

Tena Medialdea, José et al.

Article

Potential of science to address the hunger issue: Ecology, biotechnology, cattle breeding and the large pantry of the sea

Journal of Innovation & Knowledge (JIK)

Provided in Cooperation with:

Elsevier

Suggested Citation: Tena Medialdea, José et al. (2018) : Potential of science to address the hunger issue: Ecology, biotechnology, cattle breeding and the large pantry of the sea, Journal of Innovation & Knowledge (JIK), ISSN 2444-569X, Elsevier, Amsterdam, Vol. 3, Iss. 2, pp. 82-89, <https://doi.org/10.1016/j.jik.2017.12.007>

This Version is available at:

<https://hdl.handle.net/10419/190734>

Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

Terms of use:

Documents in EconStor may be saved and copied for your personal and scholarly purposes.

You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.

If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.



<https://creativecommons.org/licenses/by-nc-nd/4.0/>

Conceptual paper

Potential of science to address the hunger issue: Ecology, biotechnology, cattle breeding and the large pantry of the sea

José Tena Medialdea*, Jesús A. Prieto Ruiz, Carmen Fagoaga García, Antonio Calvo Capilla, Jerónimo Chirivella Martorell, Joel Bueso Rodenas

Catholic University of Valencia San Vicente Mártir, Facultad de Veterinaria y Ciencias Experimentales, IMEDMAR, Spain



ARTICLE INFO

Article history:

Received 13 December 2017

Accepted 18 December 2017

Available online 23 April 2018

JEL classification:

Q01

Q1

Q22

Keywords:

Hunger

Ecology

Biotechnology

Veterinary

Aquaculture

ABSTRACT

The knowledge about the real possibilities that current science gives us is basic to support everything that is not negative either for men or for our environment. In this way, it is an advantage to win this battle against hunger with rational use of science advantages. In this paper, we start from the basis that the solution to the problems of hunger requires the multidisciplinary action of sciences and knowledge. We provide a reflection on the possibilities to be considered from disciplines such as ecology, biotechnology, veterinary and aquaculture. The need for ecological studies where the role of human beings as part of ecosystems is considered. In addition, advances in molecular biology and precision agriculture are analyzed, evaluating their advantages and associated problems, as well as understanding the role of veterinary science and animal genetic improvement in the problem of hunger. Finally, the bases the sustainable use of sea products and expectations generated by marine crops are presented.

© 2018 Journal of Innovation & Knowledge. Published by Elsevier España, S.L.U. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

Hunger is without a doubt one of the most dire problems humanity is facing in our times. Many, such as myself, fortunate enough to live in developed countries, tend to consider it as someone else's problem, for whom we should feel sorry and provide some form of support. There is always some campaign to collect food or an NGO that helps us keep our consciences at ease. There is nonetheless something that we can do amongst us all and that would undoubtedly contribute to mitigate the problem, and it is merely knowing the actual possibilities that modern day science offers us and support anything that, without being negative to man or our surroundings, provides us with an advantage in our fight against hunger. That is why it is so important that people that are involved in science be capable of basing their research and findings on proper anthropological grounds, on a philosophical basis that would give meaning to their science. In the case of believers, the Christian worldview offers an exceptional contribution by providing a solid base whereupon the beliefs in terms of such problem may be built.

The challenge that is implied by vanquishing hunger must be addressed from a multidisciplinary perspective covering various sciences and knowledge. Scientific ecology is an experimental science that may contribute a great deal of transcendental information for decision making, on many of the aspects regarding the problems of hunger we face at present. There is excellent scientific literature speaking to the challenges of ecology in our days, from pure research to responses applied in relation to environmental restoration and management, and government policies, in addition to focusing on protected areas, post-industrial landscapes and the urban environment (Sutherland et al., 2013), which aspects must undoubtedly be very present among our objectives. Hunger and the search for solutions nonetheless would not seem to be determinedly reflected or be the focus of concern of ecology. Unfortunately, the system for valuing research is not of much help either. A scientist knows that for their research to be recognized or valued, it must be published in certain scientific journals. Would it not be more beneficial to publish the advances that our research could contribute to mitigating hunger around the world in farming, cattle breeding, fishing or other such magazines? We must nonetheless find ways for society to know of the advances and their pros and cons so that those that are not involved in science may be made aware, based on strong criteria and not on fundamentalism, the

* Corresponding author.

E-mail address: josetena@ucv.es (J. Tena Medialdea).

reason for implementing a certain technology, farming system or new food. It is obvious that the latter, the popularizing of science, is sought, but it would seem that in this case the result is not successful. Society and, therefore, politicians are who make the ultimate decisions, and these would not seem to revolve around a common solution, and this seriously hinders decision making. It is necessary, as Francisco (2015) has noted, that the urgent challenge of protecting our common house include the concern for unifying the entire family that is humanity in the search for sustainable and comprehensive development for things to change. We must be aware, as noted by Zardoya (2012) in the case of the biodiversity crisis, that mankind has an enormous capacity to alter the balance of nature and it is necessary to accomplish that the international scientific community act in coordination. At this point, it is interesting to add that these postulates should work for ecology to also focus on the problem of hunger from a positive perspective, setting aside the catastrophic vision of human activity in all that pertaining to ecosystems.

The bibliography provides various definitions of scientific ecology, where one that is current and that clarifies it quite well is provided by the Ecological Society of America: “scientific discipline that is concerned with the relationships between organisms and their past, present, and future environments. These relationships include physiological responses of individuals, structure and dynamics of populations, interactions among species, organization of biological communities, and processing of energy and matter in ecosystems”. If we were to focus on the last part of this definition, we would see that this science speaks of the resources, matter and energy that nature provides living beings, i.e., the potential food that each species could have at their disposal within an ecosystem. Undoubtedly, human beings form part of the ecosystems and have the same rights as any other organism to be able to use the available matter and energy, yet this must be done responsibly and with respect toward the rest of nature. As said by Francisco (2015), it is the duty of mankind, having been endowed with intelligence, to respect the laws of nature and the delicate balance between the beings of this world.

Our planet makes available to the living beings of our biosphere, including humans, the matter and energy for its development as a whole. This energy is used by part of the living beings as food to stay alive. In this sense, human beings need the resources of nature for nourishment. Considering our intelligence and ability to transform our environment, it is our responsibility to maintain a sustainable balance with nature.

If it is positive that there be a global balance of food available to mankind, i.e., that there be more than enough food on the planet for all mankind to survive, what is going on? The problem is that these resources are not being appropriately managed. We must therefore put all sciences, such as ecology, at the service of the common good, without casting aside the possibilities that sciences such as biotechnology offer to the problem of hunger in the form of precision agriculture, advances in metabolomics and functional food, while also considering the potential of ecological agriculture, aquaculture, improvement in cattle production, changes in eating habits, etc. There are many scientists contributing extremely interesting knowledge to improve the quality of food, such as based on metabolomics studies, for instance (Johanningsmeier, Harris, & Klevorn, 2016) suggesting that 32.5% of the metabolites identified to date are incorporated in the diet and are over-conditioned in the human metabolism, which means that, learning their origin and being able to channel them appropriately would contribute to overcoming the problem. Other interesting keys are stressed by the FAO (<http://www.fao.org/docrep/006/w0073s/w0073s0x.htm>; [americas/noticias/ver/es/c/229495/](http://www.fao.org/docrep/006/w0073s/w0073s0x.htm)) in relation to the water footprint implied by the production of various types of food. A change in eating habits considering the above could also help. Or

precision agriculture based on genetically modified organisms, which although should not be considered universal and unique universal solutions, may be key in some places of our planet.

Obviously, if we look at the Earth as our great ecosystem, this planet has room for us all. It just needs to be properly managed.

Evolution of transgenic food. Current analysis of the subject

Transgenic or genetically-modified foods have allowed the increase in the availability of nutrients to the population and the improvement of the useful and shelf life of food. Such food is therefore proposed as a tool to solve the world hunger issue. It has been observed that in populations where there has been an increase in food production, in part due to the introduction of transgenic food, there has been a considerable reduction in the percentage of poverty in the region (Ravallion & Datt, 1996; Thirtle, Lin, & Piesse, 2003).

Biotechnology is a multidisciplinary science based on the knowledge and use of the biological processes of living beings which, applied to food, seeks to increase production and attend to the demands of the consumers for safer and healthier products. Food of a vegetable origin is one of the main sources of nutrients for a great part of the world population (Silva & Ortiz, 2011) but cannot guarantee the needs for micronutrients of the population and does not resolve malnutrition in certain sectors thereof. Agricultural production implies the development of better biotechnological tools, satisfying not only the increasing demand for food, but also guaranteeing nutritional quality and thus mitigating malnutrition in certain regions around the world (Pingali, 2012).

The relationship existing between diet and health by the influence exerted by nutrients on physiological processes is a proven fact (Mutch, Wahli, & Williamson, 2005). Nonetheless, for a large part of the world population, vegetable foods are used merely to provide essential nutrients and without guaranteeing a supply of micronutrients that would allow for the prevention and treatment of diseases (Newell-McGloughlin, 2008).

According to the World Health Organization, biofortification is the process whereby the nutritional quality of food crops is improved through agronomic practices, conventional plant breeding or modern biotechnology. The biofortification of the basic foods eaten by the majority of the population is an effective strategy for correcting the deficiencies of micronutrients where there is a need to supplement basic food with micronutrients.

From a biotechnological viewpoint, we could consider plants as versatile biochemical factories, capable of synthesizing micronutrients. Genetic modification allows for transferring specific features, such as the capacity to synthesize vitamins, for instance, to food that does not produce them in nature. It also allows for enhanced control of the production of crops and it is possible to express the chosen features in less time than through the use of conventional crops. Golden rice (Ye et al., 2000) is one of the first examples of biofortification, but it is not the only one. There are currently a large number of research projects to enrich the nutrient content of regularly-consumed plants, to improve health and prevent the appearance of diseases among the population. Zinc deficiency is a true problem for health among children, as it causes stunted growth. *Brassica oleracea*, has been biofortified to produce a greater amount of such trace element, guaranteeing the availability of an adequate source of Zinc (Barrameda-Medina et al., 2017). The same occurs with the obtaining of biofortification in folic acid, a key molecule for proper embryonic development (Strobbe & Van Der Straeten, 2017) or with selenium biofortification (Garousi, Kovács, Domokos-Szabolcsy, & Veres, 2017) and other micronutrients such as vitamins, essential amino acids, essential fatty acids, etc. (Hirschi, 2009).

With the appearance of new biotechnological tools, such as the CRISPR system for genetic editing, the process of obtaining transgenic food will be accelerated. It is therefore necessary to guarantee the biosafety of such food, so that it does not imply a public health hazard. It is also necessary to guarantee a design of food that is respectful of the environment and guarantees biodiversity in the ecosystems where introduced. It is further necessary to guarantee that there is an equitable access to these products in all developing countries, so that they may truly be considered a part of the solution to hunger.

Based on the foregoing, we could consider biotechnological techniques as a means that must provide a solution to many of the problems of malnourishment and hunger worldwide.

Including genetically-modified food, with improved functional and nutritional properties, in the regular diet of the people could contribute to health improvements and to the prevention of diseases. For this to be a reality, transgenic products must be proven to be safe to the population, to not pose a threat to the environment once designed, and to be easily accessible. The speed at which the research is developed is increasing in proportion to the appearance of new biotechnological tools, but there continues to be reluctance in society in terms of the acceptance of such products. A proper dissemination of the information pertaining to transgenic food at a scientific level, free of ideological ties, is one way of making society aware that biotechnology, applied to food, is a safe and effective way of guaranteeing a biohealthy diet, accessible to the world population.

Transgenic crops: possible solution to current hunger problems

Currently, most people in the industrialized world have greater access than ever to a large variety of food, mainly due to the development of science and to agrarian technology. In spite of this, many people in Sub-Saharan Africa continue to suffer great poverty due to the low productivity of their agriculture. Nearly 740 million people go to bed hungry every day, and close to 40 thousand people, half of them children, die every day of starvation or malnutrition. If current trends do not change, the number of malnourished people shall exceed one billion by the year 2020.

The destiny of human society and crops have been entwined since the birth of civilization and the appreciation of our agricultural past may help us attend to the concerns of society and also to guarantee that the negative consequences of scientific activities be minimal.

The most important factor in increasing productivity has been an enhanced knowledge of genetic principles. Each crop is the product of an artificial selection carried out by man over the past millennia. Through a process of gradual selection, our ancestors chose a very small part of the community of wild plants and transformed them into cultivable plants. Some deep changes in the phenotype of the plants took place during such selection and, little by little, they included a certain growth habit; elimination of the spreading of the grain; synchronized maturing; shorter maturing period; reduction of bitterness and hazardous toxins; reduction of the spreading of seeds, flowering and inactivity stages; greater productivity, including larger seeds or a large volume of fruit; and even the elimination of seeds. These changes reduce the survival of such crops in the wild, and therefore an aspect that transcends all our crops is the reduction of the characteristics inherent in weed in wild plants. Current agricultural plants that are feeding us today have very little in common with their ancestors, as they have been modified to provide healthy and nutritional food and are, thus, entirely dependent on human care for their survival. A bit more than 100 species of crops are now extensively grown around the world with only a small group of them providing the lion share of our current food.

When a desired characteristic cannot be found in the species or in the parent species, geneticists have created new varieties, causing mutations with radiation, chemicals or simply growing cells in a lab and allowing them to mutate spontaneously during cellular division. The use of mutations to improve crops has been common since the 1950s; and over 2250 mutated varieties have been developed in over 50 countries, including France, Germany, Italy, the United Kingdom and the United States (Mba, 2013).

Since 1960, the Green Revolution (a program that is directed to significantly increasing the production of food, with the hope of reducing hunger worldwide) entailed a great effort to increase and diversify agricultural returns in the poorest countries, and a change in paradigm in agricultural practices in numerous regions around the world, based on genetic approaches and new agricultural practices.

Nonetheless, the current agrarian situation we have arrived at is unfortunately based on the following:

- A scarce availability of land. Virtually all suitable lands around the world is being plowed. In many cases, it would be necessary to plow territories of high ecological value supporting biodiversity where humanity could obtain greater benefits through alternative and sustainable uses.
- Access to water is one of the main limiting factors. Recent agricultural practices rely heavily on water. In 2025, there could be 3 billion people without water for essential uses, and it is therefore naïve to believe that irrigation could be extended indefinitely
- The unsustainable use of agrochemical substances and the application of high levels of inputs. The abuse of nitrogenous fertilization and insecticides leaves the water contaminated, with the consequent environmental and health hazards. Between 1950 and 1998, the use of fertilizers was multiplied ninefold.
- Increasingly more energy is used, mostly derived from fossil fuels, which is a non-renewable resource.

In the light of this situation, we are facing the need to preserve the environment for future generations, along with new economic conditions in agricultural production which tend to more standardized production systems and to continuing to increase the productivity of the crops, but by other means. Biotechnological innovation shall be key to this task and, as a part of it, it would be necessary to achieve new ways of taking advantage of plant genomes (and of other organisms) to increase food production without further damaging our planet. The idea is to prepare proposals based on modern biotechnological techniques that would make the increase in agricultural production compatible with the conservation of the environment.

Methods based on recombinant DNA (transgenic) technology are merely an extension of the variety of techniques that have been used so far to obtain varieties of genetically improved crops. The fundamental difference is that, in this case, it is a much more precise transfer of one or more known genes, a minimum insertion of genetic material (precision agriculture) as compared to classic methods, which consist of large genetic changes, many of which are unknown and unpredictable. This technology undoubtedly complements and improves the effectiveness of traditional selection methods.

Over the last 20 years, farmers have adopted this new technology as it makes crops more efficient, protects them or increases their production, and reduces the need to rely on chemical products that they would prefer not to use, unless absolutely necessary. Crops improved through biotechnology are being farmed in 28 countries around the world, and the ingredients of the food they have produced through crops for which this biotechnology has been used are present in food eaten around the world (James, 2015).

The most frequent characteristics of the new agrobiotechnological varieties are resistance to insects and resistance to herbicides. But they also allow us to obtain varieties that are resistant to viruses and other pathogens (fungi and bacteria); crops that are capable of resisting cold, drought, salinity or hydric stress; biofortified fruits or plant products (enriched with vitamins and/or minerals) or improved nutritional content (healthier food), etc. Work is also underway in phytoremediation to eliminate land contamination and in the use of plants as mini factories to produce vaccines and biodegradable plastics, among many other possibilities, most of which are currently being tried in emerging economies (Takeshima, 2010; Schnurr, 2015). “Golden Rice” is a great example of the value of public and private research. The development of this rice was mainly financed by the Rockefeller Foundation, located in New York, and it has promised that such rice will be available to the least favored farmers at a low cost or even for free. This rice was created by scientists from public universities in Switzerland and Germany, with the assistance of the Institute for Research into Rice in the Philippines and several multinational corporations. There are scientists at other research centers funded jointly by public and private institutions that are developing many other similar crops (Parisi, Tillie, & Rodriguez-Cerezo, 2016; Subramanian & Qaim, 2010).

Two decades ago, many agricultural scientists rightfully saw in biotechnology a powerful instrument for the improvement of the productivity of crops and the quality of food, and at the same time a means of promoting the development of sustainable agriculture. The advantages obtained with these transgenic crops are: enhanced control of insects and brush, increased productivity and a more flexible management of crops. The positive impact of growing genetically modified (GM) organisms on the environment and society is seen in the reduction of the agricultural expansion to preserve wild ecosystems; an improvement in the quality of the air, soil and water by promoting less farming efforts; a reduction of the use of chemicals and fuel; an improvement of biodiversity through the recovery of ancient varieties and the promotion of beneficial insects; and the cleaning of contaminated soil and air through “phytoremediation”. Thanks to these crops, less farming machinery and fumigation vehicles are used, thereby reducing the production of greenhouse gases and contributing to the mitigation of climate change. The main beneficiaries are farmers and farming companies, but the benefit is also passed on to consumers, by producing food at lower costs (James, 2015).

Even so, in Europe, there is intense debate in terms of its value and safety. The angst of society with regard to so-called GM foods is understandable and is fed by a variety of causes, including the scarce familiarity that consumers have toward them, a lack of reliable information regarding the security measures whereupon they are developed, a permanent stream of negative opinion in the media, opposition from activist groups, increasing distrust toward the industry, and a general lack of awareness in terms of how our food production system has evolved. The scientific community has not known how to communicate the value of this technology. Skepticism can be put to bed without dismissing safety concerns, but by helping create greater awareness of its potential benefits and of the hazards that the failure to adopt the new technologies could bring. There are hundreds of regulatory agencies and scientific societies around the world that have concluded that biotechnology is a safe means for improving food and that the biotechnology crops currently on the market are safe for mankind and for the environment.

The main scientists around the world have corroborated the innocuousness of biotechnological crops for health and the environment and have asked that the technology be used to help those most in need, especially to fight hunger in developing countries. Dozens of scientific and medical institutions, such as the US

National Academy of Sciences, the American Medical Association, the Royal Society of the United Kingdom and the United Nations Development Program have backed this technology. Nearly 3500 eminent scientists from around the world, including 24 Nobel-prize laureates, have signed a declaration supporting the use of farming biotechnology. A summary of 81 independent research projects, sponsored by the European Union, concluded that crops and food derived from bioengineering are, at least, as safe as their conventional counterparts and, in some cases, even safer (Nesbitt, 2005; Qaim and Kouser, 2013).

One of the greatest threats to the populations suffering from hunger lies in the restrictive policies derived from an unjustified public alarmism. While most Americans tend to support agrarian biotechnology, Europeans have been much more cautious. Anti-biotechnology activists present in both developed and developing countries have taken advantage of such ambivalence with alarmist arguments fostering restrictive policies. Such alarmism is simply not justified by any of the many scientific reports that have been published, or by the data compiled by the thousands of rigorous field tests that have been conducted.

Growth, diversity and the benefits of transgenic crops continue to evolve and may contribute significantly in the feeding of the growing population (Pontifical Academy of Science, 2016). As the fastest adopted agrarian technology of the latest times, transgenic crops form part of the solution to the problems of food security and climate change, which are specific problems faced by consumers and farmers around the world. While transgenic crops are fundamental to world food security, they are not a panacea. Good farming practices, such as rotating crops or managing resistance, are essential to transgenic crops, just as they are for traditional crops.

Obviously, hunger and malnourishment are not only due to a scarcity of food. The main cause of starvation in some countries is corruption and political instability, infrastructure deficiencies and poverty. All these problems must be remedied if we are to ensure true food security at the world level. Over the next 50 years, world population will increase by 50%, most of which will be in countries of less resources. To produce the food necessary to support such population, the gift of incalculable value that is biotechnology will be needed.

Genetic improvement in animal production

Genetic improvement may be understood as the methodology followed to accumulate in a single individual, population or breed, the most favorable hereditary value for a certain production or trait. This way, such individuals manifest such trait and also transmit it to their future offspring, thereby increasing such trait in successive generations (Griffiths, Wessler, Lewontin, & Carroll, 2008).

There are many examples of genetic improvement achieved in our domestic species. In this sense, we could compare milk cows with average productions by lactation (305 days) of 10,000 kg of milk with those that decades ago produced a mere 3000 kg. An illustrative case is that of pig farming, where a mere 40 years ago, an average pig would breed 14 piglets a year, and at present they breed 28. Or in poultry farming, where chicken previously requiring 12.5 weeks to produce 2 kg of live weight, now do so in nine weeks, using less amount of food (Klug et al., 1998).

The main bases for genetic improvement are found in the work of Gregor Mendel, an Augustine catholic monk and natural scientist who discovered, through the work he performed with several varieties of the green pea (*Pisum sativum*), what are now known as the Mendel laws, giving origin to genetic inheritance. Currently, increasing technical availabilities have allowed for the application of increasingly more efficient and complex work forms. It is thus

foreseen that in a not-so-distant future, animal genetic improvement will go through the direct manipulation of the genome, through the multiple existing biotechnologies, a stage that has already been fully reached in certain microorganisms and vegetables of commercial interest (Griffiths et al., 2008).

Currently, in the most practical form, animal genetic improvement is still achieved through three basic principles or mechanisms (Griffiths et al., 2008):

1. The detection (selection) of the individuals of a certain genetic endowment. Such genetic endowment will allow expressing a certain trait or production that will be greater than that of the average of the population, possibly a breed, to which they belong. Such trait may or may not be quantifiable (for instance, a value of average daily gain or the presence of the double-muscle trait in an individual, respectively). This selection is to be made based on the information gathered in:
 - (a) Genealogical books, whereby we will learn the relationship between individuals, and through the recording and analysis of certain characteristics of the individuals registered therein, enabling the pinpointing of those achieving certain productive or morphological characteristics that are above the average.
 - (b) The control of the performance of the individual in question, ascertaining the productive level they actually offer. We shall also include in this section the control of performance of their offspring, thus learning the form in which their genetic potential is transmitted.
 - (c) The direct genetic evaluation of the value of a certain individual through the analysis of the traits of their parents, once the associated environmental factors are considered (herd, year and season, sex, age of mother at birth, etc.) that may influence the trait subject to improvement. To do so, specific statistical systems are used. Currently, one of the most used statistical systems is the BLUP (best linear unbiased prediction) method.
2. The design of the most adequate system for mating between males and females that are especially fit for a certain trait, to guarantee an excellent offspring for such trait. In this point, we may use two strategies:
 - (a) Inbreeding: animals specially endowed for a certain characteristic belonging to the same family or lineage and that, thus, have family ties, are reproduced. The highest expression of this type of reproduction is a blood relationship. This type of improvement is the one generally used in the cores for selection of ruminants and monogastrics. This method offers the advantage of allowing the quick standardization of the traits depending on one or few genes and maintaining the variability of other traits depending on several genes and are highly dependent on the environment. It also allows for the quick expression of the recessive genes with undesirable effects and, consequently, their prompt elimination. As a disadvantage, this method is responsible for the method known as inbreeding depression or blood-relation depression. In spite of such inconvenience, it is the most commonly used method to obtain consistent genetic breeds of laboratory animals and specific lineages used in poultry and pig farming for subsequent crossing among them.
 - (b) Outbreeding or cross breeding refers to the reproduction of animals belonging to unrelated lineages, families and breeds. These are therefore, animals without any relationship among each other. It is the procedure followed to obtain breeders in the case of monogastrics and, to a lesser extent, in meat-providing ruminants. At a practical level, we may distinguish between industrial cross breeding, two or three-way cross

breeding, etc., depending on the species and the trait to be improved.

3. Leaning toward the use of inbreeding or outbreeding will depend, first of all, on heritability (variability between individuals of a genetic origin and that is transferred to offspring) and repeatability (measure in which the trait of a certain individual is capable of predicting future measures of the same trait) of the characteristic sought to be improved; secondly, on the species in respect of which this improvement process is to be performed, specifically its generational gap (which shall depend on their sexual precociousness and the duration of their gestation) and their prolificacy (number of offspring born per litter); in third place, it shall depend on the intensity of the selection chosen, which shall refer to the level and urgency in the target improvement.
4. Establishment of a process allowing that the genetic progress obtained have an optimal dissemination. This shall refer to the designed use of the animals carrying such specific improved trait, and the reproduction method to be applied (distinguishing between natural mating, artificial insemination and, in the past years, embryonic transfer), and the population objective of such improvement (allowing the distinction of selection cores, cattle farms registered in the future improvement scheme, total population susceptible of improvement).

Bases of programs for animal genetic improvement

A program for improvement could be defined as a series of actions that are regulated, designed and implemented by an association of breeders of an officially-recognized breed (we could recognize MAPAMA as the relevant authority) the objective of which is the conservation, development or improvement of the relevant breed, with a unique trait for the breed in question and the actions of which would need to be backed by a qualified animal genetics center. According to each species and breed (census, characteristics and cataloging of the breed), two types of programs would be performed: selection programs, intended to find the best breeders in a population (in this case, breed, but we could speak of species, stock or variety) so the desirable characteristics defined be transferred to the offspring; and conservation programs, intending to maintain the necessary genetic diversity for the conservation of such population or to increase their censuses.

The basic stages of an improvement scheme or program (Castelló et al., 2002) will be the following:

1. Definition of improvement objective, where it is necessary to collate the interests of the parties involved and the beneficiaries of the improvement, which may be the producers but could also be the transformers or consumers. It is also necessary to respect the requirements that could be required of any trait sought to be improved and that would be: sufficient inheritability, economic value, possibility of efficient evaluation and economically admissible, and lack of incompatibilities with other equally important traits.
2. Proof of identification and filiation of the population to be involved in the improvement program, establishment of relationships and future Genealogical Book. This will allow for the recording of the individual identities and the genealogical relations established between such identities.
3. Control of productions associated with the various productive orientations of the population subject of improvement. These are structured based on control cores specific to the improvement trait established and according to their instructions.
4. Determination of genetic value of animals susceptible of control. This shall be accomplished following methods that may

exclude the environmental variations mentioned earlier to provide objective values of the controlled productions.

5. Choice of potential breeders, considering their genetic value and other factors allowing their effective use as breeders, i.e., sexual behavior, availability for natural mating or semen extraction, semen quality, etc.
6. Testing and categorizing of the potential breeders according to their value to transfer such productive values to their offspring.
7. Strategy for the use of the breeders chosen. The most used method is currently artificial insemination, whether it be by using fresh, refrigerated or frozen semen.
8. Dissemination of improvements obtained, achieved by two non-exclusive means:
 - (a) farm contests or auctions (offering the producers the improving animals for acquisition and use at the relevant cattle farms).
 - (b) use of reproductive material of individuals cataloged as improving (semen and/or embryos).

In practice and with large differences between various species and productive orientations, the schemes for improvement follow a very similar scheme. These reproduce the classic improvement methodology based on the data gathered of: origin, choice of progenitors of future breeders; own individual performance of possible future breeders; descendants for the confirmation of the value of the breeders initially chosen.

Regulatory guidelines in Spain for best animal genetics

The best genetics in Spain have been developed based on a large amount of provisions, initially established in Decree 733/33, establishing the bases regulating the requirements provided with regard to genealogical books and the responsible cattle breeding associations, performance controls and their use as elements for genetic improvement, and the dissemination of such genetic improvements through the previously mentioned mechanisms (availability of improving animals and their reproductive material). Based on the above, there have been a series of added circumstances, among the most noteworthy of which are the need to adapt the national regulations to community requirements that, to meet the premise of free trade in purebred animals and their reproductive material, have combined the criteria for the recognition of cattle breeding associations, the guidelines for the control of the productions (based on the indications of ICAR, the International Committee for Animal Recording), the recording of the animals in the genealogical books and the methodology for the evaluation of genetic value in the various target populations. It has also been necessary to adapt the actions to the FAO Global Strategy for Genetic Resources of Farm Animals. Finally, it has been necessary to subordinate the institutional aid that may be destined for genetic improvement to the principles of Law 38/2003, General Subventions Law, and [RD, 887/2006](#) whereby it is developed.

All these reasons have led to the establishment of a National Program for the Conservation, Improvement and Fostering of cattle breeds, the scope of which encompasses: classification of breeds in the Official Catalog of Cattle Breeds of Spain, recognition of the associations of purebred cattle breeders, the approval of genealogical books, the approval of improvement programs, performance control, the valuation of breeders, development of improvement dissemination programs and holding cattle breeding contests, the designation of bodies for analysis, and coordinations integrating the representatives of the various administrations, entities and sectors involved and, finally, the designation of authorized reference centers for animal reproduction and genetics.

Future of animal genetics improvement: genetic engineering

Transgenic animals are currently one of many significant advances in genetic engineering. The increasingly frequent and successful manipulation is due to a long period of discoveries in the area of genetics. The application of these techniques in several areas and for various purposes on the animals has repercussions on human life.

Among the most useful applications for the human being, directly, are the design of individuals with greater productions and less nutritional and environmental requirements, the recovery of extinct species, positive for maintaining the biodiversity of the ecosystems, and, indirectly, their applications in xenotransplants (the use of animal organs in humans) or the production of medication (insulin, growth hormone and clotting factor).

Genetic engineering currently has indirect applications in animal production, as in the case of primer materials for animal food of transgenic origin. The first transgenic food hit the market in the 1990s: soy, corn, sunflower seeds and cotton. Currently, in the EU, animal production based on transgenic individuals is not permitted. Nonetheless, at a scientific level, various applications have already been developed with potential applications in this field. In this sense, in 2006, a transgenic pig was created to produce omega 3 fatty acids by altering one of its genes. Recently, in the United States, the Food and Drug Administration (FDA) approved a salmon genetically modified to grow in one half of the time. It is the first transgenic animal that is to be used as food in the world. Chinese scientists have also announced the creation of transgenic dairy cows that are more resistant to tuberculosis.

The subject of transgenic food is controversial around the world and it moves in a bipolar medium: the groups that defend genetically modified food, and another group that speaks against them. In any case, the ethical acceptance of these biotechnological products and their bioethical implications in the modern world should be a matter of study over the next years to establish limits to human action, preventing the consideration of what has been created as a mere object susceptible of appropriation.

The challenge of sustainability for the great pantry of the sea

The oceans are an important source of food. They account for 80 percent of the biodiversity of the planet, and are the largest ecosystem on the earth. Fish provide 20 percent of the animal protein for close to 3 billion people. A mere 10 species represent 30 percent of the marine catch and 10 species provide around 50 percent of the fish production.

Additionally, fishing and aquaculture directly employ 56 million people. And many other people are engaged in activities relating to handling, processing and distribution. Overall, fishing and aquaculture contribute to the way of life of some 600–800 million people, representing 12 percent of the world population.

The Food System includes all processes implied in global feeding, from production to consumption, including trading in and distribution of food; it is responsible for 25% of the emission of greenhouse gases. It also leads to deforestation and to the loss of biodiversity, soil degradation, overconsumption of water and contamination, also creating and perpetuating social inequalities.

With its current configuration, the Food System cannot effectively feed us all; while the problems associated with obesity and food disorders are skyrocketing, hunger and malnourishment persist.

As the world population grows and its degree of development increases, it becomes more opulent and demands larger amounts of food. That trend would seem to be heading in an upward direction.

A systemic approach is needed, simultaneously studying food production, consumption and equity (Garnett, 2016).

The group approach of the food systems provides valuable information in relation to the ties between dietary habits and environmental and health impacts. In this sense, for instance, the replacement of meat of a land source with aquaculture fish would merely imply a transfer of impact (Troell, Ziegler, & Henriksson, 2016).

In 2012, the Secretary General of the UN, Ban Ki-moon, launched the Zero Hunger Challenge, a world call to action for every human being to have the right to proper Nutrition.

The elements that make up the Zero Hunger Challenge include:

- That all food systems be sustainable.
- Zero wasting of food and post-harvest losses.

(Source: <http://www.un.org/es/zerohunger/challenge.shtml>)

The UN proposes certain guidelines to face such elements:

- That all food systems be sustainable.
- Assuring that all producers, governments, social agents and civil society establish standards for sustainability, verifying their performance and accounting for them; stimulating and remunerating the universal adoption of sustainable agrarian practices, resistance to climate change; seeking coherence between sectoral policies (encompassing energy, the use of the soil, water and weather).
- Zero wasting of food and post-harvest losses.
- Minimizing food losses during storage and transportation and the wasting of food in the businesses and by the consumers; empowering the consumers to choose through proper labeling; committing all producers, merchants and consumers in all nations; achieving progress through economic incentives, collective commitments, locally-appropriate technologies and behavioral changes.

The seas are an essential component of the ecosystem of the planet earth, a source of biodiversity, food and life. According to the FAO, over 40 percent of the world population lives at some 100 km from the coast. A better management of the ocean resources is crucial to guaranteeing food security in the world.

At the United Nations Conference for Sustainable Development Rio+20 in 2012, the concept of “blue economy” was coined, emphasizing on the conservation and sustainable planning of seas and oceans, based on the premise that healthy oceanic ecosystems are more productive and essential.

To support the turning to this new approach, the FAO has implemented the Initiative on blue growth, whereby it will help countries prepare and implement programs focusing on blue economy and growth.

Blue growth seeks to take advantage to a greater extent of the potential of the oceans, seas and coasts to:

- Eliminate hazardous fishing practices and overfishing, while at the same time fostering approaches favoring growth, conservation and sustainable fishing, and putting an end to illegal, unreported and unregulated (IUU) fishing.
- Striving for the adoption of measures adapted to each situation, fostering cooperation between countries.
- Facilitating the drafting of policies, investment and innovation to support food security, the reduction of poverty and the sustainable planning of aquatic resources.

This blue growth is based on:

- Aquaculture, through the promotion of policies and good practices for the growing of marine animals and plants in a responsible and sustainable manner.
- Fishing, through the application of the Code of Conduct for Responsible Fisheries (CCRF) and other related instruments to restore the fish populations, combat IUU fishing and promote good fish production practices and sustainable growth.
- The fish processing productive sectors, through the promotion of efficient value chains and improvements in the ways of life of the workers in the fishing sector.
- Ecosystem approach to the development of regulations tending to restore vital coastal habits, biodiversity and the ecosystem services (including carbon sequestration, defenses against storms and tides, tourism, etc.).

Fishing is the only large-scale food production system based on a wild resource. If fish is caught in a sustainable manner, respecting biological limits and using smart fishing methods, fishing could produce low-impact food without requiring land, pesticides, fertilizers or irrigation (Gephart et al., 2014). This system is unique on our planet.

While currently many wild fish populations are fully exploited, or overexploited, the number of fishing boats around the world could increase by up to 20% with proper fishing management (Costello et al., 2016).

With current fishing management systems, production has been stabilized at its peaks for several decades; it has only been possible to cover the demand for food of a marine origin through the aquaculture production of such food. In fact, in 2016, for the first time, the production of food of an aquatic origin through aquaculture has surpassed fishing production. Nonetheless, a good part of aquaculture production is more similar to the production of meat through cattle breeding. It is necessary to produce feeds, implying a large part of the environmental impact of cattle and fish farming. Even so, the production of fish through aquaculture is more efficient than the production of meat through cattle breeding, as no energy is wasted in maintaining the homeostasis of the temperature, or in defeating the strength of gravity. Food of a marine origin, from both fishing and aquaculture, has repeatedly been proven to be more competitive than the production of cattle in terms of environmental impact (Pelletier et al., 2011; Tilman & Clark, 2014).

Nonetheless, food of a marine origin in general, and fish in particular, represent a very diverse product, with very different environmental profiles (Cao et al., 2015; Troell et al., 2014). It is therefore essential to encourage consumption of products with low-impact production methods (Troell et al., 2016).

Fish further provides health benefits and is an essential source of proteins and micronutrients, especially in developing countries (Béné et al., 2016; Beveridge et al., 2013).

The substitution of meat with sea products of a sustainable origin could accelerate the necessary transformation of the food system. Such strategy is not contrary to the necessary general reduction of the excessive consumption of proteins of animal origin, but introducing more food of a marine origin at the expense of meat is an important solution that is necessary to achieve world food security (Troell et al., 2016).

Other aspects affecting food security are those addressed by The Beijer Institute for Ecologic Economy, sponsored by the Swedish Royal Academy of Sciences and dedicated to the impact of climate change on the economy.

Sudden changes or crises in the production of food could adversely affect access and trade in food products. Fish is the most traded food product worldwide and is essential to human nutrition. The system of production of fish products and their trade are

exposed to a variety of disorders, including fishing collapses, natural disasters, oil spills, policy changes, outbreaks of aquaculture diseases, access to aquaculture food resources and price peaks.

The patterns and trends of this fishing and aquaculture crises are poorly characterized and this limits the capacity to generalize or predict responses to political, economic and environmental changes.

Gephart, Deutsch, Pace, Troell, and Seekell (2017) apply a statistical approach for the detection of impact on the historic data of events in fisheries and aquaculture to identify disorders during the 1976–2011 period. This work uses an approach to complementary case studies to identify possible key social and political dynamics relating to such events. The lack of a trend in the frequency or magnitude of the impacts identified and the array of causes identified suggest that these negative events are common characteristics of these food production systems and are the result of a variety of causes, with multiple and simultaneous frequencies.

Disorders in the production of food of a marine origin occurred most frequently in the Caribbean and Central America, the Middle East and North Africa and South America, while the most impacts of magnitude were produced in Asia, Europe and Africa. The events were also more frequent in aquaculture systems than in fish catching systems, especially over the last years.

In response to the crises, countries tend to increase imports and experience reductions in supply. The specific combination of changes in trade and supply has a specific context. The analysis of the historic disturbances data may help answer the impacts and identify possible risks and opportunities to increase resilience in the world food system.

References

- Barrameda-Medina, Y., Blasco, B., Lentini, M., Esposito, S., Baenas, N., Moreno, D. A., et al. (2017). Zinc biofortification improves phytochemicals and amino-acidic profile in *Brassica oleracea* cv. Bronco. *Plant Science*, 258(May), 45–51.
- Béné, C., et al. (2016). Contribution of fisheries and aquaculture to food security and poverty reduction: Assessing the current evidence. *World Development*, 79, 177–196.
- Beveridge, M. C. M., et al. (2013). Meeting the food and nutrition needs of the poor: The role of fish and the opportunities and challenges emerging from the rise of aquaculture. *Journal of Fish Biology*, 83(4), 1067–1084.
- Cao, L., et al. (2015). China's aquaculture and the world's wild fisheries. *Science*, 347(6218), 133–135.
- Castelló, A., Cedó, R., Cepero, R., García, E., Pontes, M., & Vaquerizo, J. M. (2002). The chicken for meat industry. In *J. Production of chicken for meat*. Barcelona: Real Escuela de Avicultura.
- Costello, C., et al. (2016). Global fishery prospects under contrasting management regimes. *Proceedings of the National Academy of Science of the United States of America*, 113, 5125–5129.
- Francisco, P. (2015). Laudato si: On care for our common home. *Our Sunday Visitor*, Garnett, T. (2016). Plating up solutions. *Science*, 353(6305), 1202–1204.
- Garousi, F., Kovács, B., Domokos-Szabolcsy, É., & Veres, S. (2017). Biological changes of green pea (*Pisum sativum* L.) by selenium enrichment. *Acta Biologica Hungarica*, 68(March (1)), 60–72.
- Gephart, J. A., et al. (2014). Freshwater savings from marine protein consumption. *Environmental Research Letters*, 9(14005).
- Gephart, J. A., Deutsch, L., Pace, M. L., Troell, M., & Seekell, D. A. (2017). Shocks to fish production: Identification, trends and consequences. *Global Environmental Change*, 42, 24–32.
- Griffiths, A. J. F., Wessler, S. R., Lewontin, R. C., & Carroll, S. B. (2008). *Genetics*. McGraw-Hill Interamericana.
- Hirsch, K. D. (2009). Nutrient biofortification of food crops. *Annual Review of Nutrition*, 29, 401–421.
- James, C. (2015). *Global status of commercialized biotech/GM crops: 2015*. Ithaca, NY: International Service for the Acquisition of Agri-biotech Applications.
- Johanningsmeier, S. D., Harris, G. K., & Klevorn, C. M. (2016). Metabolomic technologies for improving the quality of food: Practice and promise. *Annual Review of Food Science and Technology*, 7, 413–438.
- Klug, W. S., & Cummings, M. R. (1998). *Concepts of Genetics*. Spain: Prentice Hall.
- Mba, C. (2013). Induced mutations unleash the potentials of plant genetic resources for food and agriculture. *Agronomy*, 3, 200–231.
- Mutch, D. M., Wahli, W., & Williamson, G. (2005). Nutrigenomics and nutrigenetics: The emerging faces of nutrition. *FASEB Journal*, 19, 1602–1616.
- Nesbitt, T. C. (2005). *GE foods in the market*. Ithaca, NY: Cornell University Cooperative Extension.
- Newell-McGloughlin, M. (2008). Nutritionally improved agricultural crops. *Plant Physiology*, 147, 939–953.
- Parisi, C., Tillie, P., & Rodriguez-Cerezo, E. (2016). The global pipeline of GM crops out to 2020. *Nature Biotechnology*, 34, 31–36.
- Pelletier, N., et al. (2011). Energy intensity of agriculture and food systems. *Annual Review of Environment and Resources*, 36, 223–246.
- Pingali, P. L. (2012). Green revolution: Impacts, limits, and the path ahead. *Proceedings of the National Academy of Science of the United States of America*, 109, 12302–12308.
- Pontifical Academic of Science. (2016). *Summary and statement on the 2016 Plenary Session of the Pontifical Academic of Science, titled «Science and sustainability: Impacts of scientific knowledge and technology on human society and their environment»*.
- Qaim, M., & Kouser, S. (2013). Genetically modified crops and food security. *PLoS ONE*, 8, e64879.
- Ravallion, M., & Datt, G. (1996). How important to India's poor is the sectoral composition of economic growth? *World Bank Economic Review*, 10, 1–25.
- Royal Decree 887/2006, of 21 July 2006, approving the Regulations of Law 38/2003, of 17 November.
- Schnurr, M. (2015). Can genetically modified crops help African farmers? Webinar presentation to the National Academy of Sciences' Committee on Genetically Engineered Crops. *Past Experience and Future Prospects*.
- Silva, J., & Ortiz, R. (2011). In J. Janick (Ed.), *Transgenic vegetable crops: Progress, potentials, and prospects*, in *plant breeding reviews*. Hoboken, NJ: John Wiley & Sons, Inc.
- Strobbe, S., & Van Der Straeten, D. (2017). Folate biofortification in food crops. *Current Opinion in Biotechnology*, 44(April), 202–211.
- Subramanian, A., & Qaim, M. (2010). The impact of Bt cotton on poor households in rural India. *Journal of Development Studies*, 46, 295–311.
- Sutherland, W. J., Freckleton, R. P., Godfray, H. C. J., Beissinger, S. R., Benton, T., Cameron, D. D., et al. (2013). Identification of 100 fundamental ecological questions. *Journal of Ecology*, 101(1), 58–67.
- Takeshima, H. (2010). Prospects for development of genetically modified cassava in sub-Saharan Africa. *AgBioForum*, 13, 63–75.
- Thirtle, C., Lin, L., & Piesse, J. (2003). The impact of research-led agricultural productivity growth on poverty reduction in Africa, Asia and Latin America. *World Development*, 31, 1959–1975.
- Tilman, D., & Clark, M. (2014). Global diets link environmental sustainability and human health. *Nature*, 27, 518–522.
- Troell, M., et al. (2014). Does aquaculture add resilience to the global food system? *Proceedings of the National Academy of Science of the United States of America*, 111, 13257–13263.
- Troell, M., Ziegler, F., & Henriksson, P. (2016). Is fish a fish – Adding fish to the global food sustainability transformation. *Science*, 353(6305), 1202–1204.
- Ye, X., Al-Babili, S., Klöti, A., Zhang, J., Lucca, P., & Beyer, P. (2000). Engineering the provitamin A (beta-carotene) biosynthetic pathway into (carotenoid-free) rice endosperm. *Science*, 287(5451), 303–305.
- Zardoya, R. (2012). The biodiversity crisis: Scientific and political challenges. *Lychnos*, (9), 4–11.

Further reading

- FDA-regulated products. <https://www.fda.gov/ForConsumers/ConsumerUpdates/ucm472487.htm> (19.11.15)
- ICAR Recording Guidelines. (2016). *International Committee for Animal Recording*. ICAR.
- United National Food and Agriculture Organization (FAO). <http://www.fao.org/agriculture/dairy-gateway/produccion-lechera/seleccion-y-mejora-genetica/es/#.WRRkXkygDU>.