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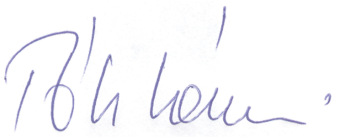
PREFACE

In the name of the Committee of Agricultural and Biosystem Engineering of the Hungarian Academy of Sciences we would like to welcome everyone who is interested in reading our journal. The Hungarian Agricultural Engineering (HAE) journal was published 30 years ago for the very first time with an aim to introduce the most valuable and internationally recognized Hungarian studies about mechanization in the field of agriculture and environmental protection. In the year of 2014 the drafting committee decided to spread it also in electronic (on-line and DOI) edition and make it entirely international. From this year exclusively the Szent István University's Faculty of Mechanical Engineering took the responsibility to publish the paper twice a year in cooperation with the Hungarian Academy of Sciences. Our goal is to occasionally report the most recent researches regarding mechanization in agricultural sciences (agricultural and environmental technology and chemistry, livestock, crop production, feed and food processing, agricultural and environmental economics and energy production) with the help of several authors. The drafting committee has been established with the involvement of outstanding Hungarian researchers who are recognized on international level as well. All papers are selected by our editorial board and a triple blind review process by prominent experts which process could give the highest guarantee for the best scientific quality. We hope that our journal provides accurate information for the international scientific community and serves the aim of the Hungarian agricultural and environmental engineering research.

Gödöllő, 30.12.2019.



Dr. László KÁTAI
editor in chief



Dr. László TÓTH
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ACCELERATING TRANSIENT DYNAMICS: TARGETET MODAL INTERACTION

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Abstract

Vibrations occur in many areas ranging from heavy-duty industry over micro sensors to appliances in the private household. A key concept for limiting such vibrations is vibration control that avoids or at least minimize unintentional product behavior or negative effects on the health and safety of humans and animals. A concept for attacking vibrations in mechanical systems is outlined based on time-periodic modulation of a physical parameter in the system. This concept can be applied in parallel to existing controls and allows the artificial increase of damping transient dynamics.

Keywords

vibration control, parametric anti-resonance

1. Introduction

Vibrations occur in many areas ranging from heavy-duty industry over micro sensors and production machines to appliances in the private household. A key concept for limiting such vibrations is vibration control that avoids or at least minimize unintentional product behavior or negative effects on the health and safety of humans and animals, see (ISO 5349-1). For example, the whole-body vibrations in agricultural track-laying tractors may affect the operator's health and work efficiency [1-2]. Another example is the generation of electrical energy in heavy-duty power plants [3]. The efficiency with which such power plants translate gas/oil to electrical energy depends strongly on the gap between blades and casing. This gap needs to be large enough for allowing transient operation of the power plant due to steadily changing power needs but small enough for ensuring a cost-effective and efficient operation. A further example are wind turbine blades in the so-called green industry [3-4]. The trend towards longer blades makes wind turbines prone to wind-induced vibrations that may limit the turning speed or reduce the lifetime of the blade material. A modern concept for attacking vibrations in mechanical systems is outlined that can be used in parallel to existing controls and allows the artificial increase of damping transient dynamics [4].

Introducing a time-periodic modulation of a system parameter may trigger an energy transfer between vibration modes [5]. If this energy transfer induces a vibration reduction the associated modulation frequency is called parametric anti-resonance frequency. For a system with multiple natural frequencies, the simplest parametric anti-resonance may occur at the sum or difference between two of the many natural frequencies

$$\nu = \frac{|\omega_i \mp \omega_j|}{n} \quad i,j,n = 1,2,\ldots \tag{1}$$

The main benefit is outlined in Fig. 1 for the example of a linear, unstable system. The original system possess some unstable and stable poles. Additional poles may be located on the left half-plane. Introducing a time-periodic modulation of a physical parameter in the system, for example modulating the original stiffness k, leads to the time-periodic stiffness *k(t)*. Tuning the modulation close to a parametric anti-resonance frequency induces a modal interaction between the original system modes and allows for an energy transfer between these two

vibration states of the system. This is a selective, externally triggered energy transfer. Translated to the complex plane in Fig. 1, the original system poles move with respect to the real parts towards a fix point, which eventually results in a stable system. The concept goes back to the pioneering idea of Tondl (1978) [6] and was verified theoretically and experimentally for different test rigs with flexible structures [7].

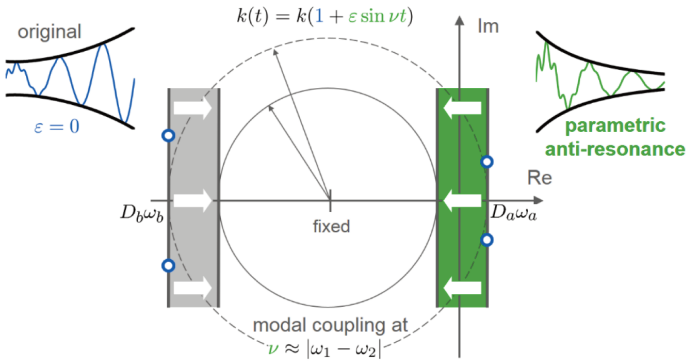


Figure 1. Movement of the system poles at induced modal interaction: The original system poles of the unstable system with constant stiffness k (left) move with respect to the real parts towards a fix point if an intentional modal interaction is triggered by k(t) which results in a stable system at parametric anti-resonance (right).

Potential applications

The strength of this concept is that it is applicable in parallel to already existing control concept. Some potential areas for different mechanical systems are outlined in the following. The first experimental verification was performed by Tondl using an analog electronic circuit. This work motivated analytical, numerical and experimental work on systems utilizing a parametric anti-resonance [7-8]. A test rigs of flexible structure is shown exemplary in Fig. 2: an uniaxial electromagnetic actuator used as a time-modulated support of a flexible cantilever. The effective damping observed during transient dynamics of the cantilever are collected at different modulation frequencies *ν*. It is clearly shown that if the modulation frequency hits a parametric resonance frequency, the effective damping is decreased and the system response may become unstable. However, tuning the modulation frequency *ν* close to a parametric anti-resonance frequency as defined in eq. (1), triggers a significant increase of the effective damping. A comparison between the transient vibrations for the nominal system and at activated time-periodic modulation of the additional support shows the increase in effective damping.

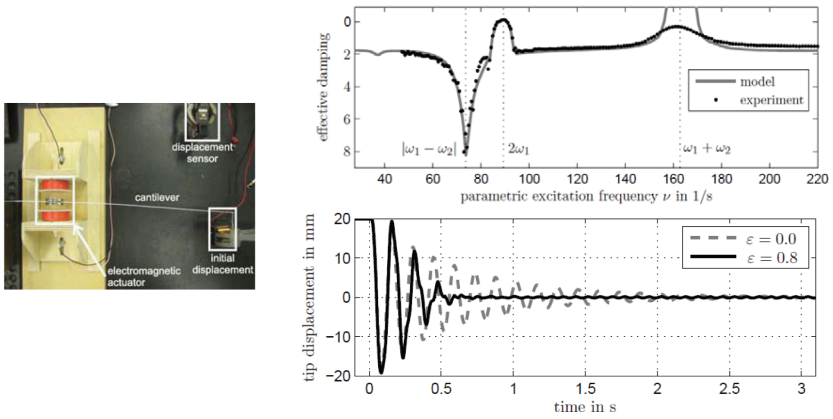


Figure 2. Uniaxial electromagnetic actuator [7]: (left) Cantilever with additional electromagnetic mount, (right, top) Effective damping at a parametric excitation amplitude of ε = 0.8, (right, bottom) Comparison of transient vibrations for the nominal system and at activated parametric anti-resonance.

Since then, the concept was tested for different applications in structural dynamics at macroscale, e.g. rotordynamics and micro scale, e.g. micro-electromechanical systems (MEMS). A milling machine may experience vibrations, a kind of self-excited vibration mechanism, that occur above a certain cutting depth. A typical stability map is shown in Fig. 3. Employing a magnetically supported spindle for the milling operation [1] [8] allows for an additional time-periodic modulation of the bearing stiffness. Tuning the frequency of this modulation properly generates a dense region of stable milling operation even for large values of the cutting depth.

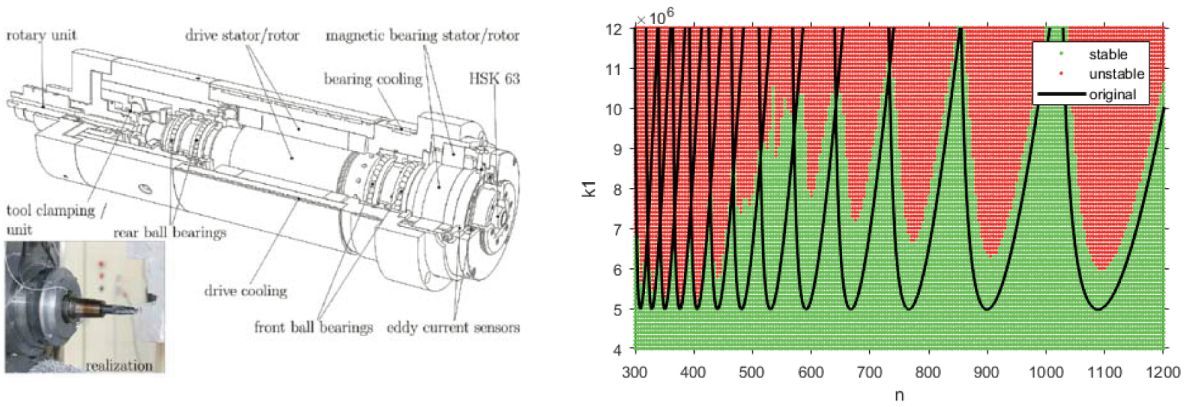


Figure 3. Chatter suppression by parametric anti-resonance: (left) Spindle with active bearings [1]: (right) Stability map of spindle speed over cutting depth for a tool holder at original support stiffness and a time-periodically modulated support showing enlarged stability region at 550 rpm [7]

An efficient implementation of time-periodic modulation in MEMS is shown in Fig. 5. A sensor beam driven at a forced excitation during the time interval td allows for a desired measurement. After the successful measurement, the sensor beam vibrations need to be mitigated quickly for getting ready for the next measurement cycle. A parametric anti-resonance triggers an energy transfer between the first mode of the sensor beam and the first mode of the auxiliary beam [9-10]. The transient time histories are depicted in Fig. 4 on the top right. The energy transferred to the auxiliary beam is eventually dissipated by structural damping.

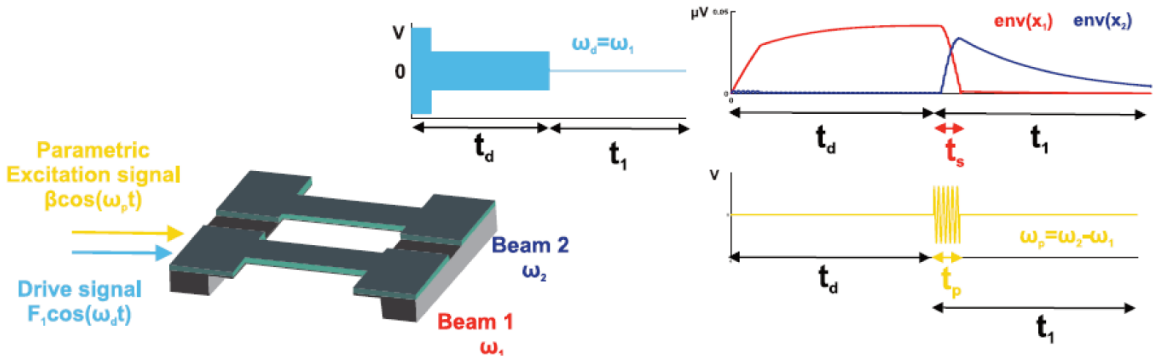


Figure 4. MEMS with multiple degrees of freedom: a modulation at parametric anti-resonance triggers a targeted energy transfer between sensor beam 1 (red) and auxiliary beam 2 (blue) and allows for a significant reduction of the ring-down time of the sensor at repeated measurement operation [11]

Vibrations play also an important role in the power conversion industry. Rotors in this industry are typically supported by fluid-film bearings that may show instability (whirl) above a critical speed, see Fig. 5 [12]. Introducing an adjustable bearing enables the implementation of a time-periodic modulation and

the chance of mitigating vibrations by a parametric anti-resonance. The vibration mitigation was confirmed theoretically in [13-14] and experimentally in [14]. A real rotor was analyzed [14-15] and shows a significant increase of the onset speed of rotor whirl. It is also possible to perform high speed balancing of a rotor without turning the rotor at high speed [15].

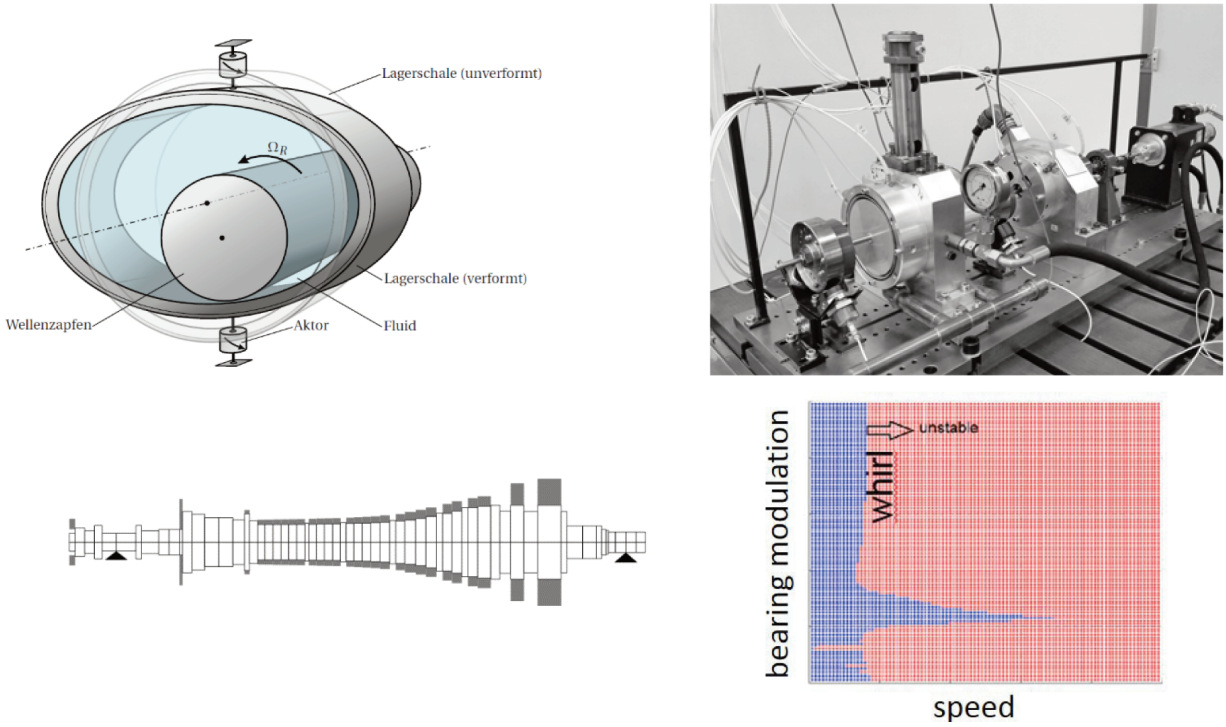


Figure 5. Rotordynamic systems at parametric anti-resonance: (left, top) active deformation of the bearing shell [13], (right, top) experimental test rig of a fluid-film bearing with moveable bearing half shell [14], (bottom) typical rotor for power generation up to 12 MW and the corresponding stability map showing a significant increase of the whirl speed [15]

The concept of parametric anti-resonance is most beneficial for systems with low structural damping. A minimum requirement is that the system possesses at least two vibration modes. If the original system has only one vibration mode, an additional subsystem must be attached. It should be noted that the concept allows for the reduction, and sometimes even suppression of transient vibrations. Other potential applications that should be investigated in future are the transient vibration of long wind turbines blades [16-17], the drivetrain of cars and wind turbines in Fig. 6 [18] or the seat dynamics of a farming vehicle [19-20].

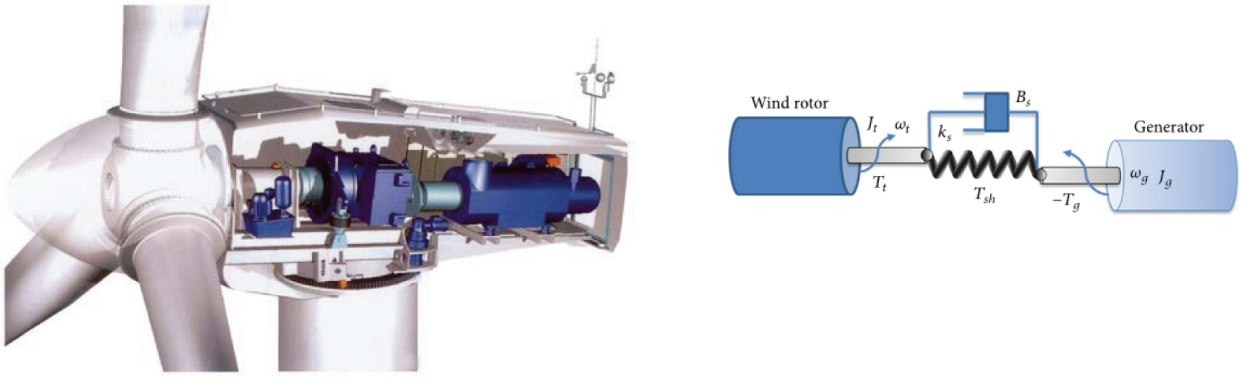


Figure 6. Drivetrain of a wind turbine: (left) assembly, (right) simplified mechanical model [18]

Conclusions

The concept of parametric anti-resonance is applicable in parallel to existing control strategies and allows for suppressing or at least damping of transient vibrations. Several proven examples and future directions are outlined briefly. Time-periodic systems have been analyzed since decades due to their severe vibration response at parametric excitation. On the contrary, the concept of parametric anti-resonance at macroscale systems was understood recently and enable a structured and efficient implementation in real engineering applications.

References

[1] Dohnal, F. (2012a), A contribution to the mitigation of transient vibrations: Parametric anti-resonance: Theory, experiment and interpretation, Habilitation thesis, Technical University Darmstadt, Germany.

[2] Altintas, Y. (2012), Manufacturing automation: metal cutting mechancis, machine tool vibrations, and CNC design, Cambridge University Press.

[3] Becker, K. (2019), Dynamisches Verhalten hydrodynamisch gelagerter Rotoren unter Berücksichtigung veränderlicher Lagergeometrien (in German), PhD thesis, Karlsruher Institut für Technologie (KIT).

[4] Dohnal, F., Hörtnagel, W. and Zamojski, M. (2019), Numerical and analytical investigation of chatter suppression by parametric excitation, Proceedings of the 15th International Conference Dynamical Systems – Theory and Applications, DSTA, Łódź, Poland, 8 pages.

[5] ISO 5349-1, International Standard, Mechanical vibration and shock, Human exposure to mechanical vibration and shock.

[6] Li, C., Zhou, Y., Lim, T.C. and Sun, G. (2016), Dynamic responses of a wind turbine drivetrain under turbulent wind and voltage disturbance conditions, Advances in Mechanical Engineering, Vol. 8(5), pp. 1–12.

[7] Chasalevris, A. and Dohnal, F. (2016) Improving stability and operation of turbine rotors using adjustable journal bearings, Tribology International, Vol. 104, pp. 369–382.

[8] Al-Hadad, M., McKee, K.K. and Howard, I. (2019), Vibration characteristic responses due to transient mass loading on wind turbine blades, Engineering Failure Analysis, Vol. 102, pp. 187–202.

[9] Dohnal, F. (2012b), Experimental studies on damping by parametric excitation using electromagnets, Proceedings of the Institution of Mechanical Engineering, Part C: Journal of Mechanical Engineering Science, Vol. 226, pp. 2015–2027.

[10] Abele, E., Dohnal, F., Feulner, M., Sielaff, T. and Daume, C. (2018), Numerical investigation of chatter suppression via parametric anti-resonance in a motorized spindle unit during milling, Production Engineering, Vol. 12, pp. 309–317.

[11] Mendes, R.U. and Dohnal, F. (2019), Tuning of parametric excitation for rotor balancing, Journal of Physics: Conference Series, Vol. 1264, 012036, 11 pages.

[12] Mohanta, R.K., Chelliah, R.C., Allamsetty, S., Akula, A. Ghosh, R. (2017), Sources of vibration and their treatment in hydro power stations – A review, Engineering Science and Technology, Vol. 20, pp. 637–648.

[13] Ramírez Barrios, M., Dohnal, F. and Collado, J. (2019), Enhanced vibration decay in high-Q resonators by confined of parametric excitation, submitted to Archive of Applied Mechanics

[14] Tondl, A. (1978). On the Interaction between self-excited and parametric vibrations, Monographs and Memoranda, Vol. 25, Prague: National Research Institute for Machine Design.

[15] Tondl, A. and Dohnal, F. (2013), Using time-periodicity for inducing energy transfer between vibration Modes, Proceedings of ASME 9th International Conference on Multibody Systems, Nonlinear Dynamics, and Control, USA, DETC2013-12936, 10 pages.

[16] Cutini, M., Brambilla, M. and Bisaglia, C. (2017), Whole-body vibration in farming: Background document for creating a simplified procedure to determine agricultural tractor vibration comfort, Agriculture, Vol. 7(84), 20 pages.

[17] Vallone, M., Bono, F., Quendler, E., Febo, P. and Catania, P. (2016), Risk exposure to vibration and noise in the use of agricultural track-laying tractors, Annals of Agricultural and Environmental Medicine, Vol. 23, pp. 591–597.

[18] Yang, J., Mu, A. and Li, N. (2019), Dynamical analysis and stabilization of wind turbine drivetrain via adaptive fixed-time terminal sliding mode controller, Mathematical Problems in Engineering, Vol. 2019, 8982028, 14 pages.

[19] Staino, A. and Basu, B. (2015), Emerging trends in vibration control of wind turbines: A focus on a dual control strategy, Philosophical Transactions of the Royal Society A, Mathematical, Physical and Engineering Sciences, Vol. 373(2035), 16 pages.

[20] Pfau, B. and Markert, R. (2017), A two-lobe journal bearing with adjustable gap geometry for vibration reduction of flexible rotors, Technische Mechanik, Vol. 37, pp. 109–119.

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POSSIBILITIES TO PROMOTE THE AGRICULTURAL MECHANIC PROFESSION

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Abstract

MEGFOSZ (Hungarian Association of Agricultural Tool and Machinery Distributors) has started a program to promote the profession six years ago. This year became necessary to review the running program and find more effective tools to make more attractive the agricultural mechanic profession. This paper shows the results of the research based on two surveys answered by 855 young people. The main conclusions of the research pointed out what should be changed in the communication channels and messages to make a more effective marketing program.
Keywords
agricultural mechanic, sector promotion, communication

Introduction

Labor shortage in recent years has grown a very important problem in the agricultural machinery sector. To resolve this situation MEGFOSZ (Hungarian Association of Agricultural Tool and Machinery Distributors) has started a program to promote the profession six years ago. This year became necessary to review the running program and find more effective tools to make more attractive the agricultural mechanic profession.

Methodology

The paper shows the results of the researches, which searched the tools of a more effective program to promote the agricultural mechanic profession. First it was made a deep interview with the colleagues of MEGFOSZ and the members of Presidency. The focus of this research was to find the answers for the questions how they see the current situation and how they operate the program. Then a focus group research was conducted with students, newly graduated and experienced professionals, teachers, employers and institutions. The question was: What are the specialties of the field of mechanical engineering that can be built upon to promote the profession?

Based on the first two qualitative researches it was made two questionnaires. First questionnaire contained 4 questions, which was answered by 101 students at the AGS exhibition in Mezőhegyes. The questions were: What is the programme's reputation and perception of the profession? Where is it worth promoting the program? The second questionnaire contained 15 questions and it was answered by 754 young people using the google forms questionnaire posted on facebook. The second survey's questions were based on the first 3 studies.

Results

The presentation of results focuses to increase the efficiency of the MEGFOSZ promotional program. For this reason only that results will be presented which is needed for the conclusions. In the second questionnaire it was searched the answer which aspects are important when choosing a profession. Similar question has already explored in the first survey too. The results of the two studies are mutually reinforcing each other. In both cases, work in nature (fieldwork, plants, animals), flexible working hours (freedom) and using the latest technologies (innovation) were important (see Fig. 1). The results also show that working in office is the least important

aspect. Knowledge that can be used internationally and travel opportunities are also not so important to respondents, which we think is good news, as it may confirm that the young professionals do not plan to leave the country in the future.

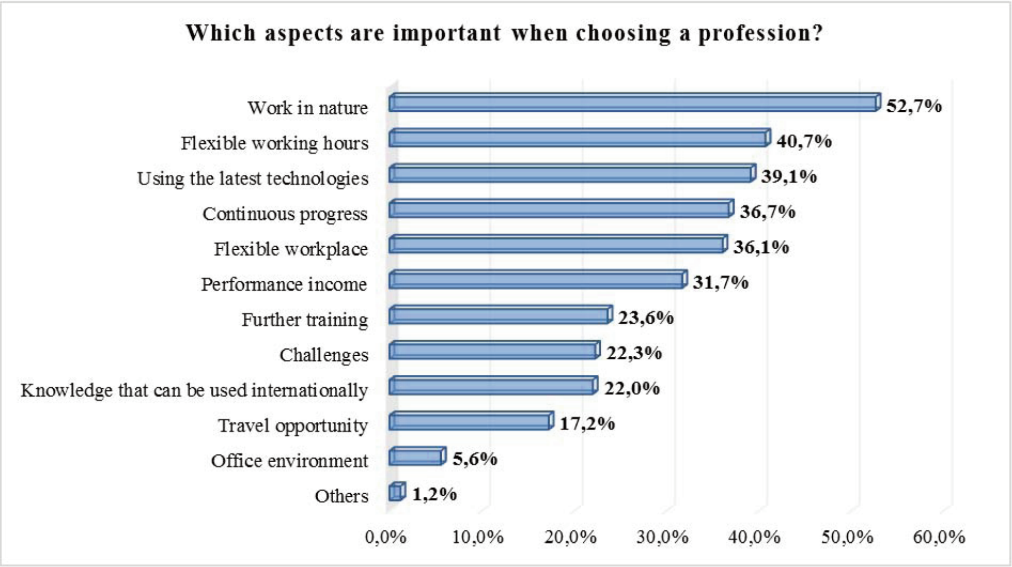


Figure 1. Which aspects are important to you in your future profession?

With the next question we sought to find out what does agricultural mechanic profession mean for young people and what they think about this profession. In the previous survey it has also already examined this question, and its results strengthen the answers of this questionnaire. Nowadays, more than half of young people identify the agricultural mechanic with modern machinery and technology, well-equipped workshops. But it is important to mention that, a significant proportion, 42% of young people think that the profession means still dirty and oily work (see Fig. 2).

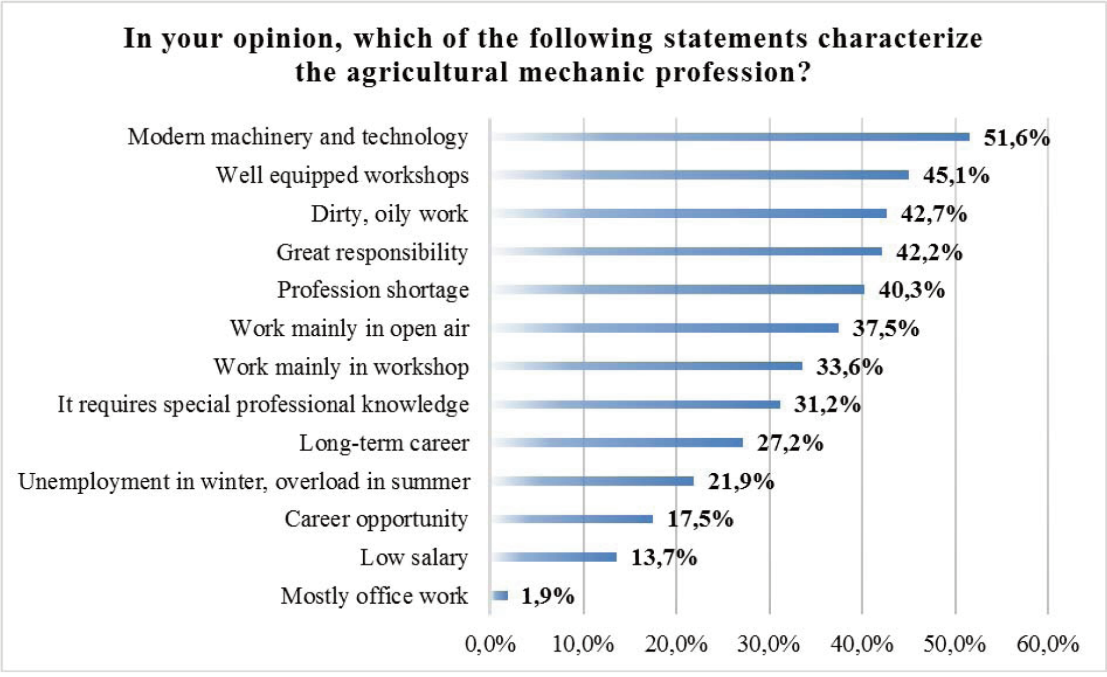


Figure 2. In your opinion, which of the following statements characterize the agricultural mechanic profession?

Young people's perception about the profession is ambivalent. For this reason it was asked how to attract people to agricultural mechanic profession. More than half of those were surveyed believe that organizing modern machine demonstration is the best way to attract young people to the profession. Provision of vocational trainings can also help to make more attractive the job when they gain a better understanding of the profession, and they can use there modern machines that they do not meet at school (see Fig. 3).

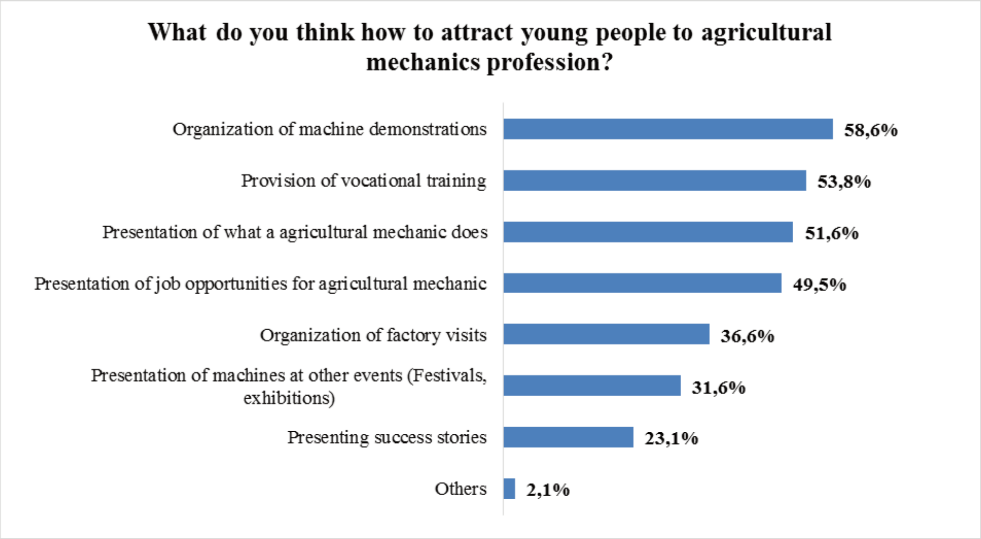


Figure 3. What do you think how to attract young people to agricultural mechanics?

Generally, one of the most common inhibitory factors for any decision is the uncertainty because of lack of information. This could be eliminated if we show for young people what an agricultural mechanic does exactly. Based on this they could make a better decision what they would like to work later, and everybody can avoid any later disappointments due exaggerated expectations. Informing young people about specific job opportunities can improve the image of the profession because they will have information how well they will be payed and what kind of positions they will be able to fill. It was an interesting result that presenting success stories is considered to be the least useful. The background of this fact could be that a story does not give a very realistic picture about the profession and may create excessive expectations, which will lead to disappointments.

In the next phase of the survey it was examined what platforms should be used to get through efficiently to students before they choose a career. To communicate with students who are facing a career choice it was offered the Internet as the main tool with a particularly high rate (Figure 4). TV was mentioned in second place, ahead of facebook. This was an interesting result because, based on the answers of other questions, the program "Become an Agricultural Mechanic!" was get to know from social media. The response rate also confirms the credibility of the survey, because at the time of the examination the program had a much stronger appearance on Facebook than on television.

The next group of recommended platforms are events, instagram and youtube appearances. Based on this result, the attendance at events was in the right proportion, but it is suggested to MEGFOSZ reinforce the instagram and youtube appearances, as instagram has only just started and the program is barely present on youtube. According to the survey, newspapers and radio play little role in reaching young people. These two media mainly play a role to get at parents, so it is recommended to use newspapers and radio with parental contents.

Upon graduation, the gateway to the world of work opens to newcomers. The crucial question in the first instance is whether they will remain on the chosen path. Research shows that 70% of them stay in the profession they are studying and are trying to find a job (see Fig. 5). Fortunately, this result confirms that young people are quite committed to agricultural mechanic. Only 9% who are disappointed and confident that they do not want to stay in their profession but want to switch. It is important for the future that there are 21% more respondents who are still uncertain. The "Become an Agricultural Mechanic!" program needs to pay close attention to them to keep them motivated and skilled in the profession.

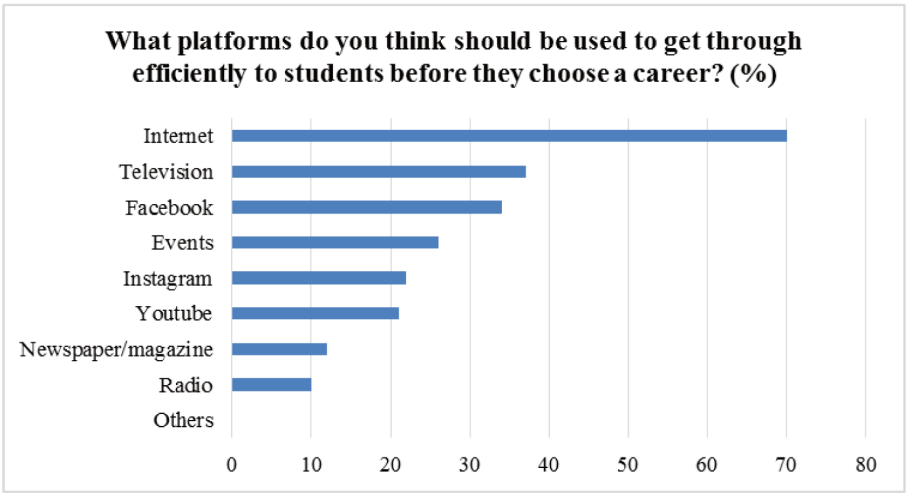


Figure 4. What platforms do you think should be used to get through efficiently to students before they choose a career? (%)?

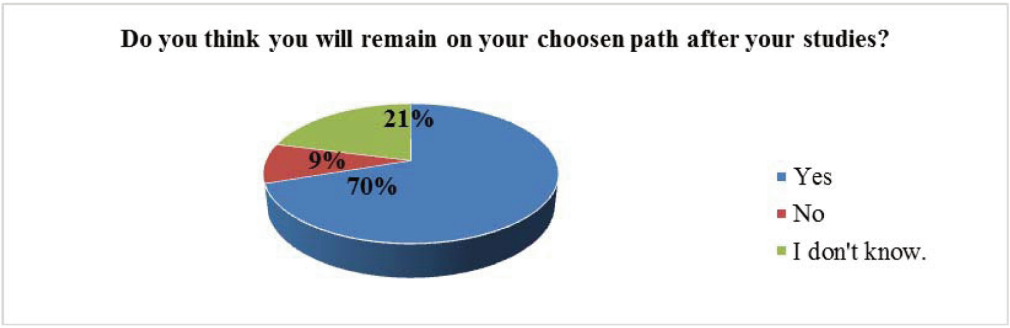


Figure 5. Title of the figure

It has been revealed above that most young people do not plan to give up their profession, but some of them do not seclude themself from other opportunities. It can be seen that 46% love their profession and do not plan to change, but there is a significant 42% who are currently satisfied but open to change (see Fig. 6). This can mean staying in his/her current profession, but also if they receive a good opportunity they easily lured into a related profession like the automotive industry. This openness characterizes the younger age group. They can easier adapt to new situations or change jobs. For this reason it is highly recommended to develop a program that will help young people start their careers and stay in their profession. If this succeeds, they will be satisfied with their job and will not change their profession in the future.

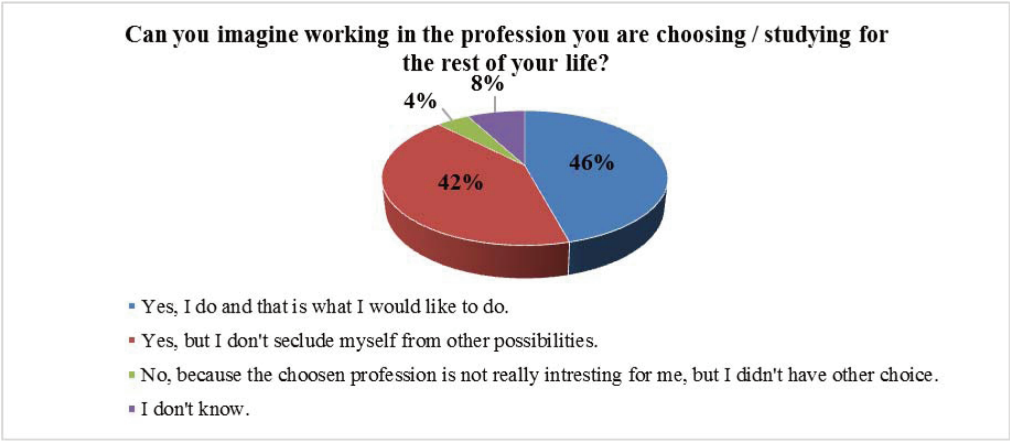


Figure 6. Can you imagine working in the profession you are choosing / studying for the rest of your life?

Conclusions

In Hungary 82% of young people would take up work near their place of residence. The agricultural mechanic profession is not well known or often has an unfavorable image. It would be a great help to gain a better image of the profession by obtaining information on the modern technology and the high technical level of the latest agricultural machinery [1,2,3,4]. Young people are overwhelmingly committed to their chosen profession, but 42%, especially younger ones, are open to change. We propose to develop a program to help young people start their careers and stay in the profession.

One of the most common inhibitor factors of decisions is uncertainty due to lack of information. This can be eliminated by showing to young people what an agricultural mechanic does. We propose to draw the attention of young people to the enormous technical development of the last years [5], which was mainly for the convenience of the producers and to repair quickly the machines.

The current training system has not been able to keep up with the significant technical and technological development of the last years in the case of knowledge and equipment [6,7]. Dual training system, vocational training programs, thesis writing, summer internships, company visits, events, exhibitions are all program points that can help to solve the previous two points. We propose that career guidance in schools should not only be campaign-oriented, but a continuous and well-planned activity.

The qualitative research and the two questionnaire surveys confirmed that the Internet is the most important channel for reaching young people. In addition to the classic web appearances, we propose also to use Facebook, instagram and youtube for reaching young people. The latter two are barely present now in the MEGFOSZ program. Parents can be reached mainly by television and the newspaper in addition to the classic Internet content.

References

[1] Bauer András - Berács József - Kenesei Zsófia (2007): Marketing basics. Aula Kiadó, Budapest
Erickson, R. (2005): Why emotion work matters: Sex, gender and the division of household labour. Journal of marriage and family, 67(2), 337-351

[2] Ferry, Natalie M. (2006): Factors Influencing Career Choices of Adolescents and Young Adults in Rural Pennsylvania, Journal of Extension, 44 (3), p1-6.

[3] Keller, Briana K. - Whiston, Susan C. (2008): The role of parental influences on young adolescents' career development. Journal of Career Assessment, 16, 198-217.p

[4] Lankard Bettina A. (1995). Family role in career development Washington DC : Office of Educational Research and Improvement, ERIC Digest No. 164

[5] Szilágyi Klára (2011): Career psichology. Digital book. Szent István University, Gödöllő. http://www.tankonyvtar.hu/hu/tartalom/tamop412A/2010-0019_palyalelektan/index.html (Downloaded: 2019.03.01)

[6] Fogarassy, Csaba; Toth, Laszlo; Czikkely, Marton; Finger, David C. (2019): "Improving the Efficiency of Pyrolysis and Increasing the Quality of Gas Production through Optimization of Prototype Systems." Resources 8, no. 4: 182.

[7] Bacskai, Istvan; Madar, Viktor; Fogarassy, Csaba; Toth, Laszlo. (2019): "Modeling of Some Operating Parameters Required for the Development of Fixed Bed Small Scale Pyrolysis Plant." Resources 8, no. 2: 79.

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UTILIZING MACHINE LEARNING TECHNIQUES TO PROCESS CUSTOMERS CLAIMS AUTOMATICALLY

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Abstract

In this paper, Supervised Machine Learning was used to develop a new approach to handle customers' claims which were gathered from a real-case company. Supervised machine learning was used with accurate data in order to develop a machine learning model. This model was deployed and used to evaluate new un-evaluated claims by examining their content variables and assigning a ranking value for each claim expressing its priority.

The goal of this experiment was to show evidence on the ability of new technologies such as Machine Learning to automate quality management traditional activities, improve efficiency and effectiveness, and support a new approach to "Quality 4.0". Other goals were to improve customer satisfaction by enhancing responsiveness to their claims and to convince the company (the real case of this study) to extend the project for further applications.

Keywords

Industry 4.0, Quality 4.0, TQM, Machine Learning, Artificial Intelligence, Customer Satisfaction.

Introduction

Artificial Intelligence (AI) is radically developing nowadays in many different fields, empowered by the development of computer and telecom technologies such as big data and supercomputers which are able to analyze large volumes of data at a super-fast speed [1]. Machine Learning (ML) is one of the AI technologies, it is used in many fields of our lives, based basically on extracting knowledge from big data, trying to detect patterns or predict future behaviors [2]. ML is being widely used by large scale businesses such as Google. Microsoft, and Facebook benefiting from the massive amounts of data accumulated through the usage of their services [3]. Currently, ML is being used at other sectors such as health [4], finance [5], and in many business management fields such as logistics and workflow optimization [6], customer care [7] and more. There are many ML tools and platforms, some examples are Google TensorFlow, Scikit-learn, Google's Cloud AutoML, Microsoft, etc. [2], [8].

Arora et al (2009) [7] utilized supervised ML to categorize online customers' comments either by categorizing them to qualified, or bad claims. In their experiment, a sufficient number of online customers' reviews which were written in two languages was collected and used as training data to develop a logarithm that will be deployed later to analyze customers' comments. [9] used Natural Language Processing (NLP) and Deep Learning (DL) to extract meaningful insights from customer's perceptions. They used historical data about a specific car model and used NLP/DL to understand the customers' favorite features. The goal was to improve future cars to fulfill customers' expectations.

Customers' complaints are very critical not only to resolve customer's problems but also to understand important information about them and their behavior, which if well managed could be very expensive knowledge for the company's development. Complaints are reported through different channels and the most important part of it is the narrative content that describes the product's problems [10]. Therefore, it is important to develop automated and efficient tools that can handle large volumes of complaints containing complex and interconnected data automatically and in a highly responsive manner.

This paper summarizes the results of a real-life experiment resulted from scientific cooperation with large manufacturing company in Hungary. At present,

claims are being received, registered at the ERP system of the company, and later viewed and handled manually by the experienced quality management staff. The company adopts Issue Priority Ranking (IPR) strategy to evaluate and rank every claim by a scale of 1-300 points based on detailed evaluation criteria. According to the IPR value of every single claim, the quality team decides the next handling steps. Time and experience playing an important role in this system; therefore, it was important to improve the process of evaluating claims and lever the current experience by utilizing machine learning.

Accordingly, one-year data of claims was extracted from the ERP system and used as training data to develop a machine learning model that was deployed later and tested to handle new claims. The model was trained to automatically analyze every claim content and return an IPR value to each based on the information provided. Moreover, the model was trained to categorize the source problem process where the defect problem came from.

In this experiment, Google AutoML service was used to develop and deploy the model. Google AutoML was selected for its user-friendly environment as there is no need to have any earlier coding practice. Later, the model can be deployed and integrated into the company's ERP system. The results showed relatively high-quality results with acceptable accuracy, given the volume of data used for training and the accuracy expected in filling the data of every claim filled at the customers' end.

The industrial partner in this research work is CLAAS Hungária Kft (CLH)[1] , established in 1997 in Hungary as a member company of CLAAS Group. CLAAS group is an international German family-owned business company based in Germany and owns many manufacturing plants worldwide. CLAAS is a world-leading manufacturer of agricultural engineering equipment and machinery, acknowledged by its high quality and innovation. Since establishment, CLAAS Hungária expanded from 350 workers and 8 hectares plant to more than 700 workers working on a 14- hectare plant and became a center of excellence for combine harvester tables and trolley carts production. The connection with CLH was started in 2017 and resulted research cooperation with the Quality Management Department.

Materials and methods

In this research work, supervised machine learning was used to improve the customers' claim processing process. Claims are being received from different sources, analyzed, categorized and ranked based on a defined internal procedure. Claims are reported by agents and service centers to the quality management office through the company's (ERP) system. The industrial partner uses Issue Priority Ranking (IPR) methodology were all claims are being evaluated by experienced quality management staff based on well-defined criteria. Accordingly, claims are ranked and prioritized based on their importance and critical impact. Mainly, claims priority is ranked based on three major factors: (Gravity, Occurrence, and Impact). *Gravity* represents the consequences of the claim from customer and company perspectives, this includes the cost of resolving this issue and the safety impact on operator. The weight of this factor ranges between 1 to 10 points, where 1 is the lowest impact and 10 is the highest. Occurrence represents the number of incidents a specific claim has been witnessed in a specific period. The weight of this factor is similar to gravity. *Impact*, weighted by a value between 1 to 3 points, represents the repair efforts, time, repetition of the same work, and the overall impact of the claim on the reputation and image of the company.

$$IPR = Gravity * Occurance * Impact \quad (1)$$

As in equation 1 the multiplication of the three factors values will result in an IPR value between 1 and 300 points. An IPR value above 160 points is categorized to be at a very high priority, lower but still high priority if the IPR value more than 100 points, medium priority if the IPR value is above 35 points, and low priority if less than that.

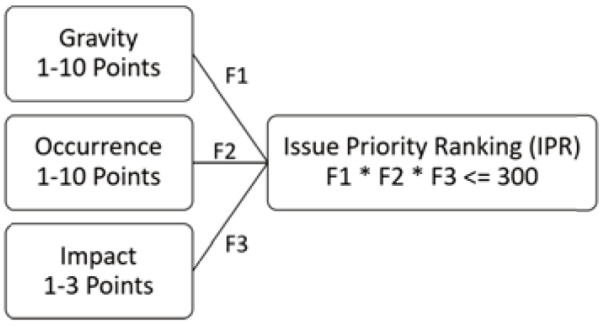


Figure 1. Factors affecting claim ranking and the weight of every factor

Although such a process requires highly experienced people to evaluate and rank claims, the volume and velocity of claims reported, and their processing time is very critical from quality management perspective. It is important in such a high-value industry to resolve issues as soon as they

[1]https://www.claashungaria.hu/

are reported. Early and fast processing of quality issues will be translated to a lower quality cost and will positively enhance the general business performance. Moreover, standardization of the evaluation process and ensuring consistency is vital to guarantee subjective IPR value every time. Also, given the machine learning capabilities and capacities to analyze several features (columns) at one dimension, aligned with large volume of data (rows) at the other dimension, will help to discover and analyze unseen factors, considering that the best quality practices focus on the claim root cause analysis. Additionally, utilizing technology whenever it is possible is very promising in industry, especially its capacity to work at any time (24/7) under any conditions and its ability to go deeper in analysis beyond human capacity. Leaving such task to machines will let human intelligence to focus on higher strategic issues.

Accordingly, this solution proposes utilizing supervised machine learning technology to replace human intervention in processing, evaluating, and categorizing claims. The current flow of claims from other involved parties is illustrated in fig. 2. In this figure, claims are flowing in from internal company quality product audit activities and issues that were detected during further production processes such as assembly (Cross Company Claims). The claims are pipelined in the company's ERP system and human intervention is important at one point to evaluate claims. Based on the evaluation results, the quality management decides how to deal with every single claim to find the root cause of the problem, either by following the Eight Disciplines of Problem Solving (3I-8D methodology), or by just updating the quality checklists in order to ensure quality of next produced items, or by ignoring the issue, as it is occasional and occupies a very low IPR value.

The proposed solution aims at developing an automatic claim filtering and evaluation system based on developing a machine learning algorithm that can read, analyze, evaluate, and assign a ranking numeric value (IPR) for every processed claim. In order to do so, historical data of already evaluated claims was used to train the model, later the model was deployed to evaluate new claims based on the experience learned by the historical data.

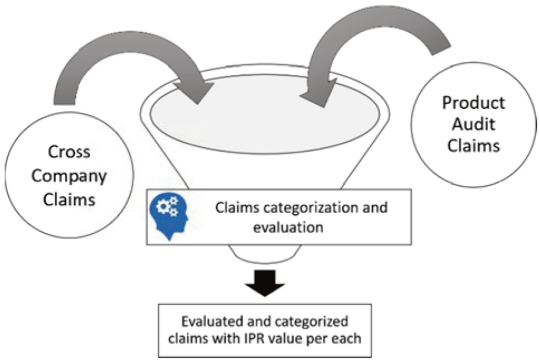


Figure 2. The flow of internal quality audit and cross-company claims to quality management



Figure 3. Development of machine learning model

A dataset contains an adequate volume of claims' data has been received from the industrial partner of this research project. Every claim in the dataset was described by 23 different input features, which will be used later to build up the machine learning model. The first step was to prepare the data for the machine learning platform, this included ensuring all features of the dataset are organized and data types are well defined. Additionally, some claims were not evaluated and had no IPR value. Therefore, these claims were evaluated manually by the quality management team at the partner company using a specially developed tool that facilitated the manual evaluation process. The top relevant 5 key input features in the dataset are defined in table 1 below.

Table 1. Top 5 Input key features for the ML model

Input Feature Name	Input Type	Input Description
Description	Natural Language Text	Describes in natural language text the details of the claim
Damage Code/Text	Categorial Text	Categorize the claim and describes the category
Root Cause	Natural Language Text	Describes the root cause of the problem as from the operator opinion
Task	Natural Language Text	The correction action which was taken in order to resolve the issue
Work hrs	Numeric	Describes the time used to resolve the issue

Google Cloud Auto Machine Learning Platform (Google AutoML) was used in order to analyze data and develop the ML model. Google AutoML was developed by Google to help researchers in handling big data and building high accuracy ML models. The dataset was uploaded, input features were defined, and targeted values were selected. The data plot in fig 4 shows the distribution of the data, where the x-axis is the number of readings, and y-axis is the IPR value.

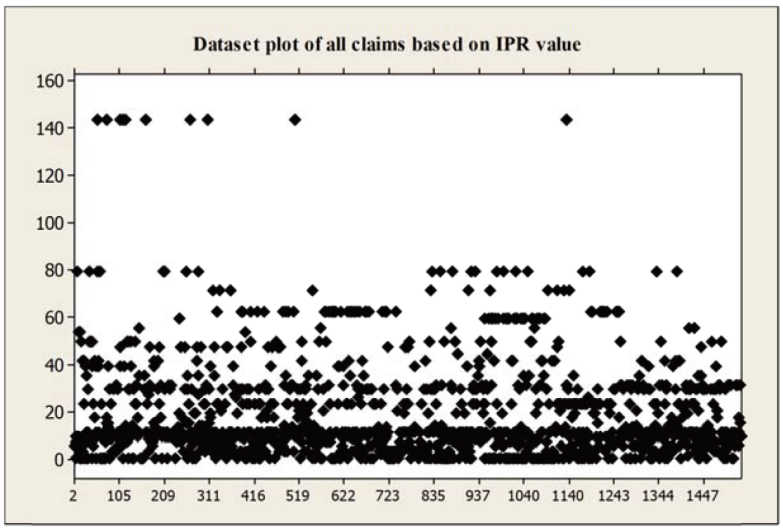


Figure 4. Dataset plot of all claims based on IPR value

At this stage, two approaches were used to predict the IPR using Google AutoML, the first approach by using the dataset including all input features as exported from the ERP system along with the accurate IPR value for each claim and then train the ML model to predict the IPR value for new un-evaluated claims. The second approach by training the ML model three independent times using the same data but every time targeting one of the three evaluation factors (gravity, occurrence, and Impact) and after apply equation 1 to calculate the IPR value. Figure 5 elaborates the two approaches.

In addition, to train a model to predict the IPR and the three factors, it is also important to categorize the root source process of every claim. Therefore, a fifth ML model was trained based on the same dataset, but the targeted value was the category of the claim, so the trained model will also predict the claim category based on historical categorization of the claims. The categories which were defined in the dataset were: (Cutting, Bending, Welding, Painting, Assembly, Packaging, Transportation, and others). As a result, autoML was not only used to predict the priority of the claim, but also to categorize the root source process of the problem.

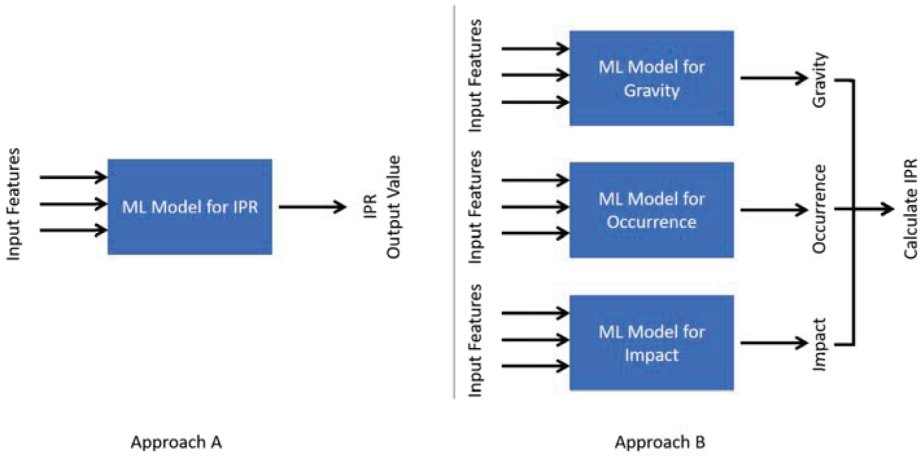


Figure 5. Two approaches to predict the IPR value

Results and discussion

Firstly, the initial training data used here consisting of 23 input features and 5 output variables. The input features included the details about every claim, the top important features were explained in table 1, while the output variables are defined in table 2.

Five machine learning models were trained successfully. Table 2 shows the training results and accuracy metrics for four regression models including (IPR, Gravity, Occurrence, and Impact). Table 3 shows the training results and classification accuracy metrics for Claim Category, which was trained as a classification model as the claim category could be either in process (a) or process (b), not in a middle point.

The input features were 23 for all models, and the validation sample was automatically selected and tested by the auto-machine learning platform. The mean absolute error (MAE), Root mean square error (RMSE), Root mean squared logarithmic error (RMSLE), and Determination Coefficient (R2) as elaborated in Table 2 are the accuracy metrics for the regression models, which are relevant for all values being predicted. For example, the MAE for the IPR is 5.350 and RMSE is 9.740 points respectively. Both metrics values elaborate accepted model quality given the range of IPR value is between 1 and 144 points. Which means in other words that the predicted IPR values are ± MAE or RMSE to the actual values.

Table 2. Model Training Accuracy Measures for IPR, Gravity, Occurrence, and Impact

Dataset targeted value	Analysis Type	Input Features	Validation Sample	MAE	RMSE	RMSLE	R^2
IPR	Regression (Numeric)	23	146 test rows	5.350	9.740	0	0.669
Gravity	Regression (Numeric)	23	141 test rows	0.489	0.842	0.177	0.762
Occurrence	Regression (Numeric)	23	162 test rows	0.448	0.724	0.183	0.855
Impact	Regression (Numeric)	23	131 test rows	0.193	0.316	0.116	0.749

Table 3. Model Training Accuracy Measures for Claim Category

Dataset targeted value	Analysis Type	Input Features	Validation Sample	Score threshold	AUC PR	AUC ROC	Precision	Recall
Claim Category	Classification (Categorial)	23	134 test rows	0.5	0.877	0.972	86.6%	76.9%

In table 3, the area under the precision-recall (AUC-PR) curve and the area under the receiver operating characteristic (ROC) curve are close to 1, which indicates a high-quality classification model. Moreover, the model precision is about 86.6% which means that the model was correct in predicting the category of claims for 86.6% of the total claims population.

Accordingly, the values predicted for IPR, Gravity, Occurrence, and Impact is plotted in figure 6. For every actual value vise predicted. The histogram in black line represents the actual values. It is noticeable that the IPR actual and predicted values are almost overlapping, which represents a higher accuracy of the model.

Calling back the two approaches to predict the IPR value as illustrated in fig 5, the second approach multiplies the predicted values for Gravity, Occurrence, and Impact according to equation 1. After calculations, the resulted IPR value was plotted in figure 7 (left) and the two IPR (Approach 1, Approach 2) were after plotted against the actual IPR as shown in figure 7 (right).

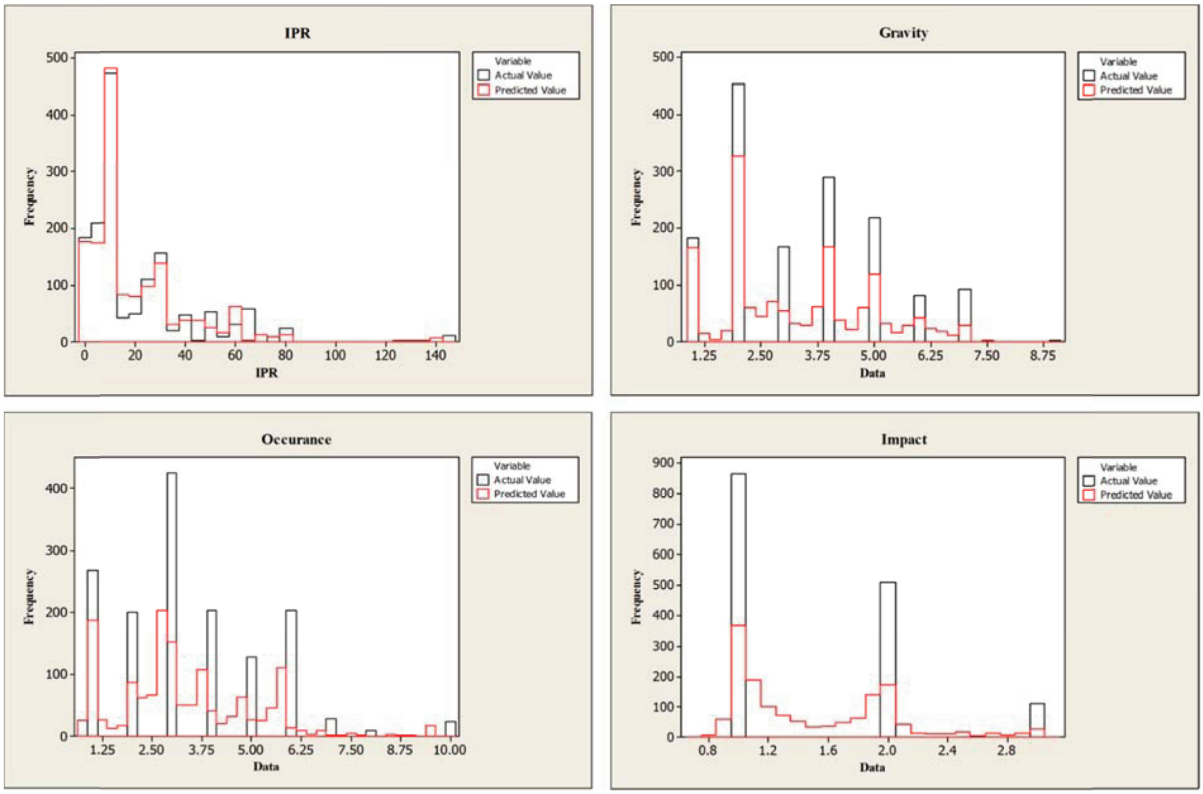


Figure 6. Actual Vs. Predicted plots for (IPR, Gravity, Occurrence, and Impact)

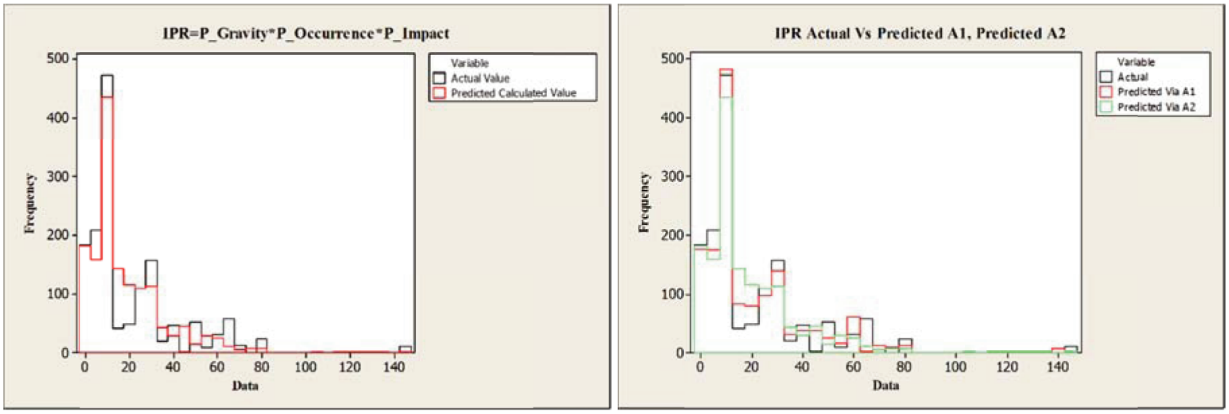


Figure 7. Actual Vs. Predicted plots for IPR according to Approach A(Left) and Actual Vs. Approach A Vs. Approach B for IPR (Right)

Conclusions

This research work first suggested machine learning as a tool to replace human involvement in evaluating customers' claims by assigning a ranking value (IPR) for every claim and categorizing claims according to the problem root cause. Utilizing such technology will enhance the capabilities of quality management team to handle any volume of the claims data under any flow velocity. The benefits of such technology do not end by this, but also could be furtherly extended to link claims and defects to the relevant manufacturing process/machine, so once a claim is reported to the quality management it will be processed by the model and instantly will be communicated to the relevant operators or managers.

One more result for this project is that the production quality checklists for the selected product became dynamically updated based on the top ten IPR value which is updated frequently. Such improvement enhanced the quality of processes and products.

Finally, it is important to highlight the affecting factors that control the quality and accuracy of the developed model. For example, the accuracy of the

model is strongly depending on the quality of the data originating at the first point where the problem or defect was first detected. Empty data rows or ambiguous data could forfeit important features that can help in predicting more accurate IPR value for the claim. Furthermore, it is also important to keep updating and maintaining the ML model by conducting periodical review sessions for the predicted IPR values and correct them when needed. Retraining the model using a larger volume of data will accumulate the model experience and though improve the model accuracy.

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References

[1] Y. Duan, J. S. Edwards, és Y. K. Dwivedi, „Artificial intelligence for decision making in the era of Big Data – evolution, challenges and research agenda”, Int. J. Inf. Manag., köt. 48, o. 63–71, okt. 2019, doi: 10.1016/j.ijinfomgt.2019.01.021.
[2] K. M. Lee, J. Yoo, S.-W. Kim, J.-H. Lee, és J. Hong, „Autonomic machine learning platform”, Int. J. Inf. Manag., köt. 49, o. 491–501, dec. 2019, doi: 10.1016/J.IJINFOMGT.2019.07.003.
[3] I. Guyon és mtsai., „Analysis of the AutoML Challenge Series 2015–2018”, Springer, Cham, 2019, o. 177–219.
[4] L. Faes és mtsai., „Automated deep learning design for medical image classification by health-care professionals with no coding experience: a feasibility study”, Lancet Digit. Health, köt. 1, sz. 5, o. e232–e242, szept. 2019, doi: 10.1016/s2589-7500(19)30108-6.
[5] I. SADGALI, N. SAEL, és F. BENABBOU, „Performance of machine learning techniques in the detection of financial frauds”, Procedia Comput. Sci., köt. 148, o. 45–54, jan. 2019, doi: 10.1016/J.PROCS.2019.01.007.
[6] A. Lyutov, Y. Uygun, és M.-T. Hütt, „Managing workflow of customer requirements using machine learning”, Comput. Ind., köt. 109, o. 215–225, aug. 2019, doi: 10.1016/J.COMPIND.2019.04.010.
[7] S. Arora, M. Joshi, és C. P. Rosé, „Identifying types of claims in online customer reviews”, 2009, o. 37, doi: 10.3115/1620853.1620865.
[8] B. Liu, „A Very Brief and Critical Discussion on AutoML”, sz. Ml, o. 1–5, 2018.
[9] S. Ramaswamy és N. DeClerck, „Customer Perception Analysis Using Deep Learning and NLP”, Procedia Comput. Sci., köt. 140, o. 170–178, jan. 2018, doi: 10.1016/J.PROCS.2018.10.326.
[10] B. A. Galitsky, M. P. González, és C. I. Chesñevar, „A novel approach for classifying customer complaints through graphs similarities in argumentative dialogues”, Decis. Support Syst., köt. 46, sz. 3, o. 717–729, febr. 2009, doi: 10.1016/j.dss.2008.11.015.

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SYNERGY OF ROBOTICS AND ICT IN THE SMART FARMING

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Abstract

There are many concept and technology to robotize in agriculture. The robotization has an intensive synergy with artificial intelligence (AI), information and communication technology (ICT) and sensor technology (ST). These technologies drive into the 4th revolution industry. The industrial processes help the automatization in agriculture. The demand for food products are growing, the working force getting old, these impacts forces the robot applications. This article introduce the robots in the agriculture, and the Szent István University current research on the fields.

Keywords

robots, artificial intelligence, sensor technology, smart farming

Introduction

What is a robot? In general robot is every entity which able to sense the environment, process, and acting based on dynamical changing environment. The most important properties are: sensing, autonomy intelligence, adaptive behaviour and working, able to acting. Another important capability: communication and cooperation. In the agriculture the environment is very challenging. The robot swarm can be a good solution for dynamically changing environment and complex task.

From Industry 4.0 to Agricultural 4.0

According to some definitions, Industry 4.0 is a frame of automation and data exchange in manufacturing technologies. It includes cyber-physical systems, the Internet of Things and cloud computing. Industry 4.0 includes all those innovative solution, methods that can compose an intelligent production system called „Smart Factory". Within the modular structured smart factories, cyber-physical systems monitor physical processes, create a virtual copy of the physical world and make decentralized decisions. Over the IoT, cyber-physical systems communicate and cooperate with each other and with humans in real time, and via the Internet of Services. Both internal and cross-organizational services offered and used by participants of the value chain. Cloud computing is already a well-known IT technology. It has the following five features: on-demand service, internet access, resource polling, rapid elasticity and calculability. In this way some sensors –controlling the process- connect to the internet ensuring the adequate information. The so called "Smart Agriculture" based on Cloud Computing, and IoT realize concentrated management and control of machine, equipment and personnel, based on the internet and improve production through more detailed and dynamic means. This is useful for effective integration between human society and the physical world, and regards as the third wave of information industry development following computerisation and internet. IoT technologies include RFID, sensor network technology, and internetwork communication, all of which have been involved in the four links of IoT industrial chain, namely: identification, sensing, processing and information delivery [1].

Agriculture 4.0 -analogy to Industry 4.0- stands for the integrated internal and external networking of farm operations. Information in digital form exists for all farm sectors and processes; communication with external partners - suppliers and end customers- is performed electronically; and data transmission, processing and analysis are largely automated. The use of Internet-based portals can facilitate the handling of large volumes of data, as well as networking within the farm and with external partners [2].

Other terms frequently used are "Smart Agriculture" and "Digital Farming". It is based on the emergence of smart technology in agriculture. Smart devices consist of sensors, actuators and communication technology.

Specialities

Another very important working condition is the livestock and bio materials. These materials are very sensitive and vulnerable. Figure 1 shows same sample for harvesting.

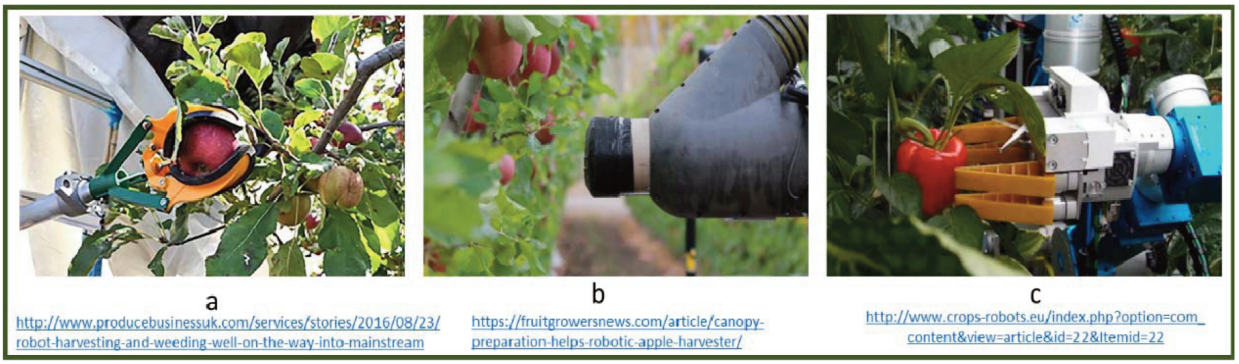


Figure 1. Bio materials

Section *a* and *c* shows mechanical grippers. In the section c the robot use 3D camera for positioning. Section b presents a vacuum gripper, which has a very soft touch.

Sensing the environment is the most important area on agriculture robotization. There are limitations on resolution, range.

Sample: steering

Nowadays autonomous steering getting more popular in the fields. The autonomous unit works on total field, save the tracks and turns. It is able to repeat the whole process autonomously. The sensing base is the Real Time Kinematic (RTK) system. Inertial Measurement Unit (IMU), angle sensors, adaptive controller are for current steering angle. The system is able the turn back at the end of the line, make the working conditions more comfortable for the operator.

Variable Rate Control

One definition for precision agriculture is the location based acting. Location means every plant gets the optimal chemicals, seeds etc. The field is not a homogeny area, there can be differential demands. The map can be predefined or based on-board calculation. The communication is the general used CAN BUS. Connecting of the smart implements is realised through ISOBUS. ISOBUS connects the tractor ECU to the implement ECU [3].

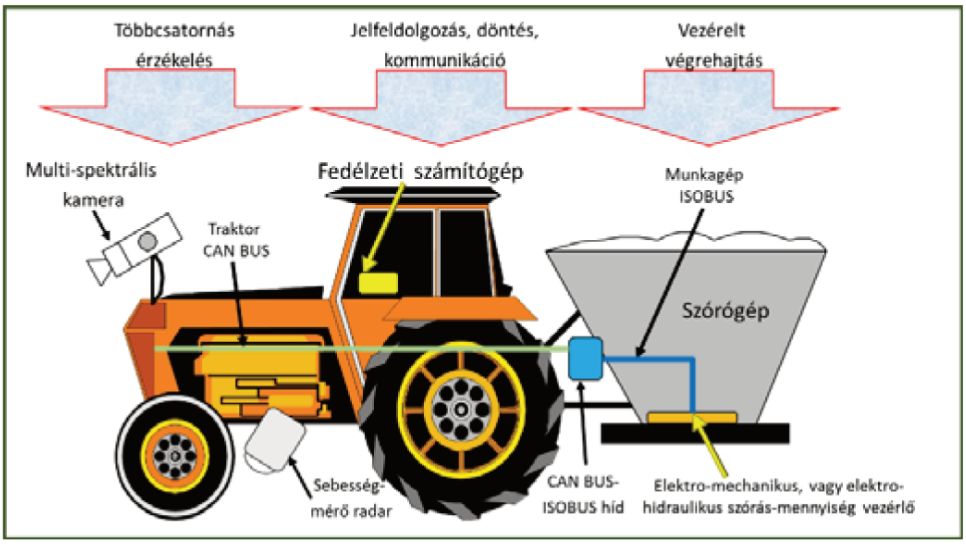


Figure 2. Real time on-board calculation

Figure 2 shows a tractor using camera for sensing, CAN bus, ISOBUS for data communication and sprayer with variable rate control and section control.

Mini robots and drones

These fields have a big extension. For precision agriculture is an important input value what can be static or dynamic based on time or location. Environment protection is getting more important. Using less (optimal) quantity of chemicals is not only an economical question but environmental too. Collect information from a large area usually use aerial or satellite photos. Drones are getting popular in agriculture too.

Monitoring systems can be:

– Mobil robots
– Drones
– Robot swarm.

Currently the development of autonomous soil monitoring systems/robots is in the focus. These sensing technologies can be autonomous or build in tractors. In the EU there are providers for field level aerial photos from drones. They use colour and infra cameras for sensing. The scanning be real time. There are many processes to post process. The infra photos are very useful to monitoring plants. It is also very effective to detect watering deficiency.

Wireless sensor network is a very extensive sensing technology. To install motes (put on the fields) is a simple robot application. Mote is able to measure many environmental parameters.

Drones are good for aerial photos. Motes are good for measuring soil parameters. Synergy of these technologies gives more detailed input data for precision agriculture. Figure 3 and 4 show autonomous information collecting.



Figure 3. Drone and mini robot

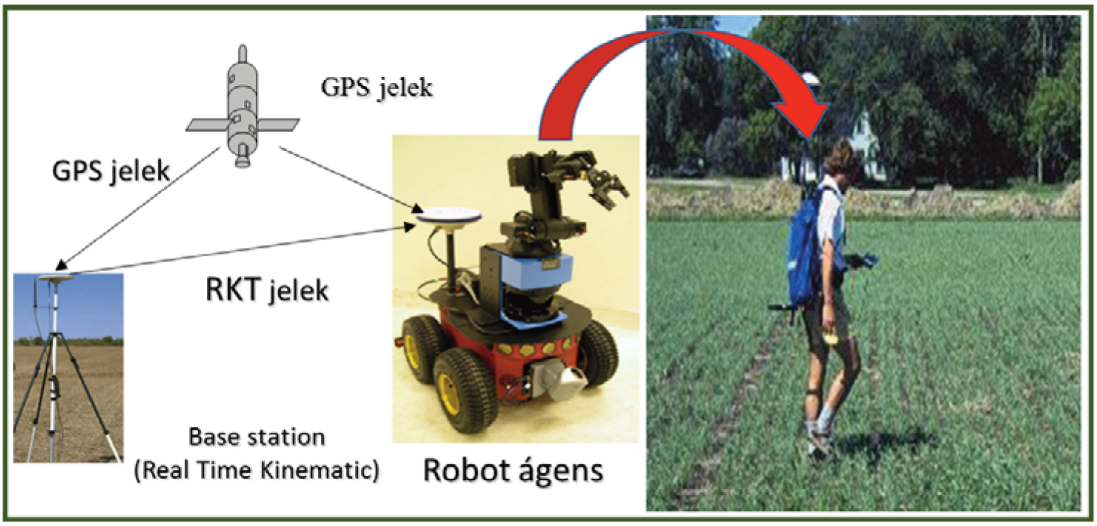


Figure 4. Mini robot for weed infection

Drones and mobile robots can be utilised in:

–Research, data collection, synergy with wireless sensor network
–Agriculture field work (spray, mote)
–Monitoring

Typical mobile robot sensors:

– GNSS, RTK (location, speed)
– Encoder
– Laser scanner
– Sonar
– Stereo camera
– IMU (acceleration, angle speed)

Camera recognition can be improved artificial intelligence to identify plants and weeds.

Method

Automation of the agricultural processes has been an important concept in the agricultural mechanisation. Nowadays many tractor developers perform intensive research for autonomous or partial autonomous working. [4]. These are mostly conceptual research for machine construction and system architecture.

There are new viewpoints like:

– security,
– safety
– role of the man
  – competence
  – responsibility
– collaboration
– infrastructure
– autonomous moving on public roads
– economical questions.

Case IH introduced ACV (Autonomous Concept Vehicle). This tractor has not cabin for crew. Wireless connection to control the work. Tractor implement connection is also remote controlled (fig 5)



Figure 5. Case IH ACV [5]

Robor swarm

Robot swarm can be organized from homogeny or heterogenic robots. The Australian SwarmFarm company introduce a platform for spraying on field. Figure 6 shows the swarm.

In our institute we carry on a unique research on the field of precision agricultural technologies. I this research we concentrate the eye focus of the operator. Human-centred-design approach is considered one of the most effective factors enhancing the productivity of vehicles used in the industrial and agricultural fields. The development of operator's workstation needs to be based on deterministic data which is validated, verified and dependable.

Tractors are companions for many agriculture workers. Well-designed human – tractor interfaces, such as well-accommodated tractor operator enclosures can enhance operations productivity, comfort and safety [6-10].

Many studies have been carried on to find preferred locations of in certain types of tractor controls (Casey & Kiso, 1990), moreover; emphasizing how critical is the placement of controls in some tractors stating that; it actually creates an impediment to body movement [10].

Driving is not only a physical task but also visual and mental tasks. The eyes of a driver are indispensable in performing visual tasks such as scanning the road, and monitoring in-vehicle devices.

A study conducted in 2015 by Gonçalves & Bengler [11] claims that Highly Automated Driving (HAD) will be commercially available in a near feature, yet human factors issues like the influence of driver state can have a critical impact in the

success of this driving paradigm and also in road and field safety.

For the purpose of this research, we focus on measuring the focusing scheme of the operator inside the tractor cabin in the lining operation showing by durations the time spent by the operator focusing on selected areas of interest and its change along working hours.

To the purpose of this research, the processes is limited to the data extraction and analysis. The followed methodology is summarized in process map showed in (Fig. 7) However; the scope is subjected to be extended upon the accomplishment of the all research phases to test new design enhancements and engineering solutions.



Figure 6. Robot swarm for spraying

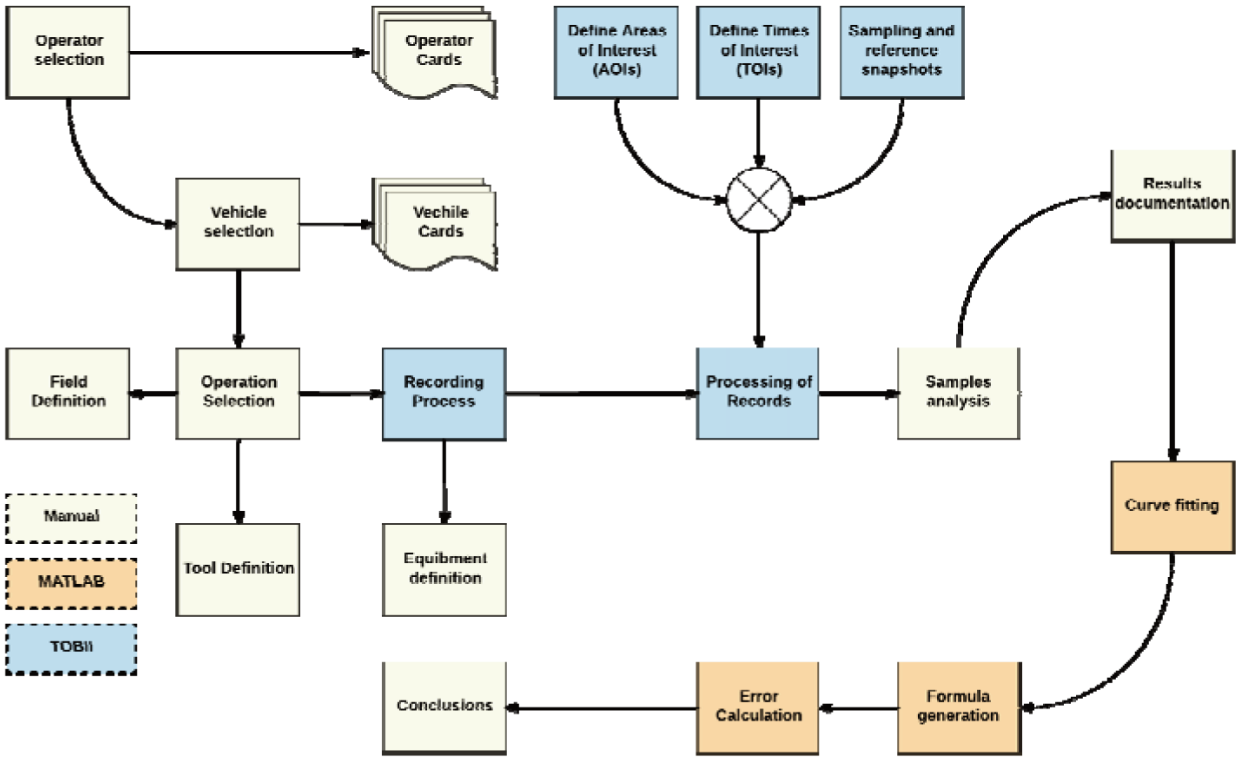


Figure 7. Methodology process map

Soil surface monitoring is another focus area.

Soil parameters are very important for the agricultural production. There are many automated measurement method, some of them are implemented in our research projects. One of our projects focuses on soil surface monitoring. Clot size is the target value on

seeding preparation. Clot size also influences the followings:

– surface to connect the air
– hydrology
– life in the soil
– gas emission
– erosion
– working machine vibration.

To optimize these effects, we have to describe the soil surface as detailed as can be. Field work change soil surface significantly. Every implement make a special structure of the soil and shape up the surface. The working direction and the perpendicular direction are usually different. Ploughing make big clot sizes. Seeding preparation makes optimal clot size, where the pieces are mostly small, 3-5 cm for crops in Hungary. In our research project we made lots of measurements on soil surface detection. Clots on soil surface are random place and size. Our method calculate a statistical value, which describe the surface colts. We use Pioneer P3-AT (All terrain) mobile robot to move on the surface. The robot is cruising with a constant speed. The mobile robot platform carry an inertial measurement unit. It measure all direction (3D) acceleration and angle speed.

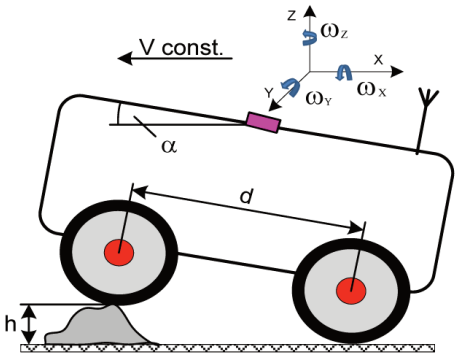


Figure 8. Mobile robot climb to a clot with IMU

Conclusions

First measurement was in the floor with same obstacle. The floor is smooth, there is no acceleration and angle speed changing. This environment shows the accelerations what obstacle generate. This way we could calibrate the system to determine the clot size based on acceleration and angle speed. We applied statistical methods classifying the clot size by cm-s. After the validation we drive the mobile robot at well-known clot size stony walk ways. The developed method turned out a success, able to detect the most representative clot size of the examined surface.

Results can be studied in Fig. 9.

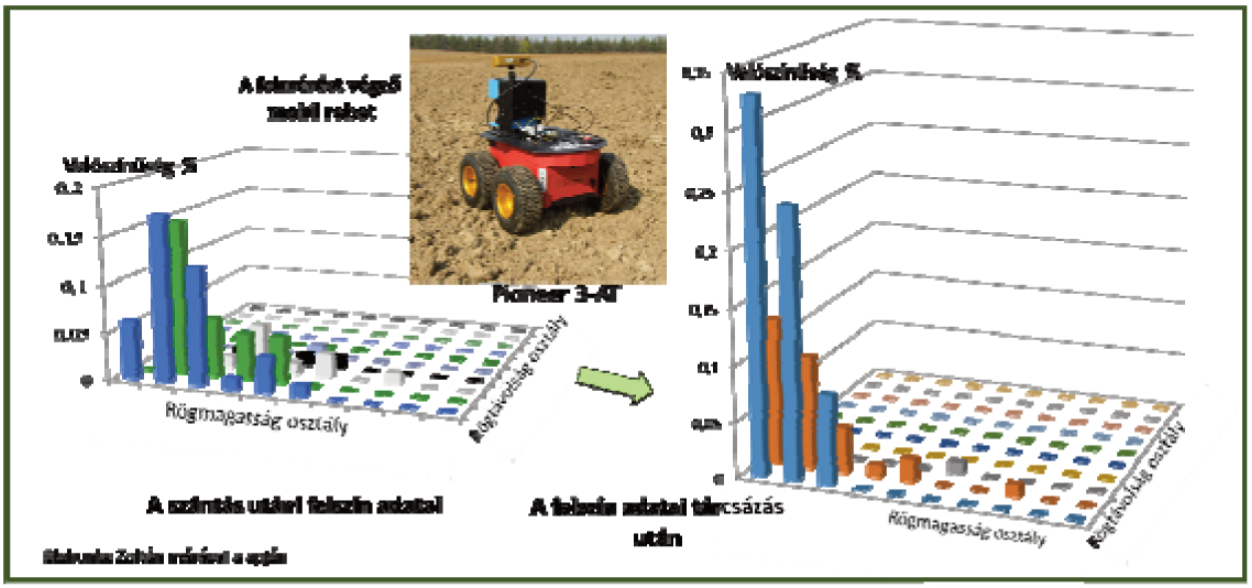


Figure 9. Significant clot size after ploughing and seeding preparation

Nomenclature

RTK real time kinematic
AI artificial intelligence

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Szarvas research and training profile with intelligent specialization in the themes of water management, hydroculture, precision mechanical engineering, alternative crop production

References

[1] F. TongKe (2017): Smart Agriculture Based on Cloud Computing and IOT. Modern Education Technology Center of Xi'an International University, Shaanxi, 710077
https://pdfs.sematicscholar.org/62ee/b701c40626811a1111ca5d1db37650f1ea0b.pdf

[2] Casey, S.M., & Kiso, J.L. 1990. The acceptability of control locations and related features in agricultural tractor cabs. In Proceedings of the Human Factors Society 34th annual meeting (Santa Monica, CA: Human Factors Society). 743 – 747.

[3] Magó L., Kovács I.: (2019) Technical and Technological Parameters of ISOBUS System Supported Machinery Management, Hungarian Agricultural Engineering, 35/2019. p. 34-38. Published online: http://hae-journals.org/
DOI: 10.17676/HAE.2019.35.34

[4] Magó L. (2019) Robot traktorok alkalmazásának gépesítésre és géphasználatra gyakorolt hatása, The Effect of the Application of Robotic Tractors on Mechanisation and Machinery Usage. Mezőgazdasági Technika, Vol. LX, No 9, p. 2-7.

[5] JURISICA L., DUCHON F., KASTAN D., BABINEC A. (2012): High Precision GNSS Guidance for Field Mobile Robots. International Journal of Advanced Robotic Systems

[6] Husti I.-Kovács I. (2017): A digitalizáció alkalmazási lehetőségei a mezőgazdaságban
Mezőgazdasági technika, 2017/7

[7] Szabó I.–Hushki M.–Bártfai Z.–Kátai L.–Lágymányosi A (2018).: Examination of the driver's focusing scheme during precision agricultural operation
Alkalmazkodó vízgazdálkodás: Lehetőségek és kockázatok, Konferencia, Szarvas, 2018.

[8] Blahunka Z.-Bártfai Z.-Faust D. (2013): Measurement optimalization by informatical entropy Synergy 2013, SZIE GÉK, Gödöllő

[9] Liljedahl, J.B., Turnquist, P.K., Amith, D.W. & Hoki, M. 1996. Tractors and Their Power Units, pp. 226 – 231 (St. Joseph, MI: American Society of Agricultural Engineers).

[10] Hsiao, H., Whitestone, J., Bradtmiller, B., Whisler, R., Zwiener, J., Lafferty, C., Kau, T.Y. & Gross, M. 2005. Anthropometric criteria for design of tractor cabs and protection frames. Ergonomics, 48. 323-53.

[11] Blahunka Z.-Bártfai Z.-Faust D.-Kátai L.-Szabó I. (2017): Terrain surface monitoring with IMU equipped mobile robot
7th International Conference on Biosystems Engineering 2017, Tartu, Észtország

[12] Harris M.C. (2010): Artificial Intelligence
Marshall Cavendish 978-1-60870-076-9.

[13] Matthews, J. 1977. The ergonomics of tractors. ARC Research Review, 3. 59 – 65.

[14] Kaminaka, M.S. 1985. Research needs in the American agricultural equipment industry. Applied Ergonomics, 16.3. 217 – 220.

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CONSUMPTION PROFILE BASED ANALYSIS OF SOLAR THERMAL SYSTEM FOR DHW IN BUILDINGS

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Abstract

Solar thermal system for domestic hot water (DHW) is one of the most common application for utilizing solar energy. Consumption profile of hot water has a significant impact on solar DHW sizing as it relates many uncertainties regarding human nature, which is difficult to predict therefore. The size of solar thermal system is roughly estimated in most cases which can results operational difficulties and efficiency losses. In this paper, different DHW consumption profiles have been analysed. The influential parameters on consumption, sizing methods and proposed modelling techniques for solar DHW are discussed and concluded with findings of several case studies.

Keywords

domestic hot water (DHW), consumption profile, solar thermal, solar thermal application in buildings

Introduction

Merging of renewable energy sources with energy consumption sectors among the hot topics attracted researcher's attention nowadays. Solar energy, in particular, is the fastest growing renewable energy industry in the last decades in both electrical and thermal directions [1]. According to the International Energy Agency IEA, building sector is the biggest consumer of thermal energy where it may accounts about 46% of total building energy and the share of renewable sources will be developed by 20% by 2023 in this sector (IEA, 2019). Thermal energy in buildings mainly delivered for space heating and hot water for domestic usage. DHW consumption has a relatively variable share of thermal energy in building sector in different countries as it depends on several physical, cultural and geographical considerations. The energy needed for DHW consumption share about 14% in Europe, 18.3% in USA, 22% in Canada, 25% in Australia, 27% in China, 29% in Mexico and 37% in South Africa [2], and ranging from 16-50% in most of developing countries [1].

Solar thermal systems for DHW

The shape and size of solar thermal system (STS) is different from a building to another depending on the total DHW consumption for end-use and building type. STS mainly consists of the same main components which their performance impact the performance of the whole solar system. These components are: solar collector, heat exchanger and storage tank in addition to the pumps and other measuring and control devices that complete the main loops of the system.

Solar collector

The main objective of solar collector (s) is (are) collecting the incident solar radiation and transfer the harvested heat to the heat transfer fluid (HTF), which the latter transfers the heat to a storage tank through the arrangements of heat exchanger. This HTF represent the blood of solar system's body and it has a specific physical and thermal properties effect the overall solar system performance significantly. The main two types of solar collectors used in DHW level are the flat plate collector (FPC) and evacuated tube collector (ETC). The FPC is the most common type used in solar thermal applications, especially for

DHW. All FPCS comprise from the following components: absorber layer, fluid network, insulation and the frame (box). Many improvements have been done to increase the efficiency of FPC by increasing the area of absorber, arranging the fluid network in zigzag manner other that the parallel, using of nano-fluids for better heat transfer etc.

The ETC is the better version of solar collectors in solar thermal systems. It comprises of a number of glass tubes mounting on a frame. Each tube has two concentric glass tubes having evacuated space between them. The HTF interring the inner tube and collects the incident solar radiation. The outer surface of inner tube is coated with absorbing material which transmitted through the outer tube. The evacuated space between the tubes play a vital role to minimize the conductive losses of solar radiation which make the collector efficient. Broadly, the performance of ETC is better than the FPC in solar thermal applications where a study- dealt with two solar thermal systems used FPC and ETC- showed that the annual solar fraction of ETC is higher than that of FPC by 16%. Moreover, the study reported that the energy generated by ETC is more than the energy of FPC by 9% which indicated more cost saving of ETC [3]. More technical and economic advantages of ETC are tabulated in Table 1.

Table 1. Comparison between FPC and ETC [4]

Criteria	FPC	ETC
Temperature range (^{o}C)	60 - 80	60 - 120
Heat generation	Slow	Quick
Efficiency at high temperature	Low	high
Emissivity	High	Low
System sizing at location of average availability of solar radiation	Required	Not required
Major maintenance requirement (Durability)	15 years or more	5 years or more

Heat exchanger

The heat exchanger is the other main part of STS which circulate the thermal energy between the collector/s and the storage tank. It usually made of materials that have excellent thermal conductivity and high corrosion resistance such as copper, Aluminium, stainless steel etc. the heat exchanger transfers heat either directly or indirectly where the direct method has more energy saving than the indirect arrangement. Furthermore, the indirect heat exchanger can be made with single or double row. The performance of single and double row heat exchangers with different lengths and cross- section area have investigated by [5-6]. Their study showed better thermal efficiency of single row heat exchanger and the initial and operational cost of STS were reduced.

Storage tank

The main objective of storage tank is storing the thermal energy harvested by the collectors and deliver it to the end-use application. The storage tank guarantees the continuous delivery of the hot water without intermittency. It represents the heart of STS where it significantly effects the design and size of solar system and as a result, the cost. The heat stores in the tank mainly in three methods: sensible, latent and thermo-chemical reaction. The method of storing depends highly on the amount of thermal energy to be stored and type of application (end-use). The main characteristics among the three type methods are tabulated in Table 2. The sensible method for storing water (as a storing medium) is the most popular and widely used method in hot water applications as it covers hot water demand in acceptable initial and operational cost. The mixing of cold and hot water is the main problem of sensible storage systems and the thermal stratification is highly recommended for this matter.

Solar fraction (the percentage of DHW consumption that covers by STS) is the most important factor that should take into account by designers to get the optimal STS with minimal cost. Some designing studies recommend the ratio of solar collector area (Ac) to the hot storage volume (V_S) to get the optimal sizing for STS, where the optimal solar fraction lies within the range ($0.05\ m \leq A_c/V_S \leq 0.18\ m$) [8].

The STS generally classified as active solar thermal systems (ASTS) and passive solar thermal systems (PSTS) where the latter has no pump(s) to force the working fluid for circulating. Moreover, ASTS also classified as direct and indirect ASTS where the working fluid flows directly or indirectly between the collector (s) and the storage tank, see Fig 1.

Table 2. Typical parameters of different storing methods [7]

TES System	Capacity (kWh/t)	Power (MW)	Efficiency (%)	Storage Period	Cost (€/kWh)
Sensible (hot water)	10–50	0.001–10.0	50–90	days/months	0.1–10
Phase-change material (PCM)	50–150	0.001–1.0	75–90	hours/months	10–50
Chemical reactions	120–250	0.01–1.0	75–100	hours/days	8–100

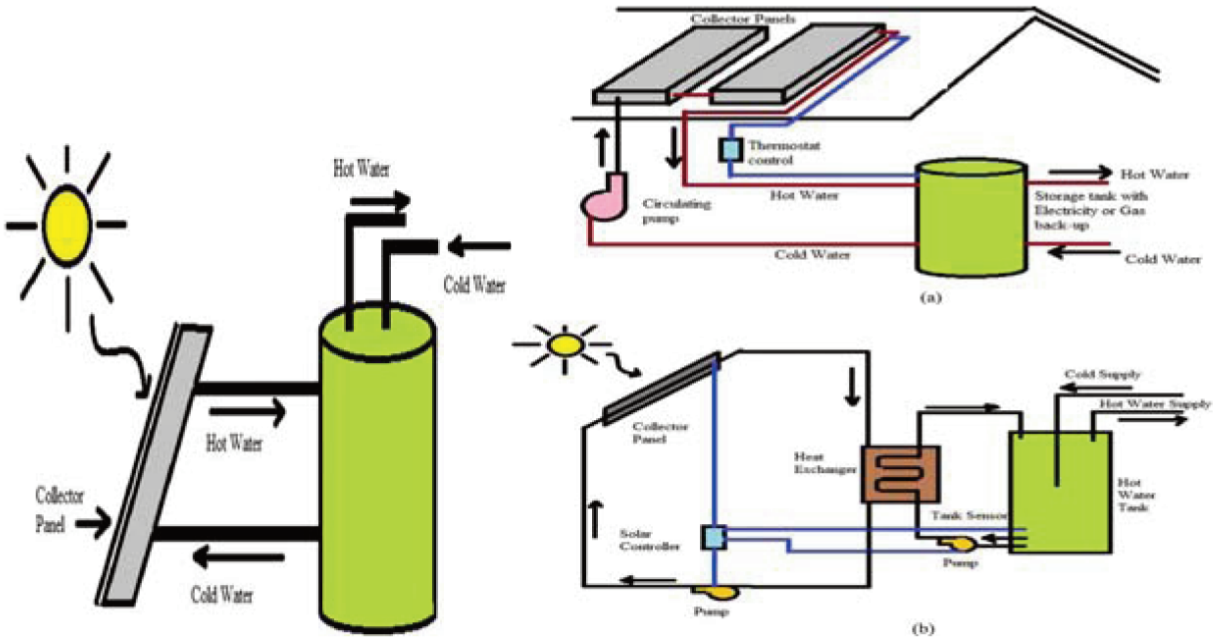


Figure 1. Schematic view of PSTS (left), (a) direct ASTS and, (b) indirect ASTS (right) [2]

DHW consumption profile in different buildings

The DHW consumption in buildings is usually linked to the daily activities of users/occupants such as hand-washing, showering, bathing, laundry, sink and dish-washing etc. The daily usage of DHW is fluctuated from time to time during the day depending mainly on the human activities and the pattern of use.

The DHW consumption profiles in buildings is different because we are dealing with a variable number of users, different peak periods and different activities. The consumption profile in residential buildings is variable from one activity to another where they mostly relevant to social, behavioural and lifestyle aspects. The peak consumption can be noted in the morning and evening with less consumption in the afternoon [9]. For the DHW consumption point of view, a study of Jordan & Vajen, 2001 [10] indicated that the extractions of DHW for a European household of 200 l/day at 45oC in Switzerland and Germany are separated as following: 80 l for shower, 20 l for bath, 28 l for sink and 72 l delivered for dish and cloth-washing. In the same direction, a recent study done by [11] summarized the range of DHW consumption profiles in residential buildings for several EU countries namely in Denmark, Netherlands, Austria, Germany, Sweden, Spain and Estonia. The study showed that the flow rates for bathroom sink, kitchen sink, shower and bathtub are ranged between 0.03 − 0.1 l/s, 0.08 − 0.2 l/s, 0.13 − 0.58l/s and 0.11/s − 0.3 l/s, respectively. Hendron, 2010 [12] reported that the average DHW consumptions in a household of 300 l/day consumption (cold & hot) in Network city, USA are 105 l for showering, 95 l for bath-sink, 57 l for laundry, 26 l for bath and,19 l for dish-washing. More consumption ranges can be seen in Table 3, regarding different EU countries, USA and Canada according to Annex 42 report based on average usage of 100-120 l/day at 45 oC for households of 100 m2. The duration and frequency of using the DHW is another effective factors in the consumption profiles in residential buildings. Most of DHW extractions are relevant to the use of shower and bath during activity period in the morning and evening, and the duration of 2-3 min. presents about 30% of the daily consumed DHW [13].

Table 3. Daily hot water and energy consumption for different countries [14]

Country	Daily DHW consumption per household (l/day)	Daily DHW consumption per occupant (l/occupant.day)	Daily DHW energy usage per household* kWh/day
Canada	236–303	94	12.3
USA	202–250	40	5.22
Switzerland	138	55 at a 50 °C rise	7.18
Finland	135	43	5.61
UK	102–117	20–39	3.85
Germany	160	64	8.36
France	1.74 per m^2 (at a 30 °C rise)	69.6	9.1
Spain	75	30 (at 60 °C)	3.92
Portugal	100 (at a 45 °C rise) (apartments)	40	5.23

In hotel buildings, the total energy consumed for DHW accounts to be ranged between 10- 40% [15]. The DHW consumptions in hotels are set to deliver optimal comfort levels to the guests where the main activities regarding the restaurant, kitchen, baths, gym, laundry, swimming pool etc. Many studies reported that the luxury hotels are consuming hot water more than the others compared to its size. Hamele and Eckard, 2006 [16] reported that the hot water consumption in the EU hotels is so high. Their study which done based on 191 hotels separated in different European countries has indicated that the average consumption is 231 l/guest. Another study done by Deng, 2003 [17] stated the about 40% of hot water share for laundry, 30% for guest usage and 22% shared by the kitchen. This study also indicated that most hotels tend to use external laundry services and that may share the DHW consumed for guest usage and kitchen extractions by about 44% and 55%, respectively.

The hospital buildings are characterized as a big consumer of DHW. Many activities regarding patient care, kitchen activities and cleaning services. Several studies reported the importance of the amount of hot water consumed by hospitals. A study showed that the average daily consumption of DHW in the European hospitals is ranged from 80-130 l/bed, while it is between 100-150 l/bed in USA [18]. Another study indicated that the DHW profile in the Norwegian hospitals are vary within the day and the peak load start at 8:00 and it gets constant later until evening period [19]. Moreover, the study stated that the energy delivered for heating the water account as 7.1 W/m2. Other details regarding DHW profiles for different buildings can be seen in Table 4 and Fig. 2.

Table 4. DHW consumption in different type of buildings.

Reference	Location	Type of building	Main findings/ Consumption load
(Agnieszka et.al, 2017)	Wroclaw, Poland	Multi-apartment building (626 apartment)	-Average daily DHW/ apartment, (m^3): 1 room (0.051), 2 rooms (0.074), 3 rooms (0.104) & 4 rooms (0.105).
(Dzintars et. al, 2015)	Riga, Latvia	Apartment buildings	- Energy consumption for DHW is 33 kWh /m^2 - Energy for DHW = DHW needs+ distribution losses
(Janusz B., 2010)	Bydgoszcz, Poland	Hospital (2-hospitals)	-The average DHW consumption during weekdays (Mon.-Fri.) was higher than weekend days. - The highest consumption between 8:00 and 19:00 while, the lowest between 1:00 and 6:00. - Daily DHW consumption 111-124 l/bed
(Ahmed K. et. al, 2016)	Helsinki, Finland	Dwellings (86 apartments & 191 occupants)	-Higher peak in evening hours (2-4 times higher than non-peak hours). -Morning peak hours (7:00 - 9:00) while, evening hours (20:00 t0 22:00) during weekdays. -Daily average DHW consumption are: 38.5, 47 and 45.2 l/person/day for the month of Aug., Nov and Jan., respectively. -In peak hours, the consumption varied from 0-107 l/person/day.
(Barbern R. et al., 2013)	Zaragoza, Spain	Hotel (4-star, 117 rooms & □190 beds)	-Water saving devices in taps in shower and other areas -Reduction by 33.2% in the total hot water consumption - Average daily DHW fallen from 321 to 252 l/guest (21.4%)
(Tortella B, & Tirado D., 2011)	Mallorca, Spain	Hotels (1-5 stars)	□541.6 l total water/guest day

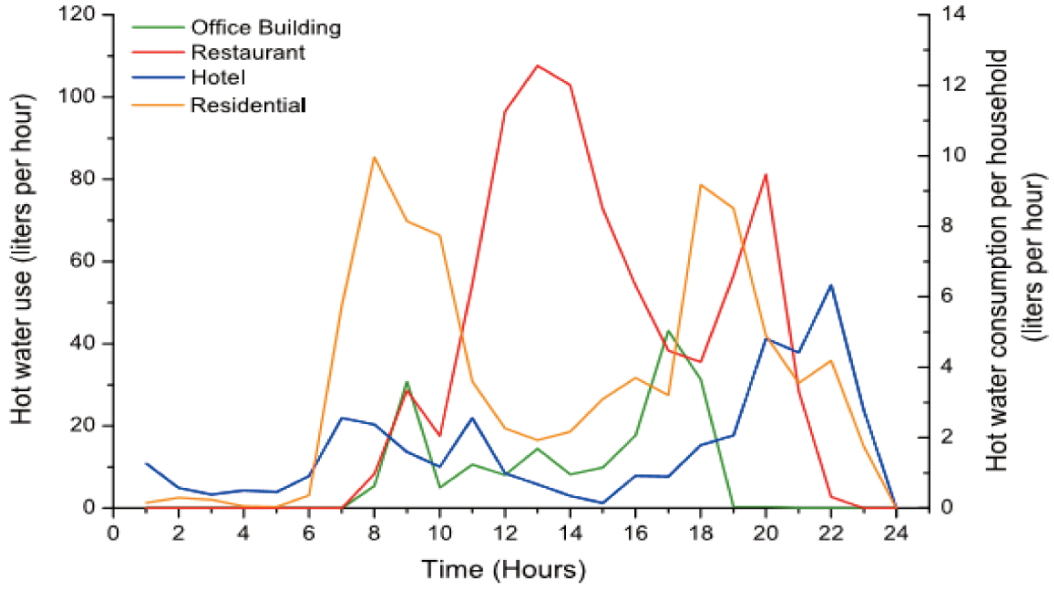


Figure 2. Average hourly DHW profiles for different building types, the residential profile type is represented on the right [20]

Modelling and sizing methods of sts for dhw application

Many researchers are developing predicting software and modelling tools for DHW consumption in the commercial buildings (hotels, hospitals, offices etc.) more than the residential buildings. The main reason of that is the lake of data-based sensors and the complexity of predicting occupant behaviour of residential buildings due to the huge number of uncertainties relevant to residential occupants [21]. Different methods have adapted to estimate/ forecast the demand for DHW and thus, offering the information for designing the adequate shape of STS. The popular sizing methods of STS for DHW demand in buildings are summarised as follows:

–Technical standard based method,
–Time series forecasting models,
–Time series models based data-learning modelling methods (Artificial Neural Network (ANN)),
–Stochastic models, and,
–DHW consumption profiles based real database.

Table 5. Selected technical standards for designing the DHW, estimating the energy consumed and water profiles [22-23]

Technical Standard	Zone	Relevant information for DHW installations design
EN 15316	EU	Methods to determine the daily/yearly DHW volume requirements of a dwelling/ a building. It provides data on annual average mains water supply temperature for different European climates and locations
EN 12976-2	EU	Dimensioning and design of solar thermal facilities for DHW applications. It provides a relationship for the annual estimation of the mains water temperature following a sinusoidal function.
EN 12831-3	EU	Calculating the power and storage volume required for the dimensioning of domestic hot water systems (DHW). Calculation method of the energy needs for DHW-Systems for residential and non-residential buildings or a zone of a building.
EVS 835:2003	Estonia	Estimation of domestic water installations design values for Estonian buildings.
AICVF	France	Guidelines about dimensioning sanitary water facilities. Annual estimations of DHW energy consumption for different buildings. Estimations of water consumption for different type of buildings.
VDI 4655	Germany	Guideline that supplies reference DHW load profiles as a basis and tool for the design of combined heat and power systems in residential buildings. It covers single-family houses for up to 12 occupants and multi-family houses with up to 40 flats.
UNE 94002	Spain	Design and dimensioning of solar thermal facilities for DHW applications. It provides equations for the monthly estimation of the DHW energy demand as a function of the occupancy, data of average DHW consumption per person and day for different buildings and monthly average mains water temperature data
CTE DB HE4	Spain	Technical guideline for the design and installation of DHW solar thermal facilities in buildings
BS 6700	UK	Design, installation and maintenance of services supplying water for domestic use inside buildings

The technical standards offer guideline information to design and size the DHW system based on nominal consumption values for the end-use devices. Moreover, the standards give an information for daily consumption per person in different types of buildings, residential buildings in particular. Table summarised several technical standards for the EU countries regarding DHW. A study investigated the accuracy of the technical standards for estimating DHW consumed by a residential building located in UK [22]. The study presented 5- dynamic models based national and international standards and used the same input data regarding the building case study. The results of each tool compared against the real consumption profiles of the building based on different variables (volume of water, energy consumption and losses, system efficiency, temperature of produced hot water etc.) and showed as underestimate as -30% for some tools and overestimation up to 40% for others of system sizing when compared to the measured data of case study.

For time series method (TSM), the future estimation of building consumption can be forecasted based on the historical profiles of the system. Such method showed good outcomes regarding DHW consumption in buildings. Other study used this method to analyse the results they had from previous study of a Finnish apartment buildings [24]. The study applied in the weekdays (WD) and weekend (WE) of the month of August and November. The generated data based TSM showed close behaviour of consumption profiles based on the previous work profiles and indicated accurate hourly consumption profiles of the current case study which showed effectiveness after validated against the measurements. The predicting of DHW consumption also can be done based on data learning methods like Artificial Neural Networks (ANNs). Such models found to be able to predict the profile consumption as they have the ability to approximate the non-linearity of DHW behaviour in buildings. ANN algorithm used to predict the end-use demand of a household (toilet tap, clothes water, dishwasher and bath demand) taking household income, number of adults, number of children, number of teenagers, and appliance efficiency as key determinants [25]. The study indicated that the ANN based modelling is a feasible method to forecast the end-use demand for residential buildings.

Stochastic models used to estimate DHW profiles depending on monitoring application data and survey information. Such method uses data usage based time to determine the probability of user activities and the energy used by these activities. Then, the probability calibrated with the measurements of consumption and time use data. A study constructed a stochastic end-use model to study the DHW profile for a single family house. The model simulated the diurnal DHW for each minute of a day using database offered by previous international study. Furthermore, the model indicated accurate data of DHW demand compared to the previous studies [26].

A group of scientists claim the estimation of DHW consumption profiles based modelling techniques as it rely on a set of engineering expectations so, the real collected data is more reliable than stochastic data-based. A study discussed the DHW profiles based on the database of Halifax Regional Municipality's Solar City project, Canada [27]. The study dealt with the hot water flow rate and its temperature for 119 homes. The study concluded that the average DHW consumption/ home is 172 l/day with high dependency on occupant's number, the peak load is twice daily, consumption on Sunday is the higher during the week and the average draw temperature of DHW is 51.8 oC which is lower than the temperature proposed in simulation/ modelling tools for DHW forecasting (55 °C).

Case studies

The body of literature has many case studies of STS for DHW application in buildings. Most of case studies based software work and only limited number dealing with real case studies. Table 6 details some important technical parameters of STS fabricated mainly for delivering hot water to a domestic usage purposes.

Conclusion

This article presented a general overview of the STS for DHW application in several building types. The main aspects pointed within the article were: the general shape of STS including the main element types used, DHW profiles and consumption pattern in the end-use draws, the main sizing and modelling methods adapted for forecasting hot water demand and finally, operational parameters of STS used for this purpose have indicated for several case studies.

The statistics of this research showed the importance of DHW application in building sector where the people spending about 80% of their life. Several conclusions drawn from the review of different studies mentioned in the body of this work, they can be summarised as following:

– Most of research work focused on DHW consumption and energy used in residential buildings and less attention has given to the

other building types such as the restaurants, educational buildings, and airport lounges etc.
– There are many complex methods and modelling tools developed to forecast the hot water demand with no specific method for better estimating of STS size.
– Long-term solar DHW consumption prediction studies are missed as the human behavior and consumption needs are changing with time and should taking into account.
– Most of the reviewed case studies showed underestimating of solar systems which is mainly because the fluctuating of available solar radiation and that may call the attention to adapt another renewable source for water heating.

Table 6. Residential building case studies dealing with STS technical parameters

Reference	Region/ Location	Building type/ Load	Determinant parameters	Shape of STS and main outcomes of study					
				Coll. area (m^2) (No. of coll.)		Storage volume (m^3)		Solar Fraction %	
				FPC	ETC	FPC	ETC	FPC	ETC
(Polo V.& Cesare B., 2018)	Italy (**Bolzano**, Turin, **Bologna**, Rome, Brindisi and Trapani)	residential building of 20 apartments (48 people) (□50/p/ day at 38 °C)	Period of year, day of week, climate condition for each city	*37.12 (16) ** 46.4 (20)	17.94 (6)	5	4.5	51.4 52.0	51.2 50.1
				*Bolzano & **Bologna - Angle of inclination of 45°					
(M. Zukowski, 2017)	Poland, (Bialystok)	Hotel (Campus)	Basic parameters of ambient air and solar radiation	-35 FPC & 21 ETC (total area of 146.29 m^2) - 8 Storage tanks of (1 m^3) - SF is 23.4% - System efficiency is 34.7% in warm months and 24.2% in cold months					
(M. Ghorab et al., 2017)	Canada	-Family house (two adults and two kids) -(172-324 l/day) at 52.2°C	DHW draws, time & duration of draws, , city water temperature, and outside weather conditions	- 2 FPC of 2.858 m^2 for each (62.48°C to 86.4°C) - 91.5% of the collected solar energy is transferred to the DHW load. 8.5% heat loss from the storage tank -Highest SF around 45.44% - 30.6% solar share with 69.4% from auxiliary gas heater					
(Allouhi A. et al., 2015)	Morocco, (**Errachidia**, Agadir, Marrakech, Tangier, Fez & Ifran)	-Individual family house (5 occupants) -(240 l/day, at 45 °C)	The location and climatic parameters	- FPC & ETC used, the ETC is better performance than FPC - Stratified storage tank (sensible) - The average value of SF is 72% FPC and 82% for ETC (Errachidia)					

References

[1] Knight IK, Manning N, Swinton M, Hajo MR (2007). European and Canadian non-HVAC electric and DHW load profiles for use in simulating the performance of residential cogeneration systems, Energy conservation in buildings and community systems programme. IEA Annex 2007; 42 (6):84.

[2] Bennett C, Steward R, Beal C (2013). ANN-based residential water end-use demand forecasting model. Expert Syst Appl, pp.1014–23.

[3] Fairey P, Parker D. (2004), A review of hot water draw profiles used in performance analysis of residential domestic hot water systems. In: FSEC RR-56-04, Cocoa, FL: Florida Solar Energy Center.

[4] Barbern R, Egea P, Gracias-de Rentera P, Salvador M. (2013), Evaluation of water saving measures in hotels: a Spanish case study. Int J Hosp Manag, Vol, pp. 34:181–91.

[5] Abhishek G., Sunil C., Alok K., Satyendra Singhc (2017), A review on technical improvements, economic feasibility and world scenario of solar water heating system, Renewable and Sustainable Energy Reviews, Vol. 68, pp. 542-562.

[6] Bertrand A, Mastrucci A, Schler N, Aggoune R, Marchal F (2016), Characterisation of domestic hot water end-uses for integrated urban thermal energy assessment and optimisation, Applied Energy. In press.

[7] Agnieszka Chmielewska, Małgorzata Szulgowska-Zgrzywa, and Jan Danielewicz (2017), Domestic hot water consumption in multiapartment buildings, E3S Web of Conferences 17, 00014 (2017).

[8] Andrea F., Kaiser Ahmed, Petri Pylsy, Jarek Kurnitski (2017), Analytical modelling and prediction formulas for domestic hot water consumption in residential Finnish apartments, http://dx.doi.org/10.1016/j.enbuild.2017.03.021

[9] Bohdanowicz P, Martinac I. (2007), Determinants and benchmarking of resource consumption in hotels. Energy Build. Vol. 39, pp.82–105.
[10] Jordan U, Vajen K (2001), Realistic Domestic Hot-Water Profiles in different time scales, Solar Heating and Cooling Program of the International Energy Agency (IEA SHC), Task 26: Solar Combisystems.
[11] Bujak J (2010). Heat consumption for preparing domestic hot water in hospitals. Energy Build, Vol. 42, pp.1047–1055.
[12] Hendron R, Burch J, Barker G (2010), Tool for Generating Realistic Residential Hot Water Event Schedules, SimBuild 2010, New York, August 1519. Conference Paper NREL/CP-550-47685 August 2010.
[13] Kadir Amasyali, Nora M. El-Gohary (2018), A review of data-driven building energy consumption prediction studies, Renewable and Sustainable Energy Reviews, Vol. 81, pp.1192-1205.
[14] Marini D, BR, Hopfe C (2015), A critical software review- how is hot water modelled in current building simulation?. Proceedings of the 14th International IBPSA conference, Hyderabad, India, 7–9 December 2015.
[15] Defra Report (2008), Department of Environmental, Farming, and Rural Affairs, Measurement of Domestic Hot Water Consumption in Dwellings.
[16] Hamele H, Eckard S. (2006), Environmental initiatives by European tourism businesses, 2006.
[17] Deng S. (2003), Energy and water uses and their performance explanatory indicators in hotels in Hong Kong. Energy Build., Vol. 5m pp. 775–84.
[18] Ahmed K., Pylsy P, Kurnitski J (2016), Hourly consumption profiles of domestic hot water for different occupant groups in dwellings, Solar Energy, Vol. 137, pp. 516–30.
[19] Allouhi A, Jamil A, Kousksou T, El Rhafiki T, Mourad Y, Zeraouli Y (2015). Solar domestic heating water systems in Morocco: an energy analysis. Energy Convers Manag, Vol. 92, pp.105–113.
[20] Dzintars Grasmanis, Normunds Talcis, Aldis Grekis (2015), Heat Consumption Assessment of the Domestic Hot Water Systems in the Apartment Buildings, Proceedings of REHVA Annual Conference 2015 "Advanced HVAC and Natural Gas Technologies" Riga, Latvia, May 6 – 9, 2015.
[21] Fuentes E., L. Arce, J. Salom (2017), A review of domestic hot water consumption profiles for application in systems and buildings energy performance analysis, Renewable and Sustainable Energy Reviews,
http://dx.doi.org/10.1016/j.rser.2017.05.229, in press.
[22] George D, Pearre NS, Swan LK (2015). High resolution measured domestic hot water consumption of Canadian homes. Energy Build, Vol. 105, pp. 304–315.
[23] Hazami Majdi, Kooli Sami, Naili Nabiha, Farhat Abdelhamid (2013), Long-term performances prediction of an evacuated tube solar water heating system used for single family households under typical Nord-African climate (Tunisia), Solar Energy, Vol. 94, pp. 283–98.
[24] Hauer, A. (2011), Storage Technology Issues and Opportunities, International Low-Carbon Energy Technology Platform. In Proceedings of the Strategic and Cross-Cutting Workshop "Energy Storage—Issues and Opportunities", Paris, France, 15 February 2011.
[25] IEA (2019), Renewables 2018: Market analysis and forecast from 2018 to 2023,
https://www.iea.org/renewables2018/heat/.
[26] Janusz Bujak (2010), heat consumption for preparing domestic hot water in hospitals, Energy and Buildings, Vol. 42, pp. 1047–1055.
[27] Marwan AL-Khaffajy and Ruth M. (2013), Optimization of the heat exchanger in a flat plate indirect heating integrated collector storage solar water heating system, Renew Energy, Vol. 57, pp. 413–21.
[28] M. Ghorab, Evgueniy Entchev, Libing Yang (2017), Inclusive analysis and performance evaluationof solar domestic hot water system (a case study), Alexandria Engineering Journal, Vol. 56, Issue 2, pp. 201-212
[29] M. Zukowski (2017), Energy efficiency of a solar domestic hot water system, E3S Web of Conferences 22, 00209 (2017),
DOI: 10.1051/e3sconf/20172200209.
[30] M.C.Rodríguez-Hidalgo, P.A.Rodríguez-Aumente, A.Lecuona, M.Legrand, R.Ventasb (2012), Domestic hot water consumption vs. solar thermal energy storage: The optimum size of the storage tank, Applied Energy, Vol. 97, pp. 897-906.
[31] Morné Richard (2016), Simulating Domestic Hot Water Demand by means of a Stochastic End-Use Model, M.Sc. thesis,
https://pdfs.semanticscholar.org/c8d6/b9b9344af6eed4533e85d6e31d159c23e316.pdf
[32] Solar Energy Industries Association (SEIA) (2016), https://m.huffpost.com/us/entry/us_8134790
[33] Sunflower renewable energy company, LTD (2019), Comparison between Evacuated Tube Collector & Flat Plate Collector. http://www.sunflower-solar.com/index.php?act=content&scheduler_id=390.

[34] Tortella B, Tirado D. (2011), Hotel water consumption at a seasonal mass tourist destination. The case of the island of Mallorca. J Environ Manag., Vol. 92, pp. 2568–2579.
[35] Ulseth R, Alonso MJ, Haugerud P. (2014), Measured load profiles for domestic hot water in buildings with heat supply from district heating. In: Proceedings of the 14th International Symposium on District Heating and Cooling, September 7–9. Stockholm, Sweden, 2014.

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SPECTROSCOPY AS A RAPID METHOD FOR DETECTING PAPRIKA POWDER ADULTERATION

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Abstract

Paprika powder, a spice known for imparting flavour, colour and aroma in foods has recently become compromised by fraudulent activities involving diverse adulterants such as corn flour and has prompted quality assurance (QA) measures. Near infrared spectroscopy (NIRS) is a non-destructive method gaining grounds in QA applications. The study applied NIRS to detect paprika powder adulterated with corn flour. Chemometric evaluation spectra showed that NIRS could discriminate corn-flour adulteration with 100% classification accuracy. Adulteration was also predicted with high accuracies coefficient of determination (R2CV) between 0.97 and 0.99 and low errors (0.72 g/100g), proving the future QA applications of NIRS.

Keywords

Spectroscopy, adulteration, quality, chemometrics, authentication

Introduction

Urbanization and increasing population has resulted in surge in demand for products and services associated to fast-paced city living, especially, convenient or semi processed food products that mostly in the ready-to-eat state and are therefore time saving [1]. More importantly, convenient food products such as powdered food products are made available in hypermarkets and supermarkets near to the consumers. Thus, it replaces the traditional ways of cooking food with those that are less involving, fast and provides the equal desired features in the food. The fast growth of disposable income among consumers in urban area has enabled them to have more opportunities to consider a wider array of products and services compared to those in rural area but this has equally triggered greed and fraudulent activities in the food chain. Capsicum annuum is a group of vegetable spices widely consumed for their nutritional benefits such as vitamin C, red pigments and carotenoids. Frequent consumption of red pepper or its products has been acknowledged to promote glucose and lipid metabolism while stimulating the immune system to delay the aging or even prevent cancer [2]. Its powdered form has recently become a preferred option as a spice for imparting flavour, color and aroma in diverse cuisines. However, its quality is often compromised. The supply chains of the paprika industry involve a matrix of lengthy sequences often involving a complex nature of the processes that avails several points of possible criminal adulteration activities. It's bright red color, mostly attributed to the presence of Capsanthin and capsorubin antioxidants [3] is, sometimes manipulated for selfish gains by producers who use diverse types of adulterants. One of such adulterants that has recently come under suspicion is corn flour. It is often done with the intention of deceiving the consumer even though consumers have the right to know that the food they eat is safe and suitable for consumption. Food fraud is disagreeable at best and at worst sometimes presents serious health concerns [4]. In view of authentication and quality assurance (QA) in this fast-moving industry, rapid, non-destructive methods are promising for future QA applications. Near infrared

spectroscopy (NIRS) is one of such methods gaining grounds for its sensitivity, ease of application and cost efficiency. It operates with a light absorption pattern at wavelengths between 700 nm (13,300 cm^{-1}) and 2500 nm (4,000 cm^{-1}) and is performed in combination with chemometrics for chemical fingerprints of foods. NIRS has been used for the determination of Sudan I-II-II-IV dye adulteration in spices [5], identification of papaya seeds in black pepper [6], paprika adulteration with lead chromate, 3% (w/w) lead oxide 5% (w/w) silicon dioxide, 10% (w/w) polyvinyl chloride, and 10% (w/w) gum Arabic [7]. The aim of this study was to test the feasibility of two different NIRS instruments in detecting adulteration of paprika powder with corn flour through chemometric data evaluations.

Materials and methods

Sample preparation

Authentic paprika powder was purchased from reputable sources in two Hungarian paprika growing regions and coded: DP and SP (Fig. 1). Each paprika type (DP and SP) was artificially adulterated in the laboratory at nine concentrations of corn flour: 40%, 30%, 25%, 20%, 15%, 10%, 5%, 3%, 1%. Each adulteration concentration was prepared in three repeats (3 grams each) and homogenized by shaking for two mins in plastic containers, before NIRS measurements. Pure paprika powder (non-adulterated) and pure corn flour (non-adulterated) was also included in the NIRS measurements.



Figure 1. Paprika powder samples and corn flour sample used for the experiment

NIRS measurements and data evaluation

Two types of spectrometers (Fig. 2): The metri analyzer (benchtop) with wavelength range of 740-1700nm and Nirscan nano NIRS (handheld) with wavelength range 900- 1700nm were used to collect diffuse reflectance spectra. Spectra was collected using a cuvette providing 0.4mm layer thickness of the tested paprika powder samples in a spectral step of 3nm. The samples were prepared in three replicates each and randomly scanned with both devices by taking three consecutive scans each, at room temperature. The collected spectra were pretreated with Savitzky-Golay smoothing filter using 2nd order polynomial and XY number of points and multiplicative scatter correction (MSC).

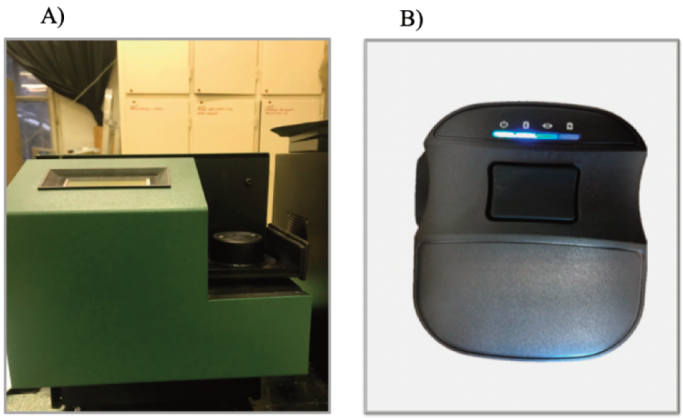


Figure 2. Spectrometers used for scanning the experimental samples; Metri NIRS (A) and Nirscan NIRS (B)

Linear discriminant analysis (LDA) was used for multi-class classification of the different corn flour concentrations. LDA is a supervised method; the class membership has to be known for the analysis [8]. Partial least squares regression (PLSR) was used to derive the models to predict paprika powder adulteration with corn flour, first in DP and SP paprika powder separately, and then in the whole dataset to see the influence of varietal differences on our model. Three-fold cross-validation (CV) was used to test the predictive significance of the results in LDA and also in PLSR to test the predictive significance of the regression. The statistical parameters used to evaluate the performance of the PLSR models were the Root Mean Square Error and the coefficient of determination both in calibration (RMSEC and R2C) and cross-validation (RMSECV and R2CV), respectively. The optimum number of latent variables was determined based on the minimum RMSECV value. All data evaluations were done in R project at a wavelength range of 950-1650nm.

Results and discussion

Discriminant analysis of paprika powder samples

The plots in Fig. 3 shows the visual classifications for corn flour adulteration in paprika powder using the Metri analyzer (A) and Nirscan nano (B). An increasing pattern of adulteration from 0% to 40% corn flour adulteration could be noticed from the left to right in both plots. Corn flour at 40% adulteration was the most discriminated. In Fig. 3A, all the other concentrations were classified separately from each even the lower concentrations of 1% 3% and 5% corn flour. There was some overlapping between 0% and 1% corn flour concentration in the case both instruments. Generally, better separation patterns were observed with the Metri NIRS (Fig. 3A) than with the Nirscan nano (Fig. 3B) and the plot confirms the prediction accuracies in Table 1 and Table 2.

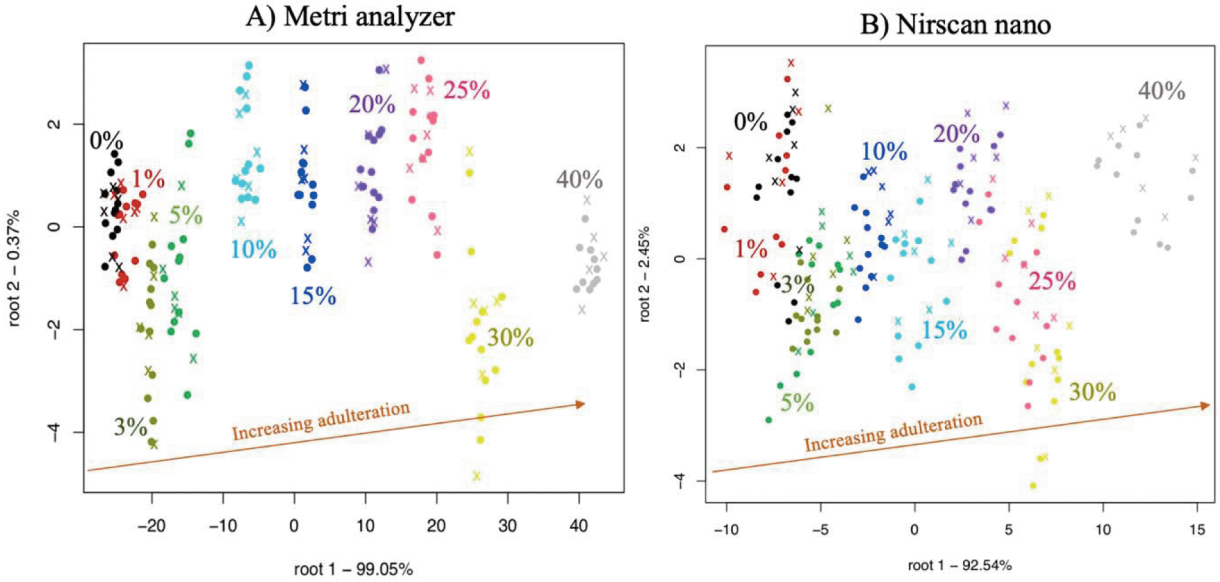


Figure 3. Discriminant analysis plot of paprika powder adulterated with corn flour at nine different concentrations and after spectral pre-treatment (smoothing and MSC) and cross-validation at wavelength of 950-1650nm (n = 177). A) Nirscan nano nirs, B) Metri nirs

Classification models built separately for SP and DP paprika types resulted in 100% average recognition and prediction accuracy for corn flour adulteration when, Metri NIRS used. An average recognition and prediction of 100% was also achieved when the Nirscan nano was used to separately classify DP and SP paprika type adulteration with corn flour. Classification models built for the whole datasets was capable of discriminating and predicting each different concentration of corn flour in paprika powder with a high accuracy, irrespective of the type of paprika. This is shown in Table 1 for Metri NIRS and in Table 2 for Nirscan NIRS.

Table 1. LDA classification results of paprika adulteration with corn flour after spectral pre-treatment and cross validation at wavelength of 950-1650nm with Metri NIRS

	0%	1%	3%	5%	10%	15%	20%	25%	30%	40%
0%	**77.83**	5.50	0	0	0	0	0	0	0	0
1%	22.17	**94.50**	0	0	0	0	0	0	0	0
3%	0	0	**100**	0	0	0	0	0	0	0
5%	0	0	0	**100**	0	0	0	0	0	0
10%	0	0	0	0	**100**	0	0	0	0	0
15%	0	0	0	0	0	**100**	0	0	0	0
20%	0	0	0	0	0	0	**100**	0	0	0
25%	0	0	0	0	0	0	0	**100**	0	0
30%	0	0	0	0	0	0	0	0	**100**	0
40%	0	0	0	0	0	0	0	0	0	**100**

Irrespective of the paprika type, all the different corn flour concentrations could be predicted in LDA with 100% recognition and 97.23% prediction accuracy when Metri NIRS was used (Table 1). With the exception of 0% and 1% corn flour concentrations, there was no misclassification (100% correct classification) in all the other different corn flour concentration levels after cross-validation. Similar results were reported for the detection of black pepper with papaya seeds using NIRS [9].

Table 2. LDA classification results of paprika adulteration with corn flour after spectral pre-treatment and cross validation at wavelength of 950-1650nm with Nirscan NIRS

	0%	1%	3%	5%	10%	15%	20%	25%	30%	40%
0%	**77.70**	46.60	0	0	0	0	0	0	0	0
1%	11.15	**53.40**	0	0	0	0	0	0	0	0
3%	0	0	**83.33**	0	0	0	0	0	0	0
5%	11.15	0	16.67	**100**	0	5.5	0	0	0	0
10%	0	0	0	0	**83.33**	16.67	0	0	0	0
15%	0	0	0	0	16.67	**77.83**	0	0	0	0
20%	0	0	0	0	0	0	**100**	16.67	0	0
25%	0	0	0	0	0	0	0	**77.83**	0	0
30%	0	0	0	0	0	0	0	5.50	**100**	0
40%	0	0	0	0	0	0	0	0	0	**100**

Irrespective of the paprika type, all the different corn flour concentrations could be predicted in LDA with an average accuracy of 85.34% when the Nirscan nano NIRS was used (Table 2). This was less than the 95.02% observed with the Metri NIRS (Table 1). There was no misclassification for 5%, 20%, 30% and 40% respectively. This was also observed with the Metri NIRS. In comparison with the Metri NIRS, there was lower classification accuracy for 0% and 1% corn flour adulteration. Generally, there was lower classification accuracies compared to the Metri NIRS. This may be due to the difference in sensitivity as benchtop instruments are often reported to be more sensitive compared to handheld devices.

PLSR prediction of corn flour adulteration after pre-treatment and cross-validation

The PLSR model for the Metri NIRS was capable of predicting corn flour adulteration in both DP and SP paprika powder with an R^2CV of 0.99 and 0.98 respectively. An R^2CV 0.99 was also achieved when a model was built for the whole dataset, with an RMSECV of 1.72 g/100g after cross validation. An R^2 close to 1 is a necessary condition for a good model [10]. This means that the Metri NIRS was capable of predicting 40%, 30%, 25%, 20%, 15%, 10%, 5%, 3%, 1% corn flour adulteration in both DP and SP paprika powder adulteration with a high accuracy and low error but the best model was the DP paprika with five latent variables.

Table 3. PLSR prediction of corn flour adulteration after spectral pre-treatment and cross-validation at wavelength of 950-1650nm using the Metri NIRS and Nirscan nano NIRS

	Model type	Data points	Components	R^2C	RMSEC	R^2CV	RMSECV
Metri NIRS	DP Paprika	87	5	0.999	0.439	0.997	0.719
	SP Paprika	90	6	0.977	1.945	0.972	2.180
	Whole dataset	177	10	0.986	1.508	0.981	1.715
Nirscan Nano NIRS	DP Paprika	90	10	0.992	1.175	0.988	1.412
	SP Paprika	87	10	0.988	1.394	0.980	1.823
	Whole dataset	177	10	0.971	2.205	0.964	2.436

The PLSR model for the Nirscan nano also capable of predicting corn flour adulteration in both DP and SP paprika powder with an R^2CV of 0.99 and 0.98, respectively. An R2CV 0.96 was achieved when a model was built for the whole dataset, the model had an RMSECV of 2.44 g/100g after three-fold cross validation. NIRS was capable of predicting 40%, 30%, 25%, 20%, 15%, 10%, 5%, 3%, 1% corn flour adulteration in both DP and SP paprika powder adulteration with a high accuracy and low error but the best model was the DP paprika with 10 components. The Nirscan nano had a better prediction accuracy for SP paprika in comparison with the Metri NIRS but Metri NIRS had an overall higher prediction accuracy when the whole dataset was analysed.

Conclusions

Two types of paprika powder samples artificially adulterated in the laboratory were classified and predicted with 100% accuracy in separate LDA models built with NIRS spectra scans from both Metri NIRS (Benchtop) and Nirscan nano NIRS (Handheld) respectively after pretreatment. Irrespective of the paprika type, LDA models could also classify corn flour adulteration when models were built for both paprika powders (whole data) with a prediction accuracy of 95.55% and 85.34% for Metri NIRS and Nirscan nano NIRS respectively. Metri NIRS was generally more effective in LDA classification compared to Nirscan nano. PLSR models could predict paprika powder adulteration with corn flour in an accuracy range of 0.97 to 0.99 for both Metri NIRS and Nirscan nano NIRS with errors less than 2.44 g/100g. Generally, the Metri NIRS could predict adulteration in SP adulterated samples better than Nirscan nano. The best PLSR model was found for DP paprika with five components using the Metri NIRS. Near infrared spectroscopy, as a non-invasive technique exhibited good potentials for paprika powder authentication when corn flour was used as an adulterant.

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References

[1] I. Osman, S. Osman, I. Mokhtar, F. Setapa, S. A. M. Shukor, és Z. Temyati, „Family Food Consumption: Desire towards Convenient Food Products”, Procedia - Soc. Behav. Sci., köt. 121, sz. September 2012, o. 223–231, 2014, doi: 10.1016/j.sbspro.2014.01.1123.

[2] X. H. Yang, Q. Zhang, J. Wang, L. Z. Deng, és Z. Kan, „Innovative superheated steam impingement blanching (SSIB) enhances drying rate and quality attributes of line pepper”, Inf. Process. Agric., köt. 4, sz. 4, o. 283–290, 2017, doi: 10.1016/j.inpa.2017.07.004.

[3] N. De Lima Petito, D. Da Silva Dias, V. G. Costa, D. Q. Falcão, és K. G. De Lima Araujo, „Increasing solubility of red bell pepper carotenoids by complexation with 2-hydroxypropyl-β-cyclodextrin”, Food Chem., köt. 208, o. 124–131, 2016, doi: 10.1016/j.foodchem.2016.03.122.

[4] J. Van Erum, D. Van Dam, és P. P. De Deyn, „Determination of seven illegal dyes in Egyptian spices by HPLC with gel permeation chromatography clean up”, Neurosci. Biobehav. Rev., o. 103304, 2019, doi: 10.1016/j.neubiorev.2019.07.019.

[5] C. V. Di Anibal, M. Odena, I. Ruisánchez, és M. P. Callao, „Determining the adulteration of spices with Sudan I-II-II-IV dyes by UV-visible spectroscopy and multivariate classification techniques”, Talanta, köt. 79, sz. 3, o. 887–892, 2009, doi: 10.1016/j.talanta.2009.05.023.

[6] I. Orrillo és mtsai., „Hyperspectral imaging as a powerful tool for identification of papaya seeds in black pepper”, Food Control, köt. 101, sz. December 2018, o. 45–52, 2019,
doi: 10.1016/j.foodcont.2019.02.036.

[7] B. Horn, S. Esslinger, M. Pfister, C. Fauhl-Hassek, és J. Riedl, „Non-targeted detection of paprika adulteration using mid-infrared spectroscopy and one-class classification – Is it data preprocessing that makes the performance?”, Food Chem., köt. 257, sz. February, o. 112–119, 2018,
doi: 10.1016/j.foodchem.2018.03.007.

[8] M. P. Callao, „An overview of multivariate qualitative methods for food fraud detection nchez”, Food Control, köt. 86, sz. December, o. 283–293, 2018, doi: 10.1016/j.foodcont.2017.11.034.

[9] A. S. Wilde, S. A. Haughey, P. Galvin-King, és C. T. Elliott, „The feasibility of applying NIR and FT-IR fingerprinting to detect adulteration in black pepper”, Food Control, köt. 100, sz. December 2018, o. 1–7, 2019, doi: 10.1016/j.foodcont.2018.12.039.

[10] J. L. Aleixandre-Tudo, H. Nieuwoudt, J. L. Aleixandre, és W. du Toit, „Chemometric compositional analysis of phenolic compounds in fermenting samples and wines using different infrared spectroscopy techniques”, Talanta, köt. 176, sz. August 2017, o. 526–536, 2018,
doi: 10.1016/j.talanta.2017.08.065.

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Faculty of Mechanical Engineering

QUANTIFICATION OF MULTIPLE ADULTERANTS IN BEEF PROTEIN POWDER BY FT-NIR

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Abstract

With its adverse effects on the health of consumers and the global economy, food adulteration is considered to be one of the pressing issues of our times. Beef Protein powders (BPP) are particularly among the most fraud-prone products mainly due to their ever-growing consumption. For the purpose of our study, FT-NIR spectroscopy was applied to quantify four commonly used adulterants: Melamine (M), Urea (U), Glycine (G) and Taurine (T) in BPP. Analysis with chemometric tools proved the efficiency of the aforementioned technique as a rapid nondestructive analytical tool for the detection of Beef protein powder adulteration.

Keywords

Beef Protein Powder, FT-NIR spectroscopy, adulteration, Chemometrics

Introduction

Meeting the demands of a more health conscious public in terms of safe, nutritious, and wholesome food is of paramount importance in the 21st century. This is partly due to the rise in fraudulent practices which are becoming more and more common with the advent of newer, more sophisticated ways of altering the quality and the composition of food matrices.
As a consequence of the high paced lifestyle of global population, the market of Protein-based supplements is set to reach unprecedented growth rates estimated at 45.27 billion U.S. dollars [1]. This ever-growing consumption makes these products among those targeted by food fraudsters. Over the course of years, counterfeits of these high value foods have been made by using compounds that mask the protein content when measured by conventional methods [1-3]. Checking whether these products comply with their marketed protein content calls for swifter and more accurate methods that offer real-time detection, high sensitivity and analytical selectivity.

Our study aimed at assessing the efficiency of Fourier Transform Near-Infrared spectroscopy (FT-NIR) regarding the quantification of four adulterants: Melamine (M), Urea (U), Glycine (G) and Taurine (T) in Beef protein powders (BPP) which have received little research attention regarding their adulteration.

Material and methods

Beef protein powder, taurine, glycine and melamine were acquired from a reputable protein powder production company. The nominal protein value of the beef protein powder was 80%. Urea was acquired from Elemental SRL (Bihor, Romania).

Experimental design

To simulate the different potential adulterations, the adulterants were added to the protein powder samples according to a matrix containing all possible combinations of (U), (G), (T) and (M) in different quantity (Figure.1). This combination pattern was developed to test the efficacy of FT-NIR spectroscopy in detecting multiple adulterants in beef protein powder. For each combination, beef protein powder was artificially adulterated with gradients consisting of six different levels corresponding to the following concentrations 0.5, 1, 1.5, 2, 2.5 and 3%. Since

melamine has the highest nitrogen content among the studied adulterants, the latter were added in melamine concentration equivalent to account for any differences.

The total number of mixtures corresponded to 90 samples (15 mixtures × 6 adulteration levels per mixture). Each of these was prepared in triplicates including a control resulting in a total number of samples of 271.

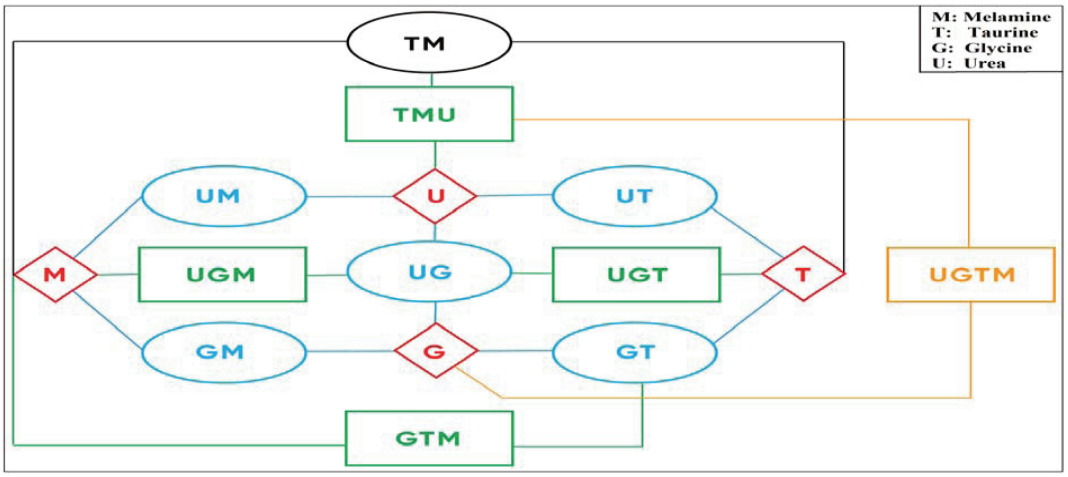


Figure 1. Mixture matrix for 15 mixtures of beef protein powder adulteration

Acquisition of NIR spectra

Prior to scanning, each mixture was poured into a 2 cm depth cuvette. The vials were then shaken for an approximate duration of 10 seconds and taped five times for a better homogenization. The samples were scanned in a random order and three consecutives were taken for each sample. The NIR spectra of pure and adulterated protein powder samples were measured over the range [800 to 2500] nm on a multipurpose analyser Fourier Transform Near Infrared Spectrometer (MPA, Bruker Optics, Ettlingen, Germany) using the OPUS software (v.7.2, Bruker Optics, Ettlingen, Germany). The data was collected by diffuse reflectance using the Integrating Sphere module (sphere macro sample) allowing the spectra of the materials to be collected through the bottom of the vials with a resolution of 8 cm-1. Each spectrum was the average of 32 scans. Background spectrum was acquired before each series of measurements.

Data analysis

The analysis of the generated spectra was performed with R-project software (v. 3.3.2, The R Foundation for Statistical Computing, Vienna, Austria) using aquap2 package. To extract the significant information contained in the spectral data, several pre-treatments were applied: Savitzky-Golay (SG) filter (second-order polynomial with 7, 11 or 21 points), second derivatives and Multiplicative Scatter Correction (MSC). (SG) parameters were optimized and the optimal window length that offered the best signal-to-noise ratio of the original spectra was set to 21 points. To minimize the effect of overlapping peaks and baseline shifts, second derivatives of pure, adulterated beef protein powder spectra as well as pure adulterants were calculated based on Savitzky–Golay derivation using 9 points. Last but not least, Multiplicative Scatter Correction was performed on smoothed spectra in order to reduce any possible baseline variations.

Multivariate data analysis

The data set was examined for its overall distribution using principal component analysis (PCA) and also, to detect outliers before building linear discriminant models (LDA). The latter were based on the type of adulteration and a three-fold cross validation was employed to ensure the inclusion of the samples at least once in the evaluation set resulting in three LDA models [1][4]. Partial Least squares Regression (PLSR) was used to develop chemometric models that could predict the concentration of the studied adulterants in adulterated beef protein powders.

The precision and accuracy of the developed PLSR models were evaluated by the coefficient of determination (R2) and root mean square error (RMSE) of both cross-validation and independent prediction. Latent variables (LV) were selected based on the lowest RMSECV (Root Mean Squared Error of Cross-validation) [5].

Results and discussion

Visual inspection of the NIR spectra

From figures (2.a and 2.b), the spectra of adulterated samples revealed some features similar to that of pure adulterants where distinctive peaks were observed at both of the spectra. When inspecting the typical absorbance of melamine, the first overtone region with N-H stretches was the most distinctive, including the absorbance peaks at 1523 nm, which was visible in mixtures containing melamine (figure 2.a). This confirms other results obtained by Tang, Cai, Shi, & Xu, 2016 [6] when quantifying melamine in different brands of milk powders using Near Infrared Spectroscopy.

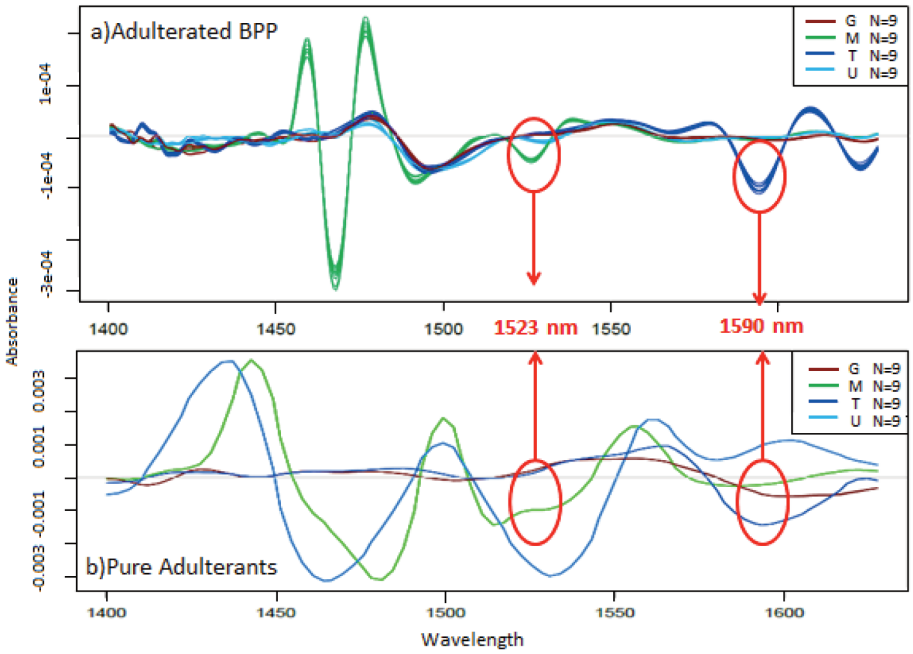


Figure 2. The 2nd derivative (Savitzky-Golay filter using 2nd order polynomial and 9 points) of the adulterated Beef Protein powder (A) and adulterants spectra (B) acquired in the 1400–1630 nm region

The most prominent absorbance peak for taurine was centred at 1590 nm, which was also present in samples containing taurine (Figure 2.a). This is in accordance with studies conducted by Lukacs et al., (2018) regarding the absorbance of Taurine in NIR spectral range. Glycine, on the other hand, presented a broad band in the region 1590 nm-1630nm which contains the N-H stretches (first overtone). In the case of urea, the first overtone region with N-H stretches had the most distinctive peaks at 1475 and 1530 nm. These findings are in agreement with the previous studies of [7]. The obtained results are quite informative regarding the typical peaks of adulterants and their effect on the original spectra of pure beef protein powder. However, for more conclusive results, the data was further evaluated by PCA.

Qualitative Data evaluation of the NIR spectroscopy results with PCA and LDA

Results of PCA analysis showed a pattern of separation of the different tested mixtures where the samples containing individual adulterants (U, G, T, and M) were more distant from those containing a combination of the adulterants. Such pattern was also confirmed when each mixture was colored by adulteration level and the most notable separation was obtained for samples adulterated by UM mixture. The pattern is recognizable in the scores plot shown in Figure.3 where PC1 represent 56.76%, while PC2 40.81 % of the total variance and an increasing pattern of adulteration could be seen based on PC2. There is a clear separation between samples containing 3% (level 6) and 2.5% (level 5) of UM compared to the rest of adulteration levels. However, what is most noteworthy is that NIRS was sensitive enough to separate even the lowest concentrations of 0.5% (level 1) and 1% (level 2) in PCA. This further confirms the efficiency of NIRS for the simultaneous detection of adulteration in protein-rich supplements. This is in agreement with what was reported by [8] .

However, the separation of the different adulteration levels by PCA was not as conclusive for

other studied mixtures where some overlapping of the different levels was observed. Further qualitative and quantitative modelling was thus performed to ensure the adequacy of NIRS for the detection of Urea, Melamine, Taurine and Glycine.

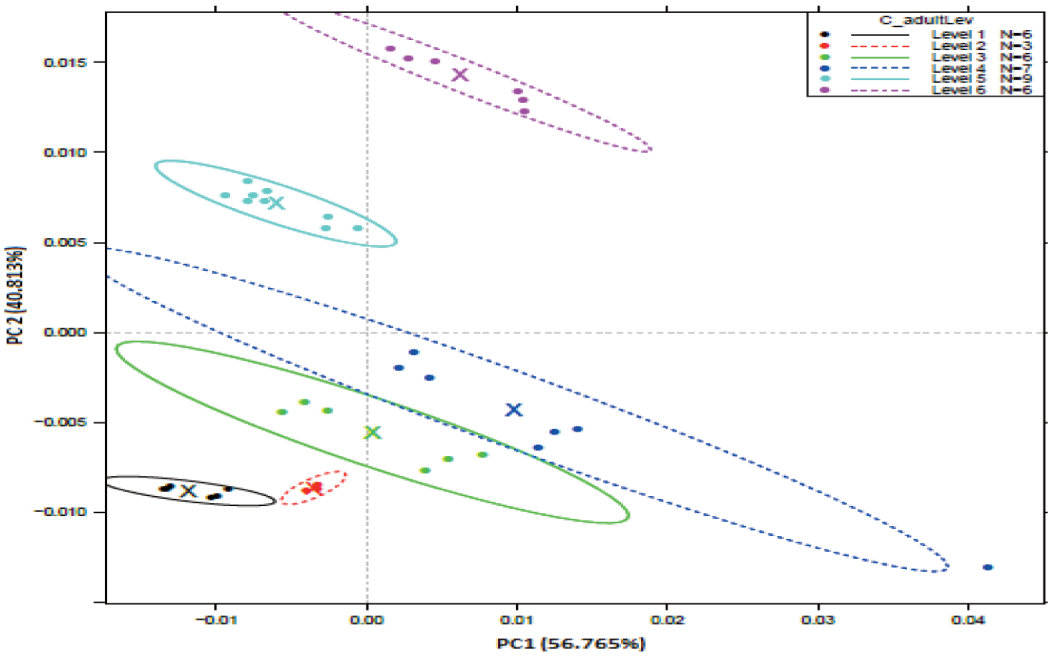


Figure 3. PCA scores plot of UM adulterated beef protein powder on the MPA smoothed (Savitzky-Golay filter; 21 points) and MSC pretreated spectra in the wavelength range 1400-1630 nm

Results of LDA classification showed that, at the lowest adulteration level corresponding to 0.5%, the model presented low accuracy and different mixtures were misclassified (Figure.4.a). The most distant points correspond to the samples adulterated with each of the individual adulterants. These are quite well separated as opposed to those containing a combination of adulterants. What is equally noticeable is that samples containing amino acid adulterants such as Glycine (maroon) and Taurine (blue) or a combination like GT are close to each other while those containing adulterants of different nature like urea (light blue), melamine or a combination of these adulterants like UM (yellow) are far(Figure.4.b).

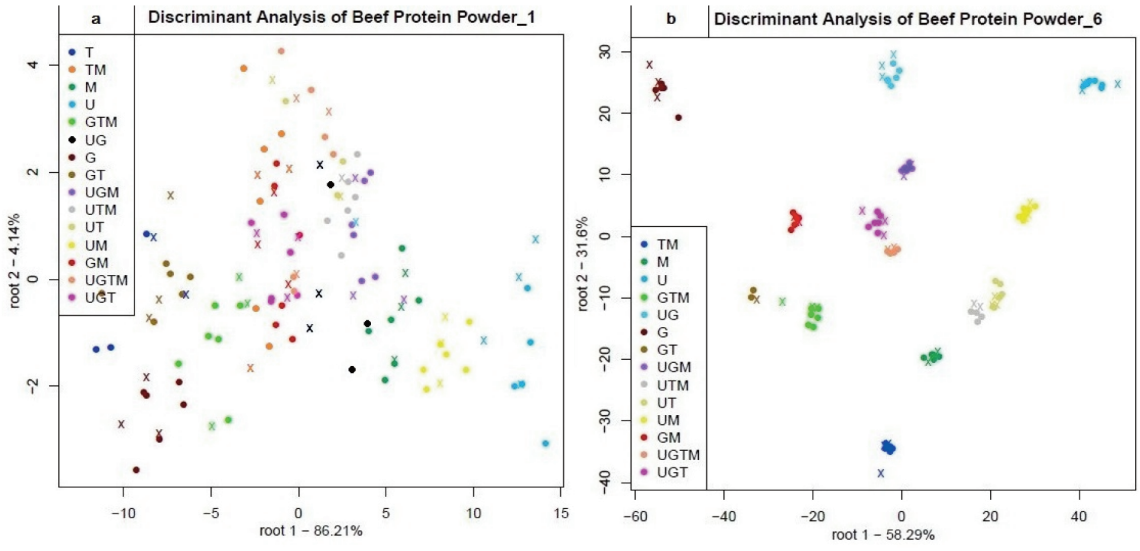


Figure 4. Results of LDA classification at level 1 (0.5%) (a) and level 6 (3%) (b) of Beef Protein Powder

When the adulterated beef protein samples were subjected to LDA at the adulteration level 6 corresponding to 3% adulteration, the different mixtures were perfectly classified based on the root 1 and 2 presenting 89.89% of the between group variance. The validation set (x) and training set (●) of each group of mixtures were perfectly fitted (figure.4.b). The different recognition and prediction performances at different levels are shown in Table 1.

Table 1. LDA recognition and prediction rates at different adulteration levels in 1400-1630nm range

	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6
Recognition	93.71%	98.5%	99.63%	100%	100%	100%
Prediction	70.87%	87.24%	97.79%	99.17%	100%	100%

It was observed that the accuracy of the applied method is dependent on the level of adulteration where a decrease of prediction rate from 100% to 70.87% when the adulteration level decreased is observable.

PLSR Prediction of beef protein powder adulteration:

The prediction accuracy depended on the tested adulterant and the best performances were obtained for the quantification of urea with coefficient of prediction (R^2Pr) of 0.89 and Root mean squared error of prediction RMSEP of 0.39%. The corresponding Y-Fit graph is illustrated in Figure.5 where test points are quite fitted to the training set points and concentrations as low as 1.5% were determined.

In case of melamine adulterated samples, the best predictive model was built using the raw spectra acquired in the region 1400-1630 nm by MPA. It was based on six latent variables and presented a coefficient of determination for the test set of 0.95 and an error of prediction (RMSEP) of 0.1961 %(Figure.6) suggesting the efficiency of NIRS when it comes to determining the concentration of melamine in BPP.

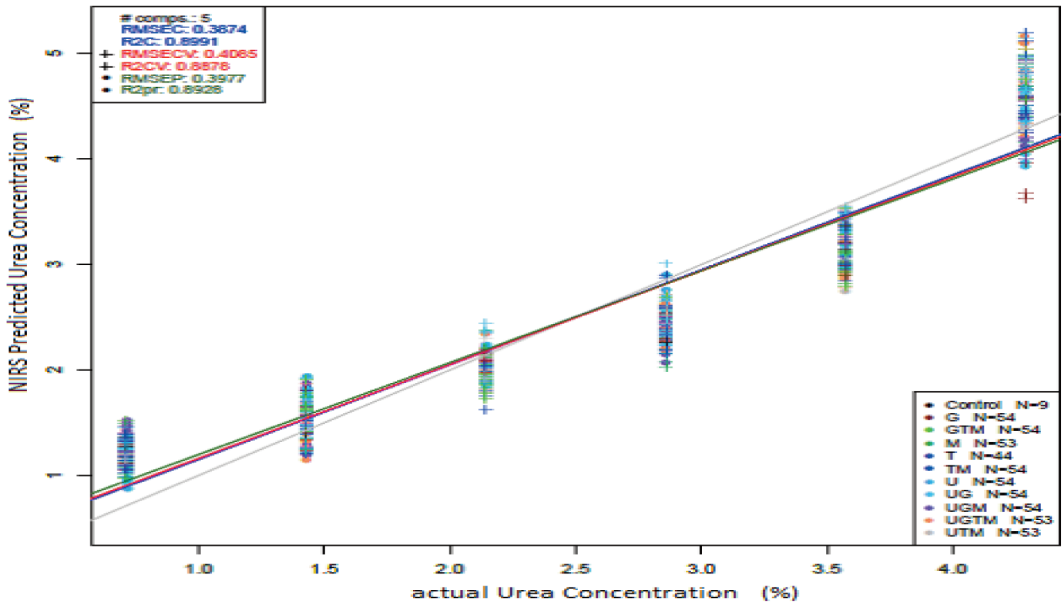


Figure 5. Y-fit graph of the prediction of urea concentration in adulterated BPP samples

In the case of adulterations with a combination of adulterants, the prediction models were also good with coefficients of prediction ranging from 0.88 to 0.96 and errors of prediction from 0.22% to 0.84%. What is notable is that the efficiency of predicting the content of adulterants in mixtures containing adulterants of similar chemical structure such as Glycine and Taurine (GT) was lower than those containing adulterants of different nature such as Urea and Glycine (UG) or Glycine and Melamine (GM).

These findings further confirm the reported results of LDA where misclassification was more probable to occur when the adulterants were similar in nature which was also reflected in the between classes distances. This also accentuates the importance of melamine and urea in conferring a certain recognizable pattern to adulterated samples when tested by PCA.

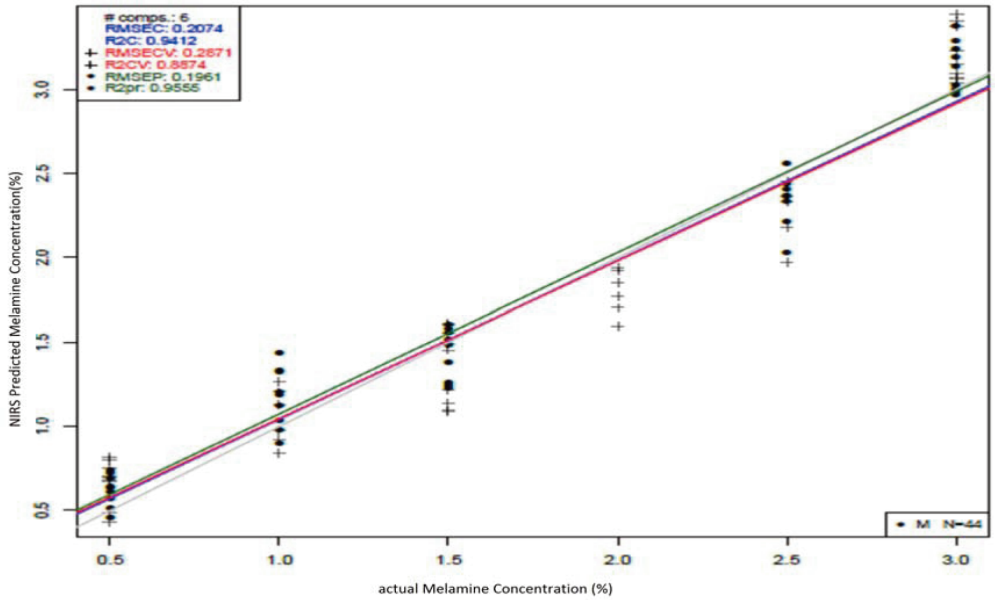


Figure 6. Y-fit graph of the prediction of melamine concentration in melamine adulterated samples

Conclusions

The study confirmed the presence of an identifiable pattern among adulterated samples, mainly due to the presence of Melamine and Taurine. The results obtained by Principal Component Analysis (PCA) could separate adulterants with concentrations as low as 0.5%. These findings were confirmed by the qualitative analysis with Linear Discriminant Analysis (LDA) where different groups were identified with performances that depended both on the adulterants present (separately or in combination) and the level of adulteration. The samples with higher levels of adulteration (level 6) corresponding to higher concentration of adulterants (3%) were easily classified compared to those adulterated with relatively lower amounts (0.5%) with LDA prediction rates of 100% and 70.87% respectively. According to adulteration type, beef protein powder samples with similar chemical structure (amino-acidic structure in case of glycine and taurine) tended to belong to groups with minor between group variance leading to some misclassifications. Partial Least Squares Regression (PLSR) had prediction coefficients (R^2Pr) ranging from 0.86 to 0.96 and errors of prediction from 0.2% to 1.01%. The results accentuate the efficiency of NIR spectroscopy as a rapid non-destructive analytical tool for the detection of Beef protein powder adulteration where levels corresponding to a concentration of adulterant as low as 0.5% can be successfully identified, classified and quantified.

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References

[1] Abernethy, G., & Higgs, K. (2013). Rapid detection of economic adulterants in fresh milk by liquid chromatography–tandem mass spectrometry. Journal of Chromatography A, 1288, 10–20. https://doi.org/10.1016/j.chroma.2013.02.022.

[2] Finete, V. de L. M., Gouvêa, M. M., Marques, F. F. de C., & Netto, A. D. P. (2013). Is it possible to screen for milk or whey protein adulteration with melamine, urea and ammonium sulphate, combining

Kjeldahl and classical spectrophotometric methods? Food Chemistry, 141(4), 3649–3655.
[3] Forchetti, D. A. P., & Poppi, R. J. (2017). Use of NIR hyperspectral imaging and multivariate curve resolution (MCR) for detection and quantification of adulterants in milk powder. LWT - Food Science and Technology, 76, 337–343.
https://doi.org/10.1016/J.LWT.2016.06.046
[4] Kalman, D. (2016). Understanding the Fitness vs Sports Nutrition Market, Corporate Conference WellNext (Champion Nutrition), Santa Cruz, CA, September 13, 2016. 10.13140/RG.2.2.30978.27848.
[5] Kovács, Z., Sipos, L., Szöllõsi, D., Kókai, Z., Székely, G., & Fekete, A. (2011). Electronic Tongue and Sensory Evaluation for Sensing Apple Juice Taste Attributes. Sensor Letters, 9(4), 1273–1281. https://doi.org/10.1166/sl.2011.1687
[6] Tang, B.-C., Cai, C.-B., Shi, W., & Xu, L. (2016). Rapid Quantification of Melamine in Different Brands/Types of Milk Powders Using Standard Addition Net Analyte Signal and Near-Infrared Spectroscopy. Journal of Analytical Methods in Chemistry, 2016, 9256102.
https://doi.org/10.1155/2016/9256102
[7] Li, B., Martin, E., & Morris, J. (2017). Latent variable selection in partial least squares modelling. IFAC Proceedings Volumes, 34(25), 463–468. https://doi.org/10.1016/s1474-6670(17)33867-3
[8] Lukacs, M., Bazar, G., Pollner, B., Henn, R., Kirchler, C. G., Huck, C. W., & Kovacs, Z. (2018). Near infrared spectroscopy as an alternative quick method for simultaneous detection of multiple adulterants in whey protein-based sports supplement. Food Control, 94, 331–340.
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TWO YEARS RESOULTS FOR WATER DEFICIT IRRIGATION IN PROCESSING TOMATO ON SANDY SOIL

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Abstract

Both the production and consumption of tomato, show a constantly increasing trend worldwide. The greatest growing areas in the World to raise Brix applied the water „cut off" method 3-4 weeks before harvest. In Hungary, we cannot successfully use this method. The target of our examination is to find out if the "deficit irrigation" method can be successfully applied on the sandy soil of Kecskemét. We have found differences in the measured parameters between non-irrigated and highly irrigated plots. The year effect on the open field is very high, which influenced our results.

Keywords

tomato, irrigation, brix, lycopene, potassium

Introduction

New investments in processing industry prospect the increase of the amount of tomato produced in Hungary. A large amount of raw material with outstanding nutrient content is needed for domestic processing in order to create high-quality tomato products. One of the biggest facilities processing industrial tomato is situated in Kecskemét. The area of Danube-Tisza Interfluve is prone to aridity, so growing industrial-scale tomato without irrigation is turning to be uncertain. The majority of soils around Kecskemét are sandy. A considerable share of the soils in these areas have reduced water retention capacity due to their structural characteristics.

The greatest growing areas in the World (e.g.: California, Italy) to raise Brix and other quality parameters without notable yield loss the water „cut off" method is generally applied 3-4 weeks before harvest. In Hungary, we cannot successfully apply the „cut off" method. In the majority of the seasons, during the main harvest period (10th August to 15th September) and 3-4 weeks before that, rains can disturb the ripening process. Hungary already has deficit irrigation researches in other soil types.

The goal of our research is to determine how yields and Brix values as the main industrial processing parameters, the colour and some HPLC crop nutrition data of industrial tomato alter as a result of water deficit irrigation and different levels of potassium replenishment. In our experiment conducted in sandy soil near Kecskemét we examined Unorosso F1 industrial tomato hybrid both in 2016 and 2017.

We have found in both years differences in the total amount of ripened fruits, in Brix %, and in the amount of lycopene and in the antioxidant capacity between non-irrigated and highly irrigated plots. Results of water deficit treatments for yield were proportionate between the extremes. The year effect on the open field is very high, which influenced our results now and in the future, so we need to continue our experiments.

Literature review

Both the production and consumption of tomato, either fresh or processed, show a constantly increasing trend worldwide. Based on FAO statistical data the total tomato production was 179.7 million tons considering the average of yields between 2015 and 2017. Out of this amount 24.4 million tons were produced in Europe, average Hungarian production

was 195,000 tons. It represents approximately 0.8% of the total European yield [1]. In case of countries with relatively arid climate optimal for outdoor tomato growing average yield can be expected around 100 to 130 t/ha. According to Hungarian data the 100 t/ha production is achievable with the use of intensive field production technology and several highly productive tomato hybrids [2]. The Vegetable Crop Research Department (ZÖKO) of National Agricultural Research and Innovation Centre (NAIK) and its predecessors have been conducting successful researches related to the improvement and selection of tomatoes, including industrial varieties, for decades [3].

Depending on the production conditions, tomato berries are developed and ripened in 7 to 8 weeks following pollination [4]. Several factors influence dry matter content, such as variety, ripeness of the berry, nutrient and water supply of the plants [5] as well as other environmental parameters [5-6]. The yield of a unit area is determined by the size and number of berries grown in a plant. It is inversely proportional with dry matter content [5-7]. Brix° is used for indicating soluble dry matter content; its value usually varies between 4 and 6.5 and is influenced by numerous factors [8-11]. Large part of soluble dry matter content (Brix°) consists of reducing sugars: this value is between 50 and 70% [12-15].

Refraction constantly changes in the berries during the different phases of ripening [16-17]. The case of using harvesting machines the ripeness of the fruits is not completely homogeneous; thus, average Brix values are calculated by using representative samples. An industrial sampler or adequate sampling methods shall be used for this purpose [18]. The case of experiments conducted in small parcels changes in Brix can be identified by frequent sampling and a seasonal average can be set. Refraction values of samples are usually higher in August than in September [19]. The proportion of green and burgeoned fruits can increase as a result of improved water supply. This phenomenon reduces economic efficiency [20]. Producers demand the development of such cultivation practices and strategies by which high dry matter content can be ensured beside higher yields, too.

Development type, berry size and the number of set fruits fundamentally determine the productivity of tomatoes, although the method of production and the technology applied to play important roles, too [20]. According to other research [21] the amount of irrigation water significantly influences the living conditions of plants. Cahn (2003) et al. [21] claim that the more water a plant receives during the phase of crop formation, the lower the Brix° will be. The weather of last weeks before harvesting considerably influences harmonised ripening and dry matter content of industrial tomato varieties. Larger rains can remarkably deteriorate the Brix value. In some years the acceleration of ripening is unavoidable [22] one way of which can be the ceasing of irrigation [23]. Water withdrawal in the last 3 to 4 weeks before harvesting (cut-off method) has not provided unambiguous results in Hungarian experiments, thus water deficit irrigation might be the solution for ensuring adequate Brix value without suffering considerable yield loss [23].

Material and methods

The plant stand representing the subject of the examinations was planted in Kecskemét, using the experimental field of the National Agricultural Research and Innovation Centre Vegetable Crop Research Department. The tomatoes were put in loose sandy soil (KA: 31) in 2016 and 2017. Following the soil analysis a nutrient supplementing plan has been elaborated by taking the specific nutrient demands of industrial tomato into account. The case of 80 t/ha yield the active substance requirements are as follows: 280 kg N; 120 kg P and 352 kg K.

Unorosso F1 variety has been used in the experiment. Seedlings were grown in heated greenhouse using KITE trays. During the five-week-long seedling production phase Ferticare (24-8-16) growing solution has been applied. The tomatoes were planted in 19 and 20 May in 2016. In 2017 the planting dates were 18 and 19 May. Complex granulated NPK fertiliser (15-15-15) and granulated poultry manure (Orgevit) was dispensed during the spring machine spading. Ferticare (15-30-15) starter fertiliser was used to promote root development at the time of planting.

Our experiment has 16 treatments (4 irrigation and 4 potassium level and their combinations), each in 4 repetitions, wich means 64 small parcels. Each parcel contained 51 plants. Planting and row distance was 22 cm and 130 cm, respectively. The space between two rows was covered by 120 cm wide geotextile in order to prevent weed growth. We used drip irrigation, therefore the experiment was 4 banded. A tensiometer was put into each band of the experiment to determine the time of irrigation with sufficient accuracy. Two-metre-wide spacings were left between the bands to avoid the mingling of the treatments and their effects.

The uniform water and nutrient supply was ceased five weeks prior to the planned date of the harvest. Tomatoes had adequate leaf area by then,

flowering has been finished, and fruits were developed. The first berries were about to reach their final size. To this point was 70% of the full amount of potassium given to the planting area. After this turning point plants were irrigated using three different amounts (100%; 75% and 50%) of water, together with three levels (100%; 75% and 50%) of potassium. The fourth parcel was the non-irrigated control group. The amount of irrigation water has been determined based on the data received from the tensiometers and the specific water demand of the plants (one-fifth of the daily mean temperature in mm).

Harvest was carried out in three different dates starting in 23 August and 21 August in 2016 and 2017, respectively. Each 64 parcel (51 plant) stands from 3 rows (17 plant in a row). We harvested weakly one row from each parcels. Machine harvest was imitated: plants were cut, all the berries shaken off and classified under four categories (ripe, burgeoned, green and unhealthy/cull). Fruits were also counted and weighted. Red and orange, evenly coloured fruits fell into the ripe category. A berry was considered burgeoned if it contained orange and green patches in varying proportions. Uniformly coloured green tomatoes belonged to the green category. All those tomatoes were considered as unhealthy which showed the signs of bacterial or fungal infections, sun-damage or Ca spots.

A sample consisting of 20 ripened berries were taken from each parcel. These samples were pressed by a juicer. From the juice we checked the Brix value by a portable automatic refractometer (Hanna HI96801). We measured the colour from the raw juice in L.a.b system by a spectrophotometer (Hunter D25). We collected another 20 ripened berries samples to measure the lycopene and antioxidant capacity in the Food Science Research Institute (NAIK ÉKI).

Results

Average yields were calculated from the four repetitions per treatment, while the average refractions were determined by the four repetitions per harvest date. Considerable difference can be observed as regards of unhealthy berries between the two years. Temperature reached, in several times, 40 °C in 2017. In spite of frequent irrigation the number of berries with Ca spots increased, thus raising the share of cull fruits. Right before harvest large amount of rain fell repeatedly balancing the effects of the applied treatments. It can be concluded that the largest amount of ripened tomatoes were harvested from parcels affected by irrigation deficit in both years (see Figure 1). Proportion of green and burgeoned categories increased as a result of better water supply, while the share of unhealthy fruits remained unchanged under the different treatments.

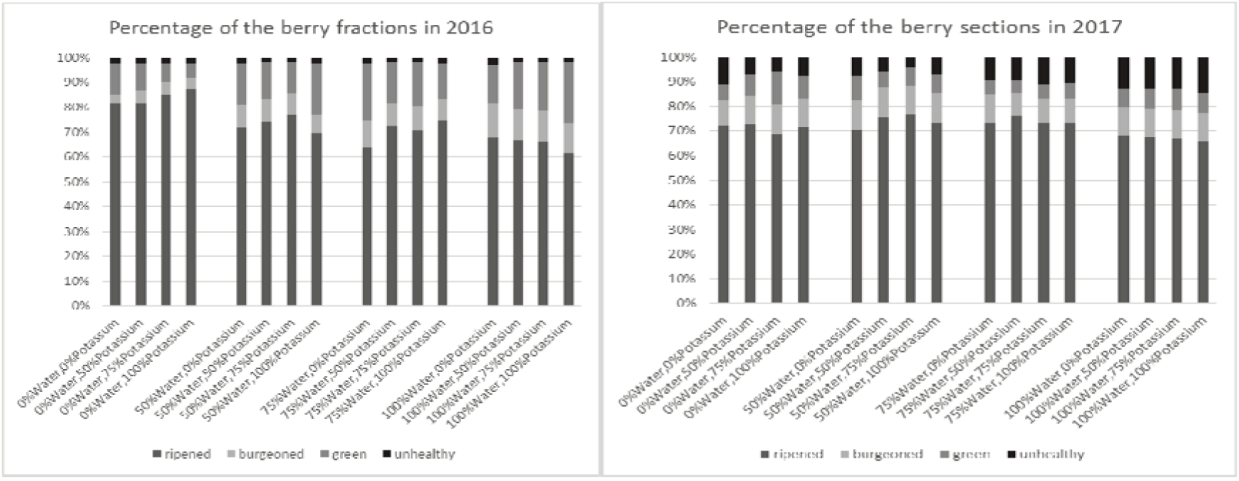


Figure 1. Distribution of fruit categories in 2016 and 2017

In case of total yield remarkable differences were detected as a result of the treatments in 2016. Highest yield was reached in the category “100% water, 50% potassium”, while the lowest value was observed in the “50% water, 0% potassium” group. The harvested mass of tomato increased proportionally to the water supply. Differences among the results of the treatments became much less articulated in 2017. Largest yield was reached in case of “50% water, 75% potassium”, while the lowest amount was harvested

in group “0% water, 0% potassium”. Although generally speaking better water supply meant higher yields, no linear correlation could be observed. Similar tendencies were identified for refraction, too. Parcels subjected to water stress showed higher Brix values compared to areas with good water supply in 2016. The highest and lowest numbers are detected at “50% water, 100% potassium” and “100% water, 50% potassium”, respectively. No such tendencies were justified in 2017: medium-supply parcels resulted lower Brix values, while the two extremities led to similar, higher refraction averages. “0% water, 100% potassium” resulted the highest Brix, while the lowest was measured at “75% water, 50% potassium” (see Figure 2).

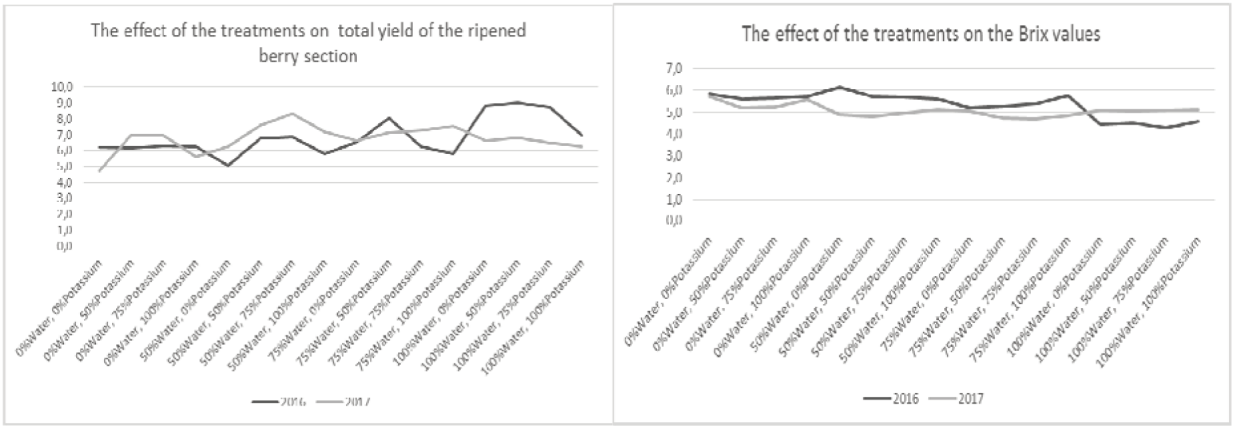


Figure 2. The effect of the treatments on the total yield of the ripened berries and on the brix values in 2016 and 2017

In case of the nutrients (lycopene and antioxidant capacity) remarkable differences were detected as a result of the treatments in 2016. We measured the highest lycopene quantity by the “50% Water, 100% Potassium” treatment and the lowest amount was by the “75% Water, 0% Potassium” treatment. We haven’t got any sample in 2016 from the “0% Water, 0%Potassium” treatment. We detected the highest antioxidant capacity by the “0%Water, 50%Potassium” treatment, and the lowest by the effect of the “75%Water, 0%Potassium” treatment. Differences among the results of the treatments became much less articulated in 2017. We realised from lycopene the highest value by the “0%Water, 50%Potassium” group, and the lowest by the ”75%Water, 50%Potassium” treatment. In the case of the antioxidant capacity we have found the highest amount by the treatment of “100% Water, 0%Potassium”, and the lowest by the “75%Water, 100%Potassium” group. (see Figure 3).

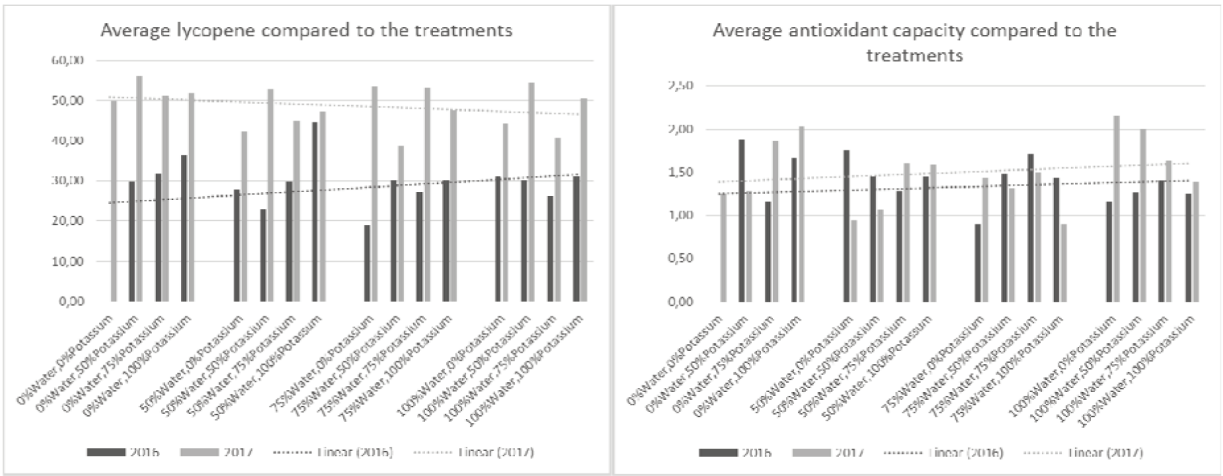


Figure 3: The average of lycopene and antioxidant capacity in 2016 and 2017 compared to the treatments

Conclusions

During the set-up of the experiments we aimed to reduce the annual fluctuation of yield and Brix value. Based on our results it can be said that the seasonal environmental effect influenced both the yields and Brix values more considerably than the applied treatments. It is important to highlight that optimal yields and dry matter contents were reached in water deficit treatments. Water supply levels induced larger differences in productivity and in the level of water-soluble dry matter content than potassium supply. 100% water supply – calculated by the specific water demand – resulted outstanding total yield, but the amount of marketable yield increased in a smaller extent. Harvested yields increased directly proportionally to water supply level. Higher Brix values were measured in parcels subjected to water stress than in ones with good water supply. In case of severe water stress the same correlation was observed in 2016 and 2017. However, at higher levels of water supply these borderlines mainly vanished in 2017. The impacts of different potassium levels are not unambiguous. In case of lycopene in 2016 it can be say that the most of the highest amounts were in water stressed parcels. The potassium top dressing has an influence of the amount of lycopene. In the amount of lycopene in 2017 and by the antioxidant capacity (in 2016 and 2017) the definite effect of the treatments was not detectable, however we have in both case significant differences. Based on our results it can be said that in case of industrial tomato the seasonal climatic effect influenced both the yields and Brix values more considerably than the applied treatments. As a conclusion it can be said that determining the optimal level of irrigation and potassium supply regarding yields and refraction can only be done for one year.

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References

[1] Algeier, W.: 2013. 70 éves a ZKI. Kertészet és Szőlészet, 27:6-8.

[2] Johnstone, P.R., T.K. Harz, M. LeStrange, JJ. Nunez and E.M. Miyao: 2005. Managing fruit soluble solids with late-season deficit irrigation in drip irrigated processing tomato production. HortScience 40(6): 1857-1861.

[3] FAOSTAT: 2019. Production of Crops. http://www.faostat.fao.org/

[4] Mahakun, N., Leeper, P. W., Burns, E. E.: 1979. Acidic constituents of various tomato fruit types. Journal of Food Science, 44:1240-1244.

[5] Mallidis, C and P. Papadopoulou: 1994. Development of a sampling methodology for the proper evaluation of the quality of the processing tomatoes. Acta Horticulturae 376, 171-175.

[6] Helyes, L., Pék, Z., Lugasi, A.: 2008b. Function of the variety technological traits and growing conditions on fruit components of tomato (LycopersiconLycopersicum L. Karsten) Acta Alimentaria, 37(4):427-436.

[7] Ho, L.C.: 2003. Genetic and cultivation manipulation for improving tomato fruit quality VIII International Symposium on the Processing Tomato

[8] Davies, J. N., Hobson, G. E. & McGlasson, W. B.: 1981. The constituents of tomato fruit- the influence of environment, nutrition and genotype. Critical Reviews in Food Science & Nutrition,15:205-280.

[9] Helyes, L.: 2013. Gondolatok és eredmények az ipari paradicsom termesztéséről. Agrofórum, 2:32-36.

[10] Helyes, L.: 1999. A paradicsom és termesztése. SYCA Szakkönyvszolgálat Budapest

[11] Schmidt-Szantner, B., Pék, Z., Molnár-Mondovics, Á., Milotay P.: 2018. Ipari paradicsom deficit öntözése homoktalajon Alkalmazkodó vízgazdálkodás: lehetőségek és kockázatok 146, ISBN 978-963-269-735-2

[12] Varga, Gy., Dimény, J., Pék, Z., &Kassai, T.: 2005. A fajta és az évjárat hatása a támrendszeres paradicsom termésképzésére. Kertgazdaság, 37:145-154.

[13] Varga, Gy.: 1983. A vízellátás hatása a paradicsom termésére. Kertgazdaság, 15(1)

[14] Cselőtei, L., &Helyes, L.: 1988. The possibility of determining irrigation requirements by means of plant temperature. Acta Horticulturae, 220:353-358.

[15] Macua, J.I, Lahoz, I., Arzoz, A., Garnica, J.: 2003. The influence of irrigation cut-off time on the yield and quality of processing tomatoes. ActaHoriculturae 613:151-153.

[16] Helyes, L., Dimény, J., Bőcs, A., Schober, G., Pék, Z.: 2008a. The effect of water and potassium

supplement on yield and lycopene content of processing tomato. Acta Horticulturae
[17] Helyes, L., Lugasi, A.,Schober, G., Pék,, Z.: 2006. Effect of Ethrel on Ripening Dynamic and Lycopene Content in Case of Two Processing Varieties. Acta Horticulturae, 758:275-280.
[18] Jauregui, J. I., Lumbreras, M., Chavarri, M. J., Macua, J. I.:1999. Dry weight and brix degreecorrelation in different varieties of tomatoes intended for industrial processing. ActaHorticulturae 487, 425–430.
[19] Lapushner, D., Bar, M., Gilboa, N., Frankel, R.: 1990. Positive heterotic effects for °Brix in high solid F1 hybrid Cherry tomatoes. Acta Horticulturae, 277.
[20] Milotay P., Schmidtné Szantner B., Molnár-Mondovics Á., Kis A., Tóth-Horgosi P.: 2016: Paradicsom vízoldható szárazanyag tartalmának változása két eltérő évjáratban. XXII.. NövénynemesítésiTudományos Nap, Abstr. 104. ISBN 978-963-396-085-1.
[21] Cahn, M. D., Herrero, E. V., Hanson, B. R., Snyder, R. L., Hartz, T. K., Miyao, E. M.: 2003. Effects of irrigation cut-off on processing tomato fruit quality. Acta Horiculturae, 613:75-80.
[22] Pék, Z., Szuvandzsiev, P., Neményi, A. & Helyes, L.: 2014. Effect of season and Irrigation on Yield Parameters and Soluble Solids Content of Processing Cherry Tomato. Acta Horticulturae, 1081:197-202.
[23] Varga, Gy.: 1988. The effect of irrigation onthe quality of processing tomatoes. Acta Horiculturae, 220:359-364.

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Faculty of Mechanical Engineering

DETECTION OF HEAT TREATMENT OF HONEY WITH NEAR INFRARED SPECTROSCOPY

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Abstract

Heat treatment of honey is usually applied due to crystallized form is not preferred by the consumers and makes handling harder to producers and beekeepers. Our aim is to find a method that can detect heat treatment of honey even at lower levels. In the study honeys were heated at 40°C, 60°C, 80°C, 100°C for one, two, three and four hours. Moisture, pH, electrical conductivity, HMF, color were determined, and spectra of honeys were recorded with NIRS. Results showed that NIRS could distinguish the honeys heated at 40°C while HMF was able to detect higher than 60°C treatment at significant level.

Keywords

honey, NIR, chemometrics, HMF, heat treatment

Introduction

Honey is produced by honeybees (Apis mellifera) from nectar, sap of plants and secretion of insects. Owing to the botanical origin, honeys are differing in their physico-chemical properties including sugar composition. Honeys mainly consist of moisture and sugar, but also contains minerals, vitamins, enzymes, aroma components, organic acids and antioxidants [1]. According to the legislations and standards moisture content of honey should be under 20%, with some exceptions (Calluna honeys should be under 23%) [2], [3]. In honey different monosaccharides and disaccharides are present, and the two main sugars in honey are glucose and fructose. The ratio of these two sugars is characteristic for unifloral honeys from different botanical origin and have an important role in the crystallization of honeys. This crystallization process also depends on the storage time and temperature, moisture content and presence of particles such as pollen and beeswax [4]. Honeys with higher relative glucose content crystallizing quicker, as glucose is less soluble in water than fructose [5]. Honeys can be divided into three categories based on the speed of crystallization: quick such as sunflower (Helianthus anuus) canola, (Brassica napus), moderate like linden (Tilia spp.) or bastard indigo (Amorpha fruticosa) and slow crystallization for instance acacia (Robinia presudoacacia) chestnut (Castanea sativa) or honeydew [6] Notwithstanding crystallization is a natural process, beekeepers, producers and consumers do not prefer crystallized honeys, owing to handling, processing and organoleptic properties are not beneficial. This lower acceptance of crystallized honeys led to application of heat treatment on honeys. According to the Hungarian legislations, the core temperature of the honeys must be between 5°C and 40°C during processing and storage, meaning that heating up to 40°C temperature is allowed [7] However, in practice heat treatment at higher temperature is sometimes applied, because liquefaction of honey at 40°C takes too long [5]. However, heat treatment at higher temperature and/or longer time influence negatively the quality of honey thus treatment above 50°C is considered as adulteration [8]. In practice detection of heat treatment and freshness of honey is examined by the determination of hydroxymethyl-furfural (HMF) content, invertase and diastase activity. The problem of using HMF content as indicator of heat treatment that it increases significantly only at higher temperature (above 60°C) or longer time of heat

treatment. Therefore, minimal heat treatment such as treatment at 40°C or 50°C for instance for two hours cannot be detected using the determination of HMF content only, in spite of changes in crystal composition, aromatic profile and antioxidant profile can be significant [9], and determination of HMF takes time and need chemicals. The determination of the aforementioned enzyme activities are more applicable to check the freshness of honey, due to at long time storage they also can decrease [10]. Therefore, there is a need to find quick, reliable and easy to use method more sensitive for the detection of heat treatment. Near infrared spectroscopy could be a good solution to fulfill these requirements, because its application does not need sample preparation and it is quick, furthermore, in previous studies NIRS was successfully used in determination of authenticity of honey [11]. Our objective was to check the applicability of NIRS for the detection of heat treatment of honey. Further aim was to develop NIRS based method for rapid determination of heat treatment of honey which could support authorities work in the long term.

Materials and methods

Honeys and sample preparation

Acacia (RP), sunflower (HA) and bastard indigo (AF) honeys were collected from a beekeeper in three bottles each that served as parallel samples in our experiments. Honeys were heated for one, two, three and four hours at 40°C, 60°C, 80°C, 100°C, resulting in 153 sample including control (unheated) honey for the three different types. In the code system the first two letters are for the type of honey, second numbers are the temperature levels, and third numbers for the time interval, for instance AF-040-120.

Quality indicators

Moisture, pH and electrical conductivity of the tested honey samples were determined according to the IHC (International Honey Commission) method book [12]. In the case of moisture two replicates, and in the case of pH and conductivity three replicates were obtained for each 153 samples.

Color

CIE L*a*b* tristimulus coordinate system was used for the determination of color of the honey samples in transmittance arrangement using ColorLite sph850 spectrophotometer (ColorLite GmbH, Germany). Each parameter was determined in tree consecutives per each sample, however results of crystallized honeys were not evaluated due to the crystals can affect the transmission of the light.

HMF content determination

HMF content of honey samples was determined according to Winkler-method, in three consecutives for each heat treatment level [12].

Near infrared spectroscopy

Transflectance spectra of the honey samples were recorded between 900 and 1700 nm with the NIRScanNano (Texas Instruments, Dallas, Texas, USA) handheld spectrometer. The layer thickness of the samples was 0.4 mm in the cuvette. Five consecutive spectra were recorded for each sample three times resulting in 765 spectra per honey type.

Statistical evaluation of the data

Results of quality indicators and color were analyzed with descriptive statistics, two-way ANOVA test was performed on the HMF results, followed by Tukey-pair wised comparison for the determination of significant changes between temperature and time levels. Results of NIR data between 950nm and 1630nm were pre-treated with Savitzky-Golay smoothing and multiplicative scatter correction. Principal component analysis was used to detect the patterns, while linear discriminant analysis models were built for the classification of temperature and time interval levels separately. LDA models were validated with three-fold cross validation. Data evaluation was performed in Microsoft Excel and R-project 3.5.2 using aquaP2 package.

Results and discussion

Results of the quality parameters and color measurement

Moisture content of the bastard indigo samples were between 16.33% and 17.27%, that suits to the EU legislation (<20%), such as the results of acacia and sunflower honeys. Moisture content - if honeys are heated in glass holders with a closed cup, - and electrical conductivity do not show clear trends. In the case of the results of pH an increasing tendency can be seen with the increase of the applied heat treatment for bastard indigo honeys, especially in the case of honeys that were treated at 100°C. Similar tendency was observed for the other two types of honey. Electrical conductivity of the AF honeys was between 537 µS/cm and 547 µS/cm, RP honeys between 108 µS/cm and 113 µS/cm and HA honeys between 378 µS/cm and 400 µS/cm. These results

also fit to the EU legislation for blossom honeys (<800 µS/cm) (Table 1.) [3].
Results of color showed similar tendency for all the three tested honey types. An increasing L* was followed by a decreasing lightness of the samples. The a* parameter increased with the elevation of the treatment temperature and applied time and similar tendency was obtained for b* resulting in more yellow intensity (Table 1.). The increasing of L* and b* in the beginning can be explained by the change of the structure of microcrystals, while the decreasing L*, (darkening of the honey) and more red intensity can be explained by the browning as a result of Maillard reaction [13]. Results of ANOVA test using color data showed that temperature, time and interaction of these two factors has a significant effect on the changes of L*, a*, and b* parameters ($p<0.001$) as a consequence of heat treatment in the case of AF honeys. For all of the parameters significant parameters were found between the three temperature and four time interval groups as a result of the pair-wised comparison ($p<0.05$).

Table 1. Results of the quality indicators and color for bastard indigo honeys

Treatment level	Moisture %	pH	Electrical conductivity µS/cm	L*	a*	b*
AF_cont_cont	16.4±0.17	4.35±0.02	536.56±2.3			
AF_040C_060M	16.33±0.26	4.36±0.01	541.22±3.42			
AF_040C_120M	16.51±0.36	4.36±0.01	542.22±5.72			
AF_040C_180M	16.98±0.04	4.39±0	546.56±4			
AF_040C_240M	16.8±0.21	4.38±0.01	540.67±1.5			
AF_060C_060M	17.04±0.1	4.34±0.02	541.67±6.24	71.26±0.77	5.89±0.12	57.92±1.08
AF_060C_120M	17.1±0.1	4.42±0.04	537.89±1.76	77.43±0.16	6.4±0.03	61.61±0.11
AF_060C_180M	17±0.27	4.44±0.01	539.44±5	77.5±0.26	6.32±0.03	62.35±0.38
AF_060C_240M	17.11±0.15	4.45±0.01	538±3.57	77±0.5	6.44±0.13	62.21±0.37
AF_080C_060M	16.93±0.19	4.43±0.01	545.22±2.17	76.02±0.6	6.52±0.1	61.57±0.79
AF_080C_120M	16.84±0.26	4.48±0.01	540.22±0.44	74.74±0.89	7.2±0.26	63.52±0.8
AF_080C_180M	17.04±0.24	4.5±0.01	538.11±1.76	75.61±0.57	8.35±0.15	66.56±0.16
AF_080C_240M	17.27±0.2	4.51±0	543.33±1.66	74.67±0.15	9.33±0.14	69.13±0.21
AF_100C_060M	17.02±0.12	4.51±0.01	542.89±2.09	73.59±0.57	8.26±0.16	65.02±0.36
AF_100C_120M	17.27±0.13	4.55±0.04	542.44±1.67	66.86±0.65	16.89±0.24	78.68±0.42
AF_100C_180M	16.93±0.22	4.56±0.01	541.89±2.03	58.83±0.21	24.85±0.27	81.45±0.23
AF_100C_240M	16.84±0.3	4.56±0.01	538.44±7.42	49.91±0.23	32.87±0.23	77.18±0.39

Average±Standard deviation

Results of HMF determination

Results of the HMF test for all of the honey types showed that extreme increase in HMF content can be reached by heating honey at 100°C. In the case of AF honeys the limit established by EU Commission and Codex Alimentarius (40 mg/kg) was reached only in honey samples heated at 100°C for at least 2 hours (Fig. 1.). Similar results were obtained for RP and HA honey types, with the exception that HA honeys also showed higher than 40 mg/kg HMF content in the case of honey heated at 80°C for 4 hours, which can be explained by the higher glucose content of this honey type. ANOVA test showed that time, temperature and their interaction have significant effect ($p<0.05$) on the formation of HMF during heat

treatment. There was no significant difference observed in HMF content between honey samples heated at 40°C and 60°C compared to control for all the honey types. In the case of AF, only honeys heated at 100°C showed significant difference comparing control honey. This results is in accordance with results of previously published works [9].

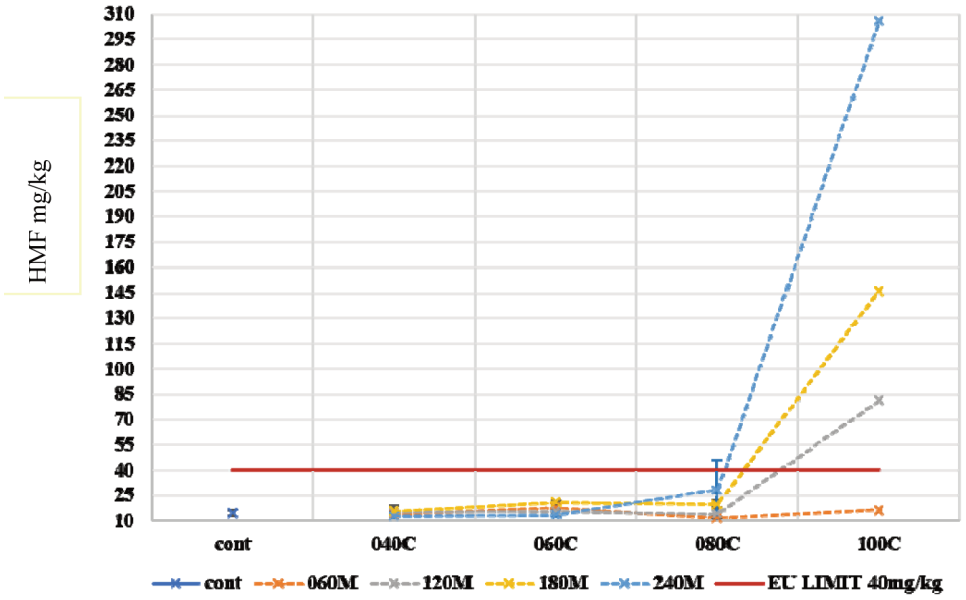


Figure 1. Results of HMF (Average and SD) content of bastard indigo honeys n= 51

Results of NIRS

PCA result of NIR spectra of AF honeys showed clear separation tendency of the tested samples according to the applied temperature through PC1 that describes the 95.52% of the total variance. The classification model built to discriminate based on the applied temperature showed the same phenomena (Fig.2).

LDA model provided average recognition and prediction abilities 77.93% and 77.26%, respectively. Control samples were classified correctly. This might be explained by the changes in phase and chemical structure as a consequence of heat treatment. Honeys heated at 40°C showed 94.45% correct classification during both training and cross-validation, misclassification was found belonging to the 60°C and 80°C. Honeys heated at higher levels showed lower than 70% correct classification for training and cross-validation, misclassifications were found belonging to other groups. Detailed results can be seen in Table 2.

Table 2 Classification table of the LDA model built for AF honeys to discriminate between temperature levels

%	Original→ Predicted↓	control	040C	060C	080C	100C
Training 77.93%	**control**	**100**	0	0	0	0
	040C	0	**94.45**	0	0	0
	060C	0	3.61	**65.64**	24.17	8.24
	080C	0	1.94	27.65	**61.39**	23.58
	100C	0	0	6.7	14.44	**68.18**
Cross validation 77.26%	**control**	**100**	0	0	0	0
	040C	0	**94.45**	0	0	0
	060C	0	3.88	**63.69**	23.88	8.52
	080C	0	1.67	29.05	**61.12**	24.43
	100C	0	0	7.26	15	**67.05**

The reason of the overlapping between the groups treated at higher temperature (60°C, 80°C, 100°C) may be due to the effect of the time interval which is also influencing the compositional changes of honey, however the average recognition and prediction abilities of the time intervals were 50.30% and 50.19%, respectively, for the whole data set of AF. The non-heated honey was classified correctly also in this model, while the other groups showed misclassification. These results show, that applied temperature has a higher effect for the absorbance spectra of the honeys. Similar results were obtained for HA honeys, while did not show clear separation in the case of RP honeys, that can be because of its chemical composition and that phase change is not as strong as in the case of the two other types.

Conclusions

Results of the tests of quality indicators of honey samples treated at different temperature and for different time intervals showed that pH of honey changes significantly as a result of heating at 100°C, while change of moisture content - if honeys are heated in glass holders with a closed cup, - and electrical conductivity do not show clear trends. Results of color measurement showed increasing tendency of L* in the beginning and b*, as a results of microcrystal structure changes, while fastened Maillard reaction caused the clear darkening of honeys at high heat treatment levels (80°C and 100°C). HMF content of honeys did not change at an extreme level below 80°C 240 minutes heat treatment, below this level the limit set by EU… was not reached. However changes in composition and phase of the honey was proven by the result of NIRS at lower heat treatment levels. Control honeys were clearly distinguished from heated ones by their NIR spectra, which can be not only because of the chemical changes occurred during heating but also because of the phase change. It is important to know that liquid phase can be elongated with the heat treatment, but later on honeys going to recrystallize, but as a results of heat treatment generate changes in the crystal structure, after recrystallization more rough crystals will be formed, and crystallization defects also could appear. Our study shows that HMF method can only detect extreme high temperature treatment or extreme long heat treatment, because significant increase in HMF content was observed only above 60°C heat treatment while NIR method was sensitive enough to recognize the changes in the phase and composition of honey treated at 40°C heat treatment.

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References

[1] P. M. Da Silva, C. Gauche, L. V. Gonzaga, A. C. O. Costa, és R. Fett, „Honey: Chemical composition, stability and authenticity”, Food Chem., köt. 196, o. 309–323, ápr. 2016, doi: 10.1016/j.foodchem.2015.09.051.

[2] CODEX STAN 12-1981, CODEX STANDARD FOR HONEY. 2001.

[3] 2001/110/EC, COUNCIL DIRECTIVE 2001/110/EC of 20 December 2001 relating to honey, köt. L 10/47. 2001.

[4] R. A. Gleiter, H. Horn, és H. D. Isengard, „Influence of type and state of crystallisation on the water activity of honey”, in Food Chemistry, 2006, köt. 96, sz. 3, o. 441–445, doi: 10.1016/j.foodchem.2005.03.051.

[5] S. Bogdanov, „Liquefaction of honey”, Apiacta, köt. 28, sz. 1, o. 4–10, 1993.

[6] L. P. Oddo és R. Piro, „Main European unifloral honeys: descriptive sheets”, Apidologie, köt. 35, o. S38–S81, 2004, doi: 10.1051/apido.

[7] Codex Alimentarius Hungaricus, 2-100 számú irányelv Megkülönböztető jelöléssel ellátott mézfélék. 2009.

[8] B. Zábrodská és L. Vorlová, „Adulteration of honey and available methods for detection – a review”, Acta Vet. Brno, köt. 83, sz. 10, o. S85–S102, 2014, doi: 10.2754/avb201483S10S85.

[9] Z. Bodor és mtsai., „Effect of heat treatment on chemical and sensory properties of honeys”, Anim. Welf. Etológia És Tartástechnológia Anim. Welf. Ethol. Hous. Syst., köt. 13, sz. 2, o. 39–48, 2018, doi: 10.17205/SZIE.AWETH.2017.2.039.

[10] S. Bogdanov, K. Ruoff, és L. P. Oddo, „Physico-chemical methods for the characterisation of unifloral honeys: a review”, Apidologie, köt. 35, o. 4–17, 2004, doi: 10.1051/apido:2004047.

[11] D. Cozzolino, „7 - Near Infrared Spectroscopy and Food Authenticity”, in Woodhead Publishing Series in Food Science, Technology and Nutrition, M. Espiñeira és F. J. B. T.-A. in F. T. T. and T. Santaclara, Szerk. Woodhead Publishing, 2016, o. 119–136.
[12] S. Bogdanov, „Harmonised Methods of the International Honey Commission”, Int. Honey Comm. IHC, sz. 5, o. 1–62, jan. 2009, doi: 10.1007/s13398-014-0173-7.2.
[13] M. Kędzierska-Matysek, M. Florek, A. Wolanciuk, P. Skałecki, és A. Litwińczuk, „Characterisation of viscosity, colour, 5-hydroxymethylfurfural content and diastase activity in raw rape honey (Brassica napus) at different temperatures”, J. Food Sci. Technol., köt. 53, sz. 4, o. 2092–2098, ápr. 2016, doi: 10.1007/s13197-016-2194-z.

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DIGITALISATION IN AGRICULTURE – FROM THE PERSPECTIVE OF A GLOBAL AGRICULTURAL MACHINERY PRODUCER

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Abstract

The Agriculture is faced with the great challenge of feeding more and more people while resources are running out. We are at the beginning of a paradigm shifts in Agribusiness due to digitization. Digital agriculture is seen as a key to mastering this challenge. Digital products on agricultural machinery are not an invention of recent years, but some have more than 30 years of history. The digitally supported Agricultural machines are working on the fields. By deploying sensors and mapping fields, farmers can begin to understand their crops at a micro scale, conserve resources, and reduce impacts on the environment.

Keywords

Precision Farming, Digital Agriculture, AGCO, device compatibility, data compatibility

1. Introduction

It is undisputed, the Agriculture faces major challenges: By 2050, the world's population will rise to 10 billion, but eating habits will also change. Especially in the so-called emerging economies, there is a trend towards higher-protein food in the form of meat, which in turn causes a greater need for crop production. In addition, there will continue to be a focus on sustainable agriculture. Consumables must therefore be used more consciously and more dosed in order to achieve the maximum effect with these. These facts are generally recognized by the agricultural engineering industry, but can also be found in the annual reports of almost all companies operating in the agricultural sector. In order to be able to meet these challenges in the future, digital agriculture has a key role to play. With the widespread use of digitalization, the human-machine relationship is becoming increasingly important, this topic is examined by Szabó et al [1, 2, and 3]. From the agricultural machine perspective, individual solutions such as automatic steering systems became the standard. It should be noted that the more "tangible" the benefit of a solution is, the adaptation is faster or further advanced on the agricultural machine. The potential for agriculture in the data usage, the big data approach is considered much higher than what has been achieved with on-board technologies so far. Standardization and compatibility between the different machines and systems on the farm are therefore the key to unlocking this potential. New solutions and services will be developed in order to exploit these potentials together with the farmer.

2. Terminology

Digital agriculture is still a young concept. Synonymous terms are agriculture 4.0, smart farming or precision farming, whereby the terms are to be considered evolutionary. The latter term has its origins back in the 90s. Griepentrog differentiates between the terms as follows [4]:

- –Precision Farming focuses on site-specific processing, in which the growth conditions are optimized by means of sensors and application technology
- –Smart Farming adds a level of decision support through fusion and analysis of information.
- –Digital Farming (or Agriculture 4.0 or Farming 4.0) includes the Internet of Things as well as Cloud Computing and Big Data.

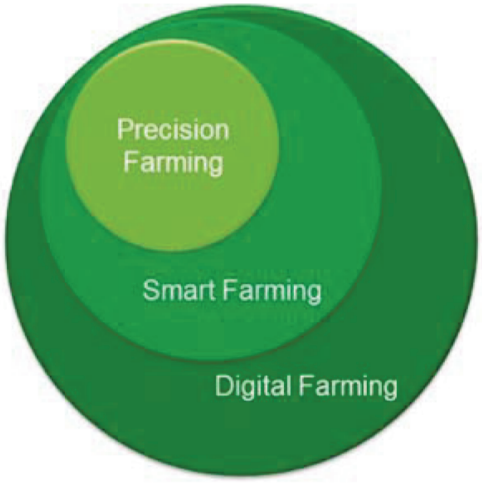


Figure 1. The development of Precision to Digital Farming

3. AGCO's history in Digital Farming

AGCO or its predecessor companies, which today belong to the AGCO Group, have a long and successful tradition in precision farming. Just few examples:

- –In 1984 Massey Ferguson introduced Datatronic 1, the first on-board computer wherein the processed area and diesel consumption by hour or area could be calculated.
- –In 1991, Massey Ferguson launched the yield monitor on MF combines for the first time in the price list commercialized.
- –End of the 1990s, then came on the first automatic steering systems on Challenger track type tractors.
- –Also in the 1990s, Ag-Chem introduced the area-specific application rate control on self-propelled application machines. Nutrients were first applied based on prescription maps.
- –In 1999, an operational telemetry system was first demonstrated on a Massey Ferguson.

In 2013, AGCO bundles its digital farming activities as part of FUSE Technologies. FUSE represents a corporate strategy and the new digital approach of AGCO. Afterwards, the corporate activities are consistently aligned with the new requirements of digital agriculture. Not only technology solutions are development goals of their own, but also Services are made possible based on on-board and off-board technology solutions.

4. Technologies in Use

Although some technologies have been on the market for 30 years or more, their acceptance and distribution is still quite manageable. The biggest breakthrough technology in terms of digital agriculture was the automatic steering systems offered by all major manufacturers in the early 2000s but also by various aftermarket suppliers. Meanwhile, these systems offer a large potential for savings on equipment but also provide increased area performance and enormous driver relief, are almost standard on large AGCO machines. Today, hardly any AGCO/Fendt 700-1000 series tractors are delivered without automatic steering system. The increasing stability due to the technical progress, better integration into the entire vehicle, cheaper electronic components or GNSS technologies as well as the simply, on-hand advantages of the driver relief were positive influencing factors.

The use of steering systems at AGCO is not limited to large tractors. Meanwhile, e.g. Fendt can offer automatic steering system solution on all tractor series from 70 to 650 hp. The Fendt 200 Vario series is now offering an ultrasound solution for fruit and wine growers. This shows that AGCO seeks the best possible integration of technology solutions into its machines. The step from an automatic steering system to an autonomous vehicle seems quite simple from a technical point of view, but there are legal as well as simply practical reasons against it, since the driver is still needed to monitor the work process, the work quality and possibly to optimize it.

Another technology that is now widely used is the Automatic-Section Control. Individual sections will be switched on or off depending on the position. There is widespread use in crop protection spraying, fertilizer technology or even single-grain sowing machines, as the increasing working widths make comfortable and precise switching more difficult. Here, the user can also learn the benefits of SC technology very easily. The average savings potential is about 4.3% based on a Research at Auburn University [5].

The site specific application rate control (VRC, VRT) is considered to have great potential to account for the heterogeneity of a plant population within a plot. The aim is to increase yields and qualities while at the same time adjusting the operating expenses and reducing the environmental impact of these. The area-specific application rate control is still used primarily on large scale farms today, but it is unstoppable spreading in mid-size and smaller farms as well. Since the necessary technical prerequisite already exists on the hardware side due to the automatic steering systems, the step to the partial surface specificity is relatively small. More tractors and implements support this feature, as most modern attachments have software release, thanks to the increasingly widespread ISO 11783 standard called ISOBUS.

Nowadays sensor technology is one of the fastest growing technology area. A sensor is a device capable of detecting a change in the physical or chemical environment which then converts it into electrical signals both electric current and voltage. A number of sensing technologies are used in precision agriculture, providing data that helps farmers monitor and optimize crops, as well as adapt to changing environmental factors including [6]:

–Location Sensors use signals from GPS satellites to determine latitude, longitude, and altitude to within feet.
–Optical Sensors use light to measure soil properties. The sensors measure different frequencies of light reflectance in near-infrared, mid-infrared, and polarized light spectrums. They have for many years offered the possibility of varying the amount of nitrogen during the fertilization process based on the chlorophyll content and the biomass. (Yara N Sensor, Trimble GreenSeeker, Fritzmeier, etc…).
–Electrochemical Sensors provide key information required in precision agriculture: pH and soil nutrient levels.
–Mechanical Sensors measure soil compaction or "mechanical resistance."
–Dielectric Soil Moisture Sensors assess moisture levels by measuring the dielectric constant in the soil.
–Airflow Sensors measure soil air permeability.
–Agricultural Weather Stations are self-contained units that are placed at various locations throughout growing fields.

An increasing number of possible data sources as a basis for the sub-area-specific application rate control will significantly increase the importance in the coming years. For example, under the Copernicus program, the EU offers free Sentinel satellite data. In addition, aerial photography using drones is becoming increasingly popular. Both the drones and the sensors have become much cheaper in recent years and will thus be accessible to a wider audience. The application cards created on the basis of the sensor data can be conveniently and easily exchanged between the machine terminal and a compatible ticket file via mobile-internet in the frame of Order Management Systems like AGCO's VarioDoc / TaskDoc. This will also promote the acceptance of this technology.

5. Standards and compatibility as the key to success

An important factor for the distribution of automatic section control (SC) or even site specific application technology (VRC, VRT) is based on the ISOBUS standard, which enables devices from different manufacturers to implement the technology solution in the overall system of tractor and attachment accordingly. As a result, most of the agricultural equipment manufacturers are registered their products in the Agricultural Electronics Industry Foundation. (https://www.aef-online.org/).

Device compatibility seems to be resolved by adopting and applying the ISO 11783 standard and its chapters.

What about the data compatibility? This topic will be essential to the success of digital agriculture. AGCO relies consistently on the ISOXML standard. There is still the big challenge of the interface, because despite the uniform format there are still different interfaces between the different systems between which data is to be exchanged. This interface maintenance is complicated and expensive. A promising, innovative approach is the DKE agrirouter for the European market. The agrirouter provides universal data exchange platform, fills a gap on the way to digital agriculture. Its underlying concept unites cross-vendor and discrimination-free data transfer. Dataflow is shown in the following figure:

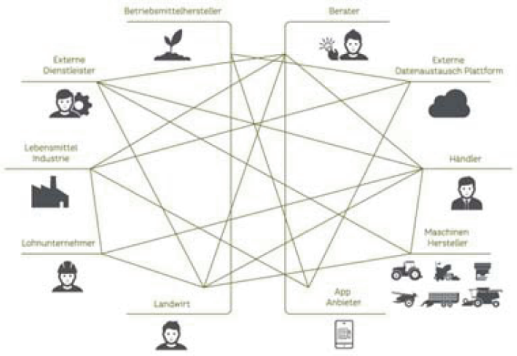


Figure 2. The current situation, dataflow without agrirouter



Figure 3. Dataflow with agrirouter

The main stakeholders:

–Farmers, growers, contractors as users can create a free account at https://my-agrirouter.com and set up his own individual ECO system consisting of

machinery and agricultural software solutions from the beginning of 2019.

– Service providers who are technically involved in the context of the agricultural production process and generates, processes or uses data for Agricultural software and telemetry solutions can join to agrirouter community

– Shareholders. The DKE is a consortium of 10 well-known agricultural machinery companies: AGCO, Amazone, EXEL Industries, Grimme, Horsch, Krone, Kuhn, Lemken, Pöttinger, Rauch, SDF. These companies already have jointly recognized that Farming 4.0 only works if a cross-manufacturer and cross-product data exchange is possible. The consortium is open to further members but only to machine producer companies.

The agrirouter offers a great opportunity to leverage the hidden potential of data stored in a wide range of systems along the value chain. The agrirouter does not save data, it only transfers data. It is guaranteed the privacy.

6. Data privacy and data ownership

The scope and range of available agriculture data is rapidly expanding. This data is being generated, collected, and managed in many forms across agriculture value-chain segments and the potential for this mass of data in its variety, velocity, and volume to impact agriculture is significant. An unprecedented number of choices for integrated systems and solutions have driven the agriculture industry towards the use of data created by computers including but not limited to tractors, combines, environmental sensors, irrigation equipment, grain carts, and unmanned aerial systems. To facilitate the demand for these highly integrated systems and to reap the benefits while reducing risks, it is important to consider how data will be managed. Farm Data has increasing value to farmers. At the same time, farmers are growing more aware of and sensitive to what this data may tell others about their operations. Farmers want transparency regarding the collection, use, sharing options and effective security controls for their data [7].

In the age of broadband internet farmers unintentionally share sensitive information on different platforms. Sometimes it is very risky. The risks also talked about, but not enough and not deep enough. Data protection should be the top priority when using digitally networked farming systems. Site-specific business and business data may only be used if authorized by the farmer. In US the Agricultural Data has become one of the most valuable commodities for agricompanies. The sensitive data has become tradable assets of significant commercial value. Farm data would provide immense benefits for agricultural-tech companies and farmers. Companies could use data on fertilizer usage, irrigation and seed type to improve the ways and regions where they market agricultural products, and better tailor their services to the individual needs of farmers. Farmers would benefit from the increased efficiency that data-based insights could provide. With more access to data would come the ability to improve production. There is already considerable interest in data from the agribusiness industry. Monsanto bought Climate Corp, a company using big data for weather services, for almost $1 billion in 2013, the biggest agriculture-technology deal in history.

It is important to highlight that the data belongs to the farmer, can only decide with whom and to what extent to share such data. AGCO has a clear message toward the farmers: the owner of the data who had generated it during the activity on his field. AGCO declares it in EULA Data Sharing section [8]: “AGCO agrees that you (customer) own any information and data about the machine that is available through the (AGCO’s) Site and Solution.” AGCO splits the data coming off the machine into two different paths like Machine data to be shared and the sensitive Agronomic data. The data is actually handled very differently between those two different areas of focus.

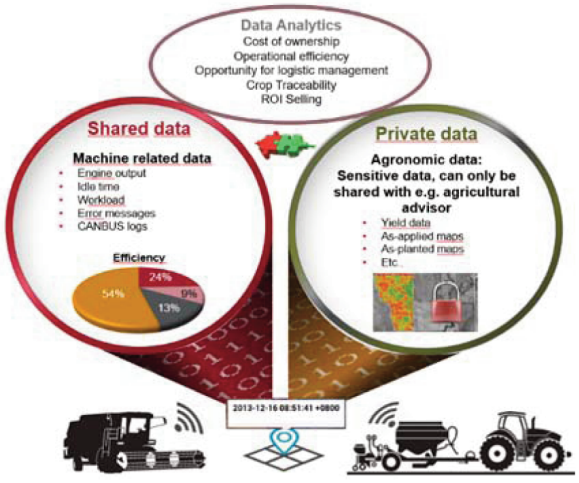


Figure 4. Data ownership model at AGCO

7. Potential developments for the future

Continuous data collection from soil using Sensor technology. Soil conditions are the most important drivers of biogeochemical processes and biological

activity in the soil, which in turn influence ecosystem properties including plant growth and ecosystem carbon exchange. To better understand these linkages automated sensors can continuously monitor a range of soil properties at terrestrial sites. These sensors can measure physical, chemical and biological properties at the soil surface and in the underground environment. The measurement results can be added to a GIS database facilitates the preparation of prescription maps to create real value of farmers and precision farming service providers.

New Services. Since the farmer cannot generate added value automatically for his business with the increasing amount of data, he will in future be dependent on specialists who translate his data into valuable information. Such value-added services can be differentiated into production-related services and machine-related services. The production-related services will relate to data evaluation on crop production. All available data are prepared for the farmer so that a recommendation for action can be derived from it. The machine-related services link to an optimal support of the machines usage targeting the maximum availability. These wide range of services already offered in the market today, such as machines monitored online via contact-centers, as has already been practiced in the construction machinery sector or transport logistic for several years. The success or failure of new services in digital agriculture based on data collected by sensors or machines will depend less on the willingness of the farmer to share the data than on the reliability and simple understanding of the added value for the farmer.

Autonomous vehicles like XAVER on the field. Fendt XAVER, formerly known as MARS (Mobile Agricultural Robot Swarm), is a concept where small, swarming robotic units use a cloud solution to plan, monitor and accurately document the precise planting of corn. Key technologies include satellite navigation and data management in the cloud, allowing 24/7 permanent data access. A key element of the XAVER project is the intelligent management of the deployed robots. For example, a Fendt robot system consists of 6–12 units, and can therefore attain an area coverage of around 1 ha/h. Each robot is in constant communication with the control intelligence. Data buffering and redundant communication helps covering breaks in the network coverage. Due to the exact mapping of the deposited sowing unit follow-up work can be carried out highly precisely matched to the individual plant. Thus, the approach has great potential in terms of resource conservation and environmental protection. The low weight of the sowing unit is also extremely gentle to the soil.



Figure 5. Model of AGCO/Fendt XAVER

Setting new interfaces and standards. This is the fundamental basis for serving the data needs of customers with a mix-fleet. Unfortunately we are still far from the ideal world, more efforts and collaboration required.

Conclusion

Although the first digital agriculture solutions were already on the market in the 1990s, the sector has only experienced a veritable boom in the recent years. Here, the configurations are still such that digital solutions are built on existing machines today and integrated. However, the XAVER approach clearly shows that in the future digital solutions will also influence the overall design of an agricultural machine. New service offerings based on big data will also change the process landscape in agriculture. It can be assumed that these developments are currently still at the beginning.

References

[1] Szabó I., Hushki M., Bártfai Z., Kátai L.: 2017. Operator's behaviour measuring methodology inside off-road vehicle cabin operator's focusing scheme In: Agronomy Research, Volume 15. No. 5. 2017. p. 2172-2182.ISSN1406-894X, https://doi.org/10.15159/AR.17.033

[2] Szabó I., Hushki M., Bártfai Z., Lágymányosi A., Kátai L.: 2018. Modelling of operator's focusing scheme along working hours: Windrowing and cultivating operations. In: Agronomy Research, Volume 16. No. 4. 2018. p. 1885-1895. ISSN 1406-894X https://doi.org/10.15159/AR.18.155

[3] Szabó I., Hushki M., Bártfai Z., Kátai L.: 2019. Modelling of operator's focusing scheme along working hours: harvesting operation. In: Agronomy Research, Volume 17. No. 1. 2019. p. 271-280. ISSN 1406-894X, https://doi.org/10.15159/AR.19.026

[4] Griepentrog H.W.: 2017. Smart Crop Farming; Landwirtschaftlicher Hochschultag, Landinfo 3/2017

, pp 13-14
http://www.landwirtschaft-bw.info/pb/site/pbs-bw-new/get/documents/MLR.LEL/PB5Documents/lel/Abteilung_1/Landinfo/Landinfo_extern/2017/03_2017_HT/Griepentrog_Landinfo3-17.pdf
[5] Winstead A., Fulton J., Mullenix D.: 2010. Considerations for Adopting & Implementing Precision Ag Technologies; Cornell Precision Agricultural Series.
http://nydairyadmin.cce.cornell.edu/pdf/submission/pdf161_pdf.pdf
[6] Schriber S.: 2019. Smart Agriculture Sensors: Helping Small Farmers and Positively Impacting Global Issues, Too; Sensor Technology on Mouser Electronics homepage;
https://www.mouser.co.uk/applications/smart-agriculture-sensors/
[7] AgGateway: 2017. Data Privacy and Use White Paper Version 1.2 Updated: March 31, 2017; Scope and Definition of Farm Data Management and Use; pp 4
[8] AGCO: 2019. FUSE Data Privacy – Telemetry and Task Data EULA;
https://www.fusesmartfarming.com/telemetry-and-task-data-eula/

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MATHEMATICAL MODELLING OF CYLINDRICAL CHIMNEY EFFECT IN SOLAR DRYER

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Abstract

A simple mathematical model of a solar chimney is proposed for the solar dryer. The physical model was made with a cylindrical channel. Outer surface of the chimney is provided with black paint which absorbing solar radiation to heat up the air inside the chimney. Openings provided at the bottom and top of the chimney allow moist air to enter from the drying chamber and leave the channel. Steady state heat transfer equations were set determining the heat transfer coefficient and the air flow in the chimney. The thermal performance of the solar chimney as determined from the surfaces, air temperatures, and air mass flow rate are presented.

Keywords

buoyancy effect, heat transfer, natural convection, solar chimney

Introduction

The systematic use of renewable energy reduces the dependency on energy supply from conventional energy sources. Solar energy can be used directly (photovoltaic cell, solar thermal collectors) or indirectly (passive cooling technique) to convert into usable source of energy. The concept of solar energy use in the chimney was proposed in 1960 by Trombe and Michel at the C.N.R.S. laboratory in France [1]. Natural convection solar dryers are normally reported poor in performance than forced solar dryers. The poor ventilation in the natural dryer leads to exceed the required temperature in the drying chamber, which in turns burn the crop instead of drying. This problem is overcome and enhanced by introducing the chimney on top of the drying chamber. The presence of solar chimney has shown its benefit in accelerated movement of moist air from the drying chamber and thus reducing the drying time for intended products. Ventilation by natural convection makes use of the fact that hot air has lower density than cold air and thus tend to rise.

The solar chimney is designed to sustain a smooth flow of air inside the solar dryer device, which use incident solar radiation. Its performance is primarily described by the induced airflow rate and air temperature in the channel. Fisher and Torrance 1999 [2] reported experimental results of chimney enhanced heat transfer from a vertical parallel plate heat sink. Their result showed that chimneys prove significant heat transfer enhancement. [3] developed a solar chimney-based drying system with the porous absorber to check the heat transfer and air flow in the system. They found a correlation between the airflow speed and the temperature difference between the outlet and the inlet due to the natural ventilation enhanced by the chimney. To enhance the performance, a solar chimney is suggested with possible chimney height, solar radiation, equal inlet and outlet, ambient air temperature, a height/gap ratio, and a solar absorber with larger absorptivity and emissivity [4]. A comparison of thermal behavior of a solar chimney with a conventional one reported by Afonso and Oliveira, 2000 [5]. In their study, thermal model and simulation on a solar chimney were applied with the assumption of unsteady state one-dimensional heat transfer using a finite difference model to the chimney brick wall and allowing heat transfer coefficients to vary along the chimney height. Their results showed that there was a significant increase in ventilation rate with the solar chimney

than a conventional one. A steady state mathematical model for a solar chimney was developed by Bansal et. al. in 1993 [6]. The system consists of a solar collector connected to a conventional chimney. The result showed that a collector area of 2.25 m^2 was able to induce an air flow rate of between 140 (m^3/hr) to 330 (m^3/hr) at a solar radiation of between 200 (W/m^2) to 1000 (W/m^2), respectively.

According to the passive passive convection application by using a chimney system, determination of heat transfer coefficient and Nusselt number are important in the investigation of free convection, mathematical simulation and application of the system. The determination of the correlation between Nusselt, Grashof and Rayleigh numbers in the vertical duct has been carried out in many research studies [7]. Heat transfer processes in solar chimney involving: internal convection heat transfer, external heat transfer to the surrounding and conduction heat transfer. This paper studies heat transfer processes on solar chimney part of the indirect passive solar dryer applying a simple mathematical approach.

System description and mathematical model

The indirect passive solar dryer with the chimney under investigation is schematically shown in Fig. 1 (a) and Fig. 1 (b) is the complete structure of a chimney under investigation. The system of 4.20 m high consists of a cylindrical chimney, a drying chamber, and a solar air collector. The chimney was firmly fixed onto sloping metal base and mounted on the drying chamber. A metal cap was fixed onto the top of the chimney to keep out the rain. A sufficient duct length is considered to ensure thermally fully developed condition at the duct outlet. The chimney outside surface was painted matt black (absorptivity 0.87 and emissivity 0.9) to obtain elevated temperature to improve air flow and increase buoyancy or "chimney effect". This is because the absorber surface absorbing more solar radiation when radiated on the surface [8]. Khanal and Lei in 2010 [9] found that the airflow rate is enhanced with a higher surface emissivity applying numerical study. These two studies showed that the heat transfer by radiation cannot be ignored for a solar chimney. Moist air enters the chimney inlet with a temperature equal to the temperature of air in the drying chamber and assumed constant. Heated moist air at the outlet temperature from the top of the chimney. Temperature of the chimney wall and mean moist air in the chimney are all assumed to be uniform. Resistance to flow due to friction along the surfaces are assumed negligible.

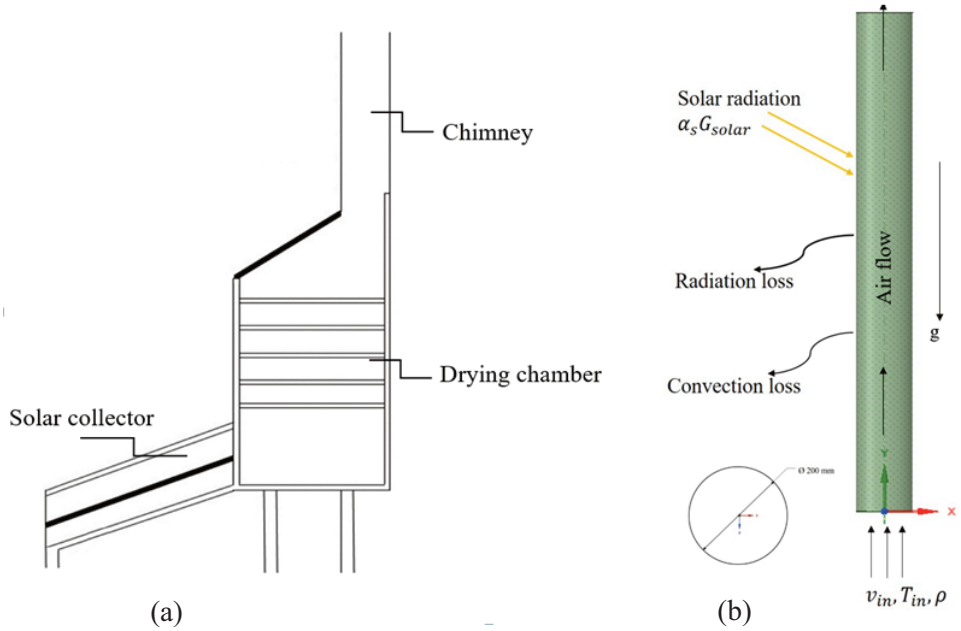


Figure 1. (a) Schematic diagram of a solar chimney dryer; (b) model of a solar chimney.

The value of the heat transfer coefficient for internal and external portion of the chimney treated separately. The heat transfer through the wall of the chimney cause buoyancy-driven flow. Assumption were made as steady operating condition exist, constant heat flux at the wall, uniform inlet velocity from the drying chamber, and the physical properties of moist air were to vary linearly with temperature

and evaluated for conditions at duct inlet. Sky temperature, ambient temperature and solar daily radiation are taken as average values from environmental weather data. The chimney inlet temperature and airflow rate are also known. The boundary conditions for these difference equations for constant heat flux from the wall to the moist air is given at chimney inlet condition.

$$y = 0; \qquad u(0,y) = V_{in};$$

$$T(0,y) = T_{in}; \qquad \rho = f(T,x)$$

The mathematical equations governing natural convection flow and heat transfer in a vertical, cylindrical chimney are the Navier-Stokes equations and the energy Eq. (1). Choosing the origin at the outlet of the drying chamber or at the bottom plane of the chimney, the y axis is directed vertically upward along the length of the chimney. The governing equations under the assumptions stated in the last section are:

$$\frac{1}{r}\frac{\partial ru}{\partial r} + \frac{1}{r}\frac{\partial v}{\partial \emptyset} + \frac{\partial w}{\partial z} = 0, \tag{1a}$$

$$-\frac{v^2}{r} = G_r - \frac{\partial P}{\partial r} + \upsilon\left(\nabla^2 u - \frac{u}{r^2} - \frac{2}{r^2}\frac{\partial v}{\partial \emptyset}\right), \tag{1b}$$

$$-\frac{uv}{r} = G_\emptyset - \frac{\partial P}{r\partial \emptyset} + \upsilon\left(\nabla^2 v - \frac{v}{r^2} + \frac{2}{r^2}\frac{\partial u}{\partial \emptyset}\right), \tag{1c}$$

$$G_z - \frac{\partial P}{\partial z} + \upsilon(\nabla^2 w) = 0, \tag{1d}$$

$$u\frac{\partial T}{\partial r} + \frac{v}{r}\frac{\partial T}{\partial \emptyset} + w\frac{\partial T}{\partial z} = \alpha\left[\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial T}{\partial r}\right) + \frac{1}{r^2}\frac{\partial^2 T}{\partial \emptyset^2} + \frac{\partial^2}{\partial z^2}\right],$$

$$where\ \alpha = \frac{k}{\rho C_p}. \tag{1e}$$

From Eq. (2), the net rate of solar energy absorbed by the surface of the chimney is calculated as the difference of heat gain and heat losses from the surface. The heat transfer loss from the outside surface of the chimney to the ambient is due to the convection and radiation transfer. The convective and radiative heat flux are calculated respectively from Eq. (4) according to Newton's law of cooling, and in Eq. (5).

$$q_{net} = q_{gain} - q_{loss} \tag{2}$$

The heat gained from the solar radiation to the surface of the chimney is:

$$q_{gain} = \alpha_s G_{solar}. \tag{3}$$

The convective heat flux from the surface to the ambient air according to Newton's law of cooling:

$$q_c = h_o(T_s - T_a). \tag{4}$$

The radiation heat flux is:

$$q_r = \varepsilon\sigma\left(T_s^4 - T_{sky}^4\right). \tag{5}$$

The net rate of energy absorbed by the surface of the chimney is then written as:

$$q_{net} = \alpha_s G_{solar} - \left[\left(\varepsilon\sigma\left(T_s^4 - T_{sky}^4\right) + h_o(T_s - T_a)\right]\right. \tag{6}$$

Sky temperature T_{sky} can be estimated from Eq. (7) [10].

$$T_{sky} = 0.0552T_a^{1.5}. \tag{7}$$

The analysis was based on the dimensionless numbers commonly used in natural convection processes. The local Rayleigh, Prandtl and Nusselt numbers are calculated, respectively. The solution of the governing conservation equations in their dimensionless form depends on the Rayleigh number based either on the chimney height:

$$Ra_L = Gr_L Pr = \frac{g\beta\Delta TL^3}{v^2}Pr, \tag{8}$$

where Prandtl number is given as:

$$Pr = \frac{C_p\mu}{K}. \tag{9}$$

Heat transfer coefficient calculation

The procedure for calculating local heat transfer coefficient inside and outside the chimney surface Eq. (8) and Eq. (10) are applied. The air density inside the system is depend on air temperature and humidity ratio of moist air entering at the chimney inlet and expressed by Eq. (10)[11]. The nature of heat transfer either forced or natural is checked by the ratio of Grashof number to square Reynold number. During the calculation of the heat transfer coefficient we have to take into consideration that the black painted heat absorbing surface heats the ambient air, instead of direct exposure to solar radiation.

$$\rho = \rho_o\left[\frac{1}{1+{}^{T}/_{273}}\right](1+x). \tag{10}$$

The heat transfer processes taking place on the external surface of the chimney are rather more complex than is the case for the inside surface coefficient. Radiation heat transfer does have a part to play. The surface of the chimney will exchange heat by radiation to the surrounding environment, and the convective heat loss will be affected by the prevailing wind speed. The effect of wind speed was neglected in this case.

The local Rayleigh number and more specifically the Grashof number, where $Gr_L = Ra_L/Pr$ is usually used in heat transfer for the definition of the flow regime to be laminar or turbulent. Ra is < 10^8 indicate

a buoyancy-induced laminar flow, with transition to turbulence occurring over the range of $10^8 < Ra > 10^{10}$. An important characteristic of the flow is the rate of heat transfer through the chimney surfaces. Using Newton's law of cooling for the local convection coefficient h the Nusselt number for free convection from outer and inner chimney walls may be expressed by Churchill and Chu [12] Eq.11.

$$Nu_L = \frac{hL}{K} = \left\{0.825 + \frac{0.387Ra^{1/6}}{\left[1+(0.437/\mathrm{Pr})^{9/16}\right]^{8/27}}\right\}^2 \quad where\ h = \frac{q}{\Delta T}\ and\ q = \int \frac{\partial T}{\partial x} dy \cdot \qquad (11)$$

The air properties in Eq. (8) and Eq. (9) are evaluated at the film temperature written as a function of the bulk temperature, that is, for internal chimney and external chimney written as $T_{film_i} = (T_s + T_i)/2$, and $T_{film_o} = (T_s + T_a)/2$ respectively. The values of thermal conductivity, Prandtl number and kinematics viscosity were reading directly for table given in any heat books.

Results and discussion

Knowledge of the climatic conditions and availability of solar radiation is a prerequisite in solar drying. Fig. 2 presents the average hourly solar radiation measured during the four days. It can be seen that higher radiation occurred between 11:00 to 12:00. This gives a higher temperature observed in the solar chimney and air velocity through the dryer was thus improved; which resulted in a lower temperature rise in the drying chamber. therefore, covering of the external surface of the chimney with black painted improved the thermal performance the system. Fig. 3 demonstrate the outlet airflow velocity along the chimney height with CFD analysis based on finite volume method under steady state condition. This result showed the chimney height with thermal input from the sun can enhance the movement of air inside the system.

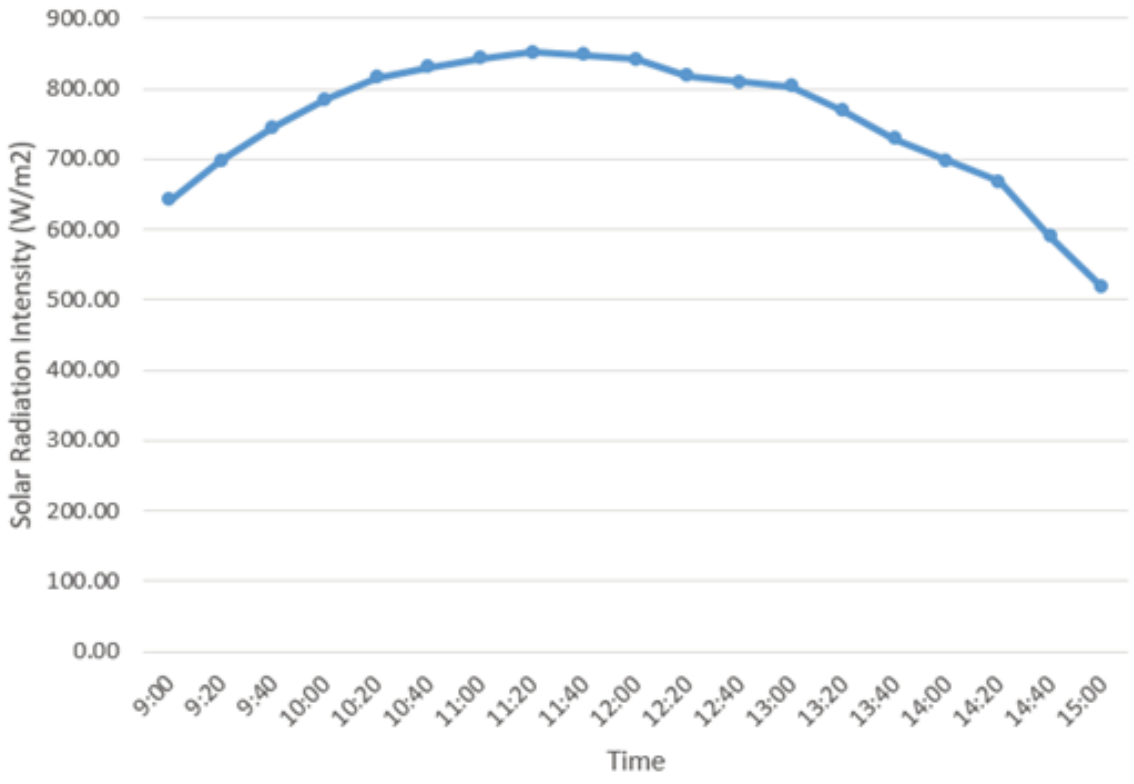


Figure 2. Average hourly solar radiation incident.

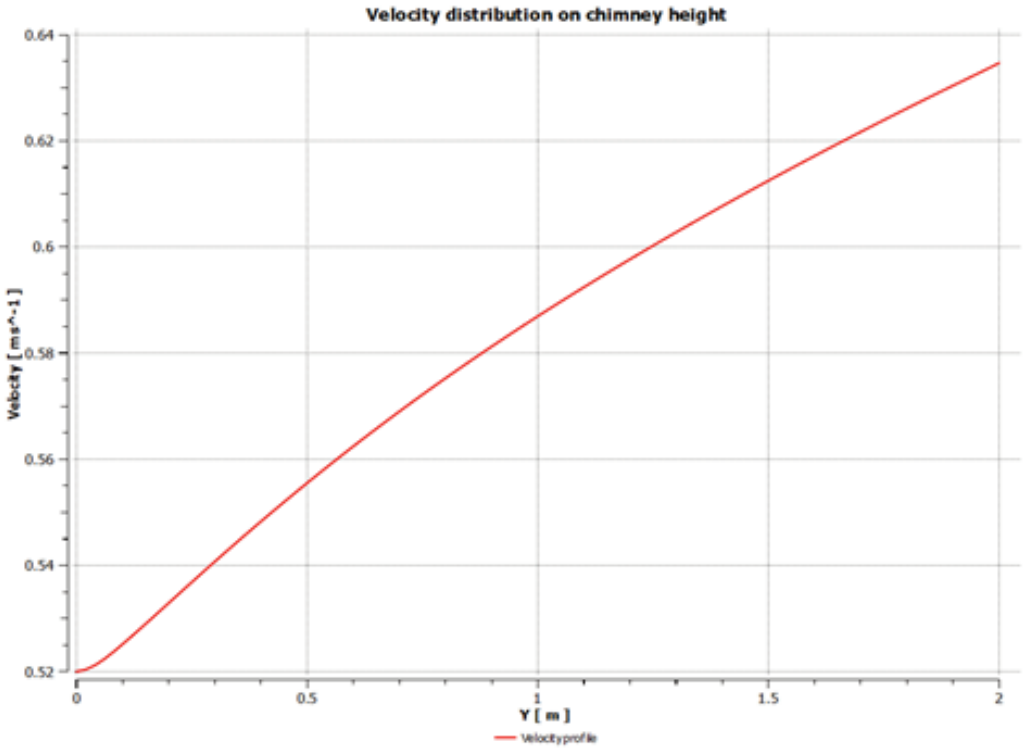


Figure 3. Variation of airflow velocity along the chimney height.

Conclusions

In this study, the comparative analysis of heat transfer coefficient for a solar chimney applied in solar drying application analysed using a simple mathematical model. The result showed that the chimney with black painted outer surface enhanced the absorbability of solar radiation in the surface. This in turns increased the temperature of the moist air inside the chimney. Moreover, the airflow rate increased along the chimney height. The performance of a solar chimney has been predicted using a simple model. Most heat transfer correlations in natural convection are based on experimental measurements. Therefore, further studies on experimental work is in progress.

Nomenclature

V_{in}	airflow velocity at inlet	ms^{-1}
T_{in}	moist air temperature at the inlet	K
G_{solar}	solar radiation incident	W
k	thermal conductivity of air	$Wm^{-1}K^{-1}$
Cp	specific heat capacity of air	$Jkg^{-1}K^{-1}$
T_s	chimney wall temperature	K
T_{sky}	sky temperature	°C
T_a	ambient temperature	°C
h_o	outside heat transfer coefficient	Wm^2K^{-1}
g	gravitational acceleration	ms^{-2}
x	humidity ratio	
N_u	Nusselt number	
RaL	Rayleigh number	
Gr_L	Grashof number	
P_r	Prandtl number	

Greek Letters

ν	kinematic viscosity	m^2s^{-1}
μ	dynamics viscosity	$kgm^{-1}s^{-1}$
ρ	moist air density	kgm^{-3}
ρo	air density	kgm^{-3}
σ	Stephan-Boltzmann constant	$5.67*10^{-8}$ $Js^{-1}m^{-2}K^{-4}$
β	coefficient of volume expansion	K-1
ε	surface emissivity	
α_s	surface absorptivity	

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References

[1] Edward, M., (1979), The passive solar energy book, Rodale press, Emmaus, PA.

[2] Fisher, T.S. and Torrance, K.E., (1999), Experiments on chimney-enhanced free convection, Journal of heat transfer, 121(3), pp. 603-609.

[3] Chen, W. and Qu, M., (2014), Analysis of the heat transfer and airflow in solar chimney drying system with porous absorber, Renewable Energy, Vol. 63, pp. 511-518.
[4] Shi, L., Zhang, G., Yang, W., Huang, D., Cheng, X. and Setunge, S., (2018), Determining the influencing factors on the performance of a solar chimney in buildings, Renewable and Sustainable Energy Reviews, Vol. 88, pp. 223-238.
[5] Afonso, C. and Oliveira, A., (2000), Solar chimneys: Simulation and experiment, Energy and Buildings, Vol. 32(1), pp. 71-79.
[6] Bansal, N.K., Mathur, R. and Bhandari, M.S., (1993), Solar chimney for enhanced stack ventilation, Building and Environment, Vol. 28(3), pp. 373-377.
[7] Ostrach, S., (1952), An analysis of laminar free-convection flow and heat transfer about a flat plate parallel to the direction of the generating body force, National Aeronautics and Space Administration Cleveland Oh Lewis Research Centre.
[8] Lee, K.H. and Strand, R.K., (2009), Enhancement of natural ventilation in buildings using a thermal chimney, Energy and Buildings, 41(6), pp. 615-621.
[9] Khanal, R. and Lei, C., (2010), Numerical investigation of the ventilation performance of a solar chimney, ANZIAM Journal, 52, pp. 899-913.
[10] Fudholi, A., Sopian, K., Ruslan, M.H., Othman, M.Y. and Yahya, M., (2011), Thermal efficiency of double pass solar collector with longitudinal fins absorbers, American Journal of Applied Sciences, 8(3), pp. 254-260.
[11] Ekechukwu, O.V. and Norton, B., (1997), Design and measured performance of a solar chimney for natural-circulation solar-energy dryers, Renewable energy, 10(1), pp. 81-90.
[12] Cengel, Y.A., Klein, S. and Beckman, W., (1998), Heat transfer: a practical approach, Vol. 141, McGraw-Hill, New York.

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THE CIRCULAR ECONOMY IN SOUTH KOREA. THE CASE OF SAMSUNG

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Abstract

This research applied a qualitative research approach in order to define the level of involvement of South Korea in the circular economy. As a case study, a strategy toward the circular economy of Samsung, one of the largest Korean multinational companies, was considered. The research results concluded that the country puts significant effort in order to achieve its goals in sustainable development. The main players are the government and private companies. The main means that help the country to implement the circular economy are government policies and technological development. However, the results show that it is hard to say that South Korea lives in the circular economy.

Keywords

Circular economy, South Korea, Samsung

1. Introduction

Through the years our economy and the environment have undergone enormous changes. As a result of changes, we are faced with problems that make us rethink our actions. For a long time, our economy has followed a linear economy model, which means producing a product and throwing it away after use. The linear economy is also referred to as "take-make-use-dispose" [7]. The last step is disposal, in other words, the product becomes waste. One of the traditional methods of waste management is landfilling. The landfill has a direct impact on the environment, as it pollutes the soil and, for example, toxic materials from waste are absorbed by groundwater and pollute them [6].

Circular economy is a regenerative system where resource input and waste, as well as emissions and energy leakage are minimized by aiming towards closed material loops [15]. Consequently, a circular economy produces significantly less waste than a linear economy. The products can be restorative thus the whole economy is able to be regenerative [7]. To simplify, the "dispose" phase in the linear economy will be replaced by the "take" phase in the cyclical economy. Ultimately, the circular economy aims to remove non-recyclable waste and recycle waste as raw materials. For the development of a circular economy, the foundation should be long-term design, maintenance, reuse and recycling [2].

Many countries seek to develop circular economy. According to OECD, in 2013 South Korea (hereinafter - Korea) had the second highest recycling rate country in OECD countries [8]. The linear approach to industrialization has been successful in Korea for decades. Korean Gross Domestic Product (GDP) currently holds a relatively high place in the world. It also has a very high Human Development Index (HDI), which is used as a general indicator of the quality of life in the world. However, since Korea faces limited natural resources, it needs to replace the linear approach to industrialization with a circular economy, a new economic model [4].

This brief research tries to define how deep Korea is involved in the circular economy. Due to the nature of the study a qualitative research approach was chosen, because this method allows to have a deeper understanding of the research area.

2. The circular economy policy in South Korea

Various policy instruments have been adopted by Korea to turn the linear economy into a circular one.

Although each tool seems to be independent of each other, all tools are emphasized by common motivation.

Recognizing that climate change is affecting the whole world, Korea has taken significant steps to move towards a circular economy. According Jin [4] selected examples of historical, legislative, and country-specific actions can be classified into

–Target Management System (TMS);
–Resource Efficiency Program (REP);
–Energy Recovery Program (ERP);
–Recycling Technology Program (RTP);
–Emissions Trading System (ETS).

Target Management System is closely linked to the reduction of GHG (greenhouse gas) emissions per capita and, thus, is the basis for overall mitigation efforts. The TMS workflow is governed by the Low Carbon Growth Fundamental Law and the Goal Management Framework. The sectors that account for most of the emissions are identified as a starting point. Then controlled entities are designated for such sectors. They report previous emissions to supervisory departments. Supervisory departments and the Greenhouse Gas Inventory and Research Center of Korea (GIR) review reports for double counting or omissions. They set GHG emissions targets for a particular facility. Controlled entities then submit implementation reports to achieve mitigation goals. They also submit emission reports to show annual emissions. Both emission reports and implementation reports are first checked by third-party inspection institutes and then checked by supervisory departments. Finally, these reports are submitted to the GIR. If their implementation reports do not comply with audit report verification standards, corrective measures can be applied to controlled entities. The whole process takes place through the national GHG management system. This system collects data related to GHG emission statistics for a specific facility. Through the system, supervisory departments can access GHG emissions data reported by controlled entities. Since TMS was created only in 2012, it may take several years to confirm that TMS is effective in achieving the medium-term goal of mitigation [4].

Resource Efficiency Program is trying to control the amount of raw materials used to convert energy to GDP. Reducing the use of resources can reduce greenhouse gas emissions. In this sense, REP corresponds to a reduction in the energy intensity of the economy. To this end, REP is trying to implement a more efficient manufacturing process and /or recycle resources. REP seeks to facilitate products embodying less resource input. For example, energy savings can lead to lower energy costs, but will be accompanied by additional costs for the implementation of an energy-efficient process. Savings in financial costs for energy consumers can be achieved when the former more than compensates for the latter. To fulfil this condition, REP provides incentives to manufacturers to increase the efficiency of their products. REP also encourages consumers to buy more energy-efficient products on the market [4].

One of examples of recycling resources can be Repaper Inc. Repaper is a Korean company, which design and develop paper cups [10]. In 2018 the company invented a new paper cup which can be recycled. According to the Repaper [10], generally a paper cup is not biodegradable because it is coated with polyethylene which is plastic. Therefore, it cannot be recycled as paper or cardboard, nor composted. Paper cups cause a huge amount of non-recyclable waste. Repaper has developed a technology to coat the cup without plastic. This new paper cup has received several patents in e.g. South Korea, U.S.A and Europe. In addition to the cup, the technology can be applied to the other disposable products [10].

As a part of REP, the Energy Efficiency Standards and Labelling Program has been in use since 1992. Marking at seven target positions shows the energy efficiency level of the model from one to five. The Certification of High Efficiency Energy-using Appliance Program was implemented, where energy-consuming products with a relatively high level of energy efficiency were certified. Government organizations must use certified products. An energy-saving program for office equipment and consumer electronics, a voluntary partnership between the government and manufacturers, has also been used since 1999. Energy-saving products are certified if they comply with the Korea Energy Management Corporation (KEMCO) energy efficiency guidelines. One standard is to automatically switch to power-saving mode when not in use. Warning labels apply to products that do not comply with the standard [4].

Another program highlighted by Jin [4] is Energy Recovery Program which closely related to the carbon intensity of the energy mix. Carbon intensity can be reduced when energy is recovered from waste. The goal of ERP is to increase the demand and supply of energy from waste. With an energy mix dominated by fossil fuels, Korea's greenhouse gas emissions rose by 39% from 2000 to 2013, the second-highest growth rate of OECD countries over the period. Korea now ranks as the OECD area's fifth-largest GHG emitter, up from ninth place in 2000, and if current trends continue GHG emissions will have

tripled by 2030 from 1990 levels [9].Therefore, the deployment of energy recovery is one of the key priorities for achieving a circular economy. Expanding the use of energy from waste is the most effective strategy for going beyond oil. The national green growth strategy aims to increase the share of renewable energy.

The Republic of Korea is a resource-limited country, accounting for 94% of energy consumption from imports from abroad, and yet it is the 9th largest energy consumer in the world. This internal problem of the structure of energy supply and demand in Korea makes it vulnerable to external environmental changes, such as rising oil prices. Against this challenge, the Korean government has set a priority energy on renewable energy. To replace nuclear and coal energy, the government announced a higher renewable energy generation goal, from 7% today to 20% by 2030. To achieve this, Korea must install an additional 53 GW of renewable energy, mainly solar PV and offshore wind energy by 2030, which together will total 68 GW [5].

Recycling Technology Program focuses on developing advanced recycling technologies. Smart litter bins in Seoul can be mentioned as example of successful implementation of the program. Seoul is the capital and largest city in South Korea with population around 10.29 million people. Therefore, litter bins fill up very quickly at all time of the day, which makes it difficult to keep the streets clean. A local company, Ecube Labs, found the solution: an innovative litter bin that compacts its contents with a solar-powered compressor. This technology allows containers to store up to four times as much waste before emptying it. Unlike the traditional method of collecting general waste and recycling materials, this method allows to control containers thanks to technologies such as IoT (Internet of Things), which allowed Seoul to reduce waste collection costs by 83% and eliminate the problem of overfilled containers. It also reduced the frequency of waste collection tasks by 66%, and the degree of recycling increased by 46%. Reducing traffic with fewer collection visits helps reduce carbon emissions and other emissions. And this, in turn, raises public awareness about the use of renewable energy sources. In addition, the recycling bins have reduced food waste by about 10% in the capital. Some food waste containers also have the special function of converting organic waste into compost. This material is then used in public gardens or transferred to farmers [13].

The main objective of the Emissions Trading System is to achieve the goal of greenhouse gas emissions in a cost-effective manner. ETS is a distinguishable market policy tool. If a company needs a higher cost for voluntary mitigation, it can buy emission permits in the market. On the other hand, if a company requires relatively lower mitigation costs, it can sell additional emission permits for profit. Thus, ETS helps to more effectively achieve the national goal of reducing greenhouse gas emissions. Companies provide strategic choices through the ETS: direct easing, trade permits, external easing and/or borrowing permits. The company can strategically choose the most profitable way with the least cost. Thus, companies within the ETS can flexibly respond to changes in the global carbon market [4].

Even before the introduction of the mandatory ETS, Korea actively used trade mechanisms, and since 2005 it has been participating in the Clean Development Mechanism (CDM). CDM allows emission reduction projects in developing countries to receive certified emission reduction credits (CER). Each CER is equivalent to 1 ton of CO2. Korean investment companies own CERs and sell them to other country on the market. In addition, the Korea Certified Emissions Reduction (KCER) was introduced in 2005. The KCER market is open to firms that have reduced their CO_2 emissions by more than 500 tons per year. KCER can also be sold on the market [4].

Government support toward sustainable development by its regulations and policies lets the country improve its position in term of environmental issues. For better understanding of circular economy of South Korea SWOT analysis was applied.

Strengths:

–Economic development of the country which facilitates capital accumulation to invest into a circular economy;
–One of the highest rates of state investments in science and R&D;
–Governmental control and regulation;
–Excellent level of industry-academia partnership. Often Korean companies and universities work together on R&D projects.
–High level of technological development.

Weaknesses:

–Lack of natural resources;
–Strict regulations might hurt business or push companies to move their activities abroad;
–Usually activities related to circular economy are capital intensive;
–Sustainability requires time.

Opportunities:

–Government's policy for encouraging IT investment and R&D;
–Emerging environmental awareness and long-term plans;
–Advanced technology;
–Existing organizations and initiatives in maximization of resource efficiency and minimization waste generation.

Threats:

–Rapid changes in environment, therefore further reinforcement of environmental policies in the world;
–Deception of companies in terms of meeting government requirements.

3. Samsung in the circular economy

Samsung Group is a South Korean group of companies, one of the largest chaebols, founded in 1938. Known in the world market as a manufacturer of high-tech components, including full-cycle production of integrated circuits, telecommunications equipment, household appliances, audio and video devices. The main office of the company is located in Suwon [14].

Samsung is a major player in outward FDI in South Korea, and also the largest exporter of goods from South Korea, accounting for about one sixth of the total value of exports, which exceeds all exports from midsize emerging economies such as South Africa, Argentina or Chile [1].

As one of the main players of Korean economy Samsung Electronics is working towards moving to a circular economy to protect the environment and make more efficient use of resources. Going beyond the practice of single-use resources and throwing them away, Samsung is working to ensure that resources are reused through recovery, reuse and recycle at the end of the product's life [12].

Samsung has made great strides in reducing e-waste and achieving a circular economy. The company conducted at least a couple of recycling promotion campaigns and established Samsung's Galaxy Upcycling program. Recycling and upcycling are two different concepts. The first is aimed at the processing of raw materials from old products and the use of these materials in new devices. The latter aims to reprofile existing products, such as Galaxy smartphones, and use this processing power in various ways [11].

According Mark Newton, head of corporate sustainability at Samsung Electronics America, a medical device built from an old Galaxy smartphone, capable of screening for eye diseases, is a prime example of how old hardware can be repurposed with the help of custom software. If a real product based on this concept would exist, it could prove useful in countries with emerging economies, where healthcare diagnostic tools may be in short supply [3].

The company abandons the previous structure of resource consumption when resources were thrown away after a single use, and performs various actions, that consider closed-loop recycling, which recovers, recycles, and then reuses used resources. One example of Samsung's recycling efforts is the Asan Recycling Center, which was created and operated by Samsung. All base metal and plastic that comes from the recycling center is reused in the electronics industry. Since its founding in 1998, the Asana Waste Recycling Center has been engaged in the recycling of electronic waste. In 2018 369,000 units of refrigerators, air conditioners, washing machines and IT devices were recycled, as a result of which 25,207 tons of base metals (steel, copper, aluminum, etc.) and plastics were recycled. Plastic from electronic waste, sorted at the Asan Waste Recycling Center, is supplied to plastics manufacturers who reformulate them for reuse. Using a jointly developed technology, Asan Recycling Center has created a closed-loop recycling system that allows the use of renewed plastic in Samsung products. 2,743 tons of renewed plastic produced using this reuse system in 2018 were used in Samsung production. Copper is separated from the main components (wires, compressors, etc.). It is recycled and used to manufacture other electronics. Another example is cobalt, which is one of the main resources used in mobile phone batteries [12].

The amount of waste generated during product development during the manufacturing process is significant. For complex electronic devices with many components, even packaging is thrown away for each piece. At the end of the project, many of the pilot products used to improve the product go to waste. If all of them are burnt or buried, the environment will be polluted, and resources depleted. Samsung is one of the biggest e-waste collectors in the world — it has taken back more than 1 billion pounds cumulatively in the United States since 2008, although it needs to be mentioned that these are not just mobile phones. Samsung makes everything from refrigerators to televisions, which are far heavier although getting lighter with each new model. Its long-term goal is to take back more than 15 billion pounds of electronics globally by 2030 [3].

Nowadays pollution of marine by plastics, microplastics, and other problems associated with

plastics have become a hot topic of discussion around the world. Therefore, Samsung Electronics has established a policy for environmentally friendly packaging and is replacing the disposable plastic materials used in product packaging with paper, bioplastics or other environmental materials. Bioplastics are environmentally friendly plastics with a lower fossil fuel content using starch, sugarcane and other biomaterials [12].

Also, in response to the increasingly serious global water crisis and as part of company's efforts to protect the environment, Samsung Electronics has launched the 3R (Reduce, Reuse, Recycle) strategy for water. They prevented wasted water by replacing old valves to prevent leaks and developed sophisticated control units that use only the right amount. In addition, the company reformed its processes so that it can reuse water and reduce water consumption. Previously, water used in one process could not be reused in another, since each process required water with different standards. However, by standardizing water, Samsung can now reuse water in several processes. Thanks to such efforts, the company was able to reuse 60 609 tons of water in 2018, which is 8% more than a year earlier, and water reuse amounted to 45.1% of the total volume of water used [12].

Thus, it can be said that the company is working on its goals of achieving a circular economy. By minimizing the type of materials used and optimizing the assembly method, Samsung has developed manufacturing methods that minimize resource use. Samsung recovers valuable materials by collecting products that reached the end of their life span. With this circular economy, Samsung is reducing the amount of natural resources it needs for production, reducing greenhouse gas and pollutant emissions from waste incineration, and preventing soil and groundwater pollution from landfills

4. Conclusion

The completion of the national medium-term goal shows that South Korea is pursuing an active strategy of transition to a circular economy. The country has undertaken intensive efforts to develop an integrated strategy at the national level. In 2008, low carbon / green growth was announced by the country, which should guide its development over the next 50 years. In 2009, the first five-year (2008–2013) Green Growth Plan was announced along with the National Strategy for Green Growth to accelerate central government policy implementation. In addition, an interim goal was announced to reduce greenhouse gas emissions at the national level. In 2010, the Framework Act on Low Carbon/ Green Growth was adopted covering economies, industries, national territories, the environment and public conduct. In 2011, the Act on the Creation and Facilitation of Use of Smart Grids was adopted as the legal basis for the creation of intelligent networks. In 2012, the Act on the Allocation and Trading of Greenhouse-Gas Emission Permits was passed to create the institutional framework for the Emissions Trading System. In 2014, it was announced that in the second five-year (2014–2018) Green Growth Plan, the institutional framework created over the past 5 years will be actively used [4].

According OECD Environment Director Simon Upton, “Korea has been a champion in framing ambitious green growth policies. It now needs to turn its vision into action by making progress towards its climate goals”, said [9].

Although the level of recycling in South Korea is high, this does not mean that Koreans live in a circular economy. In order to develop towards a circular economy, South Korea must consider this concept in a holistic way. This includes the development of circular product designs, such as reducing the use of plastic and the use of more biodegradable and bio-products. Consumers are more interested in types of materials than before, and they are trying to find new environmentally friendly products for use.

References

[1] Alvstam, Dolles, Ström (eds.): 2014. Asian Inward and Outward FDI_ New Challenges in the Global Economy. Palgrave Macmillan UK

[2] Ghisellini P., Cialani C. and Ulgiati S.: 2016. A review on circular economy: the expected transition to a balanced interplay of environmental and economic systems. Journal of Cleaner Production. Vol.114(15), 11-32.
https://doi.org/10.1016/j.jclepro.2015.09.007

[3] GreenBiz: 2019. What happened with Samsung's smartphone upcycling program.
https://www.greenbiz.com/article/what-happened-samsungs-smartphone-upcycling-program

[4] Jin I.: 2016. Circular Economy Policy in Korea. ERIA Research Project Report 2014-44, Jakarta: ERIA, pp.163-184.

[5] KIREC SEOUL: 2019. Renewable energy policies and performance in Korea.
http://www.kirec2019.kr/sub01/about.html

[6] LAMKpub: 2018. An insight on Circular economy in South Korea.
https://www.lamkpub.fi/2018/11/30/an-insight-on-circular-economy-in-south-korea/

[7] Lieder M.: 2016. Towards circular economy implementation: a comprehensive review in context of manufacturing industry. Cleaner Production. Vol.115, 36-51.
https://doi.org/10.1016/j.jclepro.2015.12.042
[8] McCarthy N.: 2016. The Countries Winning the Recycling Race. Forbes.
https://www.forbes.com/sites/niallmccarthy/2016/03/04/the-countries-winning-the-recycling-race-infographic/#41704cab2b3d
[9] OECD: 2017. Environmental Performance Reviews: Korea 2017. OECD Environmental Performance Reviews, OECD Publishing, Paris
[10] Repaper: 2020. rePAPER.
http://www.repaper.kr/index_en.php
[11] Sammobile: 2020. Samsung's Galaxy Upcycling program still lives.
https://www.sammobile.com/news/galaxy-upcycling-program-could-take-off-soon/
[12] SAMSUNG: 2020. Sustainability.
https://www.samsung.com/levant/aboutsamsung/sustainability/environment/resource-efficiency/
[13] SmartCity Lab: 2019. Success story: Smart litter bins in Seoul.
https://www.smartcitylab.com/blog/urban-environment/success-story-smart-litter-bins-in-seoul/
[14] Wikipedia: 2020. Samsung.
https://ru.wikipedia.org/wiki/Samsung
[15] Yuan Z., Bi J. and Moriguichi Y.: 2006. The circular economy: a new development strategy in China. Journal of Industrial Ecology. Vol.10 (1–2), 4-8. https://doi.org/10.1162/108819806775545321

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