The Influence of Climate Conditions and Meteorological Factors on the Nutritional Value of Wheat (Triticum Aestivum L.) Used for Human and Animals Nutrition, in Romania

Ionela Hotea1, Monica Dragomirescu2, Olimpia Colibar1, Emil Tirziu1, Viorel Herman1, Adina Berbecea3, Isidora Radulov3

1 Faculty of Veterinary Medicine, Banat’s University of Agricultural Sciences and Veterinary Medicine "King Michael I of Romania" from Timisoara, 300645, Calea Aradului No. 119, Timisoara, Romania
2 Faculty of Bioengineering of Animal Resources, Banat’s University of Agricultural Sciences and Veterinary Medicine "King Michael I of Romania" from Timisoara, 300645, Calea Aradului No. 119, Timisoara, Romania
3 Faculty of Agriculture, Banat’s University of Agricultural Sciences and Veterinary Medicine "King Michael I of Romania” from Timisoara, 300645, Calea Aradului No. 119, Timisoara, Romania

Abstract. Wheat (Triticum aestivum L.) is the basic cereal in human and animal nutrition. Every month, wheat is harvested somewhere in the world. In Romania, a country with a temperate-continental climate, the wheat is harvested between June and July, while the sowing is carried out between September and October. Climatic and meteorological factors during these periods can influence the nutritional quality of wheat. The aim of this study was to analyse the influence of annual average temperature and the amount of precipitate on the chemical composition and on the value of metabolizable energy of the wheat, respectively. The climatic and meteorological data used in this study come from NMA database. Were analysed the periods September 2017 - July 2018 (period 1, noted with 2018 - the year of harvesting) and September 2018 - July 2019 (period 2, noted with 2019 - the year of harvesting), respectively. For the chemical analysis, the NIR (Near InfraRed spectroscopy) method was used. The calculation of metabolizable energy was performed based on the ATWATER system, a system applicable to both human and animal nutrition. The statistical analysis of the climatic and meteorological data showed that the annual average temperature for period 1 was lower compared to the temperatures of period 2. Also, the precipitations were more abundant in period 1 compared to period 2. There were no significant statistical differences for any of the climatic and meteorological factors assayed during the analyzed periods. Following the statistical correlations between the nutrients studied by chemical analysis, for those 2 periods, significant differences were observed (p <0.001). The humidity of wheat grains harvested in 2018 was higher (average = 13.03%) compared to that of grains harvested in 2019 (average = 10.72%). The protein content was lower in 2018 (average = 10.02%) than in 2019 (average = 11.04%); and similar results were obtained for the fibre content (average 2018 = 2.17%; average 2019 = 2.96%). Also, the value of metabolizable energy was lower for wheat harvested in 2018 (average = 3517.90 kcal / kg) compared to 2019 (average = 3611.04 kcal / kg). In conclusion, the results of this study highlight the influence of temperature and precipitation on the chemical composition of wheat, thus having a direct impact on the nutritional quality of this grain for human and animal nutrition.
1. Introduction

Wheat is the most important cereal and the agricultural plant that occupies the largest areas in the world. In Romania, wheat is one of the most important agricultural crops, with approximately 2 million hectares cultivated every year. The area cultivated with wheat represents 38.8% of the area cultivated with grain cereals.

On the territory of our country, the wheat culture dates back over 2500 years. Archaeological discoveries attest to this fact. Wheat cultivation manages in Romania, in recent years, to bring to professional farmers increasing profits, provided by productions even of over 10 tons per hectare, with averages of 8-9 tons at farm level. Soil, wheat varieties, cultivation technology, cereal fertilization, timely treatments, climatic conditions and the volume of precipitation are the main factors on which wheat production depends each year [1, 2].

In Romania, domestic consumption of wheat amounts to about 3 million tons, of which about 2.2 million tons are used in bakery, about 500,000 tons for seed and almost 400,000 tons for feed and alcohol industry [1]. In Romania, wheat have a wide use as food and fodder due of its high content in carbohydrates and proteins, the ratio between these substances, corresponding to human body requirements, and high ecological plasticity, the grains being cultivated in areas with very different climates and soils conditions.

Romania ranked, in 2019, on the fourth place in the EU in wheat production, on the same position with Great Britain, after France, Germany and Poland, according to the National Institute of Statistics [3, 4]. Romania harvested in 2019 slightly over 10 million tons of wheat on 2.1 million hectares, less by about 80,000 tons compared to the production of 2018, according to data centralized by the Ministry of Agriculture and Rural Development (MADR). MADR statistical data show for 2019 a total production of 10,051,997 tons of wheat, compared to 10,138,546 tons in 2018, an average of 4,786 kg / ha (4,803 kg / ha in 2018) and 2,100,178 hectares harvested in 2019 (versus 2,110,665 hectares in 2018) [1].

Romania's relief is characterized by diversity and complexity, with 28% of the entire area occupied by mountains (over 800 m altitude), 42% of hills and plateaus (200–800 m altitude) and 30% of plains (below 200 m altitude). The present study took place in the western part of Romania, in the Banat region, where the relief is mainly characterized by plains and hills. Romania has a temperate continental climate of transition, with four distinct seasons, spring, summer, autumn and winter [5]. Local climatic differences are due to altitude and latitude, causing an annual average temperature that drop slightly from south (10 °C - 11 °C) to north (8.5 °C - 9 °C). In Romania, the annual average rainfall is 637 mm per year, with significantly higher values in mountainous areas (1,000 - 1,400 mm / year) and progressively lower to the east and south (400 - 500 mm / year). The annual average temperature in the Banat region is 16 °C. The warmest month of the year is July, with an average temperature of 28 °C, and the coldest is January, with an average temperature of 2 °C. Most precipitation occurs in June, with an average of 78 mm. The annual amount of precipitation in Banat is 580 mm (according to ANM - National Meteorological Authority) [6]. Regarding the types of soils at the level of the country, in the plain areas the cernisols predominate, in the plateau and hill area we will constantly find luvisols, and in the mountainous areas we are dealing with the cambisols and spodosols. In the Banat region, the largest area is occupied by zonal soils, namely leached chernozems and hay chernozems, then in the hilly area brown soils predominate. In general, the climatic conditions, soils and meteorological factors in the Banat region, Romania, offer favourable conditions for the cultivation of agricultural plants, especially for the cultivation of cereals, but also for technical and fodder plants [5, 7].

In the context of the presented data, the productivity of agricultural lands is much different in time and space (according to OSPAT), as a result of the diversity of physical and geographical conditions, intrinsic properties of soils and anthropogenic interventions in time (temperature and precipitation) [7].
Thus, the purpose of this study was to highlight the influence of climatic and meteorological factors on the chemical composition and energy value of wheat used in human nutrition, as well as animals.

2. Materials and methods
This study was conducted over two years, in accordance with the specific agricultural period of wheat in Romania, namely September 2017 - July 2018 and September 2018 - July 2019. Wheat samples were collected from various grain distributors in the Banat region, Romania. A total of 100 samples were analyzed, 50 samples each year.

To determine the crude chemical composition, the samples taken in the study were analyzed by NIRS (Near Infrared Reflectance Spectroscopy) [8, 9], using the NIR analyzer Bruker optics Matrix I, in the feed Physico-Chemical Analysis Laboratory of the Department of Animal Nutrition within the Faculty of Veterinary Medicine from Timisoara, Romania. Near InfraRed spectroscopy is a method of analysis that uses the NIR region of the electromagnetic spectrum (800 - 2,500 nm). Complete Bruker Optics calibration packages for animal feed and agricultural products are developed in accordance with ISO 12099 [10]. Bruker optics Matrix I NIR analysers works with OPUS software that ensures quality data processing.

The name and abbreviations used for the determined nutrients were those recognized in the literature: moisture (M%), dry mater (DM%), ash (A%), crude protein (CP%), ether extract (fat) (EE%), crude fiber (CF%), nitrogen-free extract (NfE%) and metabolizable energy (ME kcal / kg).

The calculation of metabolizable energy (ME kcal / kg) was performed according to the formula described by ATWATER, which initially used the formula to calculate energy from human food, according to FAO [11]. Subsequently, this formula is also applicable in estimating the general energy value of feed used in monogastric animals feeding:

\[
ME (kcal) = (4 \times CP) + (9 \times EE) + (4 \times CF) + (4 \times NfE)
\]

Data on ambient temperature and precipitation regime were taken from the database of ANM (National Meteorological Agency), for the two studied years (ANM). The monthly averages of temperature and precipitation were used, of particular interest for September-July, as the optimal period for wheat cultivation in Romania.

The obtained results were statistically analysed using Excel Data Analysis. Descriptive statistics were used, and the data were supplemented by calculating the mean, standard deviation and coefficient of variation. Statistical data were expressed in tables and diagrams.

3. Results and discussions
The results of the statistical interpretation of meteorological data (according to ANM) are represented in graph 1 (figure 1):
By comparing the average values of temperatures in 2017-2018 with those of 2018-2019, slightly lower values were identified in the wheat’s sowing months (September-November 2017), but slightly higher in the ripening months (April-May 2018). In the harvesting months (June-July), the temperatures were lower in 2018, compared to 2019. The average temperature for the entire agricultural period (September-July) specific to wheat production, in Romania, was 8.98 °C for 2017-2018 and 9.25 °C for the year 2018-2019.

Regarding the amount of precipitation for the years studied, significant differences are registered only during the ripening and harvesting period. Thus, in April-May 2018 the amount of precipitation was significantly lower compared to that of precipitation in the same months of 2019. In June-July, the wheat harvest months, the amount of precipitation was higher in 2018 compared to 2019. For the sowing months of wheat (September-November), in Romania, the quantities of precipitation registered did not show significant variations. The average amount of precipitation for the entire agricultural period of wheat (September-July) was 54.19 mm in 2017-2018 and 52.46 mm in 2018-2019.

In order to achieve the correlations regarding the influence of meteorological factors on the wheat quality, the chemical and energetic analysis of the wheat grains was performed. From this analysis, various results were obtained, for the two years studied (2017-2018 and 2018-2019) and are presented in table 1.

The statistical processing of the data and the variation of the chemical composition of the wheat, for the two years taken in the study, are presented in table 1 and figure 2. Statistically significant differences can be observed between the values obtained. The moisture content (M%) was higher for the wheat harvested in 2018 (13.03% vs 10.72%), considering that the precipitations of that year were more abundant and the temperatures slightly lower compared to 2019. By direct correlation with the value of humidity, the dry matter content (DM%) was lower for the wheat harvested in 2018 (86.96% vs 89.27%).
Table 1. Chemical and statistical results of the analysed samples

|        | M (2018) | DM (2018) | ASH (2018) | CP (2018) | EE (2018) | CF (2018) | NfE (2018) | ME/KG (2018) |
|--------|----------|-----------|------------|-----------|-----------|-----------|------------|--------------|
| Min    | 11.46    | 85.67     | 1.51       | 9.08      | 1.47      | 1.65      | 69.15      | 3452.3       |
| Max    | 14.33    | 88.54     | 2.03       | 11.1      | 2.81      | 2.67      | 72.04      | 3605.3       |
| Mean   | 13.03    | 86.96     | 1.76       | 10.23     | 2.19      | 2.18      | 70.81      | 3517.90      |
| S.D    | 0.72     | 0.72      | 0.14       | 0.32      | 0.32      | 0.25      | 0.71       | 33.54        |
| Variance | 0.53    | 0.53      | 0.01       | 0.33      | 0.33      | 0.14      | 0.71       | 33.54        |
| C.V.%  | 5.59     | 0.84      | 7.75       | 5.76      | 12.76     | 11.87     | 10.3       | 9.54         |
| C.L.(95.0%) | 0.20    | 0.21      | 0.12       | 0.11      | 0.11      | 0.14      | 0.07       | 0.20         |

|        | M (2019) | DM (2019) | ASH (2019) | CP (2019) | EE (2019) | CF (2019) | NfE (2019) | ME/KG (2019) |
|--------|----------|-----------|------------|-----------|-----------|-----------|------------|--------------|
| Min    | 8.65     | 86.17     | 1.11       | 9.61      | 1.65      | 1.96      | 68.07      | 3473.3       |
| Max    | 13.83    | 91.35     | 1.94       | 12.31     | 2.37      | 3.74      | 73.89      | 3701.8       |
| Mean   | 10.72    | 89.28     | 1.51       | 11.04     | 2.02      | 2.96      | 71.74      | 3611.04      |
| S.D    | 1.08     | 1.08      | 0.22       | 0.13      | 0.36      | 0.37      | 73.89      | 3701.8       |
| Variance | 1.15    | 1.15      | 0.05       | 0.13      | 0.37      | 0.40      | 73.89      | 3701.8       |
| C.V.%  | 10.5     | 10.0      | 14.5       | 10.5      | 12.6      | 12.6      | 73.89      | 3701.8       |
| C.L.(95.0%) | 0.30    | 0.30      | 0.06       | 0.07      | 0.10      | 0.11      | 0.37       | 0.12         |

*M – moisture; DM – dry matter; ASH – sample ash; CP – crude protein; EE – ether extract; CF – crude fiber; NfE – nitrogen-free extract; ME/KG – metabolizable energy kcal/kg; Min. – minimum value; Max. – maximum value; Mean – average value; SD – standard deviation; Variance – sample variance; CV – coefficient of variance; CL – confidence level.

The ash content (A%) of the examined wheat registered higher values in the 2018 harvesting year (1.76%), compared to 2019 (1.51%). In contrast, the crude protein content (CP%) was higher for wheat harvested in 2019 (11.04%), a year in which temperatures were higher and precipitation were lower, compared to 2018 (10.02%). For the fat content (EE%) of wheat, higher values were registered in 2018 (2.19%) vs 2.01%). Even if in this year (2018) the amounts of precipitation were higher, it seems that they did not negatively influence the fat content of wheat.

The crude fibre content (CF%) was the parameter with the most significant differences between the studied years. The higher values were obtained in 2019 (2.96%) compared to 2018 (2.17%). This important difference could be due to the higher temperatures recorded in 2019 and the lower amounts of precipitation, for the same year. In correlation with this parameter there is the content in nitrogen-free extract (NfE%), for which the higher values were registered in 2019 (71.74% vs 70.81%). These values are directly correlated with the higher temperature and the less abundant rainfall in 2019.

The nutritional quality of wheat is expressed by its energy value. Consequently, starting from the chemical composition and using the ATWATER calculation formula, the metabolizable energy for the analysed samples was established. Comparing the values obtained, a higher value of metabolizable energy was obtained for wheat harvested in 2019 (3611.05kcal / kg), compared to that determined for 2018 (3517.90kcal / kg). This is the consequence of the higher dry matter content and of the higher values for the main nutrients of organic nature (CP%, CF%, NfE%) registered in the wheat harvested in 2019 (figure 3).
Figure 2. Chemical composition variation of wheat harvested in 2018 and 2019

Figure 3. Metabolizable energy variation of the wheat harvested in 2018 and 2019
The limits of nutrient content variation were wider for 2019 than in 2018 (see table 1), and the differences were significant (p<0.001) between the analysed parameters, which highlight the influence of meteorological factors on the nutritional quality of wheat and the importance of analysing the chemical composition variation in plants used for human and animal nutrition.

The results of this study, obtained by the NIR method [8, 9], show that the nutritional value, respectively the nutrient content of crop plants, varies greatly. Thus, in 2018, a year with more abundant rainfall and lower temperatures compared to 2019, the values obtained by analysis were lower for the main nutritional components - CP%, CF% and NfE%. The NfE% content for wheat is of great nutritional importance given that 90% of this component is starch. Starting from these lower values, a lower energy value was identified; the metabolizable energy presented lower values in 2018 compared to 2019. These variations are directly correlated with the analysed meteorological factors. Precipitation, ambient temperature and soil type appear to be decisive factors in terms of cereal crop production and their organic and inorganic content [12].

In Romania, the existing soil types [13] are favourable for cereal crops, especially those in the Banat region. For example, Lato et al., 2019 presented the economic profitability of soil types in the Banat region, Romania, for wheat, corn and sunflower vegetable crops. Crop favourability was followed and out of the three studied crops, maize and sunflower were in the second class of reliability in terms of requirements in the Banat region, wheat being in the first class of favourability [13].

Jie et al., 2006, pointed out that weather conditions, including temperature, sunshine duration, and rainfall during crop growth are the primary factors that determine the variation of wheat protein content [14]. Meteorological limits of winter wheat productivity have also been assessed by Lollato et al., in the U.S.A. [15]. In another study, Vollmer and Mußhoff (2018) analysed the protein content variation in winter wheat, depending on weather parameters: the sum of annual temperature, daily temperature range, precipitation and sunshine. The results showed that 76.5% of the annual variability of the average protein content can be explained based on these meteorological parameters [16]. In China, Jiayu et al., 2018, analysed the effects of weather changes on the yield of rice and wheat crops. They concluded that by obtaining real-time agricultural meteorological information, crop production can be predicted efficiently and in a timely manner, and agricultural crop management can be done according to the degree of importance of meteorological factors in different time periods, in order to increases crop production and its quality [17].

A group of researchers coordinated by Asseng S., in 2018, conducts a study regarding the impact of climate change on wheat production and its protein content. The authors believe that the concentration of protein in wheat cereals is an important and determining factor in the quality of wheat for human nutrition, which is often overlooked in efforts to improve crop production. Due to climate change, cereal yields and their protein content are expected to be lower and more variable in most regions with low rainfall, with nitrogen availability limiting the growth stimulus from raised CO2. The introduction of wheat genotypes adapted to warmer temperatures (and taking into account changes in CO2 and rainfall) could increase overall production by 7% and protein yield by 2%, but the concentration of protein in cereals would be reduced by -1.1 percentage points, representing a relative change of 8.6% [18]. The same idea regarding the effects of climate change on wheat production and quality is supported by several representative studies for this topic [19-22].

These results can be supported by the values obtained in this study, where the average protein content was 10.02% in 2018 and 11.04% in 2019. The data obtained by us were compared with values from the literature, where Burlacu, in 2002, specified an average protein value of 13% for wheat in Romania [23].
Wheat is an important crop for human and animal consumption and it is cultivated in many countries, including in rainy conditions in semi-arid areas. It is necessary to know the environmental factors before harvesting and to determine the effect of major factors on its quality. Different methods have been suggested for yield prediction with different levels of accuracy, one of these approaches being the statistical regression model that can be widely applied [24].

A more complex study analyses the effects of climate change and meteorological factors on the availability, quantity and agricultural production of food, but also the impact on the nutritional content of food, respectively on the health and nutrition of humans and animals. This research highlights emerging evidence that climate change and ever-changing weather factors can have effects beyond agricultural productivity by affecting food nutrient content and so, on food security and global nutrition [25].

In 2021, Poole et al. expressed their views on the use of cereals in human nutrition and the importance of collaboration between agricultural producers and producers of cereal-based foods in order to prevent nutritional and metabolic pathologies. This article covers the food and overall health contribution of the main cereals, especially maize and wheat, which are often considered to be "poor-nutrient" foods. Researchers argue that the research agenda should include the full nutritional contribution of the components of the grain structure for an objective approach to nutritional diseases. Agri-food communities should take a multidisciplinary approach to farm-to-metabolism food research. Agricultural researchers should work with food stakeholders on nutrition challenges in grain production, processing and manufacturing [26].

The results of this study confirm the idea supported also, by other researchers in the field and emphasize the importance of nutritional evaluation of wheat used in human and animal nutrition.

4. Conclusions
In Romania, wheat is one of the most important food crop plant, 80% of production being used in bakery and about 15% in animal feed.

The analysis of the climatic and meteorological factors influences on the chemical composition showed a reduction in the values of nutritional components (CP%, CF%, NfE%) in 2018, a year characterized by a higher amount of precipitation and a lower average temperature, compared to 2019. These results led to a reduction in the energy value of wheat in 2018, compared to 2019. Due to weather conditions in 2018, the moisture value of wheat grain was higher than in 2019, which can endanger the quality of wheat over time and can reduce its storage period. An interesting result of the study was the fat content of the analysed wheat samples which was not negatively influenced by the increased amounts of precipitation from 2018.

The results of this study emphasize the relevance of monitoring of cereal crops used in human and animal nutrition and the importance of correlating nutritional values with climatic and meteorological parameters, in order to maintain food safety and security.

Acknowledgment
This paper is published from the own funds of the Banat’s University of Agricultural Sciences and Veterinary Medicine „King Michael the I of Romania” from Timisoara and Research Institute for Biosecurity and Bioengineering Timisoara.
References

[1] Minister of Agriculture and Rural Development, Grau [Online] 2020 [Accessed 05.05.2021] Available at: https://www.madr.ro/culturi-de-camp/cereale/grau.html.

[2] C. Lyddon, “Focus on Romania”, World-Grain.com, [Online] 2019 - https://www.world-grain.com/articles/11557-focus-on-romania - accessed in 03.05.2021.

[3] Fekete I., “Romania emerges as second-biggest wheat exporter in the EU”, Transylvanianow.com, [Online] 2019 [Accessed 05.05.2021] Available at: - https://transylvanianow.com/romania-emerges-as-second-biggest-wheat-exporter-in-eu/ - accessed in 03.05.2021.

[4] [Online] 2020 [Accessed 05.05.2021] Available at: https://inisre.ro/cms/https://inisre.ro/cms/sites/default/files/com_presa/com_pdf/prod_veg_r19_0.pdf - accessed in 04.05.2021.

[5] Geography of Romania [Online] 2020 [Accessed 11.05.2021] Available at: https://en.wikipedia.org/wiki/Geography_of_Romania.

[6] Meteo Romania [Online] 2020 [Accessed 05.04.2021] Available at: http://www.meteoromania.ro/.

[7] Ospatimisoara.ro [Online] 2020 [Accessed 11.05.2021] Available at: http://www.ospatimisoara.ro.

[8] B.G. Osborne, and T. Fearn, “Collaborative evaluation of near infrared reflectance analysis for the determination of protein, moisture and hardness in wheat”, J. Sci. Food Agric., 34: 1011-1017, 1983. https://doi.org/10.1002/jsfa.2740340919

[9] L. Liu, B. Zhao, Y. Zhang, X. Zhang, “Design and Experiment of NIR Wheat Quality Quick Detection System”. In: D. Li, Y. Chen (eds) “Computer and Computing Technologies in Agriculture VI”. CCTA 2012. IFIP Advances in Information and Communication Technology, vol 393, Springer, Berlin, Heidelberg, 2013. https://doi.org/10.1007/978-3-642-36137-1_17

[10] Bruker, Agriculture products [Online] 2020. Available at: https://www.bruker.com/en/applications/food-analysis-and-agriculture/agriculture.html.

[11] Calculation Of The Energy Content Of Foods - Energy Conversion Factors [Online] 2021. Available at: http://www.fao.org/3/Y5022E/y5022e04.htm.

[12] J.T. Tutaw, F. Baier, and F. Krottenthaler, et al., “Climate change induced rainfall patterns affect wheat productivity and agroecosystem functioning dependent on soil types”, Ecol Res, 31, 203–212, 2016. https://doi.org/10.1007/s11284-015-1328-5.

[13] K. I. Lato, M. Popa, A. Lato, M. Corches, I. Radulov, A. Berbeccea, and F. Crista, “Economic efficiency of main soil types from west region of Romania for various agricultural crops”, Journal of Environmental Protection and Ecology, Vol.20 No.2 pp.1022-1028, 2019.

[14] P. Jie, Z. Yan, C. Weixing, D. Tingbo, and J. Dang, “Predicting the Protein Content of Grain in Winter Wheat with Meteorological and Genotypic Factors”, Plant Production Science, 9:3, 323-333, 2006. DOI: 10.1626/pps.9.323

[15] R. P. Lollato, J.T. Edwards, T.E. Ochsner, “Meteorological limits to winter wheat productivity in the U.S. southern Great Plains”, Field Crops Research, 203, 212-226, 2017. DOI:10.1016/J.FCR.2016.12.014

[16] E. Vollmer, O. Mußhoff, “Average Protein Content and Its Variability in Winter Wheat: A Forecast Model based on Weather Parameters”, Earth Interactions, 22(19), 1-24, 2018.

[17] Z. Jiayi, X. Shiwei, L. Garqiong, Z. Yongen, W. Jianzhai, and L. Jiaying, “The Influence of Meteorological Factors on Wheat and Rice Yields in China”, Crop Science, 58: 837-852, 2018. https://doi.org/10.2135/cropsci2017.01.0048

[18] S. Asseng, P. Martre, A. Maiorano, R.P. Rötter, G.J. O’Leary, G.J. Fitzgerald, C. Girousse, R. Motto, F. Giunta, M.A. Babar, M.P. Reynolds, A.M.S. Kheir, P.J. Thorburn, K. Waha, A.C. Ruane, P.K. Aggarwal, M. Ahmed, J. Balkovič, B. Basso, C. Biernath, M. Bindö, D. Cammarano, A.J. Challinor, G. De Sanctis, B. Dumont, E. Eyshi Rezaei, E. Fereres, R. Ferrise R., M. Garcia-Vila, Gayler S, Gao Y, Horan H, Hoogenboom G, Izaurralde RC, Jabloum M, Jones CD, Kassie BT, Kersebaum KC, Klein C, Koehler AK, Liu B, Minoli S, Montesinos San
Martin M, Müller C, Naresh Kumar S, Nendel C, Olesen JE, Palosuo T, Porter JR, Priesack E, Ripoche D, Semenov MA, Stöckle C, Stratonovitch P, Streek T, Supit I, Tao F, Van der Velde M, Wallach D, Wang E, Webber H, Wolf J, Xiao L, Zhang Z, Zhao Z, Zhu Y, Ewert F., “Climate change impact and adaptation for wheat protein”, *Glob Chang Biol.*, 25(1):155-173, 2019. doi: 10.1111/gcb.14481. Epub 2018 Nov 22. PMID: 30549200.

[19] H. Yossife, M.M. Eldanasoury, T.B. Fayd, M.K. Hassanein, B.A.A. Ali., “Impact of Climate Change Conditions on Some Chemical Compounds of Wheat as Indicators for Photosynthetic Efficiency”, *New York Science Journal*, 10(9), 2017. DOI: 10.7537/marsnys100917.15.

[20] U. Kedir, “The Effect of Climate Change on Yield and Quality of Wheat in Ethiopia: A Review”, *Journal of Environment and Earth Science*, Vol.7, No.12, 2017. DOI: 10.18805/ag.A-342.

[21] D. Xiao, D.L. Bai H, Liu, “Impact of Future Climate Change on Wheat Production: A Simulated Case for China’s Wheat System”, *Sustainability*, 10(4):1277, 2018. https://doi.org/10.3390/su10041277

[22] K. Heil, A. Lehner, and U. Schmidhalter, “Influence of Climate Conditions on the Temporal Development of Wheat Yields in a Long-Term Experiment in an Area with Pleistocene Loess”, *Climate*, 8(9):100, 2020. https://doi.org/10.3390/cli8090100

[23] G. Burlacu, A. Cavache, and R. Burlacu, “The productive potential of fodder and their use”, Ed. Ceres, Bucharest, 2002.

[24] M. Bahrami, S. Ali, R. M. Mohammad, D. Shohreh, “Determination of Effective Weather Parameters on Rainfed Wheat Yield Using Backward Multiple Linear Regressions Based on Relative Importance Metrics”, *Complexity*, vol. 2020, Article ID 6168252, 10 pages, 2020. https://doi.org/10.1155/2020/6168252

[25] G. Scarpa, L. Berrang-Ford, C. Zavaleta-Cortijo, L. Marshall, L.H. Sherilee, J. E. Cade, “The effect of climatic factors on nutrients in foods: evidence from a systematic map”, *Environ. Res. Lett.*, 15, 113002, 2020. https://doi.org/10.1088/1748-9326/abaf64.

[26] N. Poole, J. Donovan, O. Erenstein, “Agri-nutrition research: Revisiting the contribution of maize and wheat to human nutrition and health”, *Food Policy*, 18:101976, 2020. doi: 10.1016/j.foodpol.2020.101976.