IOSUD – UNIVERSITATEA „DUNĂREA DE JOS” DIN GALAȚI

Școala doctorală de Științe fundamentale și inginerești

TEZĂ DE DOCTORAT

-abstract-

INFORMATIONAL MODEL FOR THE STANDARDIZATION OF WHEAT QUALITY IN INTERNATIONAL CONTRACTS

Doctorand,

Ing. Ciprian-Petrișor PLENOVICI

Conducător științific,

Prof. univ. dr. ing. habil. Adrian-Gheorghe ZUGRAVU

Seria I 9: Inginerie și management în agricultură și dezvoltare rurală nr. 14

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CONTENT

INTRODUCTION

Wheat and wheat products represent the most important source of energy, fiber and micronutrients in the human diet**.**

With a major role in the evolution and civilization of mankind, through the cultivation of some evolved species, wheat became the most cultivated plant from the cereal group, and later an important economic pillar of the countries with the potential to cultivate this plant, but also for the countries importers.

The development of agriculture consisted both in the evolution of culture technologies and the automation of the machines used, as well as in the use of a carefully selected seed material and the development of hybrids adaptable to the pedoclimatic conditions of the region where the culture is established.

Ample studies have been carried out regarding the improvement of some wheat varieties regarding production yield, but, in the last decades, technological characteristics and quality attributes have become a priority for researchers in the field of agricultural genetics.

The diversity of the products obtained from flour extracted from wheat made the millers prefer certain varieties of wheat and to follow the behavior of the flour in processing and baking in terms of physical, chemical and rheological properties.

Starting with the 1960s, the quality of wheat acquired new values among farmers and especially processors, being developed criteria for evaluating the quality of wheat regarding the quantity and quality of proteins in the form of gluten, the mycological load and more recently, the residual amount of heavy metals and plant protection substances used in culture technology.

International and national standardization organizations have developed methods and regulations for determining the quality of wheat, as well as quality specifications that include the optimal values of the physical and chemical indicators analyzed.

At the European level, there are regulations that aim at the maximum allowed content of pesticides and other toxic components that can be identified in wheat lots and whose presence can negatively impact the health of the consumer.

At the level of many countries with areas cultivated with wheat, their own systems of evaluation and grading of the obtained, conditioned, stored and marketed crops have been developed, the character of these rules being mandatory or optional, but very useful in generating a qualitative image of the crops and stocks in a certain region, period or agricultural year.

The non-fulfillment of some minimum conditions stipulated by the wheat quality specifications for human consumption, attracts the redirection of these lots to the production of fodder, if it falls within the limits provided for it or to the processing in order to obtain biofuels.

The international contracts aimed at the import or export of wheat are based on this minimum quality reference, but depending on the origin and final use, they are fined with specific quality clauses.

Along with the quantitative availability and logistic factors, the formation of the price on the international wheat market is also realized under the qualitative aspect of the wheat that is the object of these contracts.

The variation of these wheat quality limits in international contracts was the main motivation in the elaboration of the doctoral thesis entitled ***"Informational model for the standardization of wheat quality in international contracts"***, and its aim was to obtain a global quality index of a lot or a/ of a batch of wheat that is the object of a commercial transaction, which allows a quick interpretation and ranking based on the analyzed quality parameters.

The theme of the paper comes in the context of the constant growth of commercial transactions with cereals, Romania ranking in the last years among the top producers and exporters of wheat in Europe.

The research was carried out in the period 2018-2022 and found in the quality assessment of 25 batches of wheat, totaling 26,872 tons, which are the subject of an international contract, and the analyzes were carried out personally and by assistance in the laboratory that meets the requirements of a standard ISO 17025.

The obtained results were processed with the help of the MatLab application, starting from the objective assessment of the experts in the field of grain quality and by using the functions of fuzzification and defuzzification.

The interdisciplinary character of the work is highlighted in the course of the 6 chapters and is supported by 45 figures and 84 tables, which synthetically and illustratively reproduce the results and the research procedure.

Chapter 1 - Aspects regarding the importance of wheat culture, summarizes information and the current state of knowledge regarding the importance of culture in antiquity, the ancestral forms of today's common wheat and the natural hybridization stages of Triticum aestivum, highlighting the interest of humanity in wheat culture through its physicochemical characteristics of the component parts that make up the structure of the wheat grain and their importance in human nutrition through the supply of vitamins, minerals, fibers and enzymes, as well as the physical properties of wheat grains, useful in obtaining flour, semolina or flour and of interest to intermediate and final users.

Chapter 2 - Evaluation of wheat quality includes the main parameters used in the evaluation of wheat quality, as well as the standardized methods or used in practice. In this part of the work, the minimum conditions imposed on wheat intended for human consumption and the specifications related to the parameters for fitting into certain categories according to the final use are highlighted.

Chapter 3 - The international wheat market represents an analysis of wheat production at the international level in the period 2017-2020 and identifies the major producers, importers and exporters at the global level and especially those in the European Union, paying special attention to the wheat market in Romania. In this chapter, quality specifications used in international contracts are also presented.

Chapter 4 - The study of the international wheat classification and grading systems completes the previous chapter which took into account the quantitative component and highlights the qualitative component, aiming at the main grading systems in the evaluation of the quality of common wheat intended for human consumption at the level of large producing countries.

Chapter 5 - Determining the quality of the wheat lots describes the procedures and methods used in determining the quality of the analyzed wheat lots and generates the results in order to develop the proposed informational model.

Chapter 6 - Informational model for wheat quality standardization shows the techniques, principles and procedure for developing the informational model and obtaining global quality indices for the analyzed lots.

Chapter 7 - General conclusions. Original contributions and research perspectives present the final conclusions of own research and the original contribution in the elaboration of the thesis, deriving from them potential research directions in this topic.

At the end of the paper, the scientific works and participation in conferences during the doctoral training period are mentioned.

In the writing of the work, bibliographical references were used, as well as the expertise of 20 specialists who conferred degrees of importance of the quality parameters determined in this research in relation to the suitability of the final use of the wheat lots analyzed, as well as the objective correlation of the results obtained following the tests performed on these lots.

The thesis was developed and written under the coordination of Prof. Dr. Adrian Gheorghe Zugravu as PhD supervisor and the guidance committee with the following component: prof. univ. dr. ec. dr. ing. habil. Silvius STANCIU, prof. univ. dr. ec. Maria Magdalena Turek - Rahoveanu and conf. dr. ing. Cristian Munteniță.

CHAPTER 1 – ASPECTS REGARDING THE IMPORTANCE OF WHEAT CULTURE

Wheat is currently one of the most important agricultural crops in the world, being cultivated according to FAO data, on surfaces totaling over 216 million hectares in 2019.

According to archeological research, wheat culture has its beginnings in the period 8000-10,000 BC in the region of South-West Asia, called the Fertile Crescent due to the fertile soil and its crescent shape [2]. The Fertile Crescent or Cornucopia, encompassed the territory between the Tigris and Euphrates rivers and stretched from Egypt to southeastern Turkey, including areas in Iran, Iraq and the Nile River area.

The process called wheat domestication was achieved through natural hybridization, over time, in two successive stages.

The first stage is considered the spontaneous hybridization of the diploid species Triticum monococcum ssp. Boeticum (einkorn) with other diploid grass species of the genus Triticum (cultivated or wild), resulting in tetraploid varieties such as Triticum dicoccoides (emmer) or Triticum turgidum spp (durum wheat).

The second stage is represented by the spontaneous crossing of tetraploid grain varieties with the wild species Aegilops squarrosa, and obtaining hexaploid varieties. The hexaploid group includes most cultivated and economically important species, such as Triticum aestivum [4]

Figure 1.1 – Physical aspects of diploid, tetraploid and hexaploid wheat varieties

Sedentarism was a consequence of the development of agriculture, and bread wheat was essential to the development of civilizations. It has been shaped and selected repeatedly to serve human needs and adapted to different climatic, geographical and pedological environments.

Wheat is the main source of nutrition for many people, especially the population in developing countries, with wheat protein being among the most consumed dietary proteins in the world [5].

Triticum aestivum L. is an annual plant characterized by its straw-like stem, hollow on the inside along its entire length, which forms an inflorescence of a compound spike, aristate or non-aristate, the aristes being divergently oriented and shorter compared to the length of the spike.

From an anatomical point of view, the length and color of the wheat grain depend on the variety and variety cultivated. The surface of the grain is smooth on the dorsal side, the covering being wrinkled in the area of attachment to the ear, over the place where the embryo is located.

The outer pericarp consists of epidermis (epicarp), hypodermis and a layer of thin-walled cell debris. The internal pericarp comprises three layers of cells, the differentiation of the layers being defined by the shape of the cells, respectively flattened, wide, oblique and tubular, and are called epicarp, mesocarp, and endocarp respectively.

In the section from the outside to the inside, after the pericarp, three more layers can be distinguished, as follows: The pigment layer or the seminal coat, the hyaline layer and the aleurone layer. The illustrated representation of the structure of the grain of wheat is presented in figure 1.2.

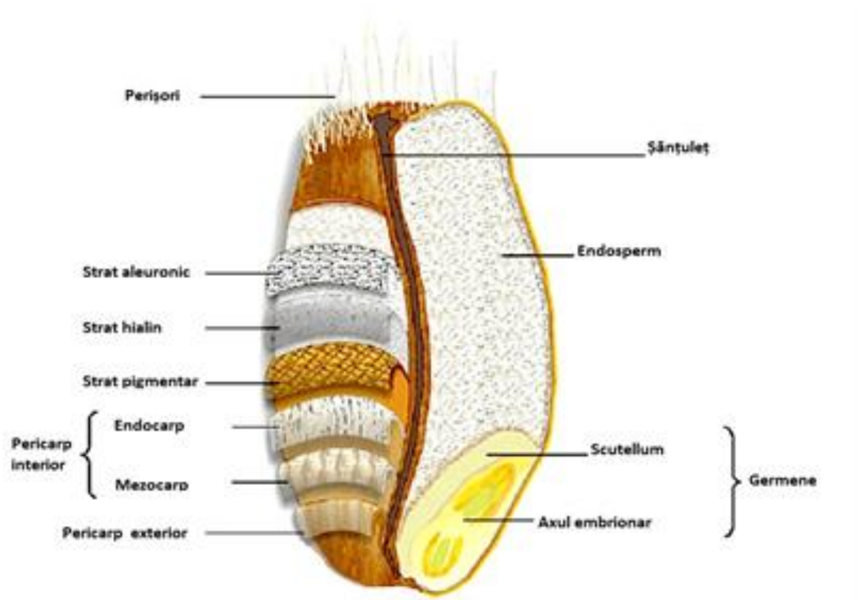


Figure 1.2 - Anatomical structure of a grain of wheat [6]

In addition to starch, the endosperm contains minerals, cellulose, enzymes, pentosans and vitamins.

Endosperm texture in wheat is the most important and defining quality characteristic, as it facilitates the classification of wheat and influences the quality of milling, baking and end use [7].

Wheat grains have a complex chemical composition. All the substances that make up the chemical composition of the wheat grain are divided into two large groups: organic and inorganic.

Organic substances include proteins, nucleic acids, carbohydrates, lipids, enzymes, vitamins and pigments, and inorganic substances include minerals and water.

Carbohydrates, mainly starch (about 58%) and non-starch polysaccharides (about 13%), are the predominant class of constituents followed by protein (about 11%). Lipids (about 2%) and minerals (about 2%) belong to minor constituents. Vitamins and phytochemicals occur in very low amounts (< 0.1%), but are important due to their biological roles. Non-starch polysaccharides (dietary fibres) include the cell wall polysaccharides arabinoxylans, cellulose and β-glucans and in addition fructans and peptides.

Water is part of the chemical composition of the wheat grain at all stages of ripening, storage and processing. Water is a prerequisite and an active participant in all reactions in the bean.

The protein content consists of albumins, globulins, prolamins and glutelins, each of which can form distinct structures that can be separated by different processes.

Prolamins and glutelins form the protein mass, called gluten, and are physically characterized by visco-elasticity.

Starch is the main carbohydrate in wheat and is the predominant source of carbohydrates for human diets, substrate for the production of alcoholic beverages, ethanol (fuel) through fermentation [8] and raw material for many other industries. Starch constitutes 60-70% of the mass of wheat flour.

Wheat lipids account for 2–4% of the whole grain weight and 1–2.5% in the flour after milling. Although lipids are a minor element in wheat, they play an important role in dough mixing, the baking process, and consumer acceptance of the finished products.

Enzymes are biocatalysts of protein origin that have the role of accelerating biochemical processes at the cellular level through the biosynthesis and degradation of substances from living matter.

The wheat grain contains a large number of enzymes, the most important being: α-amylase, β-amylase, preoteases, lipase, phytase, cellulase, lipoxygenase, tyrosinase [9].

The mineral substances are distributed in different proportions and unevenly in the component parts of the grain. The endosperm contains reduced amounts of about 0.3% in the central area, increasing towards the periphery to 0.48%.

The outer layers, which are usually removed during grinding as bran, are rich in mineral substances.

Vitamins are active biological compounds found in food, with an essential role in supporting the functions of the human and animal body and are synthesized in insufficient quantities by the body. The main vitamins present in wheat grains are vitamin A, vitamin B complex and vitamin E.

The B vitamin complex includes eight components, namely: thiamin (vitamin B1), riboflavin (vitamin B2), niacin (vitamin B3), pantothenic acid (vitamin B5), pyridoxine (vitamin B6), biotin (vitamin B7), folic acid (vitamin B9) and cyanocobalamin (vitamin B12), which play important roles in the metabolism of carbohydrates, proteins and fats.

The specialized literature has also paid more attention to the physical properties of the seed mass, taking into account the need to streamline the harvesting, transport, conditioning, drying and storage processes, identifying important aspects that influence these processes, such as friability, geometric dimensions of the grain, mass specific grain, mass of 1000 grains, volume of 1000 grains, thermal conductivity of grains, self-sorting of grain mass, hygroscopicity of grains, intergranular space of grain mass, porosity and density of grain mass, glassiness of grains, hardness of grains.

CHAPTER 2- EVALUATION OF WHEAT QUALITY

Wheat quality is a complex and widely used term to describe the ability and general potential of wheat to be used in a wide variety of finished products by milling and obtaining quality flours for the production of bread and bakery products and pastry, semolina, as well as the use in various processes in the extractive, fermentation industries or in the animal husbandry branches.

The main determinants of wheat quality are endosperm texture (grain hardness), protein content and gluten concentration. Endosperm texture in wheat is the single most important and defining quality characteristic, as it facilitates wheat classification and influences milling, baking and end-use quality.[7]

Sampling represents the stage of assessing the quality of a batch of wheat and is carried out both for grains in motion, as well as for batches of stationary grains or in packaged units (bags). The quantities of wheat that are in semi-trailers, trucks, wagons, ships, barges, silos, warehouses or sheds are considered static products.

Sampling (sampling) represents the operation that consists in taking and constituting a sample in order to determine the quality by analyzing the monitored parameters. The sample must be as representative as possible for the sampled lot.

Depending on the size of the lot, the SR EN ISO 24333 standard provides the mass of the elementary sample, the minimum number of elementary samples, the minimum mass of the laboratory sample and limits the maximum size of the lot to 1500 tons.[10]

After the sampling operation and obtaining a representative sample, the organoleptic and sanitary characteristics are determined.

Organoleptic characteristics consist of appearance, color, smell and taste. Determining the organoleptic characteristics of wheat grains is the examination through the sensory organs of qualified personnel.

International standard ISO 7971 – Common wheat. Specifications, establishes the organoleptic conditions of the wheat grains and stipulates that the grain mass subject to evaluation must be free-flowing, without foreign smell and taste that would indicate a change in the product mass (mouldiness, burning), with a normal appearance and a characteristic color. [11]

In Romania, the STAS 6253 standard describes the practical methods for determining sensory indicators.

Determining the presence of live insects in the grain mass constitutes a priority stage of quality assessment and plays a decisive role in establishing the circuit of reception, storage and processing.

The SR ISO 6639 standard describes two types of hidden infestation methods, namely rapid methods and reference methods. The use of X-rays, flotation, determination of carbon dioxide and ninhydrin, but also the acoustic method, are quick methods for identifying hidden infestation [12].

Grain moisture, implicitly wheat, represents the amount of water in the grain and is an important parameter in determining the quality of wheat, both for wheat intended for storage and for wheat intended for processing or sowing. The high moisture content decreases the storage resistance, intensifying the processes of respiration and transpiration of the seeds with the release of large amounts of carbon dioxide and heat. Failure to take measures to reduce moisture by drying in time leads to the depreciation of products through self-heating, mold and alteration. [13]

The purpose of moisture determination is to determine the moisture content at the time of taking the laboratory sample and to take the necessary measures for the lots to be harvested, conditioned (taring or drying), stored, processed or sold.

The reference method applicable to the determination of moisture content is described in the standard SR EN 712:2010 – Cereals and cereal products. Moisture determination. The reference method is based on the oven drying of a working sample at a temperature between 130-1330 C, for 120 min.[14]

Test weight or hectoliter weight represents the amount of grain that can displace a volume of 0.1 m3, equivalent to the capacity of 100 liters.

The parameter represents a volumetric quantity being expressed in kg/hl. The determination of this parameter is important for the storage of wheat in the calculation of the appreciation of the stored quantity, for estimating stocks, but also for processors, especially millers, who obtain a better yield of extracting flour from wheat with a larger hectoliter mass.

The minimum values provided in the quality specifications of common wheat for the hectoliter mass parameter are between min. 70 kg/hl [11], according to ISO 7971-1 and min 73 kg/hl [15] according to SR EN 13548:2013.

Wheat is the main source of nutrition for many people, especially those living in developing countries, and wheat protein is among the most consumed dietary proteins in the world.[5]

Bread volume generally increases with increasing protein content and is significantly influenced by the protein content and composition of the wheat grain.[16]

Wheat protein is divided into gluten and non-gluten fractions, and the processing quality of wheat mainly depends on the gluten fractions.[17]

The reference method for determining the protein content of wheat is carried out according to the international standard ISO 20483 and is based on the mineralization (digestion) of the sample with concentrated sulfuric acid, using a catalyst, distillation and titration of the nitrogen released in the form of ammonia.[18]

Following literature review in food science and nutrition journals, wheat gluten was first isolated in 1728 by Jacopo Beccari, professor of chemistry at the University of Bologna [19] and is considered the main protein of wheat grains.

Gluten provides dough extensibility and elasticity, essential characteristics for various wheat end products. Disulfide bonds form between cysteine residues, which are the chemical bases for the physical properties of dough.[17]

For a relatively small percentage of the human population, wheat grain proteins can cause a number of serious diseases, including celiac disease. Methods for detecting gluten proteins are advanced, increasing patient safety.

The determination of gluten content is regulated internationally by the ISO 21415 standard which describes methods for determining the gluten content of wheat as well as flour.

In addition to determining the gluten content by the methods indicated by the standards, additional tests can be determined in order to determine the quality and physical processes at the level of gluten, such as the gluten deformation index, the gluten index and the gluten index.

The deformation index reflects the wheat proteolytic activity and is proportional to the enzyme activity. The optimal values for the gluten deformation index parameter are between 6 mm and 13 mm [20], and the maximum value allowed in the European wheat quality specification is 15 mm

The gluten index is determined by using a calculation formula that includes the obtained value of the gluten content and the value of the gluten deformation index.

From category I wheat, flour can be extracted for current bakery products, and the higher the value of the indicator, the higher the value of pastry and bakery products can be obtained.

Category II wheat flour is suitable for baking, but may require additives, and category III wheat is not intended for baking.

The gluten index is a test recently introduced as a faster method of measuring the quality of wheat processing compared to classical instrumental methods such as a mixograph and farinograph. It is also a criterion that ranks gluten quality as weak, normal or strong. The gluten index test has gained wide acceptance as a method for determining gluten concentration and is used in international trade specifications. [21]

The method is applicable to wheat grains and wheat flour, and the principle of the method is based on the gluten separated by the glutomatic equipment by centrifugation, removing the wet gluten through a specially constructed sieve under standardized conditions.

The percentage of wet gluten remaining on the sieve after centrifugation is defined as the gluten index. If the gluten is very weak, all the gluten can pass through the sieve, and the gluten index is 0. When nothing passes through the sieve, the index is 100.[22]

Gluten index is not a predictive criterion for wheat quality, but it is considered an indicator of wheat quality for baking.

The content of impurities in the product mass negatively affects the quality of wheat and endangers food safety. They reach the grain mass mainly during the operational process of the harvester, but they can also be influenced by the conditions in the crop.

The category of impurities is defined by the SR ISO 5527 standard - Cereals. Terminology, as all the components that are conventionally considered undesirable in a batch of product [23], namely wheat, and the SR EN 15587:2019 standard specifies that all grains that are not whole and do not have an appearance are considered impurities and a healthy and product-specific state [24].

At the international level, the limits and the reference method for determining the content of impurities, as well as the definition of the subcategories that make up this wheat quality indicator, are specified in the international standard ISO 7970 and shown in table 2.1.

Table 2.1 - *ISO 7970 specification on the content of impurities in wheat [11]*

Impurity categories	Maximum level allowed, %, mass fraction
Broken grains	7,0
Low-value grains (grains that are not fully developed or with discolored germ)	12,0
Grains attacked by pests	2,0
Grains with some degree of surface discoloration that may have been caused by micro-organisms or scorched or burnt grains	1
Other cereals	3
Foreign matter	2
Foreign matter inorganic	0,5
Toxic Foreign matters	0,5
Toxic seeds, for each of the toxic seeds	0,05
Ergot	0,05

Impurities in wheat are not only an important factor affecting total grain production, but also an important indicator for measuring combine harvester quality and timely intervention on adjustments. In order for these impurities to be reduced, the recognition and testing of wheat impurities is crucial.[25]

In Romania, the official method for determining the content of impurities in wheat is reproduced in the European standard SR EN 15587:2019, and in the standard SR EN 13548:2013 - Wheat. Specifications; the limits of each indicator in the category of total impurities are stipulated, according to the data presented in table 2.2.

The total content of impurities is determined by summing the percentages obtained following the quantitative identification of the following subcategories: Broken grains, Defective grains, Sprouted grains and various impurities.

In the content of total impurities, special attention is paid to the content of toxic and harmful seeds, of grains affected by *Tilletia spp.* and the presence of ergot.

Table 2.2 *- Components and limits of the impurity category provided by SR EN 13548:2013 [15]*

Nr. crt.	Impurities	Maximum limits %
1	**Total impurities,%** din care:	12,0
1.1	***Broken grain,%***	5,0
1.2	***Demaged kernels, %*** din care:	7,0
1.2.1	Shriveled,%	1,0
1.2.2	Other cereals,%	0,5
1.3	Attacked by pests, %	0,5
1.4	Blackpoint	2,0
1.4.1	Grains with changed skin color (burnt),%	3,0
1.4.2	**Sprouted grains,%**	0,1
1.4.3	***Various impurities, % of which:***	1
1.4.3.1	Seeds of other plants,%	0,05
1.4.3.2	Toxic seeds,%	1
1.4.4	Altered grains, % of which:	1,0
1.4.5	Burnt-hot grains,%	0,05
1.4.6	Grains attacked by Fusarium,%	0,1

The falling number (FN) in wheat is an important predictor of quality and has a significant economic impact. A lower shrinkage index is associated with higher α-amylase activity and poorer end-use quality of the wheat.[26]

Hagberg (1961) and Perten (1964) developed a simple and rapid test for the determination of α-amylase activity using wheat flour as a substrate. This method has been standardized internationally and is widely used in grain classification and quality control in bread making. The method is called fall index (HFN).

The falling number (HFN) is commonly used in seed grading and commercial contracts to infer processing characteristics and end-use quality of wheat.

The optimal value for this indicator is at least 220 seconds [15], being established at the European level by SR EN 13548:2013- Common wheat. Specifications. The reference method is described in SR EN ISO 3093.

The rheological analysis of doughs provides an important picture of the behavior of flour in the dough phase at different stages of the technological process of obtaining bakery and pastry products.

Rheological properties refer to the evaluation of the behavior during deformation of the dough obtained by mixing flour with salt water. The principle consists in subjecting a disk of dough under a constant jet of air; in the first moments the dough resists the pressure, then depending on its extensibility, it swells in the form of a bubble and breaks. This evolution is measured and recorded in the form of a curve called an alveogram. [27]

Currently, the Chopin alveograph is used to determine the alveographic properties, and the method is standardized indexed under the SR EN ISO 27971 reference and includes the experimental grinding method.

The principle of the method underlying the alveographic test is based on measuring the resistance to biaxial stretching, under air pressure, of a sheet of dough prepared under standard conditions[27].

Mycotoxins are a potential threat to cereal health, including wheat. In the European Union (EU), maximum levels of mycotoxins are set for cereal raw materials and final food products for wheat and wheat-based products.

Of the four mycotoxins regulated in EU wheat-based foods deoxynivalenol (DON), zearalenone, aflatoxin and ochratoxin, most data are available for DON, while aflatoxins have rarely been studied in wheat processing. The maximum limit in the case of wheat is 1750 µg/kg. [27]

Deoxynivalenol is the mycotoxin especially associated with wheat and is mainly produced by *Fusarium spp* species such as *Fusarium graminearum* and *Fusarium culmorum.*

Due to the importance of wheat in the diet of the population, the determination of the level of lead, cadmium, arsenic and mercury, as well as other heavy metals, has become a priority and a form of wheat quality assessment.

The presence of heavy metals in wheat grains is influenced by the pH value of the soil. Soil quality is directly influenced by water quality. Untreated discharges from industrial, domestic, and stormwater significantly affect irrigation water quality in both the short and long term.[29]

The method for determining heavy metals in cereals, including wheat, is based on atomic absorption spectrophotometry [30], and the working method is regulated by the standards specific to food products.

Chemical products, such as fertilizers, herbicides, growth regulators and insecticides, used in agriculture at different stages of the culture technology, but also after harvesting for proper conservation and storage, are called pesticides.

Excessive and unprofessional use, in non-recommended doses and periods, leads to their identification in seeds in the form of residues.

The specialized literature highlights over 800 active substances found in the chemical composition of pesticides, thus forming over 100 chemical classes.

Regulation (EC) no. 396/2005 of the European Parliament and of the Council regarding the maximum contents applicable to pesticide residues in or on food products and food of vegetable origin and feed, establishes, in accordance with the general guidelines stated in Regulation (EC) no. 178/2002, the list of active substances for which maximum admissible levels are not established, but also the community and national control plans and obligations of the laboratories that perform such tests.

Pesticide residues in wheat exceeding the established limits in various measures have a severe impact on human health [31].

In recent decades, rapid wheat quality determination methods and devices have become widely adopted for the determination of moisture content, hectoliter mass and protein in general, but also for continuous monitoring of stock quality.

The analyzers are based on near-infrared (NIR) transmission technology, which can be used for the simultaneous and precise determination of several parameters, such as moisture, protein content, gluten content, fat content, but also hectoliter weight.

Granomat is commonly used in all reception points, but does not provide information on protein content. The Granolyser type analyzer and the FOSS type analyzer are widely used equipment in recent years and provide more complex information.

A comparative study on the accuracy of protein determination methods, namely the Kjeldhal method, the Dumas method and the NIR technique revealed the precision error rate below 2% for the Kjeldahl method, while the precision error rate for the Dumas method varied in a range of 2-4%. The NIR method proved to be the fastest in determining protein content; however, the error rate varied between 3% and 6%. The Kjeldahl method, due to its high precision and very small ranges of variation, have made it the major method for estimating protein in food.

CHAPTER 3 – THE INTERNATIONAL WHEAT MARKET

International trade is a benefit of economic globalization transposed through opportunity, so that the varied supply of goods and services develops and encourages a fair competitive market and sets a fair price relative to quality.

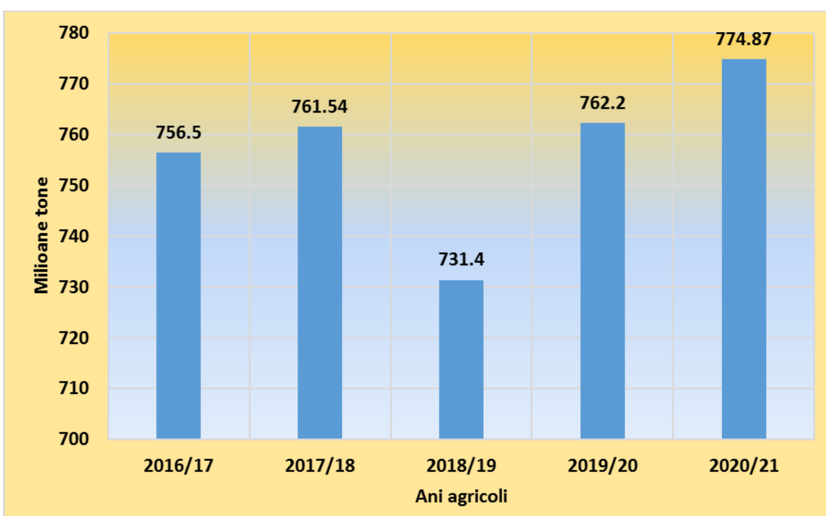
International trade in wheat is greater than all other crops combined, despite the fact that it ranks second only to corn in terms of cultivated areas.

The international wheat market depends not only on the agricultural productions obtained, but also on the consumption of wheat at the global level.

According to the data available and published by FAO, the average world wheat production in the period 2016-2021 was 757.3 million tons.

Analyzing figure 3.1, which shows global wheat production in the period 2016/17-2020/21, it can be seen that in the 2020/21 agricultural year, global wheat production exceeded the production of the previous year by more than 10 million tons, and compared to year 2018/2019 with approximately 42 million tons, being the highest amount in the analyzed interval.

Figure 3.1 – *Global wheat production in the period 2016/17-2020/21 [32]*



The main wheat producing countries are India, China, Russia, the United States of America, Canada, Argentina and Australia.

Along with the EU and the large wheat-producing countries, significant productions are also obtained in Ukraine, Pakistan, Turkey, Argentina, Iran, Australia and Kazakhstan.

In table 3.1, the quantitative productions for the main producers are presented, and it can be observed that the summation of the quantities represents approximately 85% of the world wheat production.

***Table 3.1 -** The main world producers of wheat [33][34][35][32][36]*

	Agriculturals years				
Producers	**2016/17**	**2017/18**	**2018/19**	**2019/20**	**2020/21**
UE, mil. to	143.14	129.3	148.38	129.04	131*
China, mil. to	134.25	134.33	131.43	133.59	134.25
India, mil. to	87.00	98.51	99.81	103.60	107.59
Rusia, mil. to	72.53	85.17	71.69	73.61	85.30
SUA, mil. to	62.83	47.38	51.31	52.58	49.69
Canada, mil. to	32.14	30.38	32.35	32.67	35.18
Ucraina, mil. to	26.79	26.98	25.06	29.17	25.50
Pakistan, mil. to	25.63	26.60	25.10	24.30	25.70
Turcia, mil. to	17.25	21.00	19.00	17.50	18.21
Argentina, mil. to	18.40	18.50	19.50	19.78	17.50
Iran, mil. to	14.50	14.00	14.50	16.80	16.75
Australia, mil. to	31.82	20.94	17.60	15.20	30.00
Kazahstan, mil. to	14.99	14.80	13.95	11.50	12.50
Total, mil. to	682.52	689.72	657.86	684.81	693.97
Percent in global production,%	90,2	90,5	89,9	89,8	89,5
Global production, mil. to	**756.50**	**761.54**	**731.40**	**762.20**	**774.87**

The European Union, through its 28 states until 2021, constantly occupies the first places in the top world wheat producers.

At the European level, France, along with Germany, Great Britain, Poland and Romania, are the main producers of wheat.

France frequently registers productions of over 25 million tons per year, while Germany constantly exceeds quantities of 20 million tons per year, taking into account the period 2017/17-2020/21.

The quantitative variations are mainly influenced by the low level of precipitation and crop rotation, by decreasing or increasing the agricultural areas cultivated with wheat. In the quantities reported and reproduced in table 3.2, durum wheat productions are not associated. Analyzing the production of Germany and Romania from the year 2018/19 compared to that of 2019/20, a decrease of approximately 25% in Germany and approximately 30% in Romania, compared to the previous interval, is noted.

In relation to global production, the European Union has a constant share and alternates in the analyzed interval with China, thus playing an important role in the international wheat market and in ensuring the food requirements for developing countries or those that do not have the natural framework to -and ensures the necessary wheat.

Table 3.2 - *Wheat production in the main EU wheat-producing countries [32][37][36]*

Country	Agriculturals years / million tonnes				
	2016/17	**2017/18**	**2018/19**	**2019/20**	**2020/21**
Germania	24.31	20.13	22.91	21.99	21.25
Franta	36.56	34.05	39.52	29.18	35.46
Polonia	11.67	9.82	11.01	12.67	12.12
Romania	10.01	10.12	10.28	6.38	11.35
Spania	3.77	6.71	5.10	7.03	7.56
Ungaria	5.09	5.05	5.22	5.00	5.16
Cehia	4.72	4.42	4.81	4.90	4.96
Bulgaria	6.09	5.77	6.12	4.68	7.07
Great Britain	14.83	13.55	16.22	10.13	*
Total	117.05	109.62	121.19	101.96	104.93
Total UE	143.14	129.3	148.38	129.04	131*

*Starting with January 1, 2021, Great Britain withdrew from the European Union, and the wheat production obtained in the year 2020/21 was not included in the total wheat production of the EU.

In the last two decades, the share of the USA in the international wheat trade has decreased by approximately 12%. Between 2001 and 2005, the U.S. share of global wheat exports averaged 25 percent, and for the 2020–2021 crop year, the U.S. share dropped to about 13 percent.[38] This deficit was covered by the European Union and Russia. In recent years, the Black Sea region has become the major point of interest for grain trade, especially wheat and corn.

Table 3.3 shows the volumes of wheat exported by large producing entities, generating an overview of the international wheat market.

Countries such as China, India or Iran are missing from the list of major exporters, but this is motivated by the demographic component.

Table 3.3 - *The main wheat exporters[32][36]*

Producers	Agriculturals years / million tonnes				
	2016/2017	**2017/2018**	**2018/2019**	**2019/2020**	**2020/2021**
Rusia	27.82	41.45	35.86	34.40	39.00
UE	27.44	23.38	23.31	38.40	26.50
SUA	29.32	23.23	26.09	26.30	27.00
Canada	20.30	22.02	24.45	23.40	26.50
Ucraina	18.11	17.78	16.02	21.00	17.50
Argentina	12.28	14.00	12.68	16.61	12.00
Australia	22.06	15.51	9.84	10.12	18.00
Turcia	6.32	6.39	6.31	6.21	6.70
Kazahstan	7.26	8.52	8.78	6.89	7.00

At the level of the European Union, according to the data provided by the European Commission, the average volume of wheat imported in the analyzed period (2016/17-2020/21) is 3 million tons [37].

Ciprian Petrișor PLENOVICI

Informational model for the standardization of wheat quality in international contracts

The international wheat trade targets both the quantitative and qualitative components, both acting on price formation.

The availability of stocks, the logistic and geomaritime facilities, offer the countries of the Black Sea region the advantage of easy access to the markets of the Near and Middle East.

Russia, Ukraine, Romania, Bulgaria and Kazahstan thus became the main exporters of wheat for countries such as Egypt, Lebanon, Jordan, Vietnam and Israel.

Within the European Union, Romania is the main exporter of corn and has been in second place in recent years after France in the export of wheat.

The wheat trade of the European Union states and from the vicinity of the Black Sea with Egypt has developed in recent years, Romania along with Russia, Ukraine and France being constant suppliers of wheat.

The purchase of wheat in Egypt is carried out through the General Authority for the Supply of Goods (GASC).

Tenders for securing the necessary wheat are frequently posted on the websites of the relevant ministries in Jordan, Lebanon and Israel.

The sales contracts provide clauses on the terms and conditions of delivery, insurance, price and quality, but GAFTA-type contracts are frequently used.

In international grain trade, GAFTA type contracts are used in approximately 80% of transactions. These contracts are based on both technical and legal clauses. The use of contracts of this type implies the acceptance of the rules established by the association which strictly regulate the methodology of arbitration, mediation and determination of quantity and quality.

The quality specification of wheat imported into Egypt through GASC is considered the most rigorous and complex contractual clause. It is based on the ISO standards as methods for determining quality, but the parameter limits underline the interest in purchasing a higher quality wheat.

Analyzing the quality requirements imposed by Egypt, the recognition of the superior quality of the productions from Romania, Ukraine and Russia, through the limit imposed on the protein content in wheat imports from these countries, emerges.

The quality specifications of the main importers of wheat from the Black Sea basin, namely Egypt, Jordan, Lebanon and Israel, provide in detail conditions related to the appearance and physicochemical properties of the wheat mass and do not show an interest in the alveographic and behavioral properties of flour in production.

CHAPTER 4 - STUDY OF INTERNATIONAL WHEAT CLASSIFICATION AND GRADING SYSTEMS

Wheat, together with other cereals and oilseeds, are subjected to qualitative evaluations upon their reception in warehouses, in order to establish the quality grade or class.

The operations of grading or ranking the seeds at the reception are carried out based on official national standards or on the basis of an international norm.

The grading procedure has an important role in knowing the grain market and its quality at the level of a country.

Grades are assigned based on quality determinations and classify seeds into groups, each group or grade being defined by limits of quality conditions.

A group or grade comprises seed lots with similar, but not necessarily identical, quality characteristics.

Grading systems are fundamental tools aimed at ensuring a transparency of the grain market, promoting the quality of productivity and an overview of a country's agricultural potential.

In most countries that have implemented a grading system, specific quality assessment procedures have been developed at all points of reception and delivery, and these do not only refer to the determination of quality indices, but also to storage conditions and release deposit certificates.

Mixing batches of the same product, but with different qualities, can negatively influence the quality of the mixture.

At the US level, the official grain inspection body (Federal Grain Inspection Service - FGIS) operates under the Department of Agriculture (USDA).

The role of FGIS is to facilitate the marketing of US grains. by establishing standards for quality assessment, regulating handling practices and managing a network of state and private laboratories to provide impartial inspection and quality assessment services.

The official US wheat grading plan includes 5 grades numbered 1 through 5, grade 1 representing the highest quality grade and grade number 5 comprising the lowest quality lots. [39].

Grading factors refer to the hectoliter mass value and the impurity content with the subcategories provided by ISO 7970.

Russia has become a major wheat exporter since the early 2000s and today holds high market shares in several wheat importing countries in the Middle East and North Africa region. This raised concerns that Russia could abuse its dominant market position by setting prices above marginal cost. [40]

The Russian wheat quality system is based on the references of national standards, GOST, thus classifying wheat into five classes.

According to the criteria for assigning the quality classes shown in table 4.1, it can be concluded that the indicators of major relevance in establishing quality are the protein content and the gluten content. Classes IV and V can be considered classes specific to fodder wheat.

Table 4.1 - *Wheat grading plan in Russia [41]*

Parameter	**QUALITY CLASSES**				
	I	**II**	**III**	**IV**	**V**
Condition	Free flowing, no clumps				
Smell and appearance	Specific to healthy wheat, no musty odors or specific germination odors, no foreign odors				
Protein content, min %	14,5	13,5	12,0	10,0	Not limited
Gluten content, min %	32,0	28,0	23,0	18,0	Not limited
Falling number, sec, min	200		150	80	Not limited
Test weight, kg/hl, min	75		73	71	Not limited
Moisture, max %	14				
Impurities, %, min	2,0				5,0
Other cereals, %	5,0				15,0

In France, since July 1, 2015, the last classification of common wheat has been implemented with voluntary application by the parties involved in the commercial chain, in order to increase the protein level of French wheat.

Voluntary agreement depending on the protein content, 4 quality grades of wheat can be distinguished, as follows:

- Premium grade – with a protein content of at least 11.5%;
- Superior Grade - with a protein content of at least 11% content;
- Medium grade – with a protein content of at least 10.5%;
- Access grade – the protein content is specified in the contract, and the baking force (W), the hectoliter mass and the falling index are not limited.

In Romania, the grading procedure is regulated by order of the Ministry of Agriculture and became mandatory starting in 2003, the grading operation being carried out at all reception points.

The methods, rules and procedures are developed based on international, European and national standards, European regulations, as well as some rules in force and make up the Grading Manual which is approved by order of the Ministry of Agriculture.

In our country, common wheat is assigned three quality classes, and the limit values of the parameters used in the grading operation are shown in table 4.2.

Table 4.2 - *Grading plan of common wheat in Romania [42]*

Grading factors	**Grade 1**	**Grade 2**	**Grade 3**
1. Organoleptic and sanitary characteristics	**Specific to healthy wheat**		
2. Test weight, kg/hl min.	**77,0**	**75,0**	**72,0**
3.Total impurities,% din care:	**6,0**	**10,0**	**12,0**
Broken grain,%	3,0	3,0	5,0
Demaged kernels, % din care:	3,0	5,0	7,0
Shriveled,%	3,0	5,0	-
Other cereals,%	1,0	2,0	3,0
Attacked by pests, %	1,0	2,0	-
Blackpoint	0,5	0,5	-
Grains with changed skin color (burnt),%	0,5	1,0	2,0

Sprouted grains,%	2,0	3,0	3,0
Various impurities, % of which:	1,0	1,0	1,0
Seeds of other plants,%	0,1	0,1	0,1
Toxic seeds,%	0,5	1,0	1,0
Altered grains, % of which:	0	0,05	0,05
Burnt-hot grains,%	0,3	0,5	1,0
Grains attacked by Fusarium,%	1,0	2,0	2,0
Foreign matter,%	0,05	0,05	0,05
Grains attacked by Claviceps purpurea, %	0	0,1	0,1
4. Protein content, % min.	**12,0**	**11,0**	**-**

With an important contribution to the wheat production of the European Union, Germany uses a system similar to the French grading system. In 1995 the grading system was expanded with an upper class (E), considered elite and above the A class which includes the best wheat.[43] Class B includes wheat types suitable for all types of bread, class K is represented by wheat intended for pastry, and class C includes all types of wheat that are not intended for baking.

In table 4.3, the limits of the protein content and the falling index for the purpose of assigning quality grades are given.

Table 4.3 - *Quality criteria for wheat classification in Germany [44]*

Parameter	**QUALITY CLASSES**			
	Clasa E	**Clasa A**	**Clasa B**	**Clasa K**
Protein content, %, minim	13,8	13,2	12,8	12,4
Falling number, sec, minim	285	255	255	255

The main wheat-producing countries have instituted consumer seed grading systems, which are mandatory in some countries, such as Romania, the USA, Ukraine and Russia, or can be voluntary, as is the case in France, Germany, Italy or Bulgaria.

The use of these systems confers a series of advantages to all parties involved in the production-storage-processing chain, but also to institutions mandated with national and international statistics and researchers.

The data collected through the application of these rules provides an overview of the quality of wheat from previous years and can generate new objectives in the direction of improvement and zoning of the crop.

The lack of similarities in the minimum values of the parameters in the grading plans illustrates the different qualitative production capacities of wheat from different countries and the influence of the use of competitive varieties, as well as the variation of pedoclimatic conditions.

The image of wheat quality in an agricultural year constitutes a price regulation tool being useful in defining contractual clauses regarding quality, but also a tool for national authorities to intervene by supporting farmers.

International auctions on sales or purchases of wheat can capitalize on the data of grading systems in the sense of predictability and ensuring a qualitative flow of wheat in processing units.

In recent years, as a result of economic globalization and Romania's integration into the European Union, the reception and storage units have been constantly modernized through the funds accessed or through the economic operators' own funds and the sampling conditions have been improved through the implementation of automatic pneumatic probes and modern equipment for determining the quality of wheat and agricultural seeds, favoring the knowledge of quality parameters at short time intervals during storage or after drying or conditioning operations.

CHAPTER 5 - DETERMINATION OF THE QUALITY OF WHEAT LOTS

The amount of 26,872 tons of wheat that is the subject of quality determinations in order to configure the informational standardization model came from the harvest of 2019/20 and from technical considerations in accordance with the standard of thinning and from the point of view of the storage condition were constituted 25 lots.

The wheat subject to sampling is private property and at the time of sampling, the goods were stored in 11 cylindrical cells in the ISPA type concrete silo and in 6 warehouses within the premises of the reception base.

The sampling of the lots in the warehouses was carried out by using manual probes with a length of 3 m, and their size was established in accordance with the SR EN ISO 24333:2010 standard - Sampling of cereals, without exceeding the quantity of 1500 tons.

In order to sample the quantity in the silo, 11 cylindrical cells were probed with the help of the electromechanical probe operated by the silo operator under safety and security conditions.

The electromechanical probe is composed of bars 1.5 meters long, which by joining are able to penetrate the entire layer existing in the cell. Being provided with side slits, the probe can take samples from all layers. The actuation of the slots, the insertion and extraction of the probe is done automatically by the silo operator.

The global sample related to each lot was constituted by homogenizing the elementary samples and dividing them until obtaining a laboratory sample with a minimum mass of 2.2 kg.

The 25 samples were packed in polyethylene bags, sealed hermetically and labeled with the batch code and their size.

The sensory analysis of the samples related to the batches consisted in the assessment of appearance, taste, smell and color.

All the samples analyzed in terms of organoleptic characteristics fell within the specification of the healthy product, specific color, without foreign smell and taste.

The determination of the live infestation with specific insects was achieved by sifting the entire laboratory sample through a metal sieve that allowed the passage of fine particles and insects, retaining the product to be analyzed.

Live infestation was identified in 7 lots, namely lots 1, 2, 4, 5, 9, 16 and 17. In the samples related to lots 1, 2 and 4, two live specimens of Sitophilus zeamais were identified each, and in lots 9 and 17, specimens of *Rhyzoperta domnica.* The presence of the grain rust beetle *(Cryptolestes ferrugineus)* was identified in lot 16, and in lot 5 a mixed attack produced by *Cryptolestes ferrugineus* and Sitophilus zeamais was highlighted.

The determination of the humidity of the 25 batches was carried out by using the equipment provided by the SR EN ISO 712/2010 standard, namely the analytical balance with high precision, the laboratory mill, metal capsules, thermo-adjustable oven and desiccator.

The difference in mass between the undried sample and the sample after drying represents the moisture content. The final value is obtained by performing the arithmetic mean of the two parallel samples and is expressed as a percentage with two decimal places.

Out of the 25 batches analyzed, 13 batches register moisture values below 12.5%, which indicates the need for pre-grinding moistening in order to obtain bakery flours (figure 5.1).

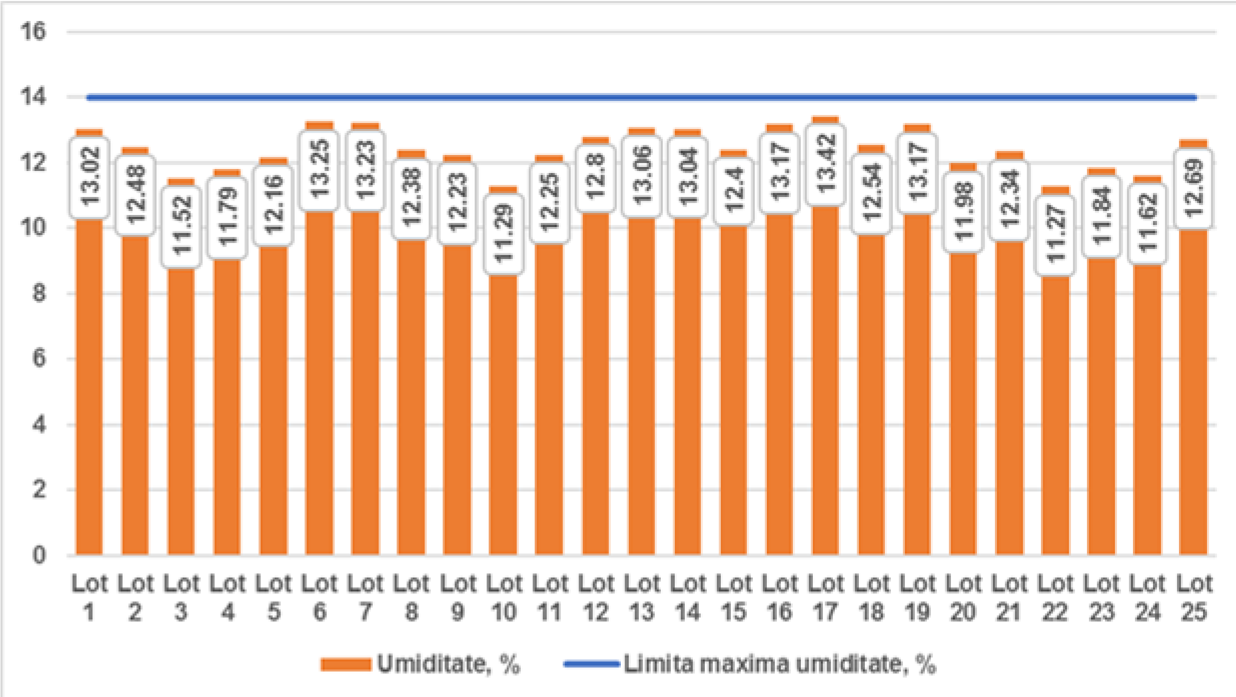


Figure 5.1 – Moisture content values in relation to the maximum allowed value

The hectoliter mass was determined by pouring, under controlled conditions, a certain amount of wheat from a filling cylinder of standardized dimensions into a container with a volume of 1000 ± 3 ml, checked metrologically, followed by weighing the amount of grains in the volume of 1000 ml on a balance characterized by a relative error of maximum ± 1 g of determinations. The expression is done in kg/hl at a given value of humidity.[45]

The results obtained and reproduced in figure 5.2 highlight hectoliter mass values of up to 80.1 kg/hl. Of the total lots analyzed, only three lots have a hectoliter mass below 75 kg/hl, respectively lots 16, 17 and 18. Below the limit established by the Romanian grading plan for wheat related to grade RO1, respectively, 77 kg/hl, 6 lots were included of which three were assigned to the RO2 grade and three to the RO3 grade, only from the point of view of this parameter.

The determination of the impurity content was carried out according to the SR EN 15587:2019 standard, by reducing the laboratory sample to a mass of approximately 250 g.

The sieves made in accordance with the ISO 5223 standard, namely the sieve with 3.5 mm elongated perforations, the sieve with elongated perforations of 1.0 mm and the sieve with elongated perforations of 2.0 mm, the precision balance of 0.01 g and the slotted divider.

By successive divisions for the purpose of extracting the sample to be analyzed, approximately 250 g of wheat was retained from each sample and consideration was given to the separation of the kernels from the hull if any.

The 3.5 mm sieve was overlapped over the 1.00 mm sieve so that the holes of the two sieves were parallel.

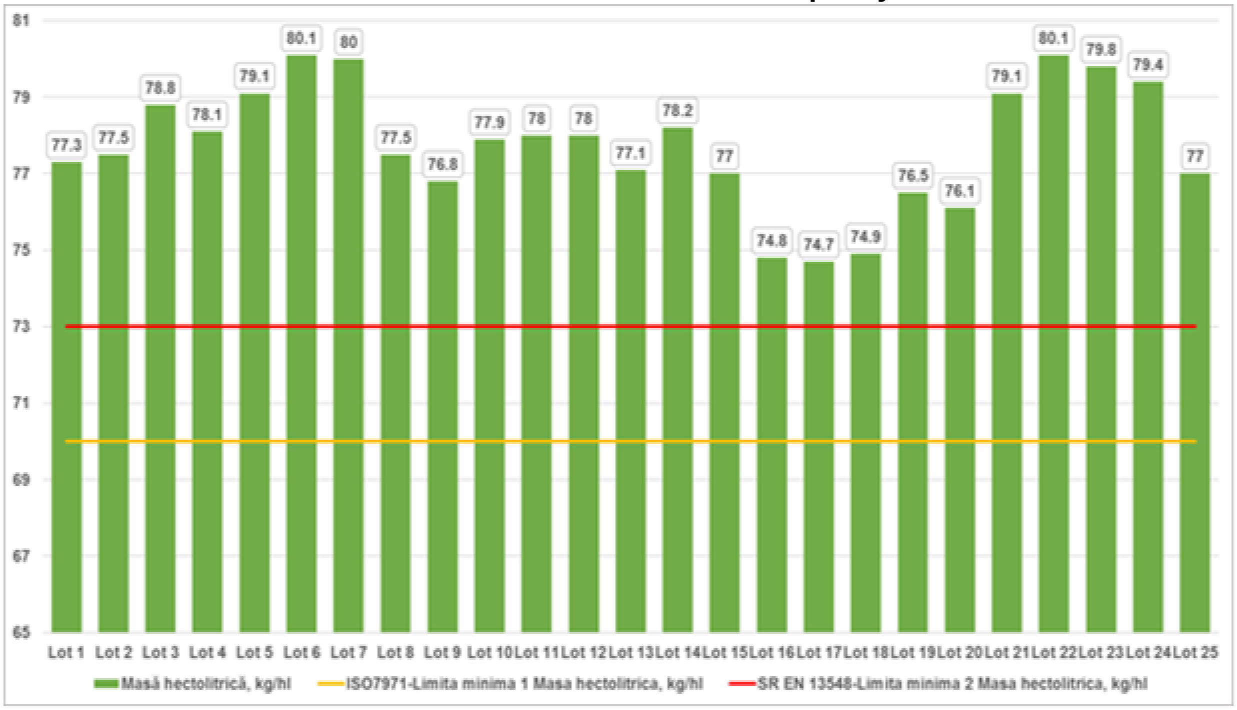


Figure 5.2 - The values obtained after determining the hectoliter mass and their variation compared to the international and European standard

The fractions remaining on the 3.5 mm sieve and the fraction that passed through the 1.00 mm sieve (with the exception of the grains of other cereals and the grains of the basic cereal) were weighed and classified as foreign bodies.

The sample remaining on the 1.00 mm sieve was reduced by division until obtaining a partial sample with a mass between 50 and 100 g.

The sample thus obtained was spread in a single layer of grains, on a white tray, facilitating the identification and separation of the components belonging to the category of total impurities, as follows:

- Broken grains – grains that have the endosperm partially visible, have been degerminated or have been damaged during harvesting;
- Grains with defects - this fraction includes flaky grains, grains with germs of a changed color, spots or black points (blackpoint), grains with a changed skin color as a result of drying (burnt), grains attacked by pests, as well as cereals other than wheat grains.
- Sprouted grains - this fraction includes all the grains that show signs of beginning germination;
- Miscellaneous impurities - category that includes the seeds of other plants, altered, moldy grains, organic (vegetable) and mineral foreign bodies, husks, impurities of animal origin (excrements, feathers, hair, etc.), rye horn, grains with a sieve.

After the separation of all the components, the sample was sieved through a sieve with elongated meshes of 2.0 mm, thus determining by weighing and calculating the percentage of coarse grains.

The presence of grains attacked by bedbugs negatively influences the extraction of flour and it is necessary to place them in storage spaces depending on the percentage of grains attacked. Wheat with a degree of 3-4% grains attacked by the bug passes into the category of wheat with poor baking properties.

The visual analysis distinguished three forms of attack:

- Grains on which the trace of the puncture was observed in the form of a black dot, around which a light-yellow spot formed, the endosperm being floury;
- Grains on the surface of which a yellow spot has developed, and the sting could not be identified under the magnifying glass, and after crushing it was observed that the embryo is atrophied;
- Grains that had a yellow spot in the embryonic area, the embryo was normal, and the prick could not be seen.

Figure 5.3 reveals the results obtained after determining the content of total impurities. 5 samples exceed the 6% limit related to RO1 grade wheat, thus ranking the lots in terms of total impurity content in a lower grade.

In the sum of total impurities, the presence of broken grains and defective grains can be noted in all analyzed batches.

Sprouted grains were identified in 9 of the 25 lots analyzed, and the maximum percentage resulting from the analysis is 0.10%, so that none of the lots presents a risk of damage or a risk of downgrading for this reason.

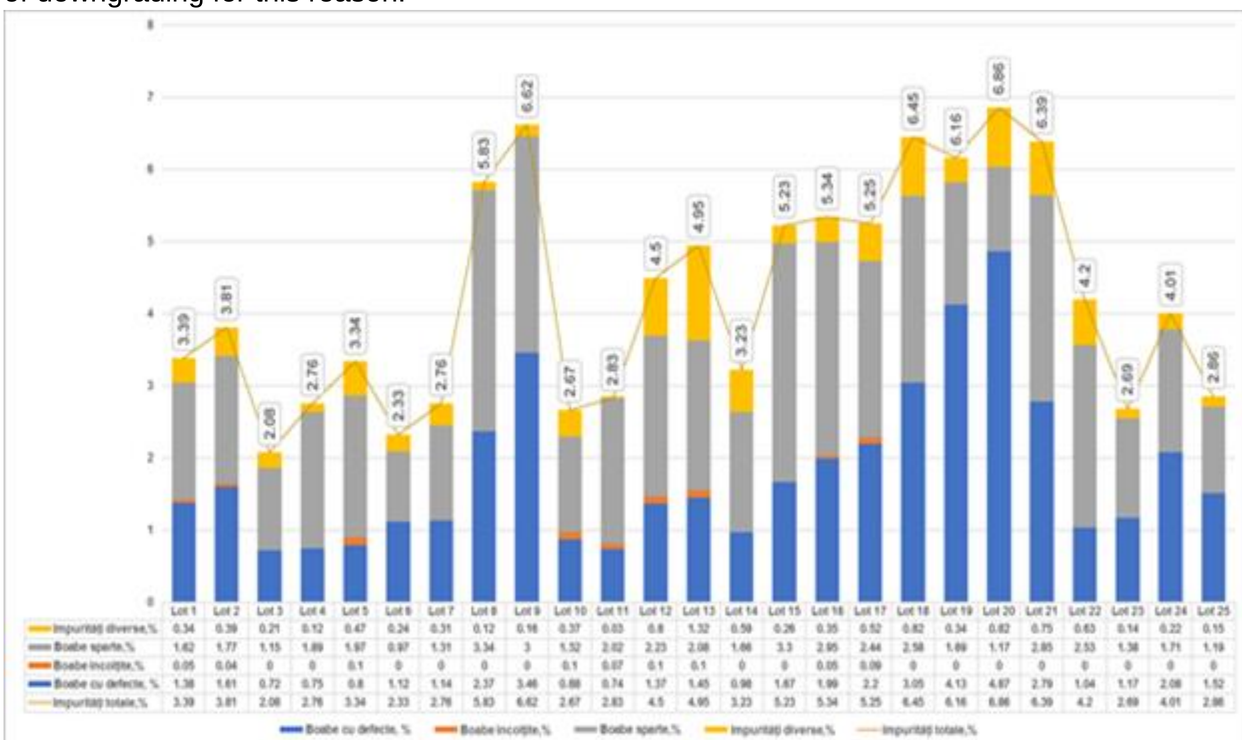


Figure 5.3 – Percentage values of total impurities and subcategories within total impurities in the lots analyzed

Analyzing figure 5.4, which reflects the percentage results of the components within the miscellaneous impurities subcategory, a high content of foreign bodies and seeds of other plants can be observed in lot 13.

In all lots, a higher share of seeds belonging to other plants is noted, but none of the subject lots exceed the limits of this category in terms of this sub-parameter.

The values of the content of foreign bodies (chaff, dust) are low, which indicates a good conditioning before storage or a correct adjustment of the harvester.

No toxic seeds, rye horn, grains attacked by common wheat blight or Fusarium spp were identified.

A remarkable aspect is the lack of burnt-hot berries, which leads to the hypothesis of a moderate dryness after reception.

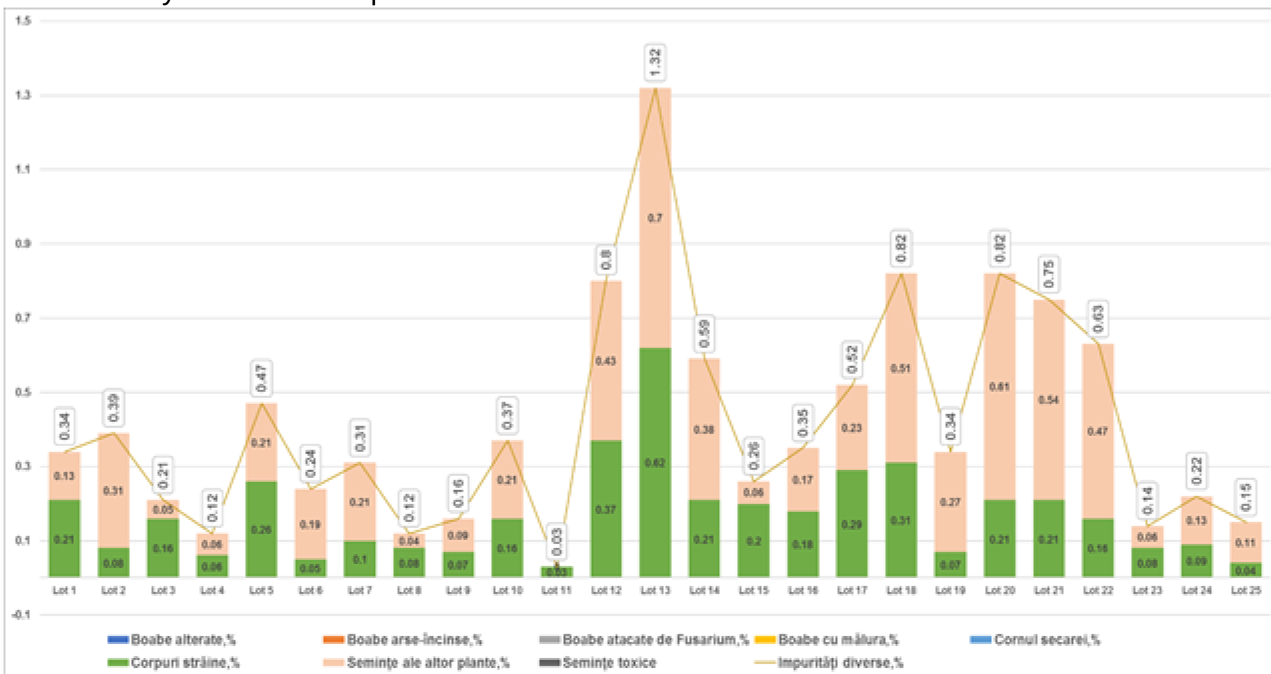


Figure 5.4 – Percentage of components within the miscellaneous impurities subcategory

The protein content was determined using the reference method provided in the standard SR EN ISO 20483:2007 – Cereals and legumes. Determination of nitrogen content. The Kjeldhal method.

The Kjeldahl method was used to determine total nitrogen. The principle of the method is based on boiling the ground sample with concentrated sulfuric acid, and the organic substances in the presence of a catalyst decompose releasing their component elements in different forms:

In order to determine the protein content, a quantity of approximately 200 grams of wheat related to each batch sample was ground, until a granularity was obtained that allowed the entire passage through the sieve of Ø 0.8 mm.

From the resulting grind, 5 grams are extracted and transferred to the mineralization tube, over which 10 g of potassium sulfate, 0.30 g of CuSO4 (pentahydrate), 0.30 g of catalyst (titanium oxide) and 30 ml of sulfuric acid are added.

The optimal boiling time is determined by using a reference material, in this case tryptophan with a difficult recovery time. Simultaneously, two blank samples were worked in which the reagents were added without ground product

After 10 minutes, the sample turns dark brown to black as the sulfuric acid reacts with the product, and after 30-35 minutes, the sulfuric acid returns to the digestion solution.

The release of a white smoke and the change in the appearance of the solution to transparent, indicates the completion of mineralization.

Figure 5.5 – Mineralization and distillation of wheat samples in order to determine the protein content

Distillation was carried out after cooling the flask in which 50 ml of water were added. 50 mL of boric acid and color indicator were added to the collection vessel, and 5 mL of sodium hydroxide was added to the working sample. The operation was carried out with the help of the Kjeldahl Gerhardt distillation system type Vapodest 500 (figure 5.5).

The titration was done using the sulfuric acid solution at the end of the distillation. An analytical balance with a precision of 0.001 g was used during this determination.

Figure 5.6 - Values of crude protein content and protein relative to dry matter

The nitrogen content, expressed as a mass fraction relative to the moisture content, in percentages, was calculated with the formula provided in the SR EN ISO 20483:2007 standard - Cereals and legumes. Determination of nitrogen content. The Kjeldhal method.

The results obtained and shown in figure 5.6, highlight a wide range of crude protein content values, as well as protein content related to dry matter.

The parameter of interest in international contracts is the protein content relative to dry matter.

Analyzing figure 5.6, only lots 17 and 19 recorded values below 12%, the maximum value was recorded in the case of lot 8 (13.75%).

From the total of the lots analyzed, 15 lots have a protein content relative to the dry substance between 12-13%, and 8 lots exceed the value of 13%.

The protein content was determined by using the SR EN ISO 21415-2 reference; Determination of wet gluten content by mechanical methods.

The method provides for the use of an automatic electronic device, equipped with washing chambers, a homogenizing arm and a distribution device.

In order to perform this determination, the Glutomatic 2200 device was used, which meets the requirements of the standard and is equipped with two determination stations.

According to the records obtained and shown in figure 5.7, it can be seen that only one sample, namely Lot 23, has a wet gluten content at the minimum limit established by the standard.

In the range of 22-25% wet gluten content there are only three lots, thus characterizing the related quantities with an average wet gluten content, and in the range of 25-31% there are 22 lots of wheat with a high gluten content, thus placing all lots in higher quality classes in terms of this parameter.

Figure 5.7 - The value of the wet gluten content in the analyzed batches

The method is based on the complete grinding of a wheat sample in a laboratory mill, and a quantity of 24 grams is weighed from the resulting meal, from which a dough is obtained by adding 12 ml of sodium chloride solution.

The dough obtained is weighed and subjected to manual washing with a sodium chloride solution, with a flow rate of 750 ml in 8 minutes, over a sieve to catch any fragments that may come off during washing.

The qualitative evaluation of wet gluten by determining the deformation index consists in the thermostating of a ball of gluten of 5 grams, positioned on graph paper, in an oven for 60 minutes. The result was obtained by measuring the initial and final diameter, horizontally, after deformation due to temperature (figure 5.8)

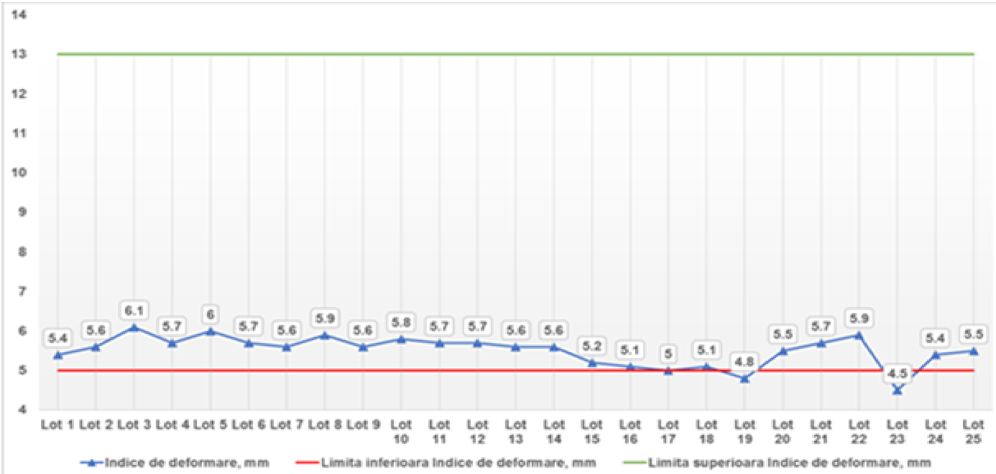


Figure 5.8 - The results obtained after determining the deformation index

The determination of the falling index was carried out in accordance with the SR EN ISO 3093 standard, whose method principle is the highlighting of the activity of α-amylase from the starch present in the sample substrate, through the rapid gelatinization of an aqueous suspension of ground wheat in a water bath at high temperatures and implicitly the measurement of starch liquefaction time.[46].

The device used is called Falling Number model 1000 and corresponds from a technical point of view to the standard that regulates this determination. The results of this indicator are expressed in seconds.

The enzyme activity is given by the germination of the grains, and lot 5 comprises a percentage of 0.10 sprouted grains. Similar percentages of sprouted grains were also identified in lots 10, 12, 13 and 17, but only in the case of lot 10 a minimal correlation can be observed.

The values obtained from the tests performed for the 25 lots are presented in figure 5.9 and it can be appreciated that all the analyzed samples recorded values above the regulated minimum of 220 seconds.

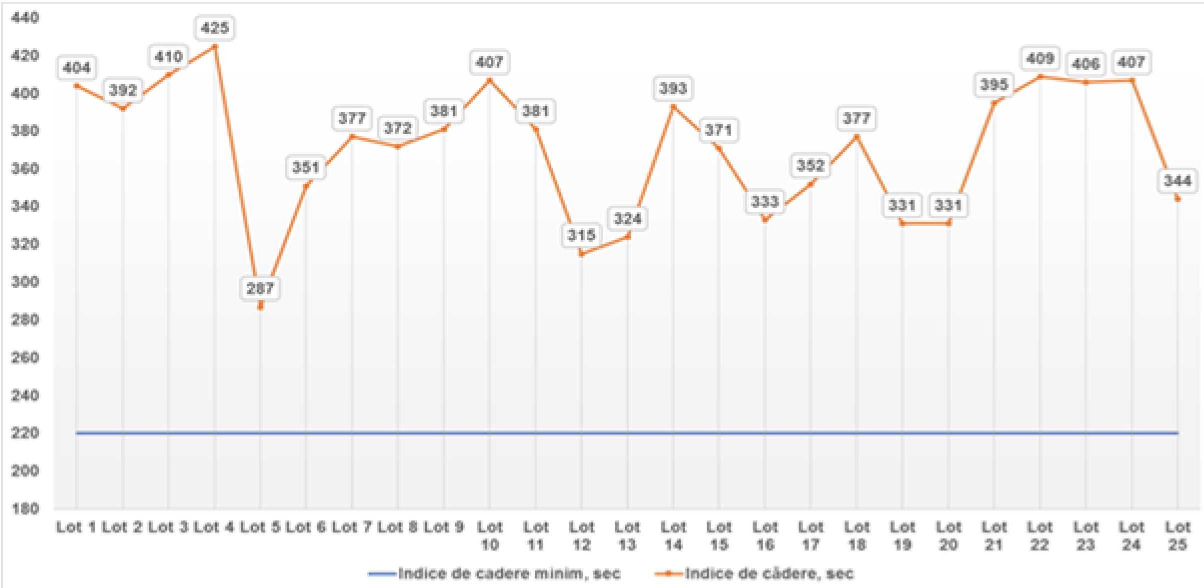


Figure 5.9 - Graphic representation of the fall index values

The principle of the method consists in assessing the behavior of dough obtained from several types of flour homogenized with sodium chloride solution. The test consists of exposing a disk of dough under a jet of air, forming a bubble following the pressure exerted, tracking the extensibility and the moment of rupture. The resulting curve is called an alveogram.

In addition to the classic laboratory equipment, the determination also requires special equipment consisting of a laboratory sieve equipped with a sieve for conditioning the wheat under analysis, a rotary mixer with a role in the hydration of the grains, a laboratory mill, a Chopin apparatus equipped with a mixer for obtaining the dough and equipped with a system for temperature regulation, manometer with pressure curve recording function and alveograph for biaxial deformations of dough samples.

The results are expressed by interpreting the curves recorded during the inflation and bursting of the bubble. In the situation where large deviations of the curve are observed in a single sample, this should not be taken into consideration, if the other four curves are similar, thus making an average of the pressure curves.

The behavior of the dough under air pressure is graphically extrapolated in the form of curves whose geometric characteristics constitute the parameters of the dough. Thus, the alveograph generates the following coordinates:

- the maximum height of the curve (H), represents the resistance (P) of the dough to extension;
- the length of the curve (L), expressed in millimeters, which describes the extensibility of the dough;
- the extensibility index (G) whose value is calculated based on the length of the curve (L) by the formula $G = 2.226\sqrt{L}$;
- the surface of the curve (S), whose value allows the calculation of the total amount of energy absorbed by the dough during stretching (W), according to one of the formulas (1.32·G·S)/L or 6.54·S·103. The results are expressed in 10-4/Jouli/gram dough;
- the elasticity index of the dough (Ie), calculated as the ratio between the resistance of the dough at the beginning of the curve (P200) and the maximum resistance (P);

- the P/L ratio, shows to what extent the dough is more extensible or more resistant and is calculated as a ratio of the two parameters of the dough [47].

The interpretation of the results presented in figure 5.10 show various alveographic values, classifying the lots analyzed, depending on the suitability of the final use as follows:

Batches 3, 4, 10 and 11 can be used in admixture with batches whose W is lower and are recommended for use in order to obtain bread or other bakery products;

- Batches 1 and 24 can be used as such, the value of W being optimal for bread and bakery products;
- Batches whose W value was between 180 and 320 can be used to obtain fast-growing products;
- Batch 8, with a W value of 155 can be used for confectionery and biscuit-type pastry products.
- The ratio between strength and extensibility (P/L), places lots 2, 3, 4, 5, 11, 14, 17, 18, 19, 21, 22, 23 and 24 in the optimal range imposed for this indicator (figure 5.10).

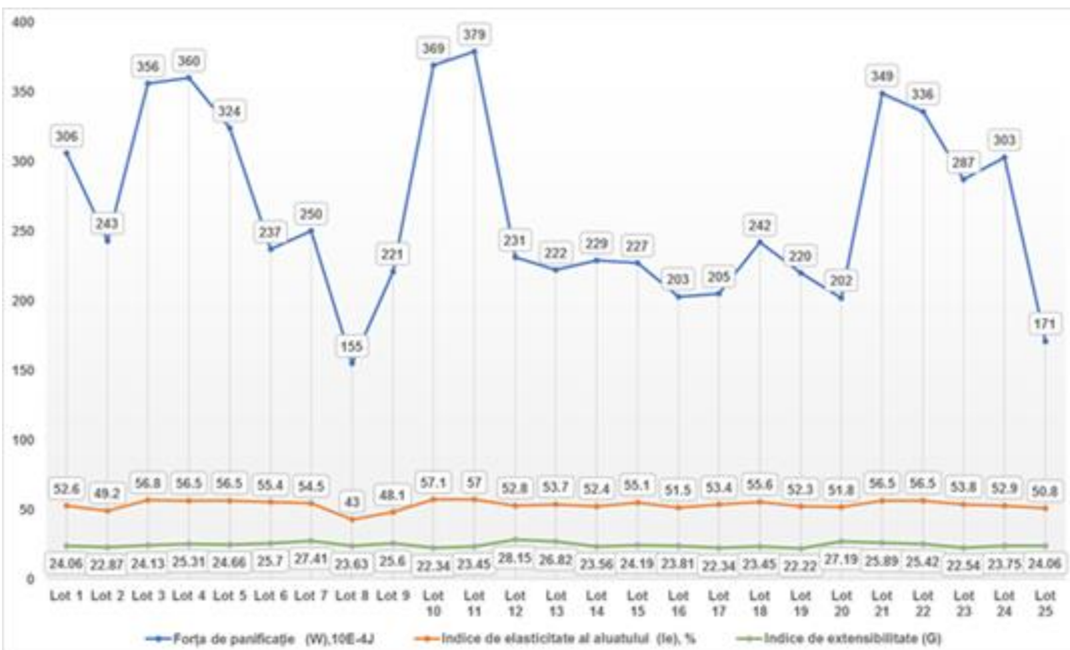


Figure 5.10 – Alveogram results for the lots analyzed

Considering the results obtained, only batches 4, 21 and 22 reach the optimal cumulative values for W, G and Ie and can be considered batches with excellent baking properties.

In terms of baking strength, all 23 lots exceed the minimum limit of 180, with lots 8 and 25 having values of 155 and 171, respectively.

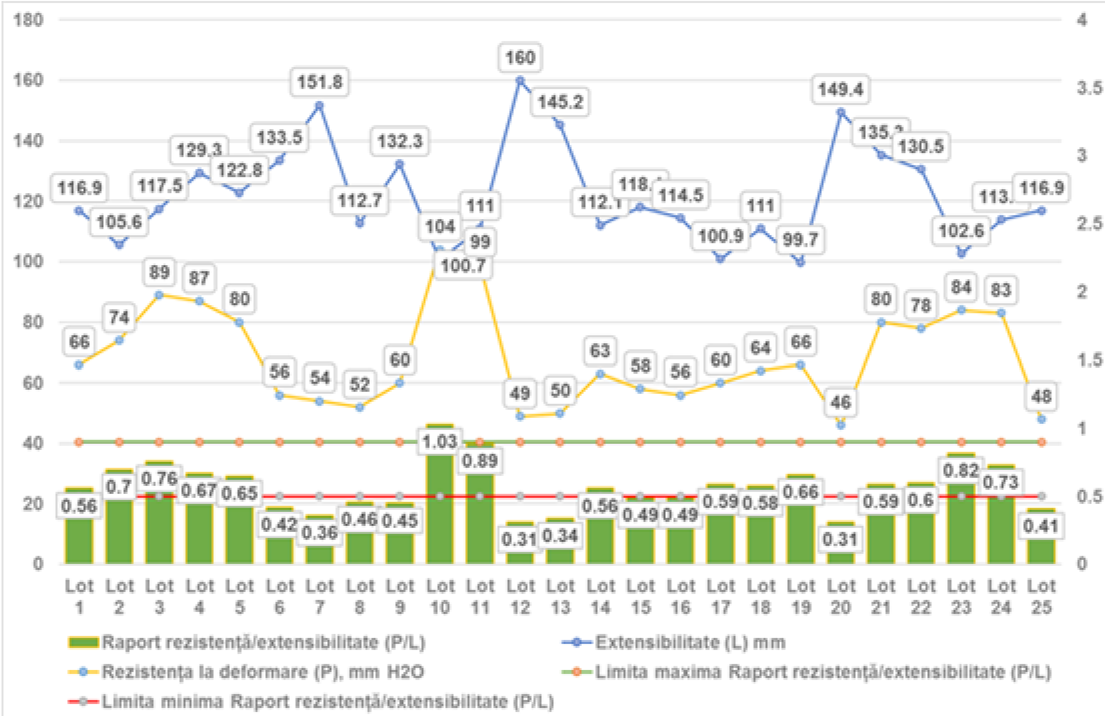


Figure 5.11- The index of extensibility, resistance to deformation, extensibility and the P/L ratio of the lots subjected to alveographic determination

The extensibility index (G) is in the optimal range only in the case of lots 4,6,7,9,12,13,21,22 and 23. (figure 5.11).

The ratio between resistance and extensibility (P/L), places batches 2, 3, 4, 5, 11, 14, 17, 18, 19, 21, 22, 23 and 24 in the optimal range of this indicator.

For the determination of DON, the immunoenzymatic method by enzyme absorption (ELISA) was used, which provides a semi-quantitative-quantitative screening.

The measurement was carried out at a wavelength of 450 nm using the Elisa microplate photometer, model BOE. The detection limit of the test is 0.125 mg/kg.

Table 5.1 shows the results obtained after determining the presence of deoxynivalnol in the analyzed batches and it can be concluded that of the 25 analyzed samples, 11 recorded values between 187-527 mg/kg, and the values of 14 samples were below the detection limit of the device , respectively 0.125 mg/kg.

Table 5.1 - DON content values in the analyzed lots

LOT	Value mg/kg	LOT	Value mg/kg	LOT	Value mg/kg	LOT	Value mg/kg	LOT	Value mg/kg
Lot 1	187	Lot 6	< LOD	Lot 11	< LOD	Lot 16	< LOD	Lot 21	< LOD
Lot 2	< LOD	Lot 7	274	Lot 12	527	Lot 17	< LOD	Lot 22	< LOD
Lot 3	< LOD	Lot 8	< LOD	Lot 13	312	Lot 18	392	Lot 23	453
Lot 4	392	Lot 9	510	Lot 14	< LOD	Lot 19	320	Lot 24	< LOD
Lot 5	328	Lot 10	470	Lot 15	< LOD	Lot 20	< LOD	Lot 25	< LOD

< LOD - below detection limit 0.125 mg/kg

The obtained values do not endanger public health, being at most 1/3 of the maximum allowed limit, i.e. 1750 mg/kg.

Fidelity of results

All the tests carried out were carried out in duplicate, and the final result was given by the arithmetic mean of two determinations carried out by the same method and on the same sample, in a short period of time and by the same person on the same equipment.

In such conditions, the repeatability limits fell within the limits provided by the method standards.

Uncertainty (Ue) is a parameter associated with the result of a measurement that characterizes the dispersion of values that can reasonably be attributed to a well-defined physical quantity that can be characterized by a single essential value.[48]

For the moisture content, the uncertainty is Ue = ± 0.30, for humidities between 10 -18 %,[14] and for the hectoliter mass it is Ue = 0.9 kg/hl for parameter values between 67.5 – 84.5 kg/hl.[49]

CHAPTER 6 - WHEAT QUALITY STANDARDIZATION INFORMATION MODEL

The main objective of this paper is to develop an informational model for the standardization of wheat quality in international contracts and obtain a global quality index of the lots analyzed.

The development of the information model is based on the assessment by experts of the results obtained from the analysis of 25 batches of wheat, through the reference methods and the transposition of these results into a mathematical modeling system, called fuzzy.

By using the fuzzy system, the quality of the lots analyzed will be translated into a global quality index related to each lot.

Fuzzy systems are oriented towards managing uncertain or imprecise information. The fuzzy system is used in fields where the input variables do not have fixed values or their value and importance may vary.[50]

The Fuzzy concept was first introduced by Zadeh (1965) to alleviate uncertainties and fuzziness problems. The technique relies on human subjectivity in decision-making due to linguistic variables that allow precise modeling of imprecise utterances[51] and has been applied to many engineering problems.[52]

This concept offers a number of advantages for users, such as reducing the costs of production, transport, storage and recovery as well as improving the costs of the companies using it. Fuzzy is used to represent process uncertainty and simulation of final product quality determination.

Fuzzy logic is a broad field of study and various tools have been developed in recent years. Food quality is a fuzzy category that could be evaluated using fuzzy logic.

> Its implementation in food quality control for the food industry has been highlighted by several authors who have focused on different applications designed specifically for this field. This is especially true when considering the reasoning process, expressed in linguistic terms, of operators and experts. However, applications are still limited and few reviews are available on the subject. [53]

By using Fuzzy logic, obtaining the global wheat quality index can be determined by going through the following stages in the development of the informational model:

- Formation of the knowledge base;
- Fuzzy inference;
- Fuzzification;
- Defuzzification.

The adopted approach regarding the evaluation of wheat quality is based on the expertise of 20 specialists in the field, with competences in the determination and evaluation of wheat quality as well as in the field of grain trading.

The allocation of qualifications by experts regarding the quality of the lots analyzed, as well as the establishment of the weight of the importance of the analyzed parameters, was carried out based on international and European standards, but also on the quality specifications used in commercial contracts, together with the professional experience of each one.

Mapping quality attributes into a fuzzy domain as multidimensional fuzzy sets results in a quality index associated with the entire batch.

In quality control, specialists may face uncertain and unclear concepts. By using the fuzzy concept and developing the information model, the quality of the wheat is qualified according to the strictness of the decision factors and the values of the obtained quality parameters.

In this thesis, we proposed a model, which can not only perform a quality assessment at all control points, but also assess the quality of wheat that is the subject of an international contract. The quantities that are the subject of commercial transactions usually come from several farmers and are stored before delivery in several storage areas (platforms, warehouses, silo cells).

Using batch mapping onbasis of the resulting quality index, represents an advantage for traders and depositors, generating a clear and objective overview.

Using fuzzy logic to describe abstract concepts and design decision-making systems much closer to the way a human does is an interesting and useful area to explore. To effectively implement these types of systems, expert knowledge of the domain in which the application is being used is required.[54]

For each linguistic term that a linguistic variable implies, a fuzzy set described by a relevance function will be created.

The semantic properties of the (linguistic) concept are described by the outline of the respective fuzzy set. Therefore, the closer the behavior of the phenomenon under study is to the curve of the relevance function, the more accurate or performing the fuzzy model is in representing the real world.[55]

In the database formation stage, the physico-chemical quality indicators obtained from the laboratory determinations by analyzing the samples of the 25 wheat lots were based on the evaluations of 20 experts using a scale with 5 linguistic terms, associated with the qualifiers:

N = unsatisfactory; S = satisfactory; M = medium; B = good; FB = very good.

The terms N, S, M, B, FB represent the linguistic variables to which the values of the analyzed parameters are associated.

Each expert evaluated the 25 wheat lots and assigned a value of 1 on the N-S-M-B-FB qualification scale to each analyzed parameter once, the assessment being expressed in accordance with the international standards and specifications used in international trade, as well as with their own expertise.

Based on relevance, the system sets each value in the fuzzy set to a value between 0 and 1, a measure that represents the degree of relevance of the fuzzy set element.

For exemplification in the summary, the results obtained following the experts' assessment of the LOT 1 are reproduced (table 6.1).

__Table 6.1__- Experts' assessment of the quality of the LOT 1

Nr. crt.	Determined parameters	Value	Rating scale				
			N	S	M	B	FB
1	Moisture, %	13.02	0	0	5	10	5
2	**Total impurities,%** din care:	**3.39**	**1**	**2**	**6**	**8**	**3**
2.1	***Broken grain,%***	**1.62**	**0**	**5**	**4**	**9**	**2**
2.2	***Demaged kernels, %*** din care:	**1.38**	**0**	**2**	**7**	**9**	**2**
2.2.1	Shriveled,%	0.80	0	2	9	7	2
2.2.2	Other cereals,%	-	0	0	0	0	20
2.2.3	Attacked by pests, %	0.19	0	1	8	9	2
2.2.4	Blackpoint	0.39	0	0	0	2	18
2.2.5	Grains with changed skin color (burnt),%	-	0	0	0	0	20
2.3	**Sprouted grains,%**	**0.05**	**0**	**1**	**2**	**6**	**11**
2.4	***Various impurities, % of which:***	**0.34**	**0**	**0**	**1**	**3**	**16**
2.4.1	Seeds of other plants,%	0.13	0	0	0	2	18
2.4.2.	Toxic seeds,%	-	0	0	0	0	20
2.4.3.	Altered grains, % of which:	-	0	0	0	0	20
2.4.3.1	Burnt-hot grains,%	-	0	0	0	0	20
2.4.3.2	Grains attacked by Fusarium,%	-	0	0	0	0	20
2.4.4	Admixture,%	0.21	0	0	1	3	16
2.4.5	Grains attacked by Claviceps purpurea, %	-	0	0	0	0	20
2.4.6	Grains attacked by Tilletia spp,%	-	0	0	0	0	20
2.5	***Animal impurities, nr./kg***	-	0	0	0	0	20
3	Test weight, kg/hl	**77.3**	**0**	**0**	**7**	**11**	**2**
4	Crude protein content, %	11.05	**0**	**0**	**5**	**8**	**7**
5	Protein content, dry matter, %	**12.7**	**0**	**0**	**5**	**8**	**7**
6	Falling number, sec	404	0	16	3	1	0
7	Wet gluten content, %	25.1	0	0	1	17	2
8	Deformation index, mm	5.4	0	0	0	5	15
9	Gluten index	73	0	0	0	0	20
10	Infestation	2 bucati*	20	0	0	0	0
11	The bakery force, (W),$10E^{-4J}$	306	0	0	0	0	20
12	DON, mg/kg	187	0	0	0	0	20

*Sitophylius zeamais / 2.7 kg sample

The second stage in the development of the informational model consisted in defining a scale of three qualifications, respectively little important (PI), important (I) and very important (FI), which was made available to the experts in order to assign a qualification to each parameter that was determined in order to evaluate the quality of the wheat.

The data obtained after the centralization of the qualifications are presented in table 6.2 and constitute the weight of the importance of the parameters in fuzzy modeling.

Table 6.2 - *Experts' assessment of the importance of quality parameters in the evaluation of a batch of wheat*

Nr. crt.	**Quality parametres**	**Rating scale**		
		PI	**I**	**FI**
1	Moisture, %	0	5	15
2	**Total impurities,%** din care:	5	15	0
2.1	***Broken grain,%***	5	15	0
2.2	***Demaged kernels, %*** din care:	5	15	0
2.2.1	Shriveled,%	5	15	0
2.2.2	Other cereals,%	5	5	10
2.2.3	Attacked by pests, %	5	15	0
2.2.4	Blackpoint	0	15	5
2.2.5	Grains with changed skin color (burnt),%	5	10	5
2.3	**Sprouted grains,%**	5	15	0
2.4	***Various impurities, % of which:***	5	15	0
2.4.1	Seeds of other plants,%	0	5	15
2.4.2.	Toxic seeds,%	0	5	15
2.4.3.	Altered grains, % of which:	0	5	15
2.4.3.1	Burnt-hot grains,%	0	5	15
2.4.3.2	Grains attacked by Fusarium,%	0	5	15
2.4.4	Admixture,%	0	5	15
2.4.5	Grains attacked by Claviceps purpurea, %	0	0	20
2.4.6	Grains attacked by Tilletia spp,%	0	0	20
2.5	***Animal impurities, nr./kg***	0	5	15
3	Test weight, kg/hl	0	15	5
4	Crude protein content, %	0	5	15
5	Protein content, dry matter, %	0	5	15
6	Falling number, sec	0	15	5
7	Wet gluten content, %	0	15	5
8	Deformation index, mm	5	15	0
9	Gluten index	0	5	15
10	Infestation	0	5	15
11	The bakery force, (W),$10E^{-4J}$	0	5	15
12	DON, mg/kg	0	5	15

By using the Matlab R2020 program and the Fuzzy Logic Designer function, the association of triplets was achieved following the evaluation of the quality of wheat lots by experts, as well as for the weights established regarding the importance of quality parameters in the evaluation of a wheat lot.

Fuzzy triplets were associated with the linguistic terms used to assess the quality of the wheat batches with the help of left-right triangular membership functions, as follows:

Unsatisfactory, (N) =[0 0 25]; Satisfactory, (S)=[25 25 25]; Medium, (M)=[50 25 25];

Good, (B)=[75 25 25]; Very good, (FB)=[100 25 0].

Linguistic terms used to determine the weights of the analysis indicators in the value of the global quality index were associated with fuzzy triplets with the help of left-right triangular membership functions as follows:

Less important, (PI) =[0 0 50]; Importantly, (I) =[50 50 50]; Very important, (FI)=[100 50 0];

For example, the summary shows the association of fuzzy triplets in relation to the values of the quality indicators obtained through the analysis of LOT 1 (table 6.3).

Table 6.3 - *The association of fuzzy triplets in relation to the values of the quality indicators obtained through the analysis of LOT 1*

Nr. crt.	**Parametri determinati**	**Value**	**Associated triplets**		
			PI	**I**	**FI**
1	Moisture, %	13.02	75.0000	25.0000	18.7500
2	**Total impurities,%** din care:	**3.39**	62.5000	23.7500	21.2500
2.1	***Broken grain,%***	**1.62**	60.0000	25.0000	22.5000
2.2	***Demaged kernels, %*** din care:	**1.38**	63.7500	25.0000	22.5000
2.2.1	Shriveled,%	0.80	61.2500	25.0000	22.5000
2.2.2	Other cereals,%	-	100.0000	25.0000	0
2.2.3	Attacked by pests, %	0.19	65.0000	25.0000	22.5000
2.2.4	Blackpoint	0.39	97.5000	25.0000	2.5000
2.2.5	Grains with changed skin color (burnt),%	-	100.0000	25.0000	0
2.3	**Sprouted grains,%**	**0.05**	83.7500	25.0000	11.2500
2.4	***Various impurities, % of which:***	**0.34**	93.7500	25.0000	5.0000
2.4.1	Seeds of other plants,%	0.13	97.5000	25.0000	2.5000
2.4.2.	Toxic seeds,%	-	100.0000	25.0000	0
2.4.3.	Altered grains, % of which:	-	100.0000	25.0000	0
2.4.3.1	Burnt-hot grains,%	-	100.0000	25.0000	0
2.4.3.2	Grains attacked by Fusarium,%	-	100.0000	25.0000	0
2.4.4	Admixture,%	0.21	93.7500	25.0000	5.0000
2.4.5	Grains attacked by Claviceps purpurea, %	-	100.0000	25.0000	0
2.4.6	Grains attacked by Tilletia spp,%	-	100.0000	25.0000	0
2.5	***Animal impurities, nr./kg***	-	100.0000	25.0000	0
3	Test weight, kg/hl	**77.3**	68.7500	25.0000	22.5000
4	Crude protein content, %	11.05	77.5000	25.0000	16.2500
5	Protein content, dry matter, %	**12.7**	77.5000	25.0000	16.2500
6	Falling number, sec	404	31.2500	25.0000	25.0000
7	Wet gluten content, %	25.1	76.2500	25.0000	22.5000
8	Deformation index, mm	5.4	93.7500	25.0000	6.2500
9	Gluten index	73	100.0000	25.0000	0
10	Infestation	2 pcs*	0	0	25.0000
11	The bakery force, (W),$10E^{-4J}$	306	100.0000	25.0000	0
12	DON, mg/kg	187	100.0000	25.0000	0

*Sitophylius Zeamais / 2.7 kg sample

The association of fuzzy triplets based on the relative weight of the physical-chemical analyzes (table 6.4) was made using the relationship:

$$Ft=F*[PI; I; FI]/20$$

Table 6.4 – The association of fuzzy triplets based on the relative weight of the physical-chemical analyses

Nr. crt.	Parametri determinati	Associated triplets		
		PI	**I**	**FI**
1	Moisture, %	87.5000	50.0000	12.5000
2	**Total impurities,%** din care:	87.5000	50.0000	12.5000
2.1	***Broken grain,%***	37.5000	37.5000	50.0000
2.2	***Demaged kernels, %*** din care:	37.5000	37.5000	50.0000
2.2.1	Shriveled,%	37.5000	37.5000	50.0000
2.2.2	Other cereals,%	37.5000	37.5000	50.0000
2.2.3	Attacked by pests, %	62.5000	37.5000	25.0000
2.2.4	Blackpoint	37.5000	37.5000	50.0000
2.2.5	Grains with changed skin color (burnt),%	62.5000	50.0000	37.5000
2.3	**Sprouted grains,%**	50.0000	37.5000	37.5000
2.4	***Various impurities, % of which:***	37.5000	37.5000	50.0000
2.4.1	Seeds of other plants,%	37.5000	37.5000	50.0000
2.4.2.	Toxic seeds,%	87.5000	50.0000	12.5000
2.4.3.	Altered grains, % of which:	87.5000	50.0000	12.5000
2.4.3.1	Burnt-hot grains,%	87.5000	50.0000	12.5000
2.4.3.2	Grains attacked by Fusarium,%	87.5000	50.0000	12.5000
2.4.4	Admixture,%	87.5000	50.0000	12.5000
2.4.5	Grains attacked by Claviceps purpurea, %	87.5000	50.0000	12.5000
2.4.6	Grains attacked by Tilletia spp,%	100.0000	50.0000	0
2.5	***Animal impurities, nr./kg***	100.0000	50.0000	0
3	Test weight, kg/hl	87.5000	50.0000	12.5000
4	Crude protein content, %	62.5000	50.0000	37.5000
5	Protein content, dry matter, %	87.5000	50.0000	12.5000
6	Falling number, sec	87.5000	50.0000	12.5000
7	Wet gluten content, %	62.5000	50.0000	37.5000
8	Deformation index, mm	62.5000	50.0000	37.5000
9	Gluten index	37.5000	37.5000	50.0000
10	Infestation	87.5000	50.0000	12.5000
11	The bakery force, (W),$10E^{-4J}$	87.5000	50.0000	12.5000
12	DON, mg/kg	87.5000	50.0000	12.5000

The fuzzy triplets associated based on the relative weight of the physico-chemical analyzes (table 6.5) were transposed into the matrix calculation function of the fuzzy application and subjected to modeling as follows:

Qt=sum(Ft(:,1)); / Ftrel=Ft/Qt;

Ftrel – represents the weight matrix of each quality indicator in the calculation of the global quality index

Table 6.5 - *Matrix of the weights of each quality indicator in the calculation of the global quality index*

Nr. crt.	Perameters	Associated triplets		
		PI	I	FI
1	Moisture, %	0.0419	0.0240	0.0060
2	**Total impurities,%** din care:	0.0419	0.0240	0.0060
2.1	***Broken grains,%***	0.0180	0.0180	0.0240
2.2	***Demaged kernels, %*** din care:	0.0180	0.0180	0.0240
2.2.1	Shriveled,%	0.0180	0.0180	0.0240
2.2.2	Other cereals,%	0.0180	0.0180	0.0240
2.2.3	Attacked by pests, %	0.0299	0.0180	0.0120
2.2.4	Blackpoint	0.0180	0.0180	0.0240
2.2.5	Grains with changed skin color (burnt),%	0.0299	0.0240	0.0180
2.3	**Sprouted grains,%**	0.0240	0.0180	0.0180
2.4	***Various impurities, % of which:***	0.0180	0.0180	0.0240
2.4.1	Seeds of other plants,%	0.0180	0.0180	0.0240
2.4.2.	Toxic seeds,%	0.0419	0.0240	0.0060
2.4.3.	Altered grains, % of which:	0.0419	0.0240	0.0060
2.4.3.1	Burnt-hot grains,%	0.0419	0.0240	0.0060
2.4.3.2	Grains attacked by Fusarium,%	0.0419	0.0240	0.0060
2.4.4	Admixture,%	0.0419	0.0240	0.0060
2.4.5	Grains attacked by Claviceps purpurea, %	0.0419	0.0240	0.0060
2.4.6	Grains attacked by Tilletia spp,%	0.0479	0.0240	0
2.5	***Animal impurities, nr./kg***	0.0479	0.0240	0
3	Test weight, kg/hl	0.0419	0.0240	0.0060
4	Crude protein content, %	0.0299	0.0240	0.0180
5	Protein content, dry matter, %	0.0419	0.0240	0.0060
6	Falling number, sec	0.0419	0.0240	0.0060
7	Wet gluten content, %	0.0299	0.0240	0.0180
8	Deformation index, mm	0.0299	0.0240	0.0180
9	Gluten index	0.0180	0.0180	0.0240
10	Infestation	0.0419	0.0240	0.0060
11	The bakery force, (W),$10E^{-4J}$	0.0419	0.0240	0.0060
12	DON, mg/kg	0.0419	0.0240	0.0060

The calculation of the global quality index of the analyzed wheat lots includes the fuzzification and defuzzification phase.

With the help of the relative weights in the form of fuzzy triplets, the global quality index was calculated for each wheat lot, using the extended pe.mat product.

The mathematical model used is: CIti= Iti Ftreli, where i = 1:30.

The mathematical model uses the extended product that was introduced as a function on .mat: %t extended product:

function C = on (A, B)/ C(1)=A(1)*B(1);/ C(2)=A(1)*B(2)+B(1)*A(2) ;/ C(3)=A(1)*B(3)+B(1)*A(3);

To calculate the quality of the wheat batch, we used the cg. mat function, which transposes the above mathematical model into the Matlab language:

%fuzzification, %quality of the wheat batch

function C = cg(A, B) / C=[0 0 0]; / for i =1:30, / C=C+pe(A(i,:),B(i,:));/end; /

Thus, through fuzzification, the quality of the wheat lots is expressed in the form of a fuzzy triplet (table 6.6).

Table 6.6 - *Fuzzification of the quality of wheat lots*

FUNCTION	SET FUZZY		
	PI	I	FI
Clt1=cg(lt1, Ftrel);	82.5150	78.3458	40.5913
Clt2=cg(lt2, Ftrel);	80.0898	76.7515	40.4192
Clt3=cg(lt3, Ftrel);	86.9386	82.2455	40.5314
Clt4=cg(lt4, Ftrel);	82.4626	78.6826	41.0404
Clt5=cg(lt5, Ftrel);	84.3787	79.2740	39.5210
Clt6=cg(lt6, Ftrel);	87.7021	82.5599	39.1617
Clt7=cg(lt7, Ftrel);	88.6078	83.3757	39.7904
Clt8=cg(lt8, Ftrel);	85.0898	80.9281	39.8129
Clt9=cg(lt9, Ftrel);	80.0225	76.7740	40.5464
Clt10=cg(lt10, Ftrel);	86.2500	82.1632	42.1632
Clt11=cg(lt11, Ftrel);	87.2455	82.6796	41.1901
Clt12=cg(lt12, Ftrel);	84.1392	80.2994	41.0554
Clt13=cg(lt13, Ftrel);	86.9386	82.2455	40.5314
Clt14=cg(lt14, Ftrel);	84.2141	80.4566	41.6617
Clt15=cg(lt15, Ftrel);	86.9311	82.5524	40.4192
Clt16=cg(lt16, Ftrel);	76.1228	73.6302	39.5434
Clt17=cg(lt17, Ftrel);	74.3263	72.4701	39.8877
Clt18=cg(lt18, Ftrel);	76.9686	74.6108	39.6332
Clt19=cg(lt19, Ftrel);	76.5719	73.1662	36.8787
Clt20=cg(lt20, Ftrel);	80.5015	76.1078	38.3084
Clt21=cg(lt21, Ftrel);	87.3578	82.1407	39.1467
Clt22=cg(lt22, Ftrel);	84.0644	78.8997	37.1856
Clt23=cg(lt23, Ftrel);	88.2036	82.6048	38.4281
Clt24=cg(lt24, Ftrel);	86.0030	81.3623	39.8428
Clt25=cg(lt25, Ftrel);	87.3278	82.3802	40.2096

By means of the defuzzification function, the fuzzy triplets indicating the quality of the wheat lots are transformed into indices:

% defuzzification

function Y = df(A)/ Y=(3*A(1)-A(2)+A(3))/3;

In this way, the ICG vector is obtained, with quality indices for each lot (table 6.7)

[CGd, Ld1]=sortrows(ICG',-1);/ [La1, L1]=sortrows(Ld1);

Table 6.7 – *Global quality indices for the lots analyzed (ICG)*

Cod lot	**Funcțion Y = df (A)**	**Indice global de calitate (ICG)**
Lot 1	ICG= [df(Clt1)	69.9301
Lot 2	ICG= df(Clt2)	67.9790
Lot 3	ICG= df(Clt3)	73.0339
Lot 4	ICG= df(Clt4)	69.9152
Lot 5	ICG= df(Clt5)	71.1277
Lot 6	ICG= df(Clt6)	73.2360
Lot 7	ICG= df(Clt7)	74.0793
Lot 8	ICG= df(Clt8)	71.3847
Lot 9	ICG= df(Clt9)	67.9466
Lot 10	ICG= df(Clt10)	72.9167
Lot 11	ICG= df(Clt11)	73.4157
Lot 12	ICG= df(Clt12)	71.0579
Lot 13	ICG= df(Clt13)	73.0339
Lot 14	ICG= df(Clt14)	71.2824
Lot 15	ICG= df(Clt15)	72.8867
Lot 16	ICG= df(Clt16)	64.7605
Lot 17	ICG= df(Clt17)	63.4656
Lot 18	ICG= df(Clt18)	65.3094
Lot 19	ICG= df(Clt19)	64.4760
Lot 20	ICG= df(Clt20)	67.9017
Lot 21	ICG= df(Clt21)	73.0264
Lot 22	ICG= df(Clt22)	70.1597
Lot 23	ICG= df(Clt23)	73.4780
Lot 24	ICG= df(Clt24)	72.1632
Lot 25	ICG= df(Clt25)];	73.2710

In figure 6.1, the image of the quality of the 25 analyzed wheat batches is graphically represented, observing the variations of the global quality index, and in figure 6.2, the program generated a color map through which the critical points from the analyzes performed can be easily identified.

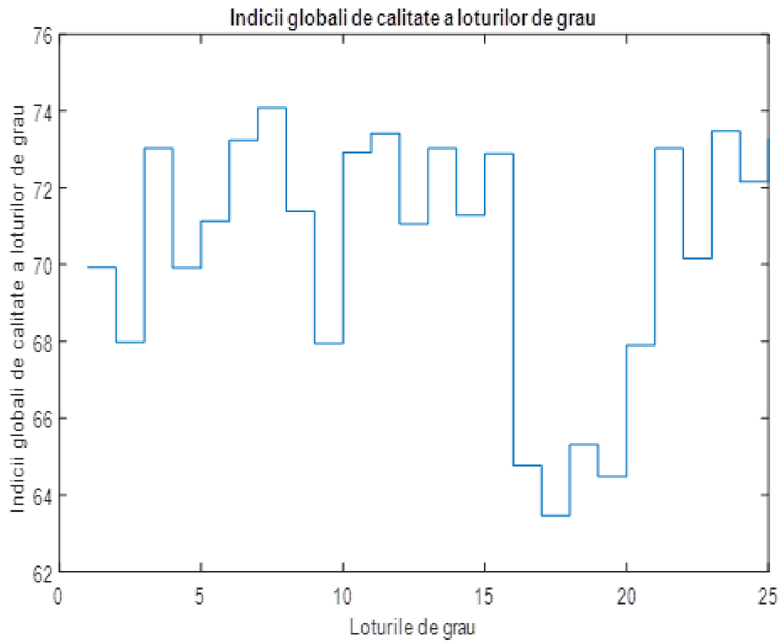
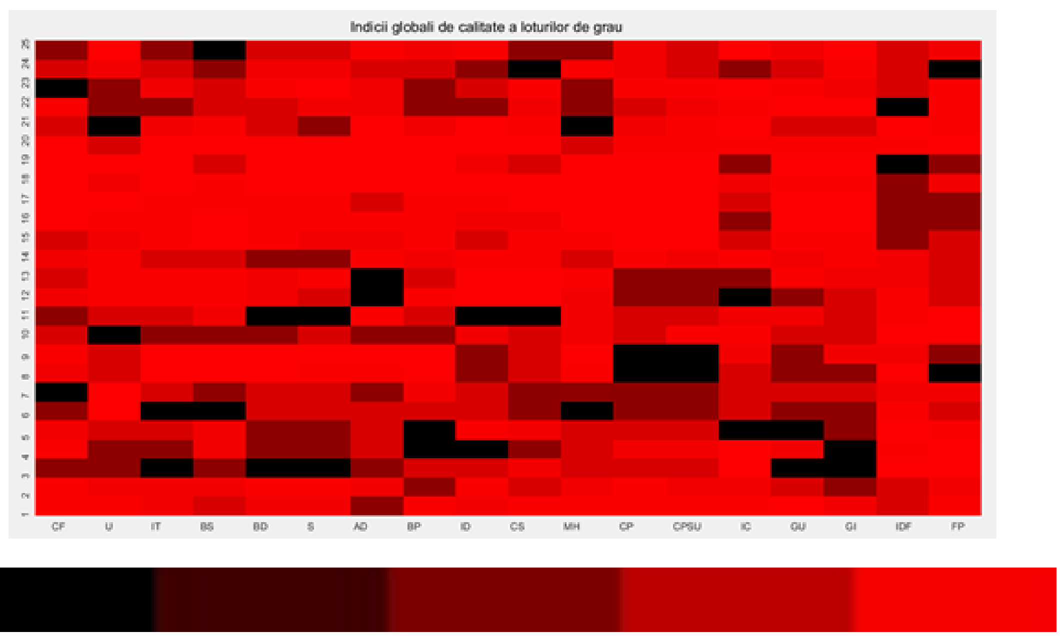


Figure 6.1 - Global quality indices of wheat lots



Very good **Good** **Medium** **Satisfactorily** **Unsatisfactorily**

CF- infested; U=Moisture; IT=total impurities; BS=broken grains; BD=demaged grains S= Shriveled; AD= Attacked by pests; BP=blackpoint; ID= Various impurities; CS=foreign matter; MH= test weight; CP=crude protein content; CPSU=protein content on dry matter; IC=falling number; GU=gluten content; GI= gluten index, IDF=deformation index; FP=bakery force (W)

Figure 6.2 - Map of global quality indices in the analyzed commodity lot

Correlation of the global quality index by reporting to the Grading Plan for common wheat in Romania, was achieved by ordering the values of the ICG index in descending order and the association with the assigned grade.

In the grading operation, the fraction of grains attacked by blackpoint was eliminated from the value of total impurities, their identification and highlighting had the role of making a complex assessment taking into account all the fractions provided by the standard.

Table 6.8 shows the association and the determining factor that ranked the lot in a special grade or lower than the RO 1 grade.

Table 6.8 - *ICG association with the Romanian grading system*

LOT	GRADE RO (DETERMINING FACTOR)	ICG
Lot 7	RO 1	74.0793
Lot 23	RO 1	73.478
Lot 11	RO 1	73.4157
Lot 25	RO 1	73.271
Lot 6	RO 1	73.236
Lot 3	RO 1	73.0339
Lot 13	RO 1	73.0339
Lot 21	RO 1	73.0264
Lot 10	RO 1	72.9167
Lot 15	RO 3 (% broken grains)	72.8867
Lot 24	RO 1	72.1632
Lot 8	RO 3 (% broken grains)	71.3847
Lot 14	RO 1	71.2824
Lot 5	RO 1 INFEST	71.1277
Lot 12	RO 1	71.0579
Lot 22	RO 1	70.1597
Lot 1	RO 1 INFEST	69.9301
Lot 4	RO 1 INFEST	69.9152
Lot 2	RO 1 INFEST	67.979
Lot 9	RO 2 INFEST (kg/hl, test weight)	67.9466
Lot 20	RO 2 (shriveled grains)	67.9017
Lot 18	RO 3 (kg/hl, test weight)	65.3094
Lot 16	RO 3 INFEST (kg/hl, test weight)	64.7605
Lot 19	RO 2 (% protein content, dry matter)	64.476
Lot 17	RO 3 INFESTAT(kg/hl, test weight)	63.4656

After analyzing the two methods of assessing the quality of some wheat batches, it can be concluded that the minimum values of ICG obtained in the case of the 25 analyzed lots were mainly attributed to the infested batches and whose determining parameters in the grading recorded values below the limits imposed on the RO 1 degree.

The criteria that are the basis of the grading operation are the organoleptic and sanitary characteristics, the content of total impurities, the hectoliter mass and the protein content relative to the dry substance.

CHAPTER 7 - GENERAL CONCLUSIONS. ORIGINAL CONTRIBUTIONS AND RESEARCH PERSPECTIVES

7.1 GENERAL CONCLUSIONS

The design of the informational model was based on the deepening of the aspects related to the evolution, origins and physico-chemical properties of wheat, exposed in Chapter 1.

The current state of knowledge of the indicators that define the quality of wheat and the methods of their determination constitute the scientific basis as a benchmark in the methodology for evaluating the quality of wheat and in the configuration of the information model created in this thesis.

The substantiation of the importance of wheat from an economic and cultural point of view, as well as the quality conditions stipulated in the specific contracts used in the international wheat trade, highlighted the different perception on the evaluation of wheat quality.

The concept of wheat quality in large wheat-producing countries is differently perceived and adapted to the socio-cultural life of the analyzed regions. The appreciation and importance of quality parameters emphasizes the geographical character, the natural and economic resources available to each state, these aspects differentiate and limit the quality of certain wheat lots through national norms related to the international standards and regulations in force.

In the stage preceding the generation of the information model, applied research was carried out regarding the determination of the main quality indicators in order to identify the critical points and the aspects related to an objective, correct and representative evaluation of the analyzed wheat lots. During chapter 5, the steps and methods used, as well as the results obtained, were described in relation to European and international product specifications.

Throughout the work, the conditions and limitations that can classify wheat batches as unfit for human consumption, as well as aspects related to food safety through potential contamination with mycotoxins or impurities difficult to eliminate in the conditioning, handling processes, were taken into account or transportation.

All the lots analyzed can be used in baking, the resulting flour being suitable for obtaining bread, some lots requiring mixing with quantities of a higher quality or additives for the valorization of the flour in pastry products or other bakery specialties.

The qualitative analysis of the lots reveals the need for quick intervention on the lots where live infestation was identified, by taking the necessary measures, namely their gassing or fumigation.

Improving the quality of the analyzed batches can be achieved through additional conditioning, thus reducing the fractions of the category of total impurities and improving the hectoliter mass parameter. Changing the hectoliter mass involves increasing the content of extracted flour and can positively influence the parameters aimed at the rheological behavior of the dough, but also the gluten content and quality.

The experts' opinions regarding the results obtained following the quality determinations of the studied lots, as well as establishing the weight of the importance of the analyzed parameters, were made by correlating the values of the analyzed indicators with international and European standards, as well as the quality specifications used in commercial contracts, together with experience professional of each evaluator.

The processing of the qualifications given by the experts both for the obtained values and the weighting of the importance of the parameters, led to the obtaining of data sets that allowed mathematical modeling in Matlab by using the functions of fuzzification and defuzzification.

The Matlab program with fuzzy functions is frequently used and there are numerous scientific articles based on statistical data processed by this method. The specialized literature emphasizes the potential of fuzzy applications used to render the uncertainty of the process and the simulation of the determination of the quality of a final product.

The mapping of the quality attributes by the fuzzy technique as multidimensional fuzzy sets and subsequent defuzzification resulted in obtaining a global quality index associated with the entire lot (ICG).

The integration of the ICG concept of wheat in the commercial area aimed at the qualitative assessment of wheat can generate a global picture of the quality for the whole lot of wheat or individually for each lot.

The multifactorial nature of the ICG related to the analyzed batches validates the objective of the doctoral thesis entitled "Informational Model of wheat quality standardization in international contracts" and can be verified by associating the ICG with the quality grades assigned following the grading operation based on the results obtained.

7.2 ORIGINAL CONTRIBUTIONS AND RESEARCH PERSPECTIVES

The objective of the doctoral thesis entitled "Informational model for the standardization of wheat quality in international contracts" represents an innovative method of approaching wheat quality and can be a landmark in the calculation of penalties and bonuses within international commercial contracts.

Going through the stages described in the chapters of the thesis generated a global wheat quality index that can be extended for use in several commercial, governmental or scientific segments.

The research transposed in the doctoral thesis "Informational model for the standardization of wheat quality in international contracts" combined the national and international standards that regulate the reference methods for wheat quality determinations frequently used in international contracts, as well as national and contractual specifications in terms of establishing quality.

In addition to the specialized literature, which mostly includes studies on changes and behavior of wheat in different phases of culture, storage or processing, personal experience in the field of quality and the appreciation of experts on the weight of the important quality parameters and the evaluation of quality based on the results obtained, have led to the configuration of the proposed informational model.

Obtaining and using the global quality index generates applicability not only to the commercial sphere as a quality reference and price setting, but also a measure of appreciation of processing opportunities.

The global quality index can also be implemented in credit contracts where wheat stocks are brought as a guarantee, credit institutions having an image not only of the quantity.

Researchers can use the global quality index in the study of culture technologies or breeding processes

In the commercial chain, the global quality index can highlight the critical points of some batches and facilitate differentiated storage in warehouses, barges, ship holds, silos, wagons or other means of transport.

From the point of view of continuing the research and development of the global quality index, the proposed informational model can be extended to other types of agricultural seeds and can be associated with an application that generates an informational model for setting the price.

In the study of wheat quality, the global quality index can also be studied by resizing the number of parameters or limiting it to certain indicators of interest.

SELECTIVE BIBLIOGRAPHY

[1] "FAOSTAT." http://www.fao.org/faostat/en/#data/QC (accessed Feb. 17, 2021).

[2] F. Balfourier *et al.*, "Worldwide phylogeography and history of wheat genetic diversity," *Sci. Adv.*, vol. 5, pp. 1–10, May 2019, doi: 10.1126/sciadv.aav0536.

[3] "Short History Website," *The term Mesopotamia and geographical position*, 2015. https://www.shorthistory.org/ancient-civilizations/mesopotamia/the-term-mesopotamia-and-geographical-position.

[4] M. Axinte, I. Borcean, G. V. Roman, and L. S. Muntean, *Fitotehnie*, IV. Iasi: Editura "Ion Ionescu de la Brad," 2006.

[5] S. Rustgi, P. Shewry, F. Brouns, L. J. Deleu, and J. A. Delcour, "Wheat Seed Proteins: Factors Influencing Their Content, Composition, and Technological Properties, and Strategies to Reduce Adverse Reactions," *Compr. Rev. Food Sci. Food Saf.*, vol. 18, no. 6, pp. 1751–1769, Nov. 2019, doi: 10.1111/1541-4337.12493.

[6] "Histological structure of wheat grain." https://www.researchgate.net/figure/Histological-structure-of-wheat-grain-Adapted-from-Surget-and-Barron-2005-color_fig1_221977734.

[7] I. Pasha, F. M. Anjum, and C. F. Morris, "Grain Hardness: A Major Determinant of Wheat Quality," *Food Sci. Technol. Int.*, vol. 16, no. 6, pp. 511–522, Dec. 2010, doi: 10.1177/1082013210379691.

[8] Y. N. Guragain, K. V. Probst, and P. V. Vadlani, "Fuel Alcohol Production," in *Reference Module in Food Science*, Elsevier, 2016.

[9] Banu Iuliana, *Principii generale de morarit*. Galati: Editura Fundatiei Universitare "Dunarea de Jos" Galati, 2007.

[10] *Organismul National de Standardizare - SR EN ISO 24333:2010. Cereale si produse din cereale. Esantionare*. 2010.

[11] ISO, *International Standard 7970:2021- Wheat (Triticum aestivum L.) — Specification*. 2021.

[12] *Organismul National de Standardizare -SR ISO 6639-1. Cereale si leguminoase. Determinarea infestarii ascunse cu insecte. Partea 1: Principii generale*. 1996.

[13] A. Mogarzan and T. Robu, *Tehnologia pastrarii produselor agricole vegetale*. Iasi, 2005.

[14] *Organismul National de Standardizare - SR EN ISO 712. Cereale si produse din cereale. determinarea umiditatii. Metoda de referinta.* 2010.

[15] Organismul National de Standardizare, *SR EN 13548:2013 - Grâu comun (Triticum aestivum). Specificaţii*. 2013.

[16] G. Branlard, M. Dardevet, R. Saccomano, F. Lagoutte, and J. Gourdon, "Genetic Diversity of Wheat Storage Proteins and Bread Wheat Quality," 2001, pp. 157–169.

[17] W. MA, Z. YU, M. SHE, Y. ZHAO, and S. ISLAM, "Wheat gluten protein and its impacts on wheat processing quality," *Front. Agric. Sci. Eng.*, vol. 6, no. 3, p. 279, 2019, doi:

10.15302/J-FASE-2019267.

[18] H. Wang, N. Pampati, W. M. McCormick, and L. Bhattacharyya, "Protein Nitrogen Determination by Kjeldahl Digestion and Ion Chromatography," *J. Pharm. Sci.*, vol. 105, no. 6, pp. 1851–1857, Jun. 2016, doi: 10.1016/j.xphs.2016.03.039.

[19] P. R. Shewry, R. D'Ovidio, J. A. Jenkins, and F. Békés, "CHAPTER 8: Wheat Grain Proteins," in *WHEAT: Chemistry and Technology*, 3340 Pilot Knob Road, St. Paul, Minnesota 55121, U.S.A.: AACC International, Inc., 2009, pp. 223–298.

[20] C. N. Popa, R. M. T. Berehoiu, and N. Lambrache, "Assessment of gluten index component wet gluten remaining on the sieve as predictor of wheat bakery potential," *Rev. Chim.*, vol. 70, no. 11, pp. 3994–3999, 2019, doi: 10.37358/rc.70.19.11.7690.

[21] N. A. Oikonomou, S. Bakalis, M. S. Rahman, and M. K. Krokida, "Gluten Index for Wheat Products: Main Variables in Affecting the Value and Nonlinear Regression Model," *Int. J. Food Prop.*, vol. 18, no. 1, pp. 1–11, Jan. 2015, doi: 10.1080/10942912.2013.772198.

[22] "International Association for Cereal Science and Technology," 2020. https://icc.or.at/publications/icc-standards/standards-overview/155-standard-method.

[23] *Organismul National de Standardizare - SR ISO 5527-Cereale. Terminologie*. 2002.

[24] Organismul National de Standardizare, *SR EN 15587: 2019 - cereale si produse cerealiere. determinarea continutului de impuritati in grau(Triticum aestivum L.), grau durum (Triticum durum Desf.), secara (Secale cerele L.) si orz furajer (Triticum vulgare L.)*. 2019.

[25] Y. Shen *et al.*, "Image Recognition Method Based on an Improved Convolutional Neural Network to Detect Impurities in Wheat," *IEEE Access*, vol. 7, pp. 162206–162218, 2019, doi: 10.1109/ACCESS.2019.2946589.

[26] A. M. Kiszonas, D. A. Engle, L. A. Pierantoni, and C. F. Morris, "Relationships between Falling Number, α-amylase activity, milling, cookie, and sponge cake quality of soft white wheat," *Cereal Chem.*, vol. 95, no. 3, pp. 373–385, May 2018, doi: 10.1002/cche.10041.

[27] Organismul National de Standardizare, *SR EN ISO 27971 Cereale şi produse cerealiere. Grâu comun (Triticum aestivum L.). Determinarea proprietăţilor alveografice a unui aluat cu hidratare constantă din făină industrială sau de încercare şi metodologia de măcinare experimentală*. .

[28] *REGULAMENTUL (CE) NR. 1881/2006 AL COMISIEI EUROPENE din 19 decembrie 2006 de stabilire a nivelurilor maxime pentru anumiți contaminanți din produsele alimentare*. 2006.

[29] N. U. Hassan, Q. Mahmood, A. Waseem, M. Irshad, Faridullah, and A. Pervez, "Assessment of heavy metals in wheat plants irrigated with contaminated wastewater," *Polish J. Environ. Stud.*, 2013.

[30] A. Esmaili, V. Noroozi Karbasdehi, R. Saeedi, M. Javad Mohammadi, T. Sobhani, and S. Dobaradaran, "Data on heavy metal levels (Cd, Co, and Cu) in wheat grains cultured in Dashtestan County, Iran," *Data Br.*, 2017, doi: 10.1016/j.dib.2017.08.012.

[31] B. Hou, Z. wei Wang, and R. Ying, "Pesticide Residues and Wheat Farmer's Cognition: A China Scenario," *Agric. Res.*, 2016, doi: 10.1007/s40003-015-0192-4.

[32] "STATISTA." https://www.statista.com/statistics/267268/production-of-wheat-worldwide-

since-1990/.

[33] “IndexMundi.” https://www.indexmundi.com/agriculture/?country=us&commodity=wheat&graph=production.

[34] “World Bank.” https://data.worldbank.org/indicator/AG.PRD.CREL.MT.

[35] “The Food and Agriculture Organization (FAO).” http://www.fao.org/faostat/en/#rankings/countries_by_commodity.

[36] “FAOSTAT.” http://www.fao.org/faostat/en/#rankings/countries_by_commodity (accessed Feb. 17, 2021).

[37] E. Commission, “Cereals trade Directorate-General for Agriculture and Rural Development,” 2022.

[38] U.S. DEPARTMENT OF AGRICULTURE, “Economic Research Service U.S. DEPARTMENT OF AGRICULTURE,” *Periodic and Scheduled Wheat-related Publications and Data*, 2022. https://www.ers.usda.gov/topics/crops/wheat/ (accessed Feb. 23, 2022).

[39] 2014b USDA-GIPSA, *Subpart M—United States Standards for Wheat.* Washington, 2014.

[40] K. M. Uhl, O. Perekhozhuk, and T. Glauben, “Russian Market Power in International Wheat Exports: Evidence from a Residual Demand Elasticity Analysis,” *J. Agric. Food Ind. Organ.*, 2019, doi: 10.1515/jafio-2016-0026.

[41] “GOST 9353-2016 Wheat. Specifications,” 2016.

[42] Ministerul Agriculturii si Dezvoltarii Rurale din Romania, *Ordinul nr. 228/2017 privind aprobarea Manualului de gradare pentru semințele de consum*. Monitorul Oficial, Partea I nr. 537 din 10 iulie 2017, 2017.

[43] “German Grain TAB GmbH.” https://www.german-grain.de/ (accessed Feb. 10, 2022).

[44] R. Lásztity and A. Salgó, “Quality assurance of cereals - Past, present, future,” *Period. Polytech. Chem. Eng.*, vol. 46, no. 1–2, pp. 5–13, 2002.

[45] *Organismul National de Standardizare SR EN ISO 7971-2- Cereale. Determinarea densității în vrac, denumită masă hectolitrică. Partea 2: Metoda de trasabilitate pentru instrumentele de măsură prin referire la instrumentul etalon internațional*. 2019.

[46] *Organismul National de Standardizare -SR EN ISO 3093.Grau, secara si fainuri corespunzatoare, grau durum si faina grifica de grau durum. Determinarea indicelui de cadere conform Hagberg - Perten.* 2010.

[47] X. Yang, L. Wu, Z. Zhu, G. Ren, and S. Liu, “Variation and trends in dough rheological properties and flour quality in 330 Chinese wheat varieties,” *Crop J.*, vol. 2, no. 4, pp. 195–200, Aug. 2014, doi: 10.1016/j.cj.2014.04.001.

[48] ISO, *ISO 5725-1:1994 Accuracy (trueness and precision) of measurement methods and results — Part 1: General principles and definitions*. 1994.

[49] *Organismul National de Standardizare SR EN ISO 7971-1-Cereale. Determinarea masei volumice, denumită masă hectolitrică. Partea 1: Metoda de referinţă*. .

[50] S. Thaker and V. Nagori, “Analysis of Fuzzification Process in Fuzzy Expert System,” 2018,

doi: 10.1016/j.procs.2018.05.047.

[51] C. Kahraman, T. Ertay, and G. Büyüközkan, “A fuzzy optimization model for QFD planning process using analytic network approach,” *Eur. J. Oper. Res.*, vol. 171, no. 2, pp. 390–411, Jun. 2006, doi: 10.1016/j.ejor.2004.09.016.

[52] C. Rosyidi, R. Murtisari, and W. Jauhari, “A concurrent optimization model for supplier selection with fuzzy quality loss,” *J. Ind. Eng. Manag.*, vol. 10, no. 1, p. 98, Apr. 2017, doi: 10.3926/jiem.800.

[53] N. Perrot, I. Ioannou, I. Allais, C. Curt, J. Hossenlopp, and G. Trystram, “Fuzzy concepts applied to food product quality control: A review,” *Fuzzy Sets Syst.*, vol. 157, no. 9, pp. 1145–1154, May 2006, doi: 10.1016/j.fss.2005.12.013.

[54] S.-åke Svensson, “Implementing a Fuzzy Classifier and Improving its Accuracy using Genetic Algorithms,” *53rd Annu. Conf. Stat. Comput. Sci. Oper. Res.*, 2020.

[55] M. A. R. Pessoa, F. J. de Souza, P. Domingos, and J. P. S. de Azevedo, “Índice fuzzy de qualidade de água para ambiente lótico - IQAFAL,” *Eng. Sanit. e Ambient.*, vol. 25, no. 1, pp. 21–30, Jan. 2020, doi: 10.1590/s1413-41522020147587.

DISSEMINATING THE RESULTS

Scientific articles published

A. **Ciprian Petrișor PLENOVICI**, Constanța Laura AUGUSTIN (ZUGRAVU), Cristian MUNTENIȚĂ and Gheorghe Adrian ZUGRAVU, "**Primary Assessment of Wheat Quality**," Proceedings of the 33rd International Business Information Management Association (IBIMA), ISBN: 978-0-9998551-2-6, 10-11 April 2019, Granada, Spain, p 657-662, **Scopus.**
https://ibima.org/accepted-paper/primary-assessment-of-wheat-quality/

B. **Ciprian Petrișor PLENOVICI,** Constanța Laura AUGUSTIN (ZUGRAVU), Cristian MUNTENIȚĂ and Gheorghe Adrian ZUGRAVU, "**Evolution of Wheat and Maize Productions In Romania between 2007-2018**" Proceedings of the 35th International Business Information Management Association (IBIMA), ISBN: 978-0-9998551-4-0, 1-2 April 2020, Seville, Spain, p. 5250-5255. **Web of Science**
https://ibima.org/accepted-paper/evolution-of-wheat-and-maize-productions-in-romania-between-2007-2018/

C. **Ciprian Petrișor PLENOVICI**, Constanța Laura AUGUSTIN (ZUGRAVU) and Gheorghe Adrian ZUGRAVU, "**Quality Analysis of Lots of Wheat Harvested from Areas Affected by Extreme Drought**," Proceedings of the 37th International Business Information Management Association (IBIMA), ISBN: 978-0-9998551-6-4, 30-31 May 2021, Cordoba, Spain, p 6737-6742. **Web of Science**
https://ibima.org/accepted-paper/quality-analysis-of-lots-of-wheat-harvested-from-areas-affected-by-extreme-drought/

D. Constanta Laura AUGUSTIN (ZUGRAVU), **Ciprian Petrisor PLENOVICI**, Loredana DIMA, Dragos CRISTEA, Mioara COSTACHE and Gheorghe Adrian ZUGRAVU, "**Rationalization of Transhumance in Beekeeping Through Intensive Productivity Model**" Proceedings of the 34th International Business Information Management Association (IBIMA), ISBN: 978-0-9998551-3-3, 13-14 November 2019, Madrid, Spain, p. 8014-8020. **Web of Science**
https://ibima.org/accepted-paper/rationalization-of-transhumance-in-beekeeping-through-intensive-productivity-model/

E. Alina MOGODAN, Stefan-Mihai PETREA, Ira SIMIONOV, **Ciprian Petrisor PLENOVICI**, Dragos CRISTEA, Mioara COSTACHE and Gheorghe Adrian ZUGRAVU, "**The Integration of Multi-Trophic Concept: A Solution for Modern Aquaculture Sustainable Development**" Proceedings of the 34th International Business Information Management Association (IBIMA), ISBN: 978-0-9998551-3-3, 13-14 November 2019, Madrid, Spain, p. 8021-8031. **Web of Science**
https://ibima.org/accepted-paper/the-integration-of-multi-trophicconcept-a-solution-for-modern-aquaculture-sustainable-development/

F. Constanta Laura AUGUSTIN (ZUGRAVU), **Ciprian Petrisor PLENOVICI**, Camelia FASOLA (LUNGEANU), Maria Magdalena TUREK RAHOVEANU and Gheorghe Adrian ZUGRAVU, "**Economic Feasibility Analysis in Aquaponics**," Proceedings of the 33rd

International Business Information Management Association (IBIMA), ISBN: 978-0-9998551-2-6, 10-11 April 2019, Granada, Spain,p 63-69. **Scopus.**
https://ibima.org/accepted-paper/economic-feasibility-analysis-in-aquaponics/

G. Constanta Laura AUGUSTIN (ZUGRAVU), Maria Magdalena TUREK RAHOVEANU, Ludmila MOGILDEA, **Ciprian PLENOVICI** and Gheorghe Adrian ZUGRAVU, "**Support Measures in The Beekeeping Sector**," Proceedings of the 37th International Business Information Management Association (IBIMA), ISBN: 978-0-9998551-6-4, 30-31 May 2021, Cordoba, Spain, p 1129-1134. **Web of Science**

H. Gheorghe Adrian ZUGRAVU, Constanta Laura AUGUSTIN (ZUGRAVU), Maria Magdalena TUREK RAHOVEANU, Loredana DIMA and Ciprian Petrisor PLENOVICI, "**The Policy Measures Impact on EU Beekeeping**," Proceedings of the 36th International Business Information Management Association (IBIMA), ISBN: 978-0-9998551-5-7, 4-5 November 2020, Granada, Spain, p 3011-3017. **Web of Science**
https://ibima.org/accepted-paper/the-policy-measures-impact-on-eu-beekeeping/

I. Gheorghe Adrian Zugravu, Ionica Soare, Maria Magdalena Turek Rahoveanu, Camelia Costela Fasola (Lungeanu), **Ciprian Petrisor Plenovici**, Constanța Laura Augustin (Zugravu), "**Sustainable Intensive Beekeeping",** International Conference on Trends & Innovations in Management, Engineering, Science & Humanities (ICTIMESH 2019), Dubai, 18-21 December,2019; published in special issue of International Journal of Latest Trends in Engineering & Technology/ International Journal of Engineering, Applied and Management Sciences Paradigms**.** The links for accessing the special issue of ICTIMESH 19 are: http://www.ijeam.com/special_issue_ictimesh_2019.php, https://www.ijltet.org/archive.php?id=954

J. Constanța Laura Augustin (Zugravu), Ionica Soare, Maria Magdalena Turek Rahoveanu, Camelia Costela Fasola (Lungeanu), **Ciprian Petrisor Plenovici,** Gheorghe Adrian Zugravu, **"Study on Intensive Beekeeping Practices in Romania",** International Conference on Trends & Innovations in Management, Engineering, Science & Humanities (ICTIMESH 2019), 18-21 December 2019, Dubai; published in special issue of International Journal of Latest Trends in Engineering & Technology/ International Journal of Engineering, Applied and Management Sciences Paradigms. The links for accessing the special issue of ICTIMESH 19 are:
http://www.ijeam.com/special_issue_ictimesh_2019.php,
https://www.ijltet.org/archive.php?id=954

K. Gheorghe Adrian ZUGRAVU, Cristian Muntenita, Ciprian Petrisor PLENOVICI, Constanța Laura AUGUSTIN, **Risk analysis model in aquaponics, 3rd** Complexity in Applied Science and Engineering International Conference 2019 (CASEIC 2019), 11th-13th October 2019, Phuket, Thailand, All accepted CASEIC 2019 paper will be published in Journal of Mechanics of Continua and Mathematical Sciences EISSN: 0973-8975, ISSN: 2454-7190.

L. Constanța Laura AUGUSTIN, Ciprian Petrisor PLENOVICI, Cristian Muntenita, Gheorghe Adrian ZUGRAVU, **Environmental risk assessment of intensive beekeeping integrated**

with aquaponic system, 3rd Complexity in Applied Science and Engineering International Conference 2019 (CASEIC 2019), 11th-13th October 2019, Phuket, Thailand, All accepted CASEIC 2019 paper will be published in Journal of Mechanics of Continua and Mathematical Sciences EISSN: 0973-8975, ISSN: 2454-7190.

Published works, books

A. Zugravu Gheorghe Adrian, Ionica Soare, Augustin Constanta Laura, **Ciprian Plenovici** - GHID PRIVIND POTENȚIALUL MELIFER, CONDIȚIILE CLIMATICE, CALITATEA AERULUI ȘI SOLULUI ÎN REGIUNEA BAZINULUI MĂRII NEGRE, Editura Zigotto este recunoscută de Consiliul Naţional al Cercetării Ştiinţifice din Învăţământul Superior (cod 262), Tipografia Zigotto Galaţi, ISBN 978-606-669-341-7

Papers presented at international conferences

A. A Dr. Constanta Laura AUGUSTIN (ZUGRAVU), Dr. **Ciprian Petrisor PLENOVICI**, Dr. Camelia FASOLA (LUNGEANU), Dr. Maria Magdalena TUREK RAHOVEANU and Dr. Gheorghe Adrian ZUGRAVU, Economic Feasibility Analysis in Aquaponics to the International Business Information Management Conference (33rd IBIMA) Granada, Spain 10-11 April, 2019 has been accepted for presentation at the conference. The paper will be included in the conference proceedings (ISBN: 978-0-9998551-2-6) as a full paper;

B. **Dr. Ciprian Petrișor PLENOVICI**, Dr. Constanța Laura AUGUSTIN (ZUGRAVU), Dr. Cristian MUNTENIȚĂ, and Dr. Gheorghe Adrian ZUGRAVU, “Primary Assessment of Wheat Quality” to the International Business Information Management Conference (33rd IBIMA) Granada, Spain 10-11 April, 2019 has been accepted for presentation at the conference. The paper will be included in the conference proceedings (ISBN: 978-0-9998551-2-6) as a full paper;

C. Augustin, CL (Augustin (Zugravu), Constanta Laura)[1] ; **Plenovici, CP (Plenovici, Ciprian Petrisor)**[1] ; Dima, L (Dima, Loredana)[1] ; Cristea, D (Cristea, Dragos)[1] ; Costache, M (Costache, Mioara)[2] ; Zugravu, GA (Zugravu, Gheorghe Adrian)[1], Rationalization of Transhumance in Beekeeping Through Intensive Productivity Model, 34th International-Business-Information-Management-Association (IBIMA) Conference, Location: Madrid, SPAIN, Date: NOV 13-14, 2019, Accession Number: WOS:000561117201031, ISBN:978-0-9998551-3-3;

D. Constanta Laura Augustin (Zugravu)[a,*], Maria Magdalena Turek Rahoveanu[b], Ciprian Petrisor Plenovici[c], Gheorghe Adrian Zugravu[d], **Intensive Beekeeping in Romania, 7th Edition of CSSD-UDJG, 13th and 14th of June 2019**

E. **Plenovici Ciprian Petrisor**, Zugravu Constanta Laura, Muntenita Cristian, Zugravu Adrian, “Aspects regarding the qualitative classification of wheat lots”, Galati, 18-19 of June 2020, 8[Th] Edition of SCDS-UDJG.

F. **Plenovici Ciprian Petrisor**, Zugravu Constanta Laura, Zugravu Adrian, "Romanian agricultural seeds market. Evolution and trends", Galati, 10-11 of June 2021, 9[Th] Edition of SCDS-UDJG
G. Constanta Laura Augustin (Zugravu)[a,*], Maria Magdalena Turek Rahoveanu[b], **Ciprian Petrisor Plenovici[c],** Gheorghe Adrian Zugravu[d], Intensive Beekeeping model of biodiversity growth, 7th Edition of CSSD-UDJG, 13th and 14th of June 2019;
H. **Ciprian Petrișor Plenovici,** Constanța Laura Augustin (Zugravu), Gheorghe Adrian Zugravu The main micotoxins of cereals and their impact on consumer health, 7th Edition of CSSD-UDJG, 13th and 14th of June 2019;
I. **Ciprian Petrișor Plenovici,** Constanța Laura Augustin (Zugravu), Gheorghe Adrian Zugravu Deoxynivalenol –admissible limits and analytical methods, 7th Edition of CSSD-UDJG, 13th and 14th of June 2019;
J. Gheorghe Adrian Zugravu, Ionica Soare, Maria Magdalena Turek Rahoveanu, Camelia Costela Fasola (Lungeanu), **Ciprian Petrisor Plenovici**, Constanta Laura Augustin (Zugravu), Sustainable Intensive Beekeeping, International Conference on Trends & Innovations in Management, Engineering, Science & Humanities (ICTIMESH 2019), Flora Grand Hotel, Dubai during December 18-21, 2019; published in special issue of International Journal of Latest Trends in Engineering & Technology/ International Journal of Engineering, Applied and Management Sciences Paradigms**.** The links for accessing the special issue of ICTIMESH 19 are: http://www.ijeam.com/special_issue_ictimesh_2019.php, https://www.ijltet.org/archive.php?id=954
K. Constanta Laura Augustin (Zugravu), Ionica Soare, Maria Magdalena Turek Rahoveanu, Camelia Costela Fasola (Lungeanu), **Ciprian Petrisor Plenovici**, Gheorghe Adrian Zugravu, Study on Intensive Beekeeping Practices in Romania, International Conference on Trends & Innovations in Management, Engineering, Science & Humanities (ICTIMESH 2019), Flora Grand Hotel, Dubai during December 18-21, 2019; published in special issue of International Journal of Latest Trends in Engineering & Technology/ International Journal of Engineering, Applied and Management Sciences Paradigms. The links for accessing the special issue of ICTIMESH 19 are: http://www.ijeam.com/special_issue_ictimesh_2019.php, https://www.ijltet.org/archive.php?id=954
L. Gheorghe Adrian ZUGRAVU, Cristian Muntenință, **Ciprian Petrișor PLENOVICI**, Constanta Laura AUGUSTIN, Risk analysis model in aquaponics, 3rd Complexity in Applied Science and Engineering International Conference 2019 (CASEIC 2019) on 11th-13th October 2019 in Phuket, Thailand, All accepted CASEIC 2019 paper will be published inJournal of Mechanics of Continua and Mathematical Sciences EISSN: 0973-8975, ISSN: 2454-7190;
M. Constanta Laura AUGUSTIN, **Ciprian Petrișor PLENOVICI**, Cristian Muntenință, Gheorghe Adrian ZUGRAVU, Environmental risk assessment of intensive beekeeping integrated with aquaponic system, 3rd Complexity in Applied Science and Engineering

International Conference 2019 (CASEIC 2019) on 11th-13th October 2019 in Phuket, Thailand, All accepted CASEIC 2019 paper will be published in Journal of Mechanics of Continua and Mathematical Sciences EISSN: 0973-8975, ISSN: 2454-7190;

N. Dr. Constanta Laura AUGUSTIN (ZUGRAVU), Dr. **Ciprian Petrisor PLENOVICI**, Dr. Loredana DIMA and Dr. Gheorghe Adrian ZUGRAVU, "Rationalization of Transhumance in Beekeeping through Intensive Productivity Model" to the International Business Information Management Conference (34th IBIMA) Madrid, Spain 13-14 November 2019 has been accepted for presentation at the conference. The paper will be included in the conference proceedings (ISBN: 978-0-9998551-3-3) as a full paper

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