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Gene Editing versus Gene Modification: Awareness, Attitudes and Behavioural Intentions of Lithuanian Consumers, Producers, and Farmers

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Gene editing (GE) and gene modification (GM) technologies demonstrate noticeable differences. GE technologies introduce changes in DNA, which are intrinsic to the species, while GM technologies incorporate changes from foreign species. The potential benefits of GE have been highlighted in a number of recent scientific studies, pointing to the opportunities that are opening up in addressing the food availability problems as a result of the growing world population. However, the implementation of GE technology in food production would rely on public awareness, acceptance, and attitudes toward genetically modified and genetically edited food products. Based on the Theory of Reasoned Action (TRA), we surveyed Lithuanian consumers, farmers, and producers for their awareness, attitudes, and behavioural intentions towards GM and GE food. The 251 consumers, 50 farmers, and 56 food producers participated in the survey. Consistent across all samples (consumers, farmers, and producers, respectively), GM technology-related products' self-assed awareness was significantly higher than the level of self-assed awareness of GE products. Awareness of GEO in all samples is relatively low. The level of support for GMO and GEO is also low in all groups of respondents. All groups – consumers, farmers, and producers – are less negative about food produced from GE than from GM raw materials. There was a statistically significantly higher overall likelihood for future use of GEO than the GMO. Producers would be less likely than consumers and farmers to use GMOs in the future. The same inclinations are observed with regard to GEO, with statistically significant differences in the sample of consumers, farmers, and producers.

1. Introduction

Surging population numbers along with climate change foretell a future riddled with such issues as trying to achieve higher agricultural productivity while at the same time preserving the environment and reverting the damage already done to it (Wheeler and von Braun, 2013). In practice, scientists must find solutions to these complex problems to keep up with the growing global food demand, and simultaneously curtail unsustainable use of resources that lead to a degraded environment.

Recent developments in biotechnology resulted in new breeding techniques (NBTs), which can also be used in agriculture. Reverse breeding, cisgenesis, intragenesis, site-directed nucleases (SDNs), oligonucleotide-directed mutagenesis (ODMs), RNA-dependent DNA methylation, and clustered regularly interspaced short palindromic repeats with associated protein 9 (CRISPR/Cas9) systems are just a small part of the NBTs used for gene editing (GE) and modifications (GM). The most promising GE technique is CRISPR/Cas9 system, which allows to precisely change DNA or to inject a new sequence in it.

Environmental applications of GE technologies could enable novel approaches to conservation, bioremediation, control of invasive species, and protection of biodiversity as well as for sustainable food production, including the reduction of food scarcity in developing countries. GE could be used to obtain plants resistant to pests and diseases, reducing the use of pesticides and fertilizers, generating resilience to harsh weather conditions, or

enhancing nutrients in foods (Haque et al., 2018; Georges and Ray, 2017; Palmgren et al., 2015). Several GE crops and horticultural plants with novel features, such as healthier nutrient composition, are already in development, which can provide direct benefits to the consumer (Khandagale and Nadaf, 2016; Modrzejewski et al., 2018).

Whereas these techniques enable the development of a wide range of agricultural applications, the ethical, legal, social and economic issues of their use are discussed extensively. From the point of view of the EU GMO legislation (Directive 2001/18/EC), the status of products obtained using precision methods of directed mutagenesis is subject to debate. Meticulous assessment and complex authorization procedures are enforced on any product deemed as GMO. Compared to that, non-GMO products have very loose procedures. Thus, to meet GMO Directives, businesses need to invest time and money in the expensive approval processes, the scale of which is accessible only for huge enterprises (Callaway, 2018; Stokstad, 2018). On the one hand, strong legislation creates high costs, which reduces investments and innovations in GMOs, subsequently limiting such products' commercialization (Georges and Ray, 2017). On the other hand, week legislation influences public opinion, which might kill the GMO product even before commercialization (Huang et al., 2016).

Consumers around the world are still concerned about GM foods (Wunderlich and Gatto, 2015). Such negative attitudes are also reflected in consumers' behavioural intentions (Bredahl, 2001; McFadden and Lusk, 2016). A meta-analysis conducted by Lusk et al. (2005) revealed that consumers attribute a greater value to non-GM foods over GM foods. Consumers tend to avoid such products believing that such foods are not of good quality and that GMOs can threaten their health (Savadori et al., 2004; Ingrassia et al., 2017). Thus, such risks reduce consumers' willingness to buy GM foods (Hakim et al., 2020). This concern is likely to stem from a poor understanding of GMO and genetically modified organism technologies in the food industry (Hwang and Nam, 2020). The prevalent stereotypes and low popularity of GM technologies-related products can have a significant impact on other market participants. The preferences and intentions of market participants representing the supply side generally reflect consumer attitudes and intentions on the demand side. Companies are reluctant to invest in breaking established stereotypes among consumers, as changing a deeply held belief is costly and time-consuming.

On the contrary, to adapt to market trends or to seek differentiation, some companies even use messages such as "GMO-free" in their product promotion because GMO-free labelled products are considered healthier (Hartmann et al., 2018). Such promotional initiatives further contribute to the fuelling of negative attitudes towards GMO and GEO technologies in the food industry. These trends potentially undermine the prospects for the use of new mutagenesis organisms in food production and agriculture. In this context, policymakers have a key role to play in finding ways to educate the market. Because the success of GE technology implementation in food production is dependent on public acceptance, it is becoming increasingly important to explore market participants' current attitudes and behavioral intentions toward GM and GE foods.

The relationship between consumer attitudes and behaviour has been studied in detail in social psychology, marketing, and consumer behaviour studies. Consumer attitudes towards food and nutrition have been found to influence food buying and consumption behaviour (Pieniak et al., 2010; Altamore et al., 2017). According to The Theory of Planned Behaviour (Ajzen, 1985; Ajzen and Fishbein, 2000), people's attitudes determine their behaviour through the intervening factor of behavioural intentions. In view of the above, this study aims to investigate the awareness, attitudes, and behavioural intentions towards GM and GE foods and raw materials of Lithuanian consumers, farmers, and producers and to conduct a comparative analysis.

2. Methodology

2.1 Data collection and measures

A quantitative descriptive study was conducted to assess consumers, farmers, and food producers' attitudes and behavioural intentions toward GM and GE foods. The selection of cases required for the study was performed by a non-probabilistic convenient sample. The survey was conducted in Lithuania between July and October of 2019. Data collection method – online-administered auto survey (surveymonkey.com). Nominal scales were used to evaluate the socio-demographic characteristics of the survey respondents. A rank-four-point or five-point scale and a nominal scale were used to measure awareness, attitude, and behavioural intentions. A separate study instrument was developed for each group of respondents. The consumers' questionnaire consisted of the following key elements: (1) self-assessed knowledge of GMO and GEO issues; (2) consumers attitudes (favourable/unfavourable) toward GMO and GEO; (3) the importance of the method by which the organism was obtained; (4) consumers intentions to buy GM and GE foods in the future. The farmers' questionnaire included the following sections: (1) farmers' self-assessed knowledge of GMO and GEO; (2) farmers' attitudes (favourable/unfavourable) toward GMO and GEO; (3) the importance to farmers of the method by which the organism was obtained; (4) farmers' behavioural intentions with regard to GMO and GEO. The following domains were covered in the producers' questionnaire: (1) producers' self-assessed knowledge of

GMO and GEO; (2) food producers attitudes (favourable/unfavourable) toward GMO and GEO; (3) the importance to producers of the method by which the organism was obtained; (4) the intentions of food producers to use GM and GE raw materials in their production. Face validity has been expertly assessed. External validity was evaluated by a small group of consumers, two farmers and one food producer. The research instruments were adjusted to consider the comments of experts and respondents who tested the instrument. The IBM SPSS 25 package was used for the analysis of the study data. Statistical analysis methods used: descriptive statistics, paired sample T-test for two dependent samples, Wilcoxon test, Kruskal-Wallis test.

2.2 Sample characteristics

251 respondents took part in the consumer survey. The number of respondents who provided socio-demographic data ranged from 189 to 195. 76.41% of women and 23.59% of men participated in the survey. Respondents represent different age groups (under 25 y.o. – 29.23%, 26-35 y.o. – 27.69%, 36-45 y.o. – 10.77%, 46-55 y.o. – 12.82%, 56 and older – 19.49%). 86.6% of respondents stated they have a higher education. The survey involved 50 farmers, 80% of whom are engaged in crop production and 20% in animal husbandry. In the case of mixed agricultural activities, respondents were asked to indicate the predominant activity. The majority of responding farmers (83.78%) indicated that they had higher education. Farmers of different age groups participated in the study. The majority of respondents belong to the 36-45 age group. The study involved 56 food producers. The sample of producers by type of activity is dominated by the production of cereals, bread, pastry, and flour confectionery (35.83%). Both large and small companies participated in the study. The position was dominated by technologists. Other positions indicated by the respondents were directors, heads of various chains and departments, and laboratory assistants.

3. Results and Discussion

3.1 Comparison of self-evaluated knowledge on GMO and GEO in different groups of respondents

Below are comparative means of self-assessed knowledge of GMOs and GEO by consumers, farmers, and food producers (Figure 1). The paired sample T-test (for two dependent samples) showed that the overall level of GMO awareness among all groups of respondents (mean 3.49, SD = 0.77) is statistically significantly (t (317) = 14.73, $p < 0.0005$, N = 318) higher than the level of awareness of GEO (mean 2.64, SD = 1.14). Food producers are the best familiar with GMO (mean 3.76), least are the farmers (mean 3.37) (Figure 1).
Kruskal-Wallis test reveals statistically significant differences in GMO awareness in the samples from consumers, farmers and food producers (consumers N = 250, farmers N = 50, producers N = 55, $Ç^2(2, N = 355) = 8.79$, $p = 0.012$). In the sample of food producers, the median value of GMO awareness (Md = 4) is higher than in the samples of consumers and farmers (consumers Md = 3, farmers Md = 3, respectively).

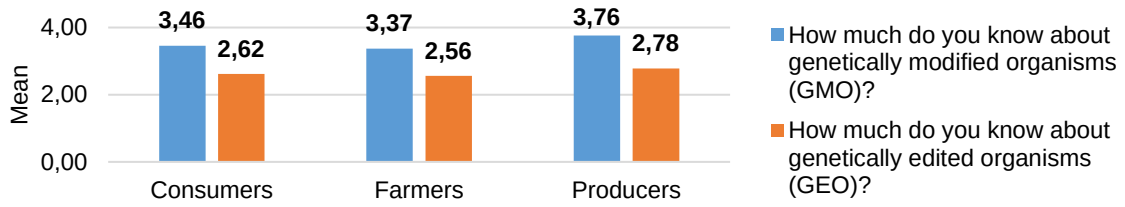

Figure 1: Self-assessed level of knowledge of GMO and GEO in different groups of respondents (1 – never heard, 2 – heard but know nothing, 3 – know a little, 4 – know moderately, 5 – know a lot)

Depending on the scale used, the means characterising GEO awareness show that in all groups of respondents, self-assessed awareness is very similar. Respondents have heard but are not aware of anything or only know a little about GEO (means fall within the range of "I heard but know nothing about GMO" and "I know a little about GMO" points on the scale) (see Figure 1). The results of the Kruskal-Wallis test confirmed that the level of awareness of GEO did not differ statistically significantly in the samples of consumers, farmers and food producers (consumers N = 224, farmers N = 43, producers N = 51, $Ç^2(2, N = 318) = 1.296$, $p = 0.523$; consumers Md = 3, farmers Md = 3, food producers Md = 3). Consumers, farmers, and producers reported knowing more about GMOs than about GEO. In all samples, the overall level of self-assessed awareness of GMOs is statistically significantly higher than GEO's awareness level. GMOs' awareness varies statistically significantly across individual samples of respondents: GMOs are best known to food producers and least known to farmers. The level of familiarity with the GEO in individual groups of respondents is very similar (no statistically significant differences were detected in individual groups of respondents) and is relatively low.

3.2 Comparative analysis of attitudes towards products from GM and GE raw materials in individual groups of respondents

Figure 2 depicts the mean values representing consumers, farmers, and food producers' attitudes toward GMO and GEO-related products. Comparing the general attitude of the respondents to foods from GM and GE raw materials, the paired sample T-test for two dependent samples demonstrate that the respondents were statistically significantly (t (318) = 6.817, p <0.0005, N = 319) more favourable for foods from GE (mean = 3.43, SD = 0.908) than from GM raw materials (mean 3.67, SD = 0.909). The Kruskal-Wallis test revealed that the respondents' attitudes towards foods from GM raw materials in individual samples are not statistically significantly different (consumers N = 251, farmers N = 50, producers N = 55, $Ç^2$(2, N = 356) = 1.761, p = 0.415; consumers, farmers and producers: Md = 4). There is also no statistically significant difference in the attitudes of consumers, farmers and producers towards food products from GE raw materials (consumers N = 225, farmers N = 43, producers N = 51, $Ç^2$(2, N = 319) = 1.356, p = 0.508; consumers, farmers and producers: Md = 3).

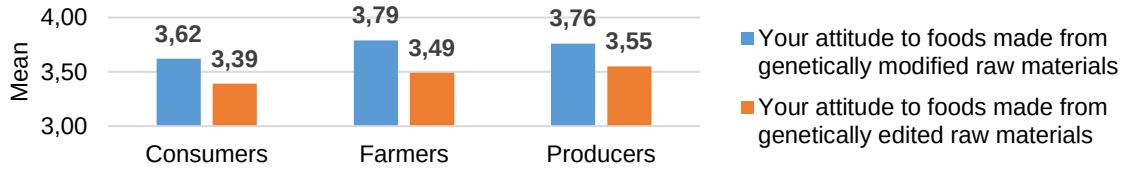

Figure 2: Attitudes towards food from GM and GE raw materials in individual groups of respondents (1 – very positive, 2 – positive, 3 – neutral, 4 – negative, 5 – very negative)

In summary, all groups of respondents have a negative attitude toward GMO foods rather than a neutral attitude. Consumers, farmers, and producers are less negative about food made from GE raw materials than they are about food made from GM raw materials. The level of favourability for GMO and GEO in various groups of respondents is very similar (not statistically significantly different).

3.3 Comparative analysis of the importance of the method in separate groups of respondents

In order to clarify the importance of the method and compare the perceptions of individual groups of respondents, they were asked to indicate how important it is for respondents to know which method (traditional mutagenesis or targeted mutagenesis – gene editing) was used to obtain the organism if the final products are identical. The attitudes were captured on a 5-point scale, with 1 being extremely important and 5 being completely unimportant. More than half of the total (54.95%) sample indicated that it is very important and important for them as to what method was used. Correspondingly, 22.53% of respondents said they were completely indifferent or indifferent to the method used. Considering the scale values, the overall mean of the assessment of the significance of the method (mean 2.495, SD = 1.23, N = 293) in the sample shows that the method used for obtaining the organism is important or slightly important for the respondents. Although the mean values of individual groups reveal that the method is slightly more important to consumers (mean 2.39) than for farmers (mean 2.70) or producers (mean 2.80), the importance placed on the method by the individual group does not differ statistically significantly (consumers N = 207, farmers N = 37, producers N = 49, $Ç^2$(2, N = 293) = 5.5, p = 0.064; consumers: Md = 2, farmers and producers: Md = 3). Even if the final products are identical, consumers, farmers, and food producers place high importance on how the organism was obtained (traditional selection or targeted mutagenesis).

3.4 Comparative analysis of the behavioural intentions of consumers, farmers and food producers

The behavioural intentions were measured on a 4 – point scale, where 1 means very probable, 2 – probable, 3 – unlikely, 4 – very unlikely. Wilcoxon test revealed that the consumers' intention to buy food from GMO and GEO raw materials does not differ statistically significantly (Z = -1.39, p = 0.165, N = 197; GMO and GEO intentions to buy: Md = 3). Consumers' future behavioural intentions regarding GMO and GEO raw materials for food are similar – they are more likely than not to purchase such products in the future.

According to the response frequencies, farmers are not likely to use GMO (unlikely and very unlikely – 79.2%) and GEO (unlikely and very unlikely – 74.5%) in their future economic activities. In the case of GMOs, there is a greater certainty that the use of this type of raw material is very unlikely (43.75%, as compared to 23.26% for GEO). Wilcoxon Signed-Rank test shows that farmers' intentions to use GMO (N = 48) and GEO (N = 43) differ statistically significantly (Z = -3.13, p = 0.002, mean rank of GMO intent to use is 8.5, Md = 3; the mean rank of

GEO intent to use is 9.07, Md = 3). It can be argued that farmers' intentions are statistically significantly more favourable to GEO than to GMOs.
Only 10.64% of producers indicated that they were likely to use GM raw materials in their production. A slightly more favourable attitude is observed toward GE raw materials, with 25.49% of producers stating that they are highly likely and likely to use such raw materials in production. In general, the frequencies suggest that respondents are not in favour of GM and GE raw materials. More than half of the surveyed producers (53.9%) indicated that they were highly unlikely to use GM raw materials in the future. By comparison, 29.41% of producers would be highly unlikely to use GE raw materials in the future. Based on the Wilcoxon Signed Rank test results, it can be stated that producers would be more inclined to use raw materials from GEO than from GMO in their future production. Producers' intentions differ statistically significantly (Z = -2.95, p = 0.03, GMO intention to use: Md = 4, GEO intention to use: Md = 3).
A comparative analysis of behavioural intentions was performed to determine whether consumers, farmers, and producers have similar perspectives on GMO and GEO's future use (purchasing intentions, intentions for use). Figure 3 illustrates the intentions of all study samples. The Wilcoxon test was used to check whether all respondents' intentions with regard to GMO and GEO were the same. Respondents' behavioural intentions concerning GMO (N = 292) and GEO (N = 291) were found to be statistically significantly different (Z = -2.037, p = 0.042, GMO and GEO intention to buy: Md = 3; mean ranks of GMO and GEO intentions are 33.17 and 32.12, respectively). Respondents were statistically significantly more favourable towards GEO than to GMO.

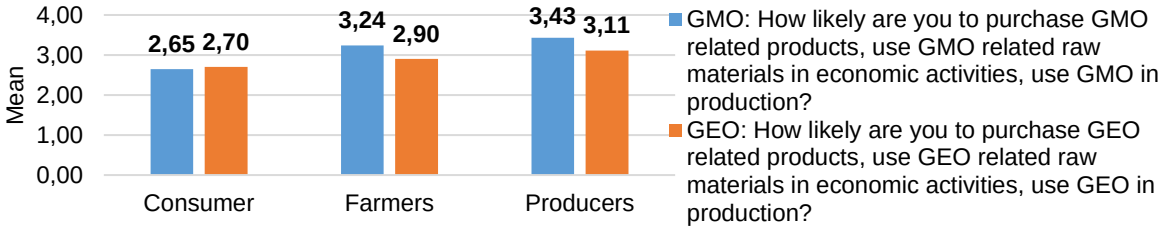

Figure 3: Mean values of behavioural intentions (1 – very likely, 2 – likely, 3 – unlikely, 4 – very unlikely)

The Kruskal Wallis test has shown that there are statistically significant differences between consumers, farmers and producers in terms of GMO intentions (consumers N = 197, farmers N = 48, producers N = 47, $Ç^2$(2, N = 291) = 36.81, p < 0.0005; consumers, farmers intentions: Md = 3, producers intentions: Md = 4; mean ranks, respectively: 127.11; 176.9; 196.72). Statistically significant differences are also found in the responses of individual groups of respondents to the intention to use GEO (consumers N = 197, farmers N = 43, producers N = 51, $Ç^2$ (2, N = 291) = 6.033, p = 0.049; consumers, farmers, producers intentions: Md = 3; mean ranks respectively: 138.21; 158.33; 165.72). The sample of producers revealed the lowest likelihood of using GMO and GEO. In comparison, consumers' sample showed the least unfavourable inclination in terms of intent to purchase GMO and GEO products.

4. Conclusions

The study revealed that both the self-assessed awareness and the level of support for the treatment of GMO and GEO products are low in all samples of subjects. Since market participants are less aware of GEO than GMO, their attitude toward GEO is slightly more favourable. The current study's findings are consistent with Shew et al. (2018), who discovered that consumers in the United States, Canada, Belgium, France, and Australia prefer GE foods to GM food. Similarly, food-related gene editing is viewed more favourably than a genetic modification in a sample of Canadian consumers (Yang and Hobbs, 2020). Although our results suggest that all groups' respondents knew more about GM than about GE products, contrarily, respondents were more willing to buy or use GE than GM food or raw material. Such inconsistencies may also imply an opportunity to overcome the scepticism about agricultural biotechnology. The relatively low familiarity and an absence of the prevailing negative stereotypes toward GE products create favourable starting conditions for market education. The efforts to increase consumers' awareness and understanding of biotechnology innovations' benefits may translate into higher acceptance and positive behavioural intentions. Consequently, the consumers' acceptance of GM and GE products is expected to have a spill over effect on producers' and farmers' behavioural intentions.

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