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Research Article

The Role of Secondary Education in Bulgaria in the Formation of Students' Ecological Awareness on the Benefit and Harm in Genetically Modified Foods – Interpretation in Terms of Fuzzy Logic Theory

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Abstract

Introduction: Nutrition with genetically modified foods divides society in the group supported it and the group worried about possible distant consequences for the health and the environment. This paper describes the results of a study aimed at monitoring how the process of knowledge accumulation and the development of environmental thinking within the secondary education influence students' judgment on the benefit and harm of eating GMFs.

Material and methods: The study was conducted with 6 independent groups of students at a different stage in their secondary education, as well as with citizens who already completed their secondary education.

Results: The results were interpreted in terms of fuzzy logic theory and three parameters of the groups' opinion were calculated – the indices of potential harm and benefit, as well as a relative harm-benefit balance.

Conclusions: In the course of secondary education, the students' attitude of both the potential harm and the benefit of the GMF nutrition change in the direction of an increase, while the opinion of the interviewed respondents becomes more dispersed, the categoricity of opinion decreases. The comparison between the relative balances for harm-benefit from GMF nutrition and from polluting industries shows that society is worrying about the potential harm from nutrition with genetically modified foods almost twice less than the potential harm from the polluting industries.

Keywords: Harm; Foods; Logic; Nutrition

Introduction

As human civilization evolves, new human-induced environmental factors affect the health, behaviour, and nutrition, of both individuals and, ultimately, the human population and the environment. Genetically modified organisms (GMOs), in particular genetically modified foods (GMFs) are an example of such a product of civilization development. On the one hand, genetically engineered (mainly plant) organisms promise cheap and large quantities of foods, drugs and fuels, but on the other hand there is uncertainty about possible negative distant consequences for the health of people and animals consuming them, for unpredictable changes in the environment as a result of the interaction of GMOs with natural organisms. To the public GMOs resemble the spirit from the bottle – they promise good things, but once released into the environment it is impossible to separate them from the natural organisms if their influence on them is unfavourable. The bitter experience of the modern man, subjected to the aggressive effects of the environment that he himself changed, forces him to be careful with the new challenge – the genetically modified organisms.

At present, each country decides whether and how much to use GMOs. In Bulgaria, their use is forbidden. The effectiveness of such prohibitions is unclear given that, for purely biological reasons, state borders are not an obstacle to the spread of organisms.

The school is called upon to form in young people and, from there, to society, a sober judgment, supported by scientific facts, about the benefit and harm of GMOs impact on the environment.

This paper describes the results of a study aimed at monitoring how the process of knowledge accumulation and the development of environmental thinking within the secondary education influence students' judgment on the benefit and harm of eating GMFs.

The surveys for the study were conducted in Plovdiv - a big city in comparison with the country's population, with thousands of years of history, traditions in secondary and higher education, with many secondary schools and several universities. The city is also a cultural centre (the European Capital of Culture for 2019).

Material and Methods

In order to trace the formation and development of awareness of the benefit and harm of nutrition with GMF in the course of secondary education, surveys were conducted with five independent groups of respondents. All groups had the same volume of 48 respondents. All surveys were conducted in the period of one school year - 2009/2010. Students were interviewed during classes. The groups consisted of:

Students from St. Patriarch Evtimiy Secondary School in Plovdiv:

- Entrance group of the secondary education (7th grade),
- A group in the middle of secondary education (9th class),
- A group at the end of secondary education (12th class).

The 12th-class group was interviewed twice – at the beginning and end of the school year. The samples sizes were limited by the number of 12th class students available (the smallest group of respondents in the studied secondary school). All 48 students from 12th class participated in the surveys, and random samples with the same size were taken from the other groups.

In addition, in order to trace the effect of secondary education on public opinion on the studied problem, two groups of people who have already completed their secondary education were also interviewed:

- Medical students at the beginning of their medical education (1st course) at the Medical University in the city. It is expected that young people who choose medicine as a profession, with interests in biology and health, will have a clear opinion on the studied problem. At the same time, for freshman students, this opinion is still not influenced by university education and reflects the impact of secondary education on this particular sample of respondents. Students were interviewed during classes.
- Citizens with secondary education. The respondents were randomly selected in places in Plovdiv, where the citizens have enough free time to participate in the poll - public parks, the railway station, the bus station.

In total, six surveys were conducted - four with groups of respondents from secondary education and two with people already completed it.

The structure of the questionnaire is shown in Table 1.

Rate the harm from a diet with GMF	Too much	Big	Moderate	Little	Negligible
Rate the benefit from a diet with GMF	Great	Big	Moderate	Little	Negligible

Table 1: Evaluation of the perceptions of the benefit and harm of genetically modified foods (GMF).

The respondents choose only one of the five rankings for the benefit and the harm by answering the paper questionnaire. In fact, respondents were asked to complete a questionnaire of the type shown in Table 1 for 10 human-induced environmental factors that affect the health and behaviour of the human population and the environment. One of them was GMF feeding.

Human choice, in particular, those of respondents, is rather subordinate to the fuzzy logic of a type "I may be willing to choose an answer ...", "as if I prefer a response ..." rather than the determined logic of the type of "my definite choice is ...". I.e. unlike the determined logic that allows only two possible alternatives (yes or no) to choose, fuzzy logic allowed additional intermediate levels of choice such as "rather YES", "maybe YES, but maybe NO", "rather NOT".

To the extent that the respondents, as human subjects in their reasoning are guided by the fuzzy type of logic, the processing of

the survey can also be expressed in terms of the mathematical theory of fuzzy logic, created in 1965 by Lotfi Zadeh. The reader can be acquainted with the practical applicability of the theory for example through the works of Wierman [1] and Gokmen., *et al*. [2].

Fuzzy logic sets - one for the benefit and one for the harm can be constructed for each set of responses of a group of respondents (Figure 1). In fuzzy logic sets, there are several inputs from which information is input into the set. In this case, the five responses in the proposed questionnaire are the five entries in the set, and the information they receive is the number of responses that respondents as a group have given for each of the benefit/harm responses proposed in the questionnaire.

Figure 1: Fuzzy Logic Set. The abscissa is a benefit/harm parameter. With the numbers on the abscissa, the entries in the set - the answers in the questionnaire - are marked. Along the ordinate, the values of membership functions are plotted. One of these triangle functions – this for response "Moderate Benefit / Harm") is coloured.

The information received from the inputs to the fuzzy logic set is processed by the so-called membership functions in a process called fuzzification. Each input has one membership function. The analytical type of membership functions takes into account the lack of clarity in human logic and the admissibility of more intermediate levels in grading for benefit and harm than the five levels (inputs) mentioned in the questionnaire. The output values resulting from the fuzzy logic set processing depend on the choice of membership functions type. The most commonly used in applications are membership functions, which have the same analytical type for all inputs. Membership functions are functions of a parameter that characterizes the benefit or harm changes. It is graphically presented as the abscissa, on which the five answers of the questionnaire (inputs) were plotted at equal distances. In this case, the parameter values are chosen to be incremented by a unit of 1 (for the first input – "negligible benefit/harm") to 5 (for last input – "great benefit/too much harm"). The points divide the segment of the abscissa at equal intervals. The simplest and most commonly used membership function is an isosceles triangle, the base of which lies on the abscissa. In Figure 1, one of these isosceles triangles representing the membership function for input 3 is coloured. The base of the triangle includes two adjacent intervals between the points, representing inputs in the abscissa, i.e. covers three adjacent responses (inputs). For the coloured triangle, these are responses 2, 3 and 4. The maximum of the membership function is 1, the minimum - 0 (they are depicted on the ordinate). The function thus built corresponds to the input indicated at the centre of the triangle base, for the coloured triangle it is input 3. The membership function value for the point of its respective input is 1. The thighs of the triangle have linear functions, representing in the fuzzy logic a gradual increase or a reduction in the perception of the respondents for the transition between the neighbouring responses. Membership functions for the first and last input are rectangular triangles, half of the other triangles in the set.

The output value of each set input is a result of the multiplication of three components:

- Input information (the number of responses of the group corresponding to the input),
- The value of its corresponding membership function (for the choice of described above triangular type of the function, the membership function value is 1 for the point of its respective input and 0 for all other inputs),
- And the value of the benefit/harm parameter at the point of the respective set input (1, 2, 3, 4 or 5).

Thus, in order to obtain the output value for input "one", the number of respondents in the group, answering as "negligible" the benefit or the harm from the GMF was multiplied by 1, for the input "two" the number respondents choosing a "little" benefit or the harm was multiplied by 2, and so on.

The benefit index (and in the same way harm index) was calculated as the sum of outputs from all inputs of the corresponding fuzzy logic set.

The results below were calculated as a consequence of the choice of triangle shaped membership functions and evenly distributed inputs. The results would be different if another analytical type of membership functions or distribution of the inputs was chosen.

The relative harm-benefit balance was also calculated – the ratio between the harm index and the benefit index for the group of respondents. If for a given environmental factor, affecting the society, the relative balance value is less than one, i.e., in the society prevails the opinion of the prevailing benefit, the average respondent (public opinion) is inclined to bear the damage (harm) from the application of the factor – he/she is the more decisive the smaller is the relative balance. If the relative balance is close to 1, it shows an approximate equilibrium in the perceptions of the potential harm and benefit of the environmental factor, and the average respondent would hesitate to undergo the influence of the factor. For the relative balance values above one, the average respondent is not inclined to approve the applications of that factor. This also applies to the use of GMF.

Results and Discussion

The responses of the 6 groups for the extent of the harm are given in table 2. Graphically they are shown in Figure 2.

	Too much	Big	Moderate	Little	negligible	Harm index
Students 7th grade	5	4	28	10	1	146
Students 9th class	2	12	26	6	2	150
Students 12th class at the beginning of the school year	4	12	15	11	6	141
Students 12th class at the end of the school year	9	13	13	9	4	158
Medical students	11	10	13	8	6	156
Citizens	7	18	8	9	6	155

Table 2: Distribution of the number of responding to a questionnaire for the harm of GMF nutrition.

Figure 2: Distribution of the responses of the 6 groups surveyed for their opinion on the harm of nutrition with genetically modified foods.

It can be seen from Table 2 and Figure 2 that, within the time span in secondary education training up to the beginning of the 12th class, the maximum of the harm index remains at the "moderate" level, although it decreases monotonously by the end of the course on training. For the same interval, the number of responses to the harm levels "negligible" and "big" increases, that is, the responses spread across the levels of harm, reducing the categoricity of judgment, typical for younger students. Within the timeframes of the 12th grade, a qualitative leap in student perceptions of harm from GMF is made – at the end of the school year, the number of responses to "big" harm increases and equals that of "moderate" harm. At the beginning of the school year, the number of responses to "too much" harm doubled, while reducing responses to "small" and "negligible" harm. Apparently, during the last year of their studies, students are given the information they need to form their own ideas about the potential harm from GMF nutrition.

Medical students evaluate the harm from GMF nutrition close to that of graduating twelfths by both the harm index and the distribution of the number of responses to the harm levels.

The distribution of citizens' responses to the harm of GMF nutrition has a small maximum at the level of "big" harm and evenly distributed number of answers to other levels, there is a lack of categorical group opinion. The difference in the distribution of responses among students on the one hand and on the other on citizens shows the lack of a link between the public opinion represented by the citizens on the harm of GMF nutrition and the one formed in the school.

The responses of the 6 groups for the benefit of nutrition with GMF are given in Table 3. Graphically they are shown in Figure 2.

	Great	Big	Moderate	Little	Negligible	Benefit index
Students 7th grade	1	1	21	15	10	112
Students 9th class	1	4	15	21	7	115
Students 12th class at the beginning of the school year	2	8	18	19	1	135
Students 12th class at the end of the school year	2	5	18	18	5	125
Medical students	1	5	20	12	10	119
Citizens	2	3	19	15	9	118

Table 3: Distribution of the number of responding to a questionnaire for the benefit of GMF nutrition.

The maximum of the students' group number of responses gravitates around levels of "moderate" and "small" benefit and slightly changes during the course of study.

Until the beginning of 12th class, the number of students' answers for "big" benefit increases monotonously, while the level of "negligible" benefit is decreasing monotonously, i.e. a process of displacement of students' attitude towards more benefit of nutrition with GMF, is observed.

In the group of 12th class students, as a result of the training in the last school year, there is a slight shift in the attitude in the opposite direction – to a lesser benefit.

The number of medical students' responses on the benefit of nutrition with GMF has a clear maximum for "moderate" benefit and the number of responses for "little" and "negligible" benefit is three times more than those for "great" or "big" benefit.

Citizens have a distribution of responses similar to medical students - with a more pronounced maximum for a "moderate" benefit. Broadly speaking, public opinion, assuming that citizens express it, is similar to that at the beginning of secondary education.

The harm and benefit indices from the right columns of Table 2 and Table 3 are shown graphically in Figures 4 and 5. They are indicators of the effectiveness of the education process.

The harm index reaches the minimum (141) and the maximum (158) for the group of 12th class students - at the beginning and end of the school year Figure 5.

Figure 3: Distribution of the responses of the 6 groups surveyed for their opinion on the benefit of nutrition with genetically modified foods.

Figure 4: Benefit and harm indices for all groups.

Figure 5: A detailed picture of the change in benefit and harm index for all groups.

shows that two transitions are noticeable in the students' attitude on the benefit and harm of nutrition with GMF - for the interval from 9th to 12th class the harm index decreases and the benefit index increases, then only for one school year trends are turning back. This dynamics of change in students' attitude clearly reflects the specifics of the educational process.

For the groups of medical students and citizens, the harm index is close to the 12th class students at the end of a school year.

The benefit index for GMF nutrition increases monotonously in the course of secondary education, reaching a maximum of 135 for the 12th class. For medical students and citizens, the benefit index is 119 and 118, respectively.

Conclusions

In the course of secondary education, the students' attitude of both the harm and the benefit of the GMF nutrition change in the direction of an increase, while the opinion of the interviewed respondents becomes more dispersed, the categoricity of opinion decreases.

The relative harm-benefit balance is close to a unit (1.25) for the surveyed groups, indicating an approximate balance in their attitude to the potential harm and benefit of GMF nutrition.

For the group of citizens, the relative balance is 1.31. If the relative balance for the citizens' group is considered as an indicator of public opinion, it shows a balance in the attitude of the society about the potential harm and benefit of GMOs, in particular for GMF nutrition.

In the framework of the same study, the same 6 groups were surveyed on their opinion on the potential harm and benefit of air, water and soil polluting industries and the harm-benefit balance regarding this factor was 2.10. The comparison between the two relative balances shows that society is worrying about the potential harm from nutrition with genetically modified foods almost twice less than the potential harm from the polluting industries.

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