Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 22, Issue 1, 2022
PRINT ISSN 2284-7995, E-ISSN 2285-3952

PROGRESS IN GENOMICS AND BIOTECHNOLOGY, THE KEY TO ENSURING FOOD SECURITY

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Abstract

Genome manipulation is one of the emerging fields with impressive implications for genetic modification and biotechnology. Targeted genome editing has the general objective of improving the quality and productivity in agriculture, which includes the creation of plants with improved value in terms of composition and nutritional properties and with characteristics that provide resistance to various biotic and abiotic stressors. On the other hand, the progress and development of biotechnology can be the most viable solution for a modern agriculture, favoring the development of sustainable production methods. In this context, the purpose of the paper was to provide a summary of the achievements of genomics and biotechnology with application in agriculture and especially the role of these modern technologies on food security, in the context of unprecedented population growth and climate change. The used methods included searching of the multiple databases and hand searching of the specialized literature with the latest publications in the field. As results, it can be appreciated that the genomics and biotechnology can be an alternative and sustainable management tools to such important sector like agriculture. Thus, the gene editing can make agricultural systems more efficient being involved in creating resistant crops to disease, pests, drought, or other climate change. Also, the biotechnology strategies lead to obtaining a higher yield, improving the quality and diversification of products, in conditions of reduced use of nitrates and other chemical fertilizers and the rational use of water. The development of genomic and biotechnological technologies is one of the few ways that can bring an extensive wave of innovation and really represents the key to effective solutions for solving of the main current global challenges.

Key words: *genome editing, CRISPR/Cas9 system, agricultural biotechnology, sustainability*

INTRODUCTION

Genetics and genomics are very closely related fields in biology. Genetics studies the whole process of inheritance and other related factors, while genomics studies the genome of organisms, *i.e.*, the nucleotide sequences of DNA or RNA. Usually, genomics tries to determine the entire nucleotide sequence of nucleic acids in organisms. In addition, the relationships and interactions within the genome are studied in genomics [17].

Because each nucleotide sequence in genes encodes proteins, and therefore the properties of each protein are determined by genes, the study of genes and its coding has great potential in identifying important DNA sequences for different applications.

Biotechnology is a top field, the development of which is supported both by recent discoveries in biology, microbiology, biochemistry, genetic engineering, etc., and by the demands of society on certain issues it is currently facing: energy and food crisis, ecological problems and bioremediation.

Modern biotechnologies have begun to take shape with the spectacular advancement of genetic engineering techniques and have become a real industry, with an exceptional potential for innovation and a wide variety of activities in agriculture, food industry, medicine industry, environmental protection, biofuels industry etc. [6, 7, 31].

Agricultural biotechnology is an integral part of the vast field of biotechnology and is based on the controlled artificial use of genetic information of plants, animals, and microorganisms.

Agricultural biotechnology consists of a set of scientific techniques used to create or modify plants, animals, and microorganisms. Basically, the term biotechnology refers to a series of methods and techniques that use, as tools, the living cells of organisms or part of these cells or their products (such as genes and enzymes).

Biotechnology integrates several modern techniques, including genetic engineering. The use of new methods in agriculture must be market-oriented, thus ensuring the sustainable viability of agricultural holdings [12, 26, 27, 28, 29, 30, 31].

Biotechnology can provide real opportunities in various fields. In addition to traditional agricultural products, such as food, animal feed and fiber, new agricultural or non-agricultural products may appear, including pharmaceutical products such as oral vaccines, products with higher levels of essential amino acids or vitamins, or with a content improved by fatty acids. The elimination of allergens and anti-nutrient factors from food products may also become possible.

It is expected that in the near future an increased range of better quality and healthier food and feed will be available in less-favored regions, in difficult climatic conditions, in drought conditions or in in the case of less fertile soil. Thus, the correct use of biotechnology can be one of the keys to this evolution.

Biotechnology can provide interesting ways to produce energy in rural areas, thus leading to an increase in the income of rural areas. These opportunities need to be considered in the light of the imperatives of security and food supply, health and environmental protection and sustainable landscape management.

Modern agricultural biotechnologies have the ability to solve many important problems in agriculture: somatic hybridization, in vitro cell cultures and tissues; improving plants and animals to obtain highly productive lines, resistant to diseases, pests and extreme environmental conditions; improving animal nutrition and health; preservation of plant and animal genetic resources; obtaining plant and animal products with an improved nutritional profile, for healthier, safer and higher quality food; recycling of agricultural waste products; soil and water bioremediation; production of auxiliary energy sources, based on organic waste resulting from agriculture, animal husbandry or food industry, etc.

Advances in genomics studies have sparked a revolution in basic and applied research, primarily in fields such as medicine and agriculture. It is said that genomics will transform science and technology and caused an extensive wave of innovation. It is therefore considered that the time has come for the world's states to become seriously involved in the research and development of genomic technologies and to start together proposing effective solutions to global challenges [31].

This review paper it started with the current certainty of two essential global challenges: the population is growing, and climate change is setting new patterns in agriculture. In this context, agrigenomics is a viable solution because, through it, researchers can adapt animal breeds and plant species for ensuring food security.

Agrigenomics refers to the genetic study of crops and animals and how genes influence their development. Thus, the application of genomics in agriculture allows improving the sustainability and productivity in the production of crops and animals.

The paper briefly outlines some of the achievements of genomics and biotechnology with application in agriculture. These achievements can be effective solutions to some prospects that are not exactly promising in terms of food security, in the context of unprecedented population growth and climate change.

MATERIALS AND METHODS

The used methods included searching of the multiple databases and hand searching of the specialized literature with the latest publications in the field. The main databases were Web of Science and Google Scholar as well as EFSA and Global Market Insights.

The topics followed in this research were: the gene editing (CRISPR) technology and its aid in the adaptation of plants and animals to climate change; plant genome sequencing; enzymatic preparations with high cellulase and hemicellulase activities to improve feed quality and milk production; biotechnological methods to increase the digestion of fiber by ruminants and thus their performance, etc.

By systematic and thorough search of some topical references, were identified a breadth of relevant results. Some data were transposed in the form of adapted tables, in order to better highlight the results in the field.

RESULTS AND DISCUSSIONS

Food security is part of the security of every state in the world and of global security. Ensuring food security means eliminating both obvious hunger - subnutrition and hidden hunger - malnutrition. Today, the issue of food security is a complex and global one, a top priority for ensuring global stability.

Any situation that disrupts the supply and access to food leads to food insecurity. Continued productivity gains are essential due to unprecedented global population growth. In addition to this real demographic explosion and climate fluctuations or changes, there are other factors that can contribute to food insecurity in a very complex way, such as: loss of some agricultural land, civil and economic disturbances, COVID pandemic, gender inequality and labor migration, limited infrastructure, etc. [1, 19, 21, 25, 32, 34].

Genetic bioengineering is the main tool with which biotechnologies are continuously improved. The genomics of an organism represent all its hereditary information and its DNA or RNA code in the case of viruses.

In the past, the selection of plants and animals was based only on phenotype, but in present, based on the molecular selection techniques, this process is faster and cheaper. At the same time, the selection is made with much greater precision. This will create improved plant varieties, healthier and more productive animals, better adapted to climate change, which will ensure food security for all mankind [2, 3, 5, 10, 11].

The gene editing aid in the adaptation of plants and animals to climate change or help mitigate the effects of climate change on agriculture [8, 9, 18]

Nuclear DNA was first edited in the early 1970s, chloroplast DNA was first edited in 1988, and animal mitochondrial DNA was edited in 2008. However, no previous instrument successfully edited the plant's mitochondrial DNA. Some researchers from Japan have used this technique to create four new lines of rice and three new lines of canola [37]. Researchers hope to use the technique to address the current lack of mitochondrial genetic diversity in crops, an extremely vulnerable point in human nutrition. The mitochondrial genome of plants is huge, the structure is much more complicated, genes are sometimes duplicated, and the mechanisms of gene expression are not well understood. The four new rice lines and three new canola lines that Japanese researchers have created are proof that the developed system can successfully manipulate even the complex mitochondrial genome of plants.

This is an important step in mitochondrial plant research. Researchers will further study the mitochondrial genes responsible for male plant infertility in detail to identify possible mutations that could create greater diversity in crops. The team says that the real benefit of the work is adding genetic diversity to crops, even more so than improving yields [37].

As for the potato, it is a genetically complex tetraploid species. The complex genome of potatoes comprises approximately 39,000 genes. From a large genetic background, the researchers identified 2,622 genes that led to the improvement of this crop at the beginning of its domestication [16]. The study of the spectrum of genetic diversity, from the wild past to its cultivated present, can provide an essential source of untapped adaptive potential.

In the near future, it will be possible to identify and study genetic introgressions and hybridization episodes throughout history in order to find the target genes during domestication to control variance for agricultural traits [16]. Many of these will help hybridization efforts focus on ensuring food security, adapting to climate differences, combating various pathogens, or improving yields.

In the context of actions aimed at helping to combat climate change that concern the entire international community, when the European economy aligns with the objectives of the Green Deal, an important achievement generated by the combined efforts of Corteva Agriscience and PepsiCo was the completion of full plant genome sequencing of oats. This great success, which has been due to a sustained collaboration between academia, government, and the private sector, aims to help increase the resilience of food systems, but also to produce more vigorous, more stable, tasteful and improved nutritional qualities of oat varieties [14].

The publication of the oat genome is a stimulus for international agronomic innovation, which could increase the resilience of the food system from several perspectives. One of these is sustainability - improvement, which aims to increase productivity and obtain stronger varieties, with increased resistance to disease and able to reduce crop losses. In terms of nutritional qualities, oats are known for fiber and essential nutrients they contain. In this sense, understanding the whole genome of the plant creates the possibility for researchers to focus on the desired qualities, being, ultimately, for the benefit of consumers, who want a higher nutritional profile of this plant and not only [14].

Among those who contributed significantly to the project are Corteva, through its advanced sequencing technology and analytical capabilities; Charlotte University of North Carolina, which provided data and studies on the Sequencing and Field Crop Development Center of the University of Saskatchewan, Canada, which provided the oat variety. Through the approach of providing free access to information, these institutions not only promote the science of oat improvement but thus contribute to solving the challenges in the field of agriculture in general but also to improving food and nutrition security in particular.

In plant breeding programs, creating the desired plant could take years and generations. The ability of researchers to accurately modify plant genomes has been limited until the advent of genome editing technology [10]. Today, genome editing allows the same result to be achieved as with traditional breeding methods, but with greater precision and efficiency [23]. DNA sequencing technology has made it possible to decipher the complete genome sequence of many plant species at an unprecedented rate and at a low cost. Knowledge of plant genomes and transcripts makes it possible to create new varieties through molecular design and bioengineering.

The CRISPR (Clustered Regularly Interspaced Short Palindromic Repeats) system is an essential feature of the bacterial genetic code and its immune system, functioning as a defense system that bacteria use to protect themselves against virus attacks [18]. Once activated, Cas (CRISPR-associated) genes produce special enzymes that can act as "molecular scissors" that can cut DNA. Basically, CRISPR technology transforms a bacterial immune mechanism into a tool that can edit in a simple and cheap way the genome of all plant and animal organisms.

The genome is the complete set of genetic "instructions" that determine how an organism develops. CRISPR allows the extremely precise "cutting" of DNA fragments from an organism's genome and the modification of its sequence, which is why it is considered a "genetic scissors" (Figure 1).

This versatile technology has rapidly expanded its use to modulate gene expression, ranging from genomic sequence correction or modification to epigenetic and transcriptional changes. CRISPR technology is an engine for basic research. Genomic editing with CRISPR/Cas9 is much faster and cheaper than previous methods [4, 18, 20, 36].

CRISPR has great potential in food production, to improve crop quality, to achieve disease resistance and herbicide resistance.

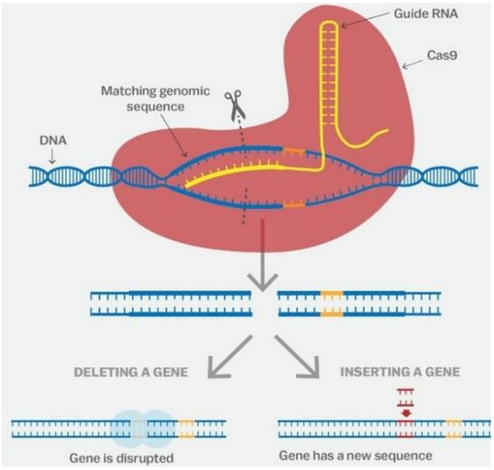

Fig. 1. CRISPR is a gene-editing technology for editing genomes.
Source: [39].

Unlike GMO (genetically modified organisms) methods, CRISPR-Cas9 does not involve the introduction of DNA from compatible plants with asexual reproduction. This key difference could allow genomic editing methods, such as CRISPR-Cas9, to gain wider consumer acceptance, as well as a slightly simpler regulatory process.
This modern genomics technology has already been successfully applied to many plant and animal species, some of which are specified in Table 1.

Table 1. CRISPR gene-editing system applications for different traits to a few species

Species	Trait targeted	Genes edited	References
Banana	Semi-dwarfed	Ma04g15900	[35]
Maize	Drought tolerance	ARGOS8	[36]
Rice	Drought tolerance	EPFL9	[40]
Cattle	Thermotolerance	SLICK	[4]
Chicken	Yield	G0S2	[24]
Goat	Yield	Fat-1 into MSTN	[41]
Pig	Yield	IGF2	[20]

Source: Own calculation based on [18].

CRISPR also offers the opportunity to address the issue of food allergies by rewriting those regions of the gene that are recognized by the immune system and that cause an allergic reaction. CRISPR-Cas9 is also being studied to modify the DNA of wheat to eliminate gluten, making it suitable for patients with celiac disease.
Climate change will further increase the need to use CRISPR technology to protect food and agricultural industries from new bacteria. Gene editing can make farming more efficient. It can reduce the global shortage of food for basic crops such as potatoes and tomatoes, and it can create crops that are resistant to drought and other effects on the environment.
In the next years, growing demand for CRISPR/Cas9 technology will favour the gene editing market value. Thus, the CRISPR/Cas9 segment is estimated to register growth of more than 15% by 2026 (Figure 2) [15].

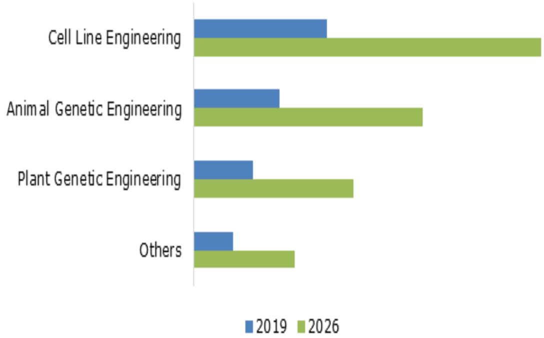

Fig. 2. Global Gene Editing Market
Source: [15].

The variety of biotechnological processes is very large, the field of application of biotechnology being constantly expanding.
The use of microorganisms for human purposes is not limited to the production of various substances by industrial microbiology, but also includes areas such as food industry, wastewater treatment, biotransformation or biodegradation of waste, biogas production, biomass production, implementation of symbiotic systems at plants and animals, genetic bioengineering, etc.
Agricultural biotechnology includes plant biotechnology and animal husbandry biotechnology. While plant biotechnology refers to the use of plant cell cultures as well as genetic engineering techniques for modern and unconventional plant and animal breeding, animal husbandry biotechnology

refers, in particular to animal nutrition, increasing animal resistance to pathogens, obtaining animals with increased production of meat, milk, eggs, wool, etc. and conservation of animal genetic resources.

The feed industry is an important sector in agriculture. A lot of feed additives are currently used, and new concepts are continuously developed: enzymes, pre-biotics, pro-biotics, dietary amino acids, metabolic modifiers, etc. Enzymes, for example, are the biological catalyst which improve the nutrient availability from feed stuffs, ensure lower feed costs and reduce anti-nutritional effects from some feed ingredient [22].

Cellulases and hemicellulases have a very wide range of applications in this industry (Table 2).

Table 2. Some enzymes used in feed biotechnology and their effects

Enzymes	Effects
Cellulases Hemicellulases	Increasing of fodder flexibility; Improving the nutritional quality of feed and animal performance
B-glucanase Xylanase	Release of nutrients from cereals; Improving the absorption of fodder and animal performance
Pectinase	Preservation of feed quality for ruminants

Source: Own calculation based on [15].

β-glucanases and xylanases have been used successfully in non-ruminant diets to hydrolyze non-starchy polysaccharides (NSP). The presence of high concentrations of NSP in the cereal-based diet leads to low feed conversion rates, low weight gain of young animals, especially of chicks [33].

The addition of β-glucanases and xylanases during feed production has led to the degradation of NSP and has significantly improved the digestion and absorption of feed components and weight gain by chicks and laying hens [33]. Carbohydrases supplementation has an important role in poultry diets with high NSP contents (Figure 3).

Econase XT is an enzyme preparation with endo-1.4-beta-xylanase as the main activity. The product is currently authorised for its use in feed for chickens and turkeys for fattening and reared for laying/breeding and for weaned piglets [13].

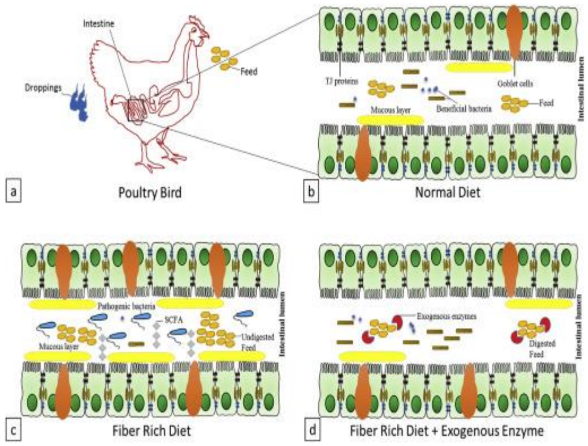

Fig. 3. Exogenous feed enzymes (EFE) supplementation with high NSP diets to improve energy utilization and performance to poultry
Source: [33].

Some of the benefits of adding Econase to the diet of chickens are: increased flexibility in diet formulation; use of cheap raw materials; increase in the energy value of cereals; improved digestibility, improved feed conversion; clean eggs with more colorful yolks; less waste, etc.

Similar results were obtained with other enzyme preparations with xylanase and β-glucanase. Due to the success of these enzymatic preparations in the diet of chickens, has been promoted their use in the diet of pigs too. In fact, supplementing the diet with xylanase-based multienzyme preparations has reduced the cost of feeding pigs and facilitated the use of cheap feed [38]. Despite this progress, more studies are needed to recommend the right combination of hydrolyzed enzymes to be included in a wide range of pig diets.

In general, there is a growing interest in the use of enzymatic preparations with high cellulase and hemicellulase activities to improve feed, milk quantity or ruminant weight gain [22]. However, the success of the use of these enzymes in the diet of ruminants depends on several factors: their stability in feed (during and after processing) and in rumen; the ability of the enzymatic components to hydrolyze the polysaccharides in the plant cell wall; the ability of the animals to use the reaction products efficiently. Therefore, enzymatic preparations should be permanently characterized by in vitro and in vivo experiments.

The ruminant feed diet, which contains cellulose, hemicellulose, pectin and lignin, is more complex than the one based on cereals for chickens and pigs. Enzyme preparations with high cellulase, hemicellulase and pectinase content have been used to improve the nutritional qualities of feed [22]. However, the results of adding enzymatic preparations containing cellulase, hemicellulase and pectinase to the diet of ruminants are still insufficient. Some studies have shown substantial improvements in feed digestibility and animal performance, while others have reported adverse effects or non-effects [22]. Considerable fundamental and applied studies are needed, along with the use of improved enzymes to increase the digestion of fiber by ruminants and thus their performance.

Attempts have even been made to clone cellulase and xylanase genes to produce transgenic animals that may secrete the necessary enzymes in the gastrointestinal tract to facilitate efficient digestion of feed [38]. Such a study would have a considerable impact on understanding the role of cellulases and related enzymes in feed digestion and animal performance.

The huge advances in genome structure and function (based on the transition from single gene analysis to whole genome analysis, complete genome and transcriptome sequencing, and understanding how genes are expressed together) provide the opportunity to genotypically select organisms based on whole genome sequences or some SNP (single nucleotide polymorphisms) matrices of the whole genome [31].

CONCLUSIONS

The discoveries in the field of genomics and bioengineering are the ones that currently have the greatest influence in terms of understanding the mechanisms that coordinate the functions of organisms and the way of transmitting data that provide the specific features of an organism. Genetic editing can make agricultural systems more efficient, reduce the overall food shortage for basic crops, and create resilient crops that are not affected by disease, pests, drought, or other climate change.

In the near future, it will be possible to identify and study genetic introgressions in as many plant and animal species as possible, in order to find the target genes during breeding, which will control the variability for the desired agricultural traits. Many of these will help hybridization efforts focus on adapting to climate differences, fighting different pathogens, or improving yields. The progress and development of biotechnology can be the most viable solution for a modern agriculture, favoring the development of sustainable production methods, obtaining a higher yield, improving the quality and diversification of products, in conditions of reduced use of nitrates and other chemical fertilizers and the rational use of water.

Some of the most important advances in genomics and biotechnology, which offer the hope of future food security, are the following: obtaining of the new cellular lines for many interest products; production of proteins, amino acids, vitamins, enzymes and other organic components for human or animal consumption; increasing the resistance of plants and animals to pathogens and tolerance towards adverse environmental factors; conservation of plant and animal genetic resources, etc.

However, these opportunities need to be considered in the light of the imperatives of human health and environmental protection as well as a sustainable landscape management.

REFERENCES

[1]Ali, H.A., Vallianatos, H., 2017, Women's experiences of food insecurity and coping strategies in the Chittagong Hill Tracts, Bangladesh, Ecology Food Nutr., Vol. 56(6):462-78.

[2]Araus, J.L., Cairns, J.E., 2014, Field high-throughput phenotyping: the new crop breeding frontier, Trends Plant Sci., Vol. 19:52-61.

[3]Bassi, F.M., Bentley, A.R., Charmet, G., Ortiz, R., Crossa, J., 2016, Breeding schemes for the implementation of genomic selection in wheat (*Triticum spp*.), Plant Sci., Vol. 242:23-36.

[4]Bellini, J., 2018, This Gene-Edited Calf Could Transform Brazil's Beef Industry, Available online at: https://www.wsj.com/video/series/moving-upstream/this gene-edited-calf-could-transform-brazil-beef-industry/, Accessed on January 16, 2022.
[5]Bian, Y., Holland, J.B., 2017, Enhancing genomic prediction with genome-wide association studies in multiparental maize populations, Heredity, Vol. 118: 585-593.
[6]Bonciu, E., 2019, The climate change mitigation through agricultural biotechnologies, Annals of the University of Craiova-Agriculture, Montanology, Cadastre Series, 49(1):36-43.
[7]Bonciu, E., 2017, Food processing, a necessity for the modern world in the context of food safety: a Review, Annals of the University of Craiova - Agriculture, Montanology, Cadastre Series, Vol. 47(1):391-398.
[8]Burkard, C., Opriessnig, T., Mileham, A.J., Stadejek, T., Ait-Ali, T., Lillico, S. G. et al., 2018, Pigs lacking the scavenger receptor cysteine-rich domain 5 of CD163 are resistant to porcine reproductive and respiratory syndrome virus 1 infection, J. Virol., Vol. 92:e00415-18.
[9]Caine, R.S., Yin, X., Sloan, J., Harrison, E.L., Mohammed, U., Fulton, T., Biswal, A.K., Dionora, J., Chater, C.C., Coe, R.A., Bandiopadhyay, A., Murchie, E.H., Swarup, R., Paul Quick, W., Gray, J.E., 2019, Rice with reduced stomatal density conserves water and has improved drought tolerance under future climate conditions, New Phytol., Vol. 221:371-384.
[10]Ding, Y., Li, H., Chen, L.L., Xie, K., 2016, Recent advances in genome editing using CRISPR/Cas9, Front. Plant Sci., Vol. 7: 703.
[11]Dong, L., Li, l., Liu, C., Liu, C., Geng, S., Li, X., Huang, C., Mao, L., Chen, S., Xie, C., 2018, Genome editing and double-fluorescence proteins enable robust maternal haploid induction and identification in maize, Mol. Plant, Vol. 11:1214-1217.
[12]Durău, C.C., Sărățeanu, V., Cotuna, O., Paraschivu, M., 2021, Impact of the grassland management planning application on some features of the grassland vegetation from Western Romania – Case Study, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol. 21(3):325-331.
[13]EFSA, 2011, Scientific Opinion on the safety and efficacy of Econase XT P/L (endo-1,4-beta-xylanase) as a feed additive for laying hens, minor poultry species(including ducks, geese, quails, pheasants and pigeons) and pigs for fattening, https://www.efsa.europa.eu/en/efsajournal/pub/2277, Accessed on January 21, 2022.
[14]Elliott, S., 2020, Oat Genome Available on ARS Website, https://www.ars.usda.gov/news, Accessed on January 17, 2022.
[15]Global Market Insights, 2019, Available online at: https://www.gminsights.com/industry-analysis/gene-editing-market, Accessed on January 10, 2022.
[16]Hardigan, M.A., Parker, F., Laimbeer, E., Newton, L., Crisovan, E., Hamilton, J.P., Vaillancourt, B., Wiegert-Rininger, K., Wood, J.C., Douches, D.S., Farré, E.M., Veilleux, R.E., Buell, C.R., 2017, Genome diversity of tuber-bearing Solanum uncovers complex evolutionary history and targets of domestication in the cultivated potato, Proc. Nat. Acad. Sci USA, Vol. 114(46):E9999-E10008.
[17]James, M.H., Chain, B., 2016, The sequence of sequencers: The history of sequencing DNA, Genomics, Vol. 107(1): 1-8.
[18]Karavolias, N.G., Horner, W., Abugu, M.N., Evanega, S.N., 2021, Application of Gene Editing for Climate Change in Agriculture, Front. Sustain. Food Syst., Vol. 5:685801.
[19]Khanam, M., Ara, G., Rahman, A.S., Islam, Z., Farhad, S., Sadat Khan, S., Sanin, K.I., Rahman, M.M., Majoor, H., Ahmed, T., 2020, Factors Affecting Food Security in Women Enrolled in a Program for Vulnerable Group Development, Current Developments in Nutrition, Vol. 4(4):nzaa037.
[20]Liu, X., Liu, H., Wang, M., Li, R., Zeng, J., Mo, D., et al., 2019, Disruption of the ZBED6 binding site in Intron 3 of IGF2 by CRISPR/Cas9 leads to enhanced muscle development in liang guang small spotted pigs, Transgenic Res., Vol. 28:141-150.
[21]Na, M., Caswell, B.L., Talegawkar, S.A., Palmer, A., 2017, Monthly food insecurity assessment in rural Mkushi district, Zambia: a longitudinal analysis, BMC Public Health, Vol. 17(1):260.
[22]Neumann, M., Leão, G.F.M., Horst, E.H., Stuani, O.F., Sangali, C.P., Castilho, R., 2018, Exogenous enzymes improve performance and carcass traits of feedlot cattle fed high-grain diet, Brazilian Journal of Animal Science, Vol. 47:e20170308.
[23]Osakabe, Y., Osakabe, K., 2015, Genome editing with engineered nucleases in plants, Plant Cell Physiol., Vol. 56: 389-400.
[24]Park, T.S., Park, J., Lee, J.H., Park, J.W., Park, B.C., 2019, Disruption of G0/G1 Switch Gene 2 (G0S2) reduced abdominal fat deposition and altered fatty acid composition in chicken, FASEB J., Vol. 33:1188-1198.
[25]Paraschivu, M., Cotuna, O., 2021, Considerations on COVID 19 impact on Agriculture and Food Security and forward-looking statements, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol. 21(1):573-581.
[26]Paraschivu, M., Cotuna, O., Sărățeanu, V., Durău, C.C., Păunescu, R.A., 2021, Microgreens - current status, global market trends and forward statements, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol. 21(3):633-639.
[27]Paraschivu, M., Ciobanu, A., Cotuna, O., Paraschivu, M., 2020, Assessment of the bacterium *Erwinia amylovora* attack on several pear varieties (*Pyrus communis L.*) and the influence on fruits sugar content, Agricultural Sciences & Veterinary Medicine University, Bucharest, Scientific Papers. Series B. Horticulture, Vol. LXIV(1):163-168.

[28]Paraschivu M., Cotuna, O., Paraschivu, M., Olaru, L., 2019, Effects of interaction between abiotic stress and pathogens in cereals in the context of climate change: an overview, Annals of the University of Craiova - Agriculture, Montanology, Cadastre Series, Vol. XLIX/2:413-424.

[29]Paraschivu, M., Cotuna, O., Paraschivu, M., Durau, C.C., Damianov, S., 2015, Assesment of *Drechslera tritici repentis (Died.) Shoemaker* attack on winter wheat in different soil and climate conditions in Romania, European Biotecnology Congress the 20th August 2015, Bucharest, Journal of Biotechnology, Vol. 208:S113.

[30]Partal, E., Paraschivu, M., 2020, Results regarding the effect of crop rotation and fertilization on the yield and qualities at wheat and maize in South of Romania, Agricultural Sciences & Veterinary Medicine University, Bucharest, Scientific Papers. Series A. Agronomy, Vol. LXIII, no.2:184-189.

[31]Popescu, A, 2019, Inovații disruptive în materie de agrigenomică și previziuni pentru viitor. România pe harta cercetărilor agrigenomice (Disruptive innovations in agrigenomics and predictions for the future. Romania on the map of agrigenomic research). In book: Agricultura. Concepte și instrumente operaționale (Agriculture. Operational concepts and tools). Club Romania Publishing House, pp. 1197-1209.

[32]Poulsen, M.N., McNab, P.R., Clayton, M.L., Neff, R.A., 2015, A systematic review of urban agriculture and food security impacts in low-income countries, Food Policy, Vol. 55:131-46.

[33]Raza, A., Bashir, S., Tabassum, R., 2019, An update on carbohydrases: growth performance and intestinal health of poultry, Heliyon, Vol. 5(4):e01437.

[34]Roy, D., Sarker, D.D., Sheheli, S., 2019, Food security in Bangladesh: insight from available literature, J. Nutr. Food Security, Vol. 4(1):66-75.

[35]Shao, X., Wu, S., Dou, T., Zhu, H., Hu, C., Huo, H. et al., 2020, Using CRISPR/Cas9 genome editing system to create MaGA20ox2 gene-modified semi-dwarf banana, Plant Biotechnol. J., Vol. 18:17-19.

[36]Shi, J., Gao, H., Wang, H., Lafitte, H. R., Archibald, R. L., Yang, M., Hakimi, S.M., Mo, H., Habben, J.E., 2017, ARGOS8 Variants generated by CRISPR-Cas9 improve maize grain yield under field drought stress conditions, Plant Biotechnol. J., Vol. 15:207-216.

[37]Steffen, A., 2019, Scientists Improve Crop Security By Successfully Editing A Long-locked Part Of Plant DNA, https://www.intelligentliving.co/scientists-editing-plant-dna/, Accessed on 16 january, 2022.

[38]Wang, H., Li, G., Zhong, C., Mo, J., Sun, Y., Shi, J., Zhou, R., Li, Z., Wu, Z., Liu, D., Zhang, X., 2020, Generation of Multi-Transgenic Pigs Using PiggyBac Transposons Co-expressing Pectinase, Xylanase, Cellulase, β-1.3-1.4-Glucanase and Phytase, Front. Genet., Vol. 11:597841.

[39]What is CRISPR? https://www.quora.com/What-is-CRISPR, Accessedd on January 21, 2022.

[40]Yin, X., Biswal, A.K., Dionora, J., Perdigon, K.M., Balahadia, C.P., Mazumdar, S., Chater, C., Lin, H.-C., Coe, R.A., Kretzschmar, T., Gray, J.E., Quick, P.W., Bandyopadhyay, A., 2017, CRISPR-Cas9 and CRISPR-Cpf1 mediated targeting of a stomatal developmental gene EPFL9 in rice, Plant Cell Rep. 36, 745-757.

[41]Zhang, J., Cui, M.L., Nie, Y.W., Dai, B., Li, F.R., Liu, D.J., Liang, H., Cand, M., 2018, CRISPR/Cas9-mediated specific integration of Fat-1 at the goat MSTN locus, FEBS J., Vol. 285:2828-2839.