained regression equations and obtained response surfaces of seed drying time and germination enable us to evaluate the process in terms of drying parameters' influence.*

**РЕЗЮМЕ**

*Цінність насіння зернових культур полягає у здатності пророщування та забезпечення високого врожаю. Основним технологічним процесом для збереження властивостей насіння є сушіння. Правильне проведення і забезпечення раціональних режимів сушіння є необхідною умовою збереження високої здатності до проростання. Для визначення раціональних режимів за об'єкт сушіння нами взято насіння пшениці. Дослідження кінетики процесу сушіння проведені на конвективному сушильному стенді за таких режимів: температура теплоносія в сушильній камері t = 50-80˚C, швидкість руху V = 0,5-1,5 м/с. Найбільша інтенсивність сушіння відбувається від збільшення температури теплоносія від 50 до 80ºС в 3 рази, але основним показником є гранично-допустима температура пшениці, що при температурі теплоносія 50°С складає 48,6°С.*

*Біохімічні показники насіння пшениці визначались в лабораторії Інституту технічної теплофізики за методикою на 7 день пророщування. Результати досліджень показали, що найкращі результати пророщування пшениці при 50°С на рівні 96%. Найбільш негативно впливає на схожість пшениці температура теплоносія 80°С і насіння втрачає свої насіннєві властивості.*

*Проведений аналіз трифакторного впливу параметрів сушіння – температури та швидкості руху теплоносія, а також початкової вологості пшениці на тривалість сушіння та схожість насіння. Отримані регресійні рівняння та отримані поверхні відгуку тривалості сушіння та схожості насіння, дають можливість оцінити процес від впливу параметрів сушіння.*

## INTRODUCTION

The problem of drying wheat seeds has been raised by various authors and it requires the choice of the most rational drying regime. Different approaches and different technological equipment may not always accurately reflect the choice of the desired drying regime. The elevated temperatures of the coolant during

wheat seeds drying are given in works (*Kovalenko O.A., Kosovska N.V., 2012; Savchenko S.V., 2009*) associated with the conditions of passing the grain through the drying chamber of the shaft dryer, where additionally the following drying factors are added: the velocity of the coolant and grain, the height of the grain layer, the hydraulic resistance of the layer, constructive features and other conditions. Under laboratory conditions, when drying in the elementary layer (*Matkivska I.Ja., Atamanyuk V. M., Symak D., 2014*), drying modes can be characterized more adequately and reliably, but there is a problem with the transfer of research results to industrial installations. The main criterion for evaluating seed grain quality is wheat heating temperature, which is determined by seed germination ability.

To determine wheat seeds germination, the author has proposed to dry the wheat seeds from 80 to 120°C and step modes with an increase in temperature of 80/100 and 80/120°C (*Podpryatov G.I., Nasikovsky V.A., 2005*). There is no indication of the effect of these drying conditions on wheat seed properties, only the storage modes are mentioned. In particular, it is indicated that wheat seeds should be stored during the first month with a moisture content of 18.0-18.5%, thus increasing the ability to germinate.

Similar modes of drying are represented in the research work of Kovalenko O.A. for drying wheat at 80 - 120°C and stepwise drying mode at 80/100 and 80/120°C. The presented studies show that at the temperature of 80°C the germination is 89-94,5%, while in stepwise mode it is 63-81%, which cannot be recommended for seed grain at all (*Kovalenko O.A., Kosovska N.V., 2012*).

In the work of Savchenko S.V. the drying of wheat seeds was carried out in a gravitational-moving layer at the temperature of the heat carrier 70 - 85ºC, and at the same time the temperature of heating the grain was 50 - 62ºC (*Savchenko S.V., 2009*). The greatest germination of wheat seeds at the temperature of 70°C is 90%, and at an increase of temperature it is 85 - 83%.

In the research work of Matkivska V., the conditions of wheat seeds drying from 40 to 80 ºC were analyzed. The germination at a drying temperature of 40, 50, 60, 80ºC, respectively, is 99, 98, 90, 30%. In this case, it is recommended to use the temperature of 60°C, although it would be desirable to choose a temperature of 50°C according to the results of the experiment (*Matkivska I.Ja., Atamanyuk V. M., Symak D., 2014*).

## MATERIALS AND METHODS

The high cost of seed grain and energy has set the task for us: to pick up such drying regimes, that can provide the high quality of seeds, while minimizing the specific heat consumption of the process.

Describing the processes of grain drying, they can be conditionally divided into soft and rigid drying regimes. The first one is characterized by a relatively low temperature and drying agent speed. In a soft mode, the processes of heating and drying the grain pass with a relatively low speed. The rigid mode is characterized by increased temperature and speed of the drying agent. From the economic point of view, it is desirable to dry the grain in rigid mode with a decrease in the drying time. However, in rigid mode due to intense heating and dehydration there is deterioration in its quality: cracking of seeds, change in colour, partial or complete destruction of the embryo, deformation of tissues.

The application of high temperatures at the beginning of wet grain drying process leads to a rapid dehydration of its surface, which makes the shells less permeable to moisture (the phenomenon of thermal "quenching" of the grain). Under these conditions, a water vapour forms in the surface layer, the output of which becomes complicated. It is therefore recommended to dry the seeds at relatively soft temperature regimes. In soft mode, drying does not have a complete guarantee of preservation of seed grain properties, so during prolonged low temperature drying (depending on the environmental parameters) the formation of mould on the surface is possible, and as a result, the damage of the seed material.

The main parameters that determine the choice of the drying mode and the achievement of high quality indicators of dried seeds are the temperature of the drying agent, the grain heating maximum temperature, the seeds initial humidity and the duration of their drying. The initial moisture content of grain $\omega_0$ greatly affects the intensity of the drying process and determines the choice of the maximum allowable temperatures for heating the grain and the maximum temperatures of the drying agent.

The maximum permissible temperature for the grain intended for seed is determined based on the conditions of energy storage of its germination capacity. With the increase in humidity and the duration of grain presence in the heated state, the maximum allowable temperature of it is reduced.

The works of S.D. Ptitsina, M. Hutchson, V.I. Zhidko, O.N. Katkova, V.A. Rezchikov, N.N. Nevsky, V.L. Prokofiev, K.S. Esbolganov are dedicated to the determination of the maximum allowable temperature of heating the grain (table 1).

Finding the maximum-permissible temperature of seed grain in the proposed formulas of S.D. Ptitsina and M. Hutchison depends on the initial humidity and the time of heating the grain *t*.

V.I. Zhidko determined the maximum allowable temperature of the grain heating by introducing the coefficients and values of the heating time *t, n, k* and the grain moisture content *ω*.

O.N. Katkova, V.A. Rezchikov on the basis of processing the experimental data proposed the empirical formula, depending on the mass air velocity *Vρ*, which characterizes the state of the layer (on which the drying time depends), the humidity ω and the initial temperature of the coolant *t*.

N.N. Nevskaya and V.L. Prokofiev, based on the mass spectrometric radiation of wheat drying features, proposed the dependence of the maximum permissible grain temperature on the humidity *ω* and the drying time *t.*

K.S. Esbolganov, under the conditions of recirculation drying, proposed to use grain mass concentration in the heating chamber *μ*, the temperature of the coolant *t* and the value of the moisture content $\omega_c$ to calculate the maximum permissible temperature of heating wheat seeds.

**Table 1**

**The equation for determining the maximum permissible temperatures for heating the seeds**

| № | Researcher | Equation | № Eq. | Source |
|---|---|---|---|---|
| 1 | *S.D. Ptitsin* | $\theta_{ГР} = \frac{2350}{0{,}37(100-\omega_0)+\omega_0} + 20 - 10\lg\tau,$<br>where: $\omega_0$ - initial humidity of grain,%;<br>$\tau$ - time of grain heating, min. | (1) | *(Melnik B.E., Malin N.I., 1980)* |
| 2 | *M. Hutchinson* | $\theta_{ГР} = 122{,}0 - 5{,}41\lg\tau - 441\ \lg\omega_0,$<br>where: $\omega_0$ - initial humidity of grain,%;<br>$\tau$ - time of grain heating, min. | (2) | *(Shchitsov S.V., Tikhonchuk P.V., Krivuta Z.F., Kolzov A.V. 2016; Shchitov S.V., Krivueca Z.F., 2012)* |
| 3 | *V.I. Zhidko* | $\theta_{ГР} = t_0 - n \cdot \omega_0 + k,$<br>where: $t_0$, n are the constant coefficients obtained experimentally for grain with normal gluten<br>$t_0 = 88,\ n = -2{,}15;$<br>*k* – coefficient depending on the duration of drying $\tau$ and moisture content of the grain:<br>$k = 0{,}03\omega_c^2 - \frac{\tau - 90}{0{,}023\omega_c^2}$<br>where: $\omega_c$ - current moisture content of grain,%;<br>$\tau$ - time of grain heating, min. | (3)<br>(4) | *(Zhidko V.I., Atanazevich V.I., 1982)* |
| 4 | *V.A. Rezchikov, R.P. Dubinicheva* | $\theta_{ГР} = 1800\frac{(V\rho)^{0,13}}{\sqrt{\omega}t^{0,4}}$<br>where: *Vρ* - mass velocity of air, kg/m²;<br>*ω* - grain moisture content,%;<br>*t* - coolant temperature, °C | (5) | *(Rezchikov V.A., Dubinicheva R.P., 1988)* |
| 5 | *N.N. Nevsky, V.L. Prokofiev* | $\theta_{ГР} = \frac{900 + 273\omega + \omega^2}{\omega} - 10\lg\tau,$<br>where: *ω* - grain moisture content,%;<br>$\tau$ - time of grain heating, min. | (6) | *(Tits Z.L., 1967)* |

It is most appropriate to determine the drying regime according to the biological properties of the grain. Acceptable values of temperatures at different time values of impact on the grains, which does not affect the processes of life in it, depend on the moisture content of the grain – the higher the humidity, the lower the permissible values of temperatures.

An irreversible decrease of wet grain lifetime begins at 55°C (coagulation of protein in the germ and aleuronic layer), and of dry grain at 65°C. During drying it is necessary to reduce the final temperature of heating of seeds by 10-12C, which will allow to preserve the seed properties of the material (fig. 1). (*The results of the investigation of physical processes during the drying of grain, 2018*).

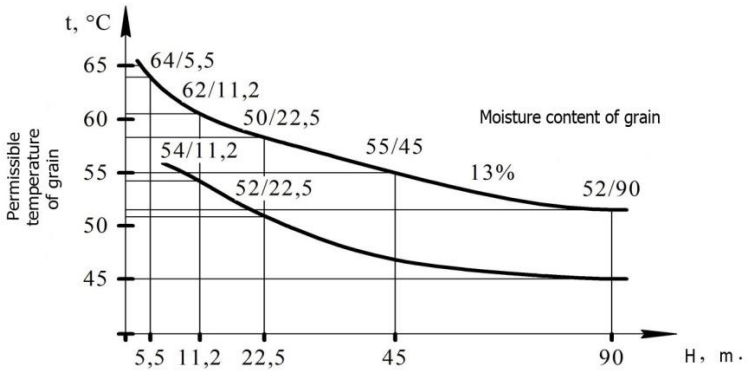



**Fig. 1 - Change grain permissible temperature during drying for different humidity of seed grain**

It is necessary to apply a milder drying regime for seed grain. According to M.G. Golik, a complete loss of wheat seeds germination occurs when heated to 60°C, at initial moisture content of 20% and higher. The germination of unprocessed seeds at a humidity of 20% was 97%, when heated to 45, 50 and 55°C, the germination was 87, 82 and 47% respectively. The intensity of moisture removal, which should not exceed 5%, was indicated in the work. (*Golik M.G., Delidovich V.N., Miller B.E., 1972*).

In the work of Savchenko, the studies on the germination of wheat seeds differ significantly from the data presented by M.G. Golik. Experimental studies are carried out at the temperature of 75, 85°C, respectively, heating the grain up to 50.56°C with a germinating capacity of 90 and 85% respectively (*Savchenko S.V., 2009*).

The temperature change of the grain and the reduction of the material mass were determined using special devices and the developed program in an automatic mode on a convective drying stand. In order to assess the quality of the wheat seeds, the standard methods of research were provided by SS 4138 - 2002 and SS 2240 - 1993 (State Standard 4138 - 2002, 2003; State Standard 2240 - 1993, 1994).

The research program involves removing the wheat drying kinetics by recording the changes in the mass of the material, temperatures of the coolant and in the middle of the material (fig. 2).

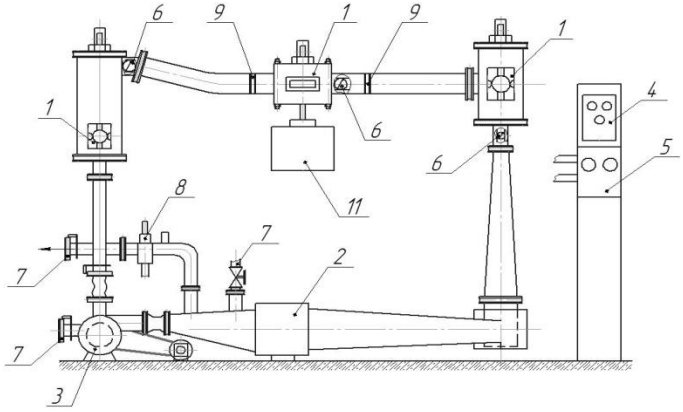



**Fig. 2 - Scheme of the experimental stand:**

*1 - drying chamber; 2 - heater; 3 - fan; 4 - temperature controller; 5 - control panel; 6 - thermometers; 7 - pipe fittings; 8 - psychrometer; 9 - special gratings; 10 - a bar of scales; 11 – scales*

**RESULTS**

An example of removing the kinetics of the wheat seed drying process at a coolant temperature of 50°C and a flow velocity of a coolant of 0.5 m/s is shown in fig. 3

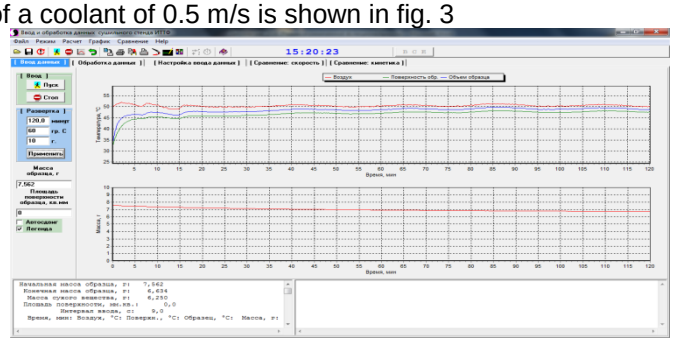


**Fig. 3 - Removal of kinetics of wheat drying at the coolant temperature of 50°C and the speed of 0.5 m/s**

The main direction of the intensification of wheat seeds drying process is coolant temperature; the higher the temperature, the drying rate increases (fig. 4).

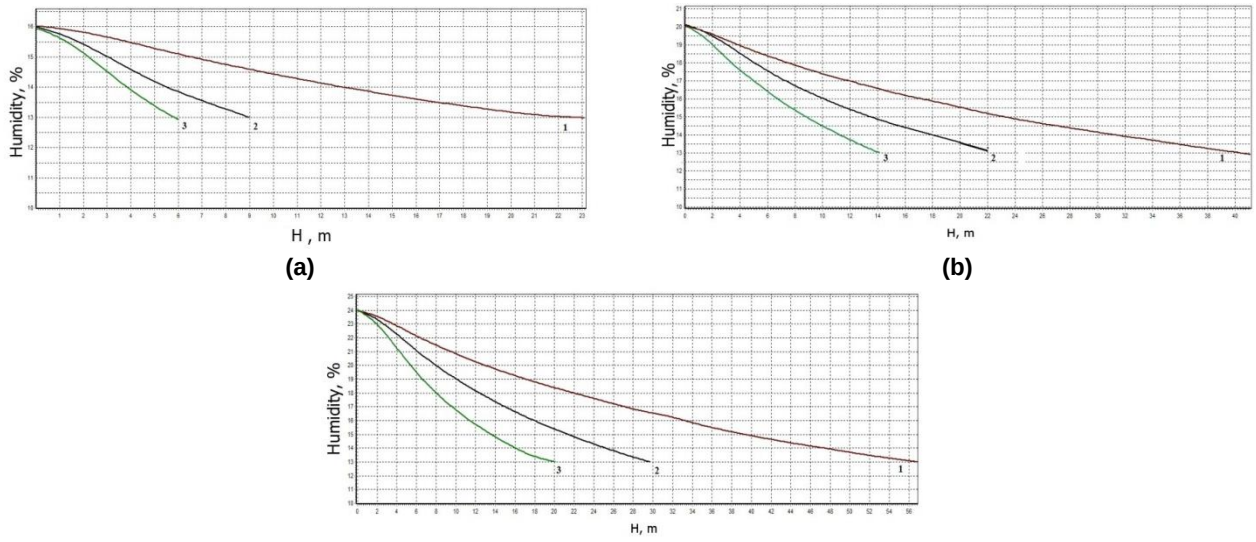



**Fig. 4 - Curves of wheat seed drying depending on the coolant temperature, at initial humidity of material 16 (a), 20 (b), 24 (c), 1.5 m/s**

*1 - 50°C; 2 - 65°C; 3 - 80°C*

The increase of the coolant temperature accelerates the drying process, so at a temperature of 80°C compared with 50°C, the wheat drying is faster by almost 3 times. The initial moisture content of the material increases the drying time, so the duration at a moisture content of 24% to the final moisture of 13% is 57 minutes, and a decrease of moisture up to 20% reduces the duration of the process by 16 minutes.

On the presented temperature curves of wheat seeds heating it can be seen that the material is most rapidly heated for 6 - 8 minutes, and then there is a gradual heating to the final temperature (fig. 5). So the final temperature is: at 50°C - 48,6°C; 65°C – 62,26°C; 80°C - 74,62°C.

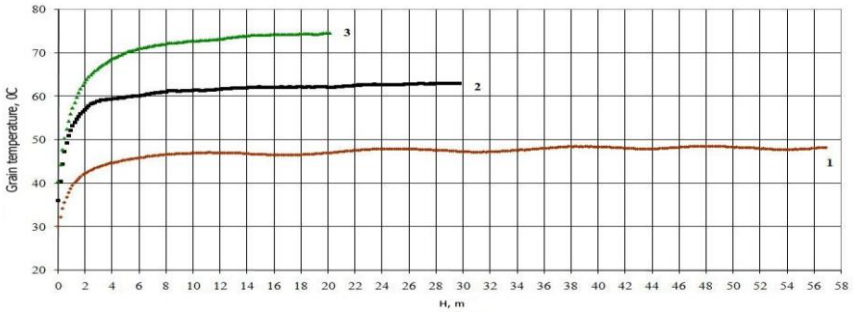



**Fig. 5 - Temperature of wheat seeds heating during drying period at initial humidity of material 16 (a), 20 (b), 24 (c), 1.5 m/s**

1 - 50°C; 2 - 65°C; 3 - 80°C

Wheat seeds drying rate, depending on the coolant temperature, is shown in fig. 6. When wheat seeds are dried, there is a period of warming up of the material and a period of falling drying rate. In the period of warming, the material is heated and a partial evaporation of the moisture from the surface layers takes place.

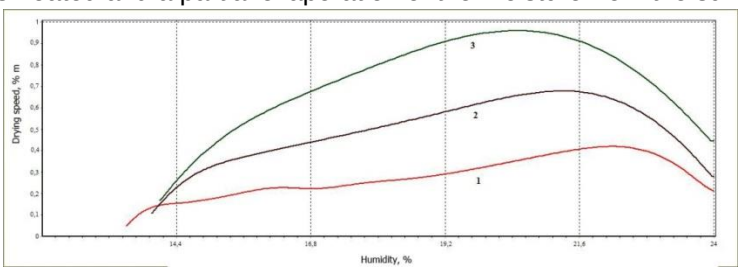



**Fig. 6. Curves of wheat drying rate at an initial humidity of 24% and coolant speed 1.5 m/s from temperature**

*1 - 50°C; 2 - 65°C; 3 - 80°C*

The maximum drying speed at a temperature of 80°C is 0.95%/min., the decrease to 65°C reduces the speed up to 0,67%/min, and when reduced to 50°C, it is 0,41%/min.

The curves of wheat seed drying from the effect of the heat transfer velocity showed that with an increase in the velocity of the coolant from 0.5 to 1.5 m/s, the increase in the drying rate is 7.3%. Drying occurs to the final moisture content of wheat 13%, which corresponds to the equilibrium moisture content of the material (fig. 7).

Fig. 8 shows the curves of the drying speed at different coolant flow velocities, so at coolant velocity of 1.5 m/s the maximum drying speed at 18.6% humidity corresponds to 0.3%/min. At coolant flow velocity of 0.5 m/s, the drying rate is reduced up to 0.25%/min, namely by 20%.

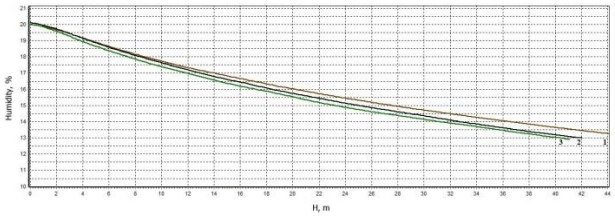



**Fig. 7 - Curves of wheat seed drying at coolant flow velocity and a temperature of 50°C**

*1 – 0,5 m/s; 2 – 1,0 m/s; 3 – 1,5 m/s*

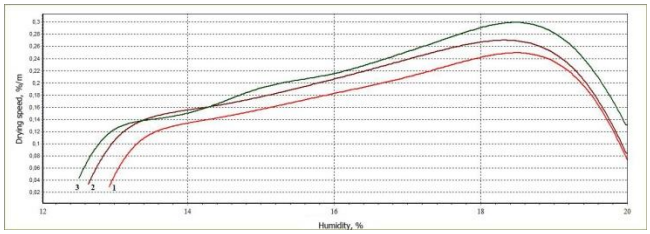



**Fig. 8 - Curves of drying rate of wheat seeds from the coolant flow velocity at the temperature of 50°C**

*1 – 0,5 m/s; 2 – 1,0 m/s; 3 – 1,5 m/s*

The rational drying regime was determined by the biochemical properties of wheat seeds, depending on the temperature, the initial humidity and the coolant flow velocity (table 2).

**Table 2**

**The influence of drying parameters on wheat germinating capacity on the 7-th day of germination**

| Temperature of the drying agent, ºC | Initial moisture content of grain,% | Drying agent speed, m/s | Seed germination,% |
|---|---|---|---|
| Output | - | - | 99 |
| 50 | 16 | 1.5 | 96 |
| 50 | 20 | 0.5 | 96 |
| 50 | 24 | 1.5 | 96 |
| 65 | 16 | 1.5 | 94 |
| 65 | 20 | 0.5 | 93 |
| 65 | 24 | 1.5 | 90 |
| 80 | 16 | 1.5 | 1 |
| 80 | 20 | 0.5 | 9 |
| 80 | 24 | 1.5 | 0 |

From the data given in tab. 2, we can draw a conclusion about the significant influence of these parameters in the area of high temperatures. Rational drying mode is the temperature of 50°C, where the influence of the initial moisture and the speed of the drying agent are not significant.

The graphs of the drying parameters' influence on wheat germinating capacity on the seventh day of germination are shown in figure 9.

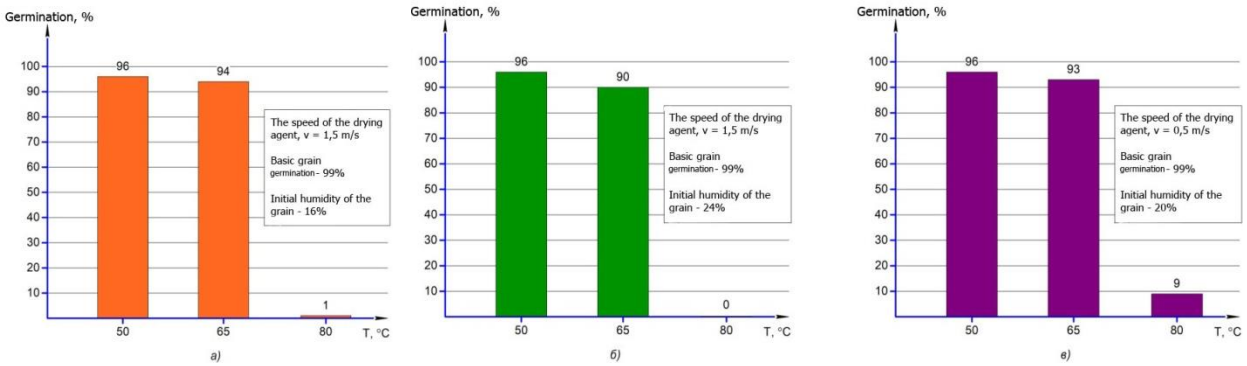
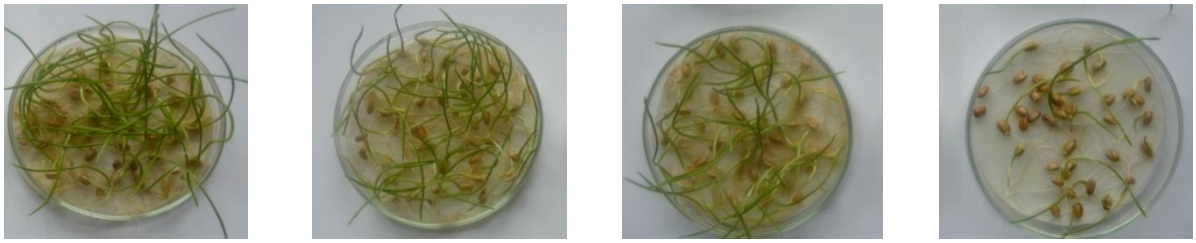



**Fig. 9 – The effect of drying parameters on wheat germinating capacity on the 7-th day of germination**

We can assess visually the influence of the coolant temperature on the presented fig. 10.



**Output** **50** **65** **80**

**Fig. 10 – The influence of coolant temperature on the germinating capacity of wheat seeds on the 7-th day of germination at the initial moisture content of 20% and the speed of 0.5 m/s**

For a mathematical description of the wheat drying process in an elementary layer, we take a three-factor experiment in accordance with an orthogonal compositional plan of the second order.

The total number of points in the plan is determined by:

$$N = 2^n + 2n + N_0; \quad (1)$$

where: $N_1 = 2^n$ - number of points of the factor space, determined by the core of the plan. For a three-factor experiment $n = 3$, that is $N_1 = 2^3 = 8$

$N_2 = 2n = 6$ - the number of stellar points;

$N_0 = 1$ is the number of central (zero) points of the plan.

So, holding a three-factor experiment on three levels requires the conducting of 27 experiments.

That's why it is necessary to establish the optimal amount of experiments required. This task can be solved using modern methods of planning an experiment, in particular mathematical, the basis of which is the creation of a mathematical model in the form of a regression equation.

In orthogonal central planning, the criterion for optimality of the experiment plan is the orthogonality of the planning matrix columns. Because of the planning orthogonality, all the coefficients of the regression equation are determined independently of each other. The core of the composite plan is the plan for a complete factor experiment CFE $2^n$.

Experiment planning included the following steps:

– compilation of the coding table of factors and levels of variation;

– drawing up a plan - matrix;

– conducting the experiments according to the plan-matrix

– compilation of the regression equation and definition of the coefficients of the equation;

– analysis of the mathematical model in the form of a regression equation.

In the first stage we will compile a table of factors and levels based on the results of the research on a convective drying stand (table 3):

**Table 3**

**Factors and levels of variation, that influence the wheat seed drying process**

| Indexes | Factors | | |
|---|---|---|---|
| | Heat carrier | | Material |
| | *Temperature t, °C* | *Speed V, m/s* | *Initial humidity $W_0$, %* |
| Top (+1) | 80 | 1.5 | 24 |
| Average (0) | 65 | 1.0 | 20 |
| Lower (-1) | 50 | 0.5 | 16 |
| Variable interval | 15 | 0.45 | 4 |
| Code mark | $x_1$ | $x_2$ | $x_3$ |

According to the plan, the research was conducted using three levels for each factor - upper (+1), zero (0) and lower (-1), the code values of which were determined by the formula:

$$x_1 = \frac{t - t_0}{\varepsilon_1} = \frac{t - 65}{15}; \qquad x_2 = \frac{V - V_0}{\varepsilon_2} = \frac{V - 1,0}{0,5}; \qquad x_3 = \frac{W - W_0}{\varepsilon_3} = \frac{W - 20}{4}, \quad (2)$$

where: $t_o$, $v_o$, $w_o$ – the value of the factors at the main level, respectively, the temperature and velocity of the coolant, the initial humidity and the height of the canola layer;

$\varepsilon_1$, $\varepsilon_2$, $\varepsilon_3$ – the interval of factors variation.

The mathematical models of the process were constructed in the form of regression equations:

$$\hat{y} = a_0 + a_1x_1 + a_2x_2 + a_3x_3 + a_{11}x_1^2 + a_{22}x_2^2 + a_{33}x_3^2 + \\ + a_{12}x_1x_2 + a_{13}x_1x_3 + a_{23}x_2x_3. \quad (3)$$

The coefficients of regression can be determined by the following formulas:

$$a_0 = \frac{1}{N}\sum_{k=1}^{N} y_k - q\sum_{i=1}^{N} a_{ii}; \quad a_i = b_1\sum_{k=1}^{N} x_{ik}y_k; \quad a_{ii} = b_3\sum_{k=1}^{N}(x_{ik}^{/2} - q)y_k; \quad a_{ij} = b_2\sum_{k=1}^{N} x_{ik}x_{jk}y, \quad (4)$$

where: $q$ - the value that provides the orthogonality of compositional plans:

$$q = \frac{1}{N}(2^n + 2R^2) = \frac{1}{15}(2^3 + 2\cdot 1,215^2) = 0,73, \quad (5)$$

$b_0$, $b_1$, $b_2$, $b_3$ – elements of the plan matrix $b_0 = 0.0667$; $b_1 = 0.0913$; $b_2 = 0.125$; $b_3 = 0.298$.

The estimation of the errors' variance when calculating the estimates of the coefficients of the quadratic regression equation is calculated by the formulas:

$$S_{a0}^2 = \frac{b_0}{m}S_y^2 + q^2\sum_{i=1}^{n} S_{aii}^2; \quad S_{ai}^2 = \frac{b_1}{m}S_y^2; \quad S_{aij}^2 = \frac{b_2}{m}S_y^2; \quad S_{aii}^2 = \frac{b_3}{m}S_y^2, \quad (6)$$

where:

$S^2_y$ - estimation of the reproduction dispersion:

$$S_y^2 = \frac{1}{N}\sum_{k=1}^{N} S_k^2. \quad (7)$$

Recommended form of the plan matrix and the results of experiments on Podolianka variety wheat seeds drying are presented in table 4.

**Table 4**

**The plan matrix and the results of the experiments on Podolianka variety wheat seeds drying**

| № | Experimental conditions | | | | | | | | | | | | τ, min | C, % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $x_1$ | $x_2$ | $x_3$ | $x^2_1$ | $x^2_2$ | $x^2_3$ | $x_1x_2$ | $x_1x_3$ | $x_2x_3$ | $x_1$ | $x_2$ | $x_3$ | | |
| 1. | -1 | -1 | -1 | +1 | + 1 | +1 | + 1 | +1 | +1 | 0.27 | 0.27 | 0.27 | 30 | 95 |
| 2. | +1 | -1 | -1 | +1 | + 1 | +1 | -1 | -1 | +1 | 0.27 | 0.27 | 0.27 | 8 | 9 |
| 3. | -1 | +1 | -1 | +1 | + 1 | +1 | -1 | +1 | -1 | 0.27 | 0.27 | 0.27 | 23 | 96 |
| 4. | +1 | +1 | -1 | +1 | + 1 | +1 | + 1 | -1 | -1 | 0.27 | 0.27 | 0.27 | 6 | 1 |
| 5. | -1 | -1 | +1 | +1 | + 1 | +1 | + 1 | -1 | -1 | 0.27 | 0.27 | 0.27 | 64 | 95 |
| 6. | +1 | -1 | +1 | +1 | + 1 | +1 | -1 | +1 | -1 | 0.27 | 0.27 | 0.27 | 24 | 0 |
| 7. | -1 | +1 | +1 | +1 | + 1 | +1 | -1 | -1 | +1 | 0.27 | 0.27 | 0.27 | 57 | 96 |
| 8. | +1 | +1 | +1 | +1 | + 1 | +1 | + 1 | +1 | +1 | 0.27 | 0.27 | 0.27 | 20 | 0 |
| 9. | -1.215 | 0 | 0 | +1.472 | 0 | 0 | 0 | 0 | 0 | 0.75 | -0.73 | -0.73 | 42 | 93 |
| 10. | +1.215 | 0 | 0 | +1.472 | 0 | 0 | 0 | 0 | 0 | 0.75 | -0.73 | -0.73 | 14 | 10 |
| 11. | 0 | -1.215 | 0 | 0 | +1.472 | 0 | 0 | 0 | 0 | -0.73 | 0.75 | -0.73 | 28 | 96 |
| 12. | 0 | +1.215 | 0 | 0 | +1.472 | 0 | 0 | 0 | 0 | -0.73 | 0.75 | -0.73 | 22. | 94 |
| 13. | 0 | 0 | -1.215 | 0 | 0 | +1.472 | 0 | 0 | 0 | -0.73 | -0.73 | 0.75 | 17 | 94 |
| 14. | 0 | 0 | +1.215 | 0 | 0 | +1.472 | 0 | 0 | 0 | -0.73 | -0.73 | 0.75 | 31 | 90 |
| 15. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -0.73 | -0.73 | -0.73 | 25 | 93 |

After carrying out the experiments, the test of experiments' reproduction using the Cohren's criterion is carried out:

$$G_{\max} = \frac{S^2_{k\max}}{\sum_{k=1}^{N} S_k^2}, \quad (8)$$

where:

$S^2_k$ is the selective variance of the output quantity y in the $k$-line of the planning matrix, obtained from "$m$" of parallel experiments.

$$S_k^2 = \frac{1}{m-1}\sum_{l=1}^{m}(y_{kl} - y_l), \quad (9)$$

If $G_{\max} < G_{кр}$, with the number of degrees of freedom $v_1 = m - 1$, $v_2 = N$ and the level of significance $\alpha = 1 - \gamma$, then the hypothesis of dispersion homogeneity is accepted.

The hypothesis about the static significance of the estimates of the coefficients of the regression equation $a_i$ is checked by means of $t$ - the Stjudent's criterion:

$$t_{ip} = \frac{|a_i|}{S_{ai}}, \quad (10)$$

The verification of the mathematical model adequacy by the results of the experiment is carried out according to Fisher's criterion in the form of the ratio:

$$F_p = \frac{S^2_{inad}}{S^2_y}, \quad (11)$$

where: $S^2_{inad}$ - estimation of inadequacy variance.

$$S^2_{inad} = \frac{1}{N-r}\sum_{j=1}^{N}(\overline{y_j} - \hat{y_j}), \quad (12)$$

where: $N$ - number of points of the orthogonal CCP;

$r$ - number of significant parameters of the regression equation;

$\hat{y}_j$ - the value of the response, calculated by the regression equation;

$\overline{y}$ - the average for the series "$m$" of experiments is the value of a real object reference.

If the condition is fulfilled:

$$F_p < F_{кр}, \quad (13)$$

then the mathematical model is considered adequate, that is, the scattering of the experimental values of the response relative to the values of the regression equation of the same order as the scattering, caused by the experimental errors.

The critical significance of the statistics is according to the corresponding tables for the given level of significance α and the degree of freedom $v_1 = N - r$ and $v_2 = N = (m - 1)$.

The results of a three-factor experiment on an orthogonal compositional plan of the second order are presented in the form of quadratic regression equations:

- for the germinating capacity of wheat seeds:

$$C = 160.4 - 3.618t - 25.06V - 2.53W - 0.16t^2 - 28.72V^2 - 0.57W^2 - 0.21tV - 0.026tW + 0.5VW; \quad (14)$$

- for drying time:

$$\tau = 204.72 - 0.54t - 13.65V + 7.78W + 0.01t^2 + 4.8\,V^2 + 0.13tV - 0.08tW. \quad (15)$$

Based on the regression equation of wheat seeds' germinating capacity and duration, the response surfaces are constructed (fig. 11).

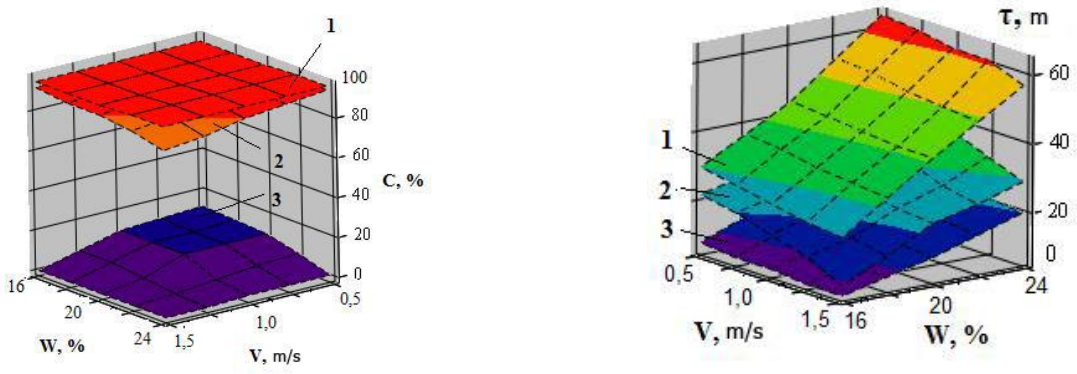



**Fig. 11 – Surface response of the germinating capacity and duration of "Podolianka" variety wheat seeds at the action of the coolant temperature, *°C***

*1 - 50; 2 - 65; 3 - 80*

## CONCLUSIONS

Analyzing the carried out research on the germination of "Podolianka" variety wheat seeds after drying, we can conclude:

- The temperature regime of drying is the most rational at a temperature of 50°C, the germination being 16%.

- At this temperature, the speed of the drying agent in the range *v* = 0.5...1.5 m/s does not significantly affect the germination.
- At this temperature, the initial moisture content of the grain in the range of 16-24% also does not significantly affect the germination.
- At the temperature of the drying agent of 65°C, the germination limits to 93-94% may be at velocity of the drying agent of 1.5 m/s and an initial moisture content of 20%, or at a velocity *v* = 0.5 m/s and an initial moisture content of 16%.
- At the increase in temperature of drying agent to 80°C, the germination is practically small (9%), which goes beyond agrotechnical requirements.

**REFERENCES**


[1] Fedorenko V.F., Buklagin D.S., Goltyapin V.Ya., (2010), Machines and equipment for post-harvest processing and storage of grain and seeds, *Rosinformagrotekh*, 92 p., Moscow / Russia;

[2] Gaponyuk O.I. Ostapchuk M.V, Stankevich G.M. (2014), Active ventilation and grain drying, *BMB*, 325 p., Odessa / Ukraine;

[3] Kovalenko O.A., Kosovska N.V., (2012), Influence of drying modes of winter wheat on the indices of its food and seed qualities. Available at: *http://lib.chdu.edu.ua/pdf/naukpraci/ecology/2012/179-167-16.pdf* (Accessed: 27 August 2018);

[4] Matkivska I. Ja., Atamanyuk V.M., Symak D., (2014), Basic regularities of filtration drying of wheat grain, *East-European Journal of Advanced Technologies*, No. 5/5 (71). - pp. 14-18, Kharkiv / Ukraine;

[5] Matkivska I.Ja., Atamanyuk V.M., Symak D., (2014), Basic regularities of the filtration drying of wheat grain, *Eastern-European Journal of Enterprise Technologies*, №5/5(71), pp. 14-18, Kharkov / Ukraine;

[6] Meledina T.V., Danina M.M., (2015), Planning and processing methods results of scientific research: *Proc. allowance, SPb: NIIT ITMO; IHBT*, 110 p., St. Petersburg / Russia;

[7] Podpryatov G.I., Nasikovsky V.A., (2005), Influence of drying modes on the heating temperature and crop properties of wheat grain, *Agrarian Science and Education*, Vol. 6, No. 1-2, pp. 74-77, Mykolayiv / Ukraine;

[8] Pohozhykh M.I., Pak A.O., Pak A.V. (2014), Hydrothermal treatment of cereals using the principles of drying with a mixed heat transfer, *KSUFTT*, 169 p., Kharkiv / Ukraine.

[9] Poperechnyy A. M., Varvarina N. M., Zhdanov I. V., (2013), Drying of food raw materiaI in a fluidized bed: monograph, *DonNUET*, 303 p., Donetsk / Ukraine;

[10] Savchenko S.V., (2009), Kinetic model for optimizing the grain drying regime, *Bread products*, №7, p. 38-39, Moscow / Russia;

[11] Shchitov S.V., Krivueca Z.F., (2012), Optimization of energy inputs in transportation and technological support of agro-industrial complex, Monograph, 151 p., Blagoveshchensk / Russia;

[12] Shchitsov S.V., Tikhonchuk P.V., Krivuta Z.F., Kolzov A.V. (2016), Investigation of the influence of kinematic parameters on the optimization of grain drying process, *Far Eastern agrarian messenger. Scientific and practical journal*, №2(38), pp. 98-102, Blagoveshchensk / Russia;

[13] Snyezhkin YU.F., Shapar R.O., Chalayev D.M. (2010) The intensification of the drying process of seed grains, *Industrial heat engineering*. P. 42-47, Kiev / Ukraine;

[14] ***State Standard 2240 – 1993, (1994), Seeds of agricultural crops. Methods for analyzing the moisture content of seeds, *DSSU*, p. 2-10, Kiev / Ukraine;

[15] ***State Standard 4138 – 2002, (2003), Seeds of agricultural crops. Methods for analyzing the moisture content of seeds, *DSSU*, p. 16-17, Kiev / Ukraine;

[16] ****Technology of drying and seeding seeds of cereals in the northern regions of the Tomsk region* (2018). Available at: http://sibniit.tomsknet.ru/files/articles/suschka_podrabotka (Accessed: 28 March 2018).

[17] ****The results of the investigation of physical processes during the drying of grain* (2018). Available at: http://insightex.com.ua/wp-content/uploads/2014/08/СЭММ (Accessed: 28 March 2018);

[18] Vasiliev A.N., Severinov O.V., Budnikov D.A., (2012), Mathematical model of optimal control of grain drying with maximum use of drying agent potential, *Collection of reports VIM*, pp. 677-682, Moscow / Russia.

**Edited by: INMA Bucharest**
6 Ion Ionescu de la Brad Blvd., sect. 1, Bucharest, ROMANIA
Tel: +4021.269.32.60; Fax: +4021.269.32.73
http://www.inmateh.eu
e-mail: ***inmatehjournal@gmail.com***