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Public Misunderstanding of Genetically Modified Organisms: How Science and Society are Interconnected

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ABSTRACT- Artificial selection, a method by which evolution occurs, is a process in which an organism is modified to fulfill a specific purpose. For instance, the evolution of corn dates back about 10,000 years ago. Farmers in Mexico recognized that not all plants were identical and that some were locally more adapted. Through unconscious selection and open pollination, the first landraces developed. Further progresses allowed for conscious selection. However, farmers and companies quickly realized that crossing parent plants to create hybrids was too time-consuming to be economically viable. Backcrossing reduced the time required to obtain an organism with the desired trait. Further technological developments made organic food possible through the utilization of atomic gardening. Recent progress in genetics has enabled creation of so-called GMOs, or genetically modified organisms. All of the developed methods (open pollination, mutation breeding, atomic farming, CRISPR/Cas) have a common goal: to adjust the organism to express a specific trait. Nevertheless, some of the methods are seen as potentially dangerous. Furthermore, the scientists' and public opinion on GMOs are different which raise concerns about scientific and critical literacy regarding GMOs. The present article investigates the misconceptions that distinguish genetically modified organisms based on the method by which they have been created and relates this misconception to literacy (scientific/critical) and critical thinking. A new term, “Adjusted Organism,” is proposed to enable a fresh, unbiased view for future discussions.

Key-words- Genetically Modified Organisms, Critical literacy, Scientific literacy, Bioethics, Gene editing, GM food, Governance of science and technology

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INTRODUCTION

Unconscious and conscious selections have both been important in genetically modifying the ancestors of our present-day vegetables. For example, *Brassica oleracea* varieties have been selected for bigger stems, leading to kohlrabi. Mutations in the leaves led to kale, selection of stem and flowers brought broccoli, selecting terminal buds allowed cabbage to be grown, and selection of flower clusters led to cauliflower [1].

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While natural selection aims to produce an organism that is better adapted to its environment, artificial selection entails inducing major changes to the features of the ancestor in order to obtain the desired traits. [2] The glucosinolate contents of cabbage, kale, kohlrabi and cauliflower subspecies were investigated and real time analysis showed significant differences in glucosinolate biosynthesis gene expression between the stems of kohlrabi and edible organs of other subspecies of *Brassica oleracea*. Consequently, these are considered genetically modified organisms, as their genomics, proteomics and metabolics have been altered. Interestingly, organic farmers use open pollination and are strictly against GMOs (genetically modified organisms as defined by the European Union). However, based on the above, the starting point for any organic farmer is already a genetically modified organism, and consequently, the product of any open pollination efforts will still be a genetically modified organism. We thus begin to understand how pointless it is to distinguish between gmo`s (small letters; genetically modified organisms that are not GMOs) and potentially dangerous GMOs (genetically modified organisms, as defined by the European Union), which must be strictly regulated. Hybridization, a method by which offspring results from the breeding of two genetically distinct individuals and backcrossing to avoid genetic garbage- because each parent contributes 50% of the genes and not only the desired gene, but many others- are more advanced technologies that can be used to obtain desired traits. However, hybridization will be only successful if a significantly large pool of genetic diversity exists.

The occurrence of natural and spontaneous mutations is rare and thus, relying on this to happen is a time-consuming and extremely inefficient economically. Therefore, mutation breeding was introduced. An important feature of mutation breeding is the randomness of induced mutations, which create multiple mutant alleles that enhance the genetic diversity. The first x-ray irradiation experiments date back to 1897, in which leaves of Calladium were irradiated. Radium ray treatments of *Datura stramonium* [3] provided the first proof of induced mutation in plants, and while by the 1930s, mutation breeding programs had been set up in many countries, the first report of induced resistance in a crop plant was published in 1942 [4]. Around the same time, first reports of chemically induced mutations appeared [5]. The importance of mutation breeding is well documented; whereas in the late 1800s grapefruits were considered a worthless fruit, mutations induced by x-rays and thermal neutrons led to the development of "Star Ruby" and "Rio Red," which now make up 75% of Texas`s grapefruit crop [6]. This grapefruit is marketed by organic farmers and sold as organic and healthy. The European Union stated in a Council Regulation [7], "Genetically modified organisms (GMOs) and products produced from or by GMOs are incompatible with the concept of organic production and consumers' perception of organic products. They should therefore not be used in organic farming or in the processing of organic products." As pointed out, mutation breeding, a method with the sole purpose of creating genetic modifications has created many fruits and crops that are used in organic farming. Mysteriously, the genetically modified organism (gmo`s; small letters) created through mutation breeding are acceptable by both organic farmers and the EU Law on organic production, while GMOs (genetically modified organisms as defined by the European Union) are not acceptable. From a scientific viewpoint, this distinction is pointless. Both gmo`s (genetically modified by mutation breeding) and GMOs are genetically modified organisms, but the EUs legislation distinguishes between them.

Mutation breeding and atomic farming (the use of high energy beams) is actively researched in Japan at the Institute of Radiation Breeding. According to Nakagawa [8], 242 mutants have been created through mutation breeding and are registered in Japan, including rice, soybeans, apple, Japanese pear, rose and many other plants. Tanaka [9] explains how heavy ion beams can be used to create mutations, a technology unique to Japan. As we will point out later, this sledgehammer methods (in which mutations are created in a nonspecific region anywhere in the organism) are still favored, while the more modern, minimally invasive methods are heavily restricted.

Modern plant cloning began with the detection of the soil bacterium *Agrobacterium tumifaciens*, which induces crown gall disease [10], the detection of the Ti-plasmid [11] and cloning experiments with this plasmid [12]. The Ti plasmid randomly inserts DNA into the host plasmid, but in contrast to mutation breeding, only some genes in the host plasmid are modified. In addition, concerns have been raised about the use of antibiotics as a marker. A recent paper [13] came to the following conclusion: "Antibiotic-resistance markers do not pose a substantial risk to human health because the contribution that recombinant bacteria might make- should the enormous barriers to transfer be overcome- is so small that its effect would be completely overwhelmed by the effect of resistance that arises through inappropriate prescribing in medical practice, transmission of mobile genetic elements between bacteria colonizing patients, and hospital environments".

Recent developments in techniques to remove marker genes [14] are being used to address the problem. The site-specific recombination systems TALENs and ZFNs are especially useful for the specific removal of marker genes. Traditional breeding methods for producing gmo`s and new methods that introduce novel genes into the plant to produce GMOs (genetically modified organisms as defined by the European Union) can be distinguished according to directive 2001/18/EC of the European Parliament and of the council [15]. "Genetically modified organism means an organism, with the exception of human beings, in which the genetic material has been altered in a way that does not occur naturally by mating and/or natural recombination." And [15] "within the terms of this definition: genetic modification occurs at least through the use of the techniques listed in Annex I A, part 1; the techniques listed in annex I A, part 2, are not considered to result in genetic modification." Thus, GMOs are defined by technocrats, and arbitrarily so, as clearly seen in the directive. Cell fusion (including protoblast fusion) of plant cells, in which genetic material is exchanged through traditional breeding methods, are specifically excluded from this directive. This exemption was included because hybrid radish and cabbage plants can be produced by cross-fertilization. If protoblast fusion were not exempted, radish and cabbage gmo`s (genetically modified by cross fertilization) and GMOs (genetically modified by protoblast fusion)- which are potentially 100% identical genetically- would require different legislative processes. This highlights how meaningless the EU directive is. Combining radish and cabbage by cell fusion would not be considered GMO, despite the fact that the genetics would definitely be altered compared to the ancestors in more dramatic ways than the insertion of a single protein. Furthermore, there exists no clear threshold that allows us to divide techniques into beneficial/good or potential harmful. This is a bureaucratic decision process, while it should be a thoughtful scientific decision.

As an example of this lack of clarity, organic farmers spray the soil bacterium *Bacillus thuringiensis* (Bt) on plants to prevent excessive use of chemicals. In Carlson's [16] landmark publication, *Silent Spring*, she wrote: "We stand now where two roads diverge. But unlike the roads in Robert Frost's familiar poem, they are not equally fair. The road we have long been traveling is deceptively easy, a smooth superhighway on which we progress with great speed, but at its end lies disaster. The other fork of the road is biological solutions, based on understanding of the living organisms they seek to control, and of the whole fabric of life to which these organisms belong." At that time, field tests showed that the use of Bt was comparable to the use of DDT, but without the terrible toxic effects. Carlson`s book can be seen as the start of the success story of Bt. Her understanding of crop cultivation was that insecticides are necessary, and that biological insecticides are, as compared to chemicals like DDT, environmentally favorable. However, Carlson [16] noted that "the main technical problem now is to find a carrying solution that will stick the bacterial spores to the needles of the evergreens." This problem remains to this day, and it accounts for the small share held by Bt in the global insecticide market. It is thus mainly used in organic farming, where the labour required to applying Bt several times is balanced by the higher market prices.

Through the use of modern genetics, the glue that allows Bt to adhere to the plant has been created. The Bt Cry protein, responsible for the insecticide death, has been inserted into the plant genome. A vast amount of research has shown that this protein is biodegradable and has no impact on non-target insects. The role of receptors in the toxin activity has also been investigated intensively [17]. As Carlson's noted [16], "Biologically they do not belong to the type of organisms that cause disease in higher animals or in plants." However, if you make it part of the plant, providing a better delivery system, you create a GMO that is heavily regulated. Spraying the Bt protein on crops is an organic farming practice, and no regulations apply, but if the crop itself produces the Cry protein, it is not organic farming and is heavily regulated. Compared to the sledgehammer method of mutation breeding, the Bt Cry genetic modification is minimally invasive, allows efficient delivery of the Cry protein, and reduces the need for chemical pesticides. Thus, the European Commission's regulations are clearly confusing and based on non-scientific decision processes.

Another example of such confusing policy regards herbicide-tolerant wheat in Canada. "CDC Imagine" crops were approved without any protest in Canada because Bayer made a smart choice. They induced the wheat's tolerance to herbicides through chemical mutagenesis, a single genetic mutation. Because of this, it is able to be marketed as "the first and only non-genetically modified" herbicide-tolerant wheat in Canada. It is a gmo (genetically modified organism), while not being a GMO (as defined by the directive); this is the consequence of current laws and guidelines.

Final examples are double-muscled cattle. In the Belgian blue cattle, double-muscled cattle that developed through natural selection, the mh allele possesses mutations within the myostatin gene, which is a negative regulator of muscle growth in cattle. Technically, these cattle are diseased, as they lack proper muscle control. No regulation applies, as these mutations are achieved by natural selection. If new technologies were used to create the same mutation, it would be heavily regulated.

To make matters more complicated, new technologies are developed that further dilute the difference between natural and unnatural selection. An anti-browning mushroom, created by CRISPR/Cas techniques, was created using deletion of a specific gene [18].

Should genetically modified organism created by these new technologies be called GMOs? The position of Greenpeace [19] is clear: "Organisms derived from the new GM techniques should be regulated like any other GMOs." Let us take a closer look at their arguments. They assume that gene editing is poorly understood. Certainly, gene editing is a novel technique, but so far, many organic farmers' products are gene edited using the sledgehammer method of mutation breeding. The previous methods of breeding can be described as non-specific gene editing; to choose a desired trait, a selection step was necessary. The novel methods work like a scalpel, inducing mutations at an exact position. The only difference with the older methods is the lack of a selection step.

As mentioned by Abbott [20], a final decision by the European Union has not yet been made regarding how to include these new technologies into the directive. In any case, the EU will be forced to decide that these new technologies are not GMOs. Otherwise, a situation will appear in which a gmo (genetically modified organism) made by traditional methods (mutation breeding, hybridization, open pollination), and a GMO made by new technologies are 100% identical but are treated in a different way. Only European law would then be able to distinguish between these organisms.

The truth is, as pointed out by Tagliabue [21], GMOs are a meaningless pseudo-category. Therefore, the directive 2001/18/EC [15] must be revised. From the beginning, it was a bad idea to distinguish between gmo`s that are less regulated (because they are created through natural selection) and GMOs, based on the method by which they are constructed. A specific product analysis is the only way to conduct a strict risk analysis. Therefore, the most straightforward possibility would be to call all genetically modified organisms GMOs and change the ill-defined category.

However, the term GMO has already has a poor image, and it will be very hard, if not impossible, to change this image. We therefore propose a new term, Adjusted Organism (AO), since all organisms have been adjusted to fulfill a specific goal. This terminology enables a fresh, unbiased view to be used in future discussions. It puts emphasis on the product rather than on the method. Any regulatory framework should apply to all AOs. Safety assessment can be done through metabolic, genomic and proteomic analysis, and by using the Stanford model for regulation of field trials [22]. In this model, it is assumed that the risk associated with field testing is independent of the process by which the modification is made. Thus, the final product strictly evaluates the adjusted organism.

Critical literacy in current agriculture debates

Critical literacy might be defined as the ability to "identify the perspectives and/or biases evident in texts and comment on any questions they may raise about beliefs, values, identity, and power (e.g., identify the narrator's attitude towards his or her topic or characters and the language that conveys that attitude; identify perspectives that are missing from a story and suggest reasons for the omission)" [23]. Here, five key concepts are important:

1. All texts are constructions
2. All texts contain belief and value messages
3. Each person interprets messages differently
4. Texts serve different interests
5. Each medium develops its own "language" in order to position readers/viewers in certain ways" [24]

Critical thinking and critical literacy are related; however, critical thinking starts from the view that we are often governed by prejudices, while critical literacy starts from the opinion that any text is used in some context, and we need tools to unmask the true purpose of the text within this context [25]. As genetically modified organisms are discussed by different interest groups, critical literacy and scientific literacy, which will be discussed in a later section, are important in order to gain an unbiased view of modern genetics. Modern GMOs (as defined by the European Union) are created to provide resistance against a specific herbicide. As an example, Monsanto's Roundup crops are resistant to glyphosate. Recently, glyphosate has been discussed in Europa as a potentially carcinogenic chemical and as a pesticide that should be banned. The discussion about glyphosate in the public is a prime example of the need for critical literacy. Taking different user manuals for glyphosate into account, the average amount of glyphosate is between 0.1 and 0.2 g/m^2. If we assume that all of this glyphosate will be concentrated into the harvested cereal (a maximum concentration), we can calculate, taking an average cereal yield for all countries of 3517.3343 kg per hectare [26], a contamination value between 570 and 280 mg/kg cereal. Interestingly, this is in the range of formaldehyde in dried shiitake mushrooms [27]. Every-day, we eat food with ingredients that are potentially carcinogenic. Of course, the European Union has strict guidelines: "The maximum residue concentration for its use to combat weeds in cereal crops, for example, is 0.1 mg per kilogram of harvest yield for buckwheat and rice. If glyphosate is used for pre-harvest treatment (desiccation), then a maximum residue concentration of 10 mg per kilogram of harvest yield applies for wheat and rye" [28]. Thus, the realistic amount of glyphosate will be much lower and similar to formaldehyde in apples (6.3 – 22.3 mg/kg), cauliflower (27 mg/kg) or pear (38.7 – 60 mg/kg). The acute reference dose (ARfD) is currently 0.5 mg/kg body weight for glyphosate, twice as high as for the known carcinogenic chemical formaldehyde (reference dose [rfd] for formaldehyde: 0.2 mg/kg body weight). Furthermore, according to the European Food Safety Authority the "peer review group concluded that glyphosate is unlikely to be genotoxic (i.e. damaging to DNA) or to pose a carcinogenic threat to humans. Glyphosate is not proposed to be classified as carcinogenic under the EU regulation for classification, labeling and packaging of chemical substances. In particular, all the Member State experts but one agreed that neither the epidemiological data (i.e. on humans) nor the evidence from animal studies demonstrated causality between exposure to glyphosate and the development of cancer in humans" [29]. Consequently, the risk from glyphosate is not higher than any other potentially carcinogenic chemical in our daily food, even if it is organic food. Ames and Swirsky [30] furthermore concluded that exogenous carcinogens are not a major cause of cancer, and that putting huge amounts of money into hypothetical risk assignments will distract the public.

Despite this, Greenpeace EU food policy director Franziska Achterberg [31], "Extending the glyphosate license would be like smelling gas and refusing to evacuate to check for a leak. As long as there is no meaningful EU-wide restriction on glyphosate use, we will continue to live in a world that is awash in a weed killer which is a likely cause of cancer." As outlined above, if one possesses critical literacy and analyses the statement in the scientific context, there is no doubt that her opinion is non-scientific and based upon ideological believes. Certainly, people who avoided glyphosate-containing food have less glyphosate detectable in the urine [32]. But should this raise any concerns? As Niemann [33] pointed out, this increase would account for less than 0.2% of the proposed reference dose, which is no point of concern. Unfortunately, our society is influenced by these statements, and without critical literacy, this opinion will lead to decision making based on fear, possibly resulting in the banning of GMOs with resistance to glyphosate.

The major question regarding glyphosate is not whether it is a carcinogenic chemical, but if the amount of glyphosate intake per day is low enough to avoid any harm, which is actually the case. On the other hand, how do organic farmers control weeds and insects? They use manure or compost that could be contaminated with pathogens. Furthermore, some "natural" pesticides used in organic farming, like rotenone, have an LD 50 from 162-1500 mg/kg, whereas glyphosate has a LD 50 of 5000 mg/kg for rats, 10000 mg/kg for mice, and 3530 mg/kg for goats. Thus, these "natural" pesticides are even more dangerous than synthetic pesticides. A letter from the International Federation of Organic Agriculture Movements [34] states: "In European organic production Azadirachtin is essential for the control of several important pests for which no alternative products are available. For instance, it is the only known product for an effective control of the rosy apple aphid *Dysaphis plantaginea*, one of the most dangerous key pests in organic fruit production." However, this pesticide is highly toxic to fish and other aquatic animals [35]. Just because a pesticide is natural it does not mean that there is no risk. Furthermore, the use of glyphosate is strictly controlled by REACH, the regulation of the European Chemicals Agency, and genetically modified organisms are controlled by the Cartagena Protocol on Biosafety to the Convention on Biological Diversity.

There exists an information bias, and this is a cause for concern. For genetically modified organisms and their pesticides, plenty of data exist that show the benefits and risks; however, for organic farming, the dataset is nearly non-existent. This has created a situation in which societal beliefs in the benefits of organic farming are based on faith, without no ability to discuss the risks because the data are sparse. At the same time the availability of data for conventional agriculture (including biotechnology) allow people to cite the risks while ignoring the benefits. For example, Krueger [32] wrote the following in their conclusion: "Glyphosate residue could reach humans and animals through feed and excreted in urine. Presence of glyphosate in urine and its accumulation in animal tissues is alarming even at low concentrations." Unfortunately, many of the readers will not use their critical literacy abilities. As discussed, Niemann [33] pointed out that the increase in urine glyphosate is irrelevant. Furthermore, the comparison is extremely biased. Krueger [32] did not mention which "natural" pesticide had been used in producing the organic food. That pesticide must also be measured in the urine of test subjects to enable an unbiased risk analysis. If it is not known how the organic food had been treated, the risk analysis is incomplete. The use of glyphosate could be beneficial if the "natural" chemical is more harmful. Using glyphosate could decrease the amount of this "natural" chemical, just as the use of the "natural" chemical decreases the amount of glyphosate. So far, there is no possibility to compare the risk between the "natural" chemical and the synthetic one.

Due to the modern media and social networks, an information overflow exists, and as result, biased information can spread.

Scientific literacy and gmo`s/GMOs

[36]Three paradigms of the public's understanding of science are distinguished. In the paradigm of "Scientific Literacy," the public has a deficit in knowledge; however, by measuring the literacy, one can change education and counteract the public deficit. In the second paradigm, "Public Understanding," the public has a deficit in knowledge because of less support for science, but they possess a sufficient amount of knowledge to understand this topic. If one understands this attitude, educates the people through public relations, increases in public understanding of science will be obtained. The third paradigm, "Science-in-Society," reverses the deficit idea. Here, the deficit is in the scientist`s ability to communicate with society, which leads to a trust deficit. In the Programme for International Student Assessment (PISA), scientific literacy is defined as "an individual's scientific knowledge and use of that knowledge to identify questions, to acquire new knowledge, to explain scientific phenomena, and to draw evidence-based conclusions about science-related issues, understanding of the characteristic features of science as a form of human knowledge and enquiry, awareness of how science and technology shape our material, intellectual, and cultural environments, and willingness to engage in science-related issues, and with the issues of science, as a reflective citizen." Consequently, the PISA definition of scientific literacy includes all three paradigms [37].

For genetically modified organisms, a complex mixture of all three parameters is responsible for the dislike and even fanatic views. Since Mendel`s law has been studied for a long time in biology classes, one can assume that society have known about gmo`s (small letters; genetically modified objects that are not GMOs) for a long time. However, as gmo`s and GMOs have been arbitrarily distinguished by the method through which they are created, the public began to misunderstand the consequences of breeding. In addition, modern biotechnology is a very young science. The polymer chain reaction (PCR) is just 31 years old. This indicates that most people around 40 years of age never learned about a polymer chain reaction, the basis of modern biotechnology, during their school years. If they did not study it later in life, half of the population has never had a formal education in modern genetics. Obviously, this is one source of scientific illiteracy in society (regarding genetically modified organisms). Another source is that some companies, especially Monsanto, with its aggressive marketing strategy and behavior of promoting the benefits while hiding the risks, destroyed public trust in modern genetics.

Unfortunately, scientists have been silent during the last decades. They have had the opportunity to play the "White knight," a mediator between companies and society, but failed to fulfill that role. This gives Greenpeace and other organization ample space to increase public distrust. Former Greenpeace boss, Mr Tindale [38], “To be scaremongering about health risks, particularly cancer, with no scientific justification is totally immoral.”

In summary, as the technologies are very new, we have a knowledge deficit in society [39]; the public does not trust science anymore because of contradicting opinions in the media (Genetic Literacy Project [40]; GM Watch [41]) and scientist failed to explain the scientific concepts [42]. As an example how knowledge deficit influences decision making, recently, the EU declaration that enables countries to opt out of importing and using foods containing biotechnology for non-scientific reasons has been the subject of controversy. A thorough risk/benefit assessment [43] should include socio-economic effects [44] and ethical recommendations. In this regard, the EU declaration is supported. However, socio-economic considerations and ethical guidelines reflect current culture, religion and society. In a society that is increasingly reluctant regarding genetically modified organisms, which has started to believe that genetically modified organisms are dangerous, and where the dislike is even faith-based and fanatical, such a decision process will be guided by ideology and not by objectivity. Confirmation bias, which is the tendency to search for information about genetically modified organisms that confirms one's beliefs, and to give less weight to other thoughts, has reached an alarmingly high level, especially in Europe. Confirmation bias and critical literacy are two different concepts. In the former, people might possess the knowledge to interpret the text (critical literacy) but do not want to use these skills, as they already believe in a specific idea. Thus, many European countries are opting out, based on fear of the unknown and reluctance to close the information gap. In this situation, allowing countries to opt out for non-scientific reasons is not reasonable and will be a major drawback for the future of Europe. Decision making processes must follow knowledge not fear. Instead of bending the rules and backing down to the information bias, the European Union should ask the question of how to counterbalance the confirmation bias and repair the public’s distorted view in order to regain scientific literacy regarding modern genetics. First, we need to educate our future citizens in a better way. Many of our solutions for the future are biotechnology based, but this is poorly reflected in the education of our children. As example, let us look to the school time table in Germany [45]. In the "Gymnasium," students take up to 12 hours of three language courses, while they only have around 8 hours for biology, physics, mathematics and chemistry (4 courses). In another country, NRW (Nordrhein-Westfalen), the situation is similar [46]. There is simply no time given during school to build an appreciation of science and encourage scientific literacy. For a technologically driven society, this is alarming. To prevent the fanatical dislike of genetically modified organisms within the European Union, the education system must be changed. STS (Science, Technology and Society) education that considers how social, political, and cultural values affect scientific research and vice versa would be a possible approach. This is sometimes referred to as the liberal arts of the new millennium; as its goal is to educate everyone on how to respond knowledgeably to future challenges. We, as scientists, should put pressure on the European Union to ensure schools provide the basics of modern genetics. "But it is only when researchers actively involve themselves in the education system in this way that we can expect science literacy to improve" [47].

Any false claims about genetics should be discussed on Facebook/Twitter and other social media (GMO compass [48]). However, we should avoid an ideological and dogmatic approach. We must respond to the concerns, openly discuss the problems, and explain how such problems can be circumvented. Until now, we have let the ideologues to lead the discussion. As scientists, we might not be used to interacting with society in such a manner, but it is our duty as part of society to tell the truth and enable a scientifically literate society, where decisions will be made based on knowledge. "Experts in the field should consider methods of educating the public more thoroughly so that they can use the information about GM contents responsibly and make fully informed judgments about their food choices" [39].

To revive an unbiased discussion, we propose the new term explained in the previous section.

AOs–A paradigm change that will enable an unbiased discussion

The idea of AOs was conceived of during the biotechnology lecture at the International College of Liberal Arts (iCLA) while brainstorming about how GMOs can be discussed in an unbiased way to make the topic more acceptable to a society with increasing reluctance towards GMOs without having or even wanting all the background information available for a competent discussion. A definition of AOs will be followed by the guidelines of how to use the concept.

“Adjusted Organisms” (AOs) can be defined as living organisms that have been genetically altered through DNA mutation, including multiple types of mutations (atomic farming, mutation breeding, open pollination), single residue changes (ZFN, TALENs, CRISPR/Cas, open pollination, mutation breeding), the exchange or addition of DNA material, or any other method in order to serve a specific purpose, such as food productivity (for example, drought resistance), preservation of nature, prevention of disease or energy production. Living AOs, however, exclude human beings from any DNA mutation, as this requires further intensive discussion.

AOs put emphasis on the product rather than on the method used to create the AO. After all, most of our crops and livestock are genetically modified organisms, and this began more than 10,000 years ago with unconscious selection.

Risk assessment: A risk assessment aims to identify and evaluate any hazards that may occur when using a specific product. Risk assessment of AOs will be publicly available in a database such as the National Center for Ecological Analysis and Synthesis to enable meta-analysis [49]. Firstly, modifying any living organism using DNA alteration carries some risks. Such risks include inducing a disease in the living organism or producing metabolites that could be potential allergens. Horizontal or vertical gene transfer, causing new mutations that may be unknown, can occur. Therefore, safety assessments should include metabolic, genomic and proteomic analysis, and should use the Stanford model for regulation of field trials [22]. A thorough risk/benefit assignment [43] should include socio-economic effects [44]. Furthermore, bioethics needs to be considered.

CONCLUSION

The term AOs may help start to regain the trust of consumers. Consumers needed to be educated in order to understand that most of our crop plants and livestock are genetically modified organisms, and that the current definitions neglect this fact and enable false claims. It is up to each scientist creating an AO what will be modified and how; the methods will not be limited as long they are ethical. The risk lies within the product not in the method used to create the product (with the exception of ethical issues). Thus, everyone may be as creative as they wish in seeking to enhance food productivity (for example, by inducing drought resistance), to preserve nature, to prevent disease, or to produce energy. However, a strict risk assessment is required, and to obtain approval, complete transparency with regard to projects and data is necessary. To emphasize, in order to regain the trust of consumers, open databases will enable all people to form their own opinions about AOs (previously gmo`s and GMOs) instead of extracting information from unreliable resources (as extreme examples: Greenpeace, Monsanto).

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