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ATTITUDES TOWARDS GENOME EDITING AMONG UNIVERSITY STUDENTS IN COSTA RICA

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Abstract

A survey was conducted to describe the level of knowledge about genome edition, attitudes regarding production and consumption of CRISPR products, and perceptions of benefits and risks among 1144 students of the University of Costa Rica. Regarding knowledge about gene editing via CRISPR/Cas9, 11.0% had heard or read a little, some (11.8%), or a lot (2.8%) about it. The students had a positive attitude toward the application of CRISPR/Cas9 for nature conservation (79.4%), healing diseases in animals (78.5%), healing diseases in humans (76.5%), and for crop improvement (72.0%). Perception of benefits and risks were similar among students in different areas of study.

Resumen

Se realizó una encuesta para describir el nivel de conocimiento sobre la edición del genoma, las actitudes con respecto a la producción y el consumo de productos CRISPR y las percepciones de beneficios y riesgos entre 1144 estudiantes de la Universidad de Costa Rica. Con respecto al conocimiento sobre la edición de genes a través de CRISPR/Cas9, el 11.0% había escuchado o leído un poco, algo (11.8%), o mucho (2.8%) al respecto. Los estudiantes tuvieron una actitud positiva hacia la aplicación de CRISPR/Cas9 para la conservación de la naturaleza (79.4%), enfermedades curativas en animales (78.5%), enfermedades curativas en humanos (76.5%) y para el mejoramiento de cultivos (72.0%). La percepción de beneficios y riesgos fue similar entre los estudiantes en diferentes áreas de estudio.

Key words: agricultural biotechnology, CRISPR/Cas9, genome editing, new breeding technologies, public perception.

Palabras clave: biotecnología agrícola, CRISPR/Cas9, edición de genomas, nuevas tecnologías de mejoramiento, percepción pública

I. INTRODUCTION

New plant breeding technologies (NPBTs) such as clustered regularly interspaced short palindromic repeats (CRISPR)-associated endonuclease Cas9 (CRISPR/Cas9) are being used to insert, delete, or modify specific genes at desired locations in the genome (Mishra, Joshi, & Zhao, 2018) (Uchiyama, Nagai, & Muto, 2018). The CRISPR/Cas9 technology is expected to revolutionize crop genetic improvement with important applications for increased yield and nutritional quality and for tolerance to biotic and abiotic stresses (Ricroch, Clairand, & Harwood, 2017).

However, new technologies can cause controversy and confusion among the general public and the CRISPR/Cas9 system is no exception. Factors related to complex public attitudes toward agricultural innovations include sociodemographic characteristics, knowledge of science, concerns about the environment, and perceptions of benefits and risks (Cui & Shoemaker, 2018). In the

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last 20 years, debate and discussion about the impact of plant biotechnology, specifically genetically modified organisms (GMOs), have caused concern among different sectors of society around the world (Cui & Shoemaker, 2018). Although CRISPR technology has important differences with respect to GM technology (Sharma, Kaur, & Singh, 2017), consumers may confuse the two and react negatively to CRISPR crops (Shew, Nalleya, Snella, Nayga, & Dixon, 2018). The perceptions of students, as members of society, on the development of biotechnology are important and could determine the successful acceptance of the applications in different areas (Tegegne, Aziz, Bhavsar, & Wiemers, 2013). Numerous studies have surveyed students' perceptions, attitudes and knowledge about biotechnology (Valdez, Rodríguez, & Sittenfeld, 2004) (Al-Khayri & Hassan, 2012) (Tegegne, Aziz, Bhavsar, & Wiemers, 2013) (Hekmat & Dawson, 2018). However, to the best of our knowledge, no surveys have focused on how CRISPR technology in agriculture is perceived among university students in developing countries. Therefore, the main objective of this survey was to investigate the degree of knowledge among university students about genome edition, their attitudes regarding production and consumption of genetically modified agricultural products, and their perceptions of benefits and risks. We also investigated the main reasons for rejection of scientific developments in this field, and reasons for negative attitudes towards the purchase and sale of this type of product.

II. MATERIALS AND METHODS

Survey

The study focused on the student population on the main campus "Rodrigo Facio" of the University of Costa Rica, specifically, on undergraduate and graduate students enrolled in at least one course in the first semester of 2018. The current survey was based on the questionnaire used in a nationwide residential telephone survey conducted by (Gatica-Arias, Valdez-Melara, Arrieta-Espinoza, Albertazzi-Castro, & Madrigal-Pana, 2019). Students enrolled in the course "Introduction to Sampling Surveys" in the Master Program in Statistics were in charge of data collection, digitalization, processing and preliminary analysis of the results. This group of students received training on the topic of genome editing using the CRISPR/Cas9 technology before starting fieldwork.

One-stage cluster sampling was used to select 70 groups systematically from a total of 5 837 groups opened in the first semester of 2018 (sampling frame provided by the Office of Registration and Records of the University of Costa Rica). All of the students in each selected group participated in the study. Considering the availability of the list of groups ordered by area of study, school and department, systematic selection was a very appropriate method for group selection and to obtain an approximately proportional sample (Kish, 1965). Data were collected during May of 2018. The survey was self-administered, and a total of 1 144 interviews were obtained, with a response rate of approximately 80%. An expansion factor was computed that included adjustments for non-response in each group and adjustments for the number of courses enrolled per student.

Statistical analysis

The correlation ratio eta (η) was used to determine non-linear associations between continuous and categorical variables. To analyze students' perceptions regarding benefits and risks, attitudes towards genome edition of agricultural products and attitudes towards consumption of products derived from gene-edited crops, four scales were created with values from 1 to 10, where 10 indicated a positive attitude or higher support. Exploratory factor analysis was used to validate the scales. A single dimension was expected for each scale (Bartholomew, 1980) and the Cronbach alpha coefficient was used to measure reliability (Cronbach, 1951), with expected values higher than 70%. Multiple linear regression (Kutner, Nachtsheim, Neter, & Li, 2005) was used to determine which factors influenced attitudes towards consumption of

genetically edited products. Data were analyzed using the statistical software SPSS V.19. (Corp., IBM, 2010).

III. RESULTS

Demographics

The majority of the students surveyed were women (56.3%). The average age of the respondents was 22.3 years old and 86.3% were under 25. Approximately half of the respondents were first or second year students. Concerning the field of studies, the majority of the students (41.0%) were from Social Science majors and 20.2% were majoring in Basic Sciences. The areas with fewer students were Arts and Letters (6.6%) and Agricultural and Food Sciences (3.2%). In terms of employment status, 79.9% of the students admitted to dedicate full-time to their studies and 50.2% admitted to be Catholic (Table 1).

TABLE 1. Student sociodemographic characteristics

Characteristics	Count	Percentage
Total	1 144	100.0
Gender		
Male	484	42.3
Female	644	56.3
NR	16	1.4
Age		
< 20	415	36.3
20 - 24	572	50.0
25 - 29	109	9.5
> 29	48	4.2
Year of university studies		
First-year	295	25.8
Second-year	290	25.3
Third-year	187	16.3
Fourth-year	295	25.8
Fifth-year	60	5.2
NR	17	1.5
Field of study		
Humanities	133	11.6
Arts and letters	75	6.6
Agriculture and Food Science	37	3.2
Basic Sciences	231	20.2
Social Sciences	469	41.0
Engineering	88	7.7
Health	111	9.7
Employment status		
Full-time student	914	79.9
Part-time employment	221	19.3
NR	9	0.8
Religion		
Catholic	574	50.2
Protestant	140	12.2
Other /non-religious	430	37.6

Knowledge about gene editing

The CRISPR/Cas9 technology for genome edition was not well known within the student population; 74.4% of the respondents had not read or heard about it, whereas 11% knew little about it, 11.8% were somewhat familiar and 2.8% were very familiar with the technique. Figure 1

shows the percent distribution of respondents who had heard or read about CRISPR/Cas9. More males than females had heard about this technique and students between 20 and 24 years old were less informed about CRISPR/Cas9 than respondents in other age groups. The percentage of students who had heard about genome editing using CRISPR/Cas9 was highest among Agricultural and Food Science majors, followed by students majoring in Arts and Letters, and Basic Sciences. The percentage of respondents who had heard about the technique was similar among Catholics and Protestant Christians, and a somewhat higher percentage of non-religious people (or people from other religions) knew about this topic.

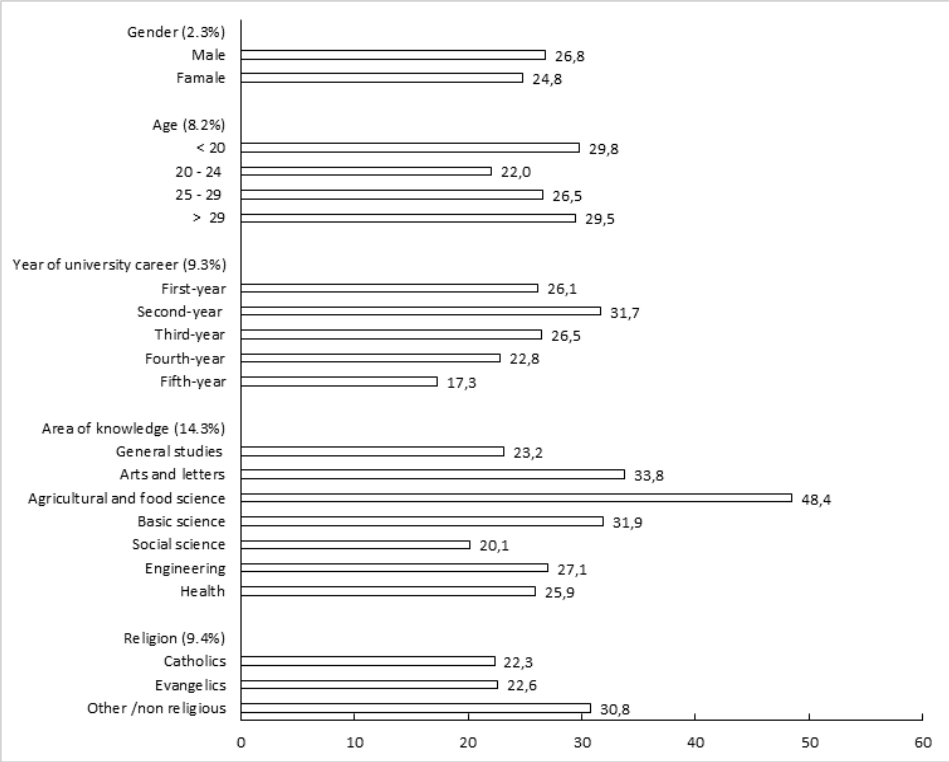

FIGURE 1. Percentage of respondents who had heard or read about genome edition using CRISPR/Cas9. The eta coefficient is given in parentheses.

The field of study was the factor with the greatest eta coefficient (14.3%), which indicated an association between the field of study and awareness of the CRISPR/Cas9 technology; however, this association was not strong. It is important to mention that since the majority of the students did not know about the genome edition technology, the students read a brief explanation before answering the survey questions: *"CRISPR/Cas9 gene editing is a new technology that allows the precise correction of gene fragments in humans, plants, or animals. This technique can be used for various purposes: from the improvement of crops to make them disease-resistant, improving their yield and nutritional quality, to studying and healing genetic disease in humans and animals."*

Attitudes towards genome editing using CRISPR/Cas9

In general, at least 70% of the students had a positive attitude (agree/strongly agree) towards the different applications of the CRISPR/Cas9 technology. The acceptance level was highest (79.4%) for genome edition for the conservation of nature (Figure 2).

There were no significant differences in the acceptance of different applications of genome editing by gender, age group or religion. However, an impressive result was that the Agricultural and Food Science majors were the least supportive of the use of this technique, especially for the purpose of curing human disease. Only 59.1% of the Agriculture and Food Science majors agreed

with the use of CRISPR/Cas9 for this purpose, compared with 87.6 of the Basic Science majors and 87.4% of the Health majors in favor of this application of the technique (Table 2).

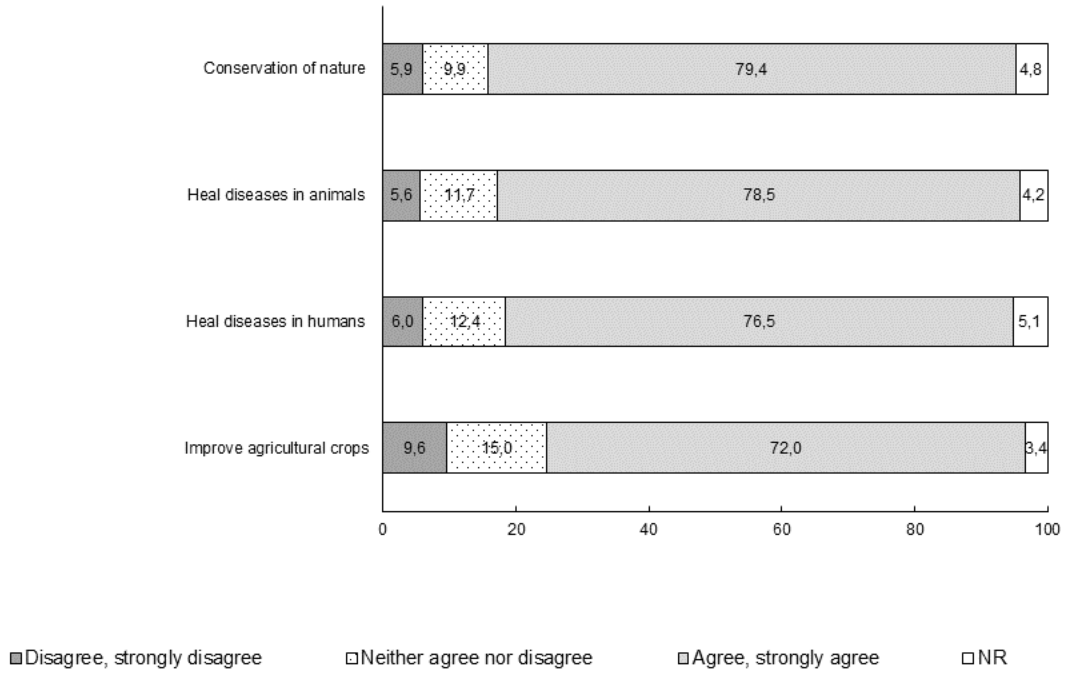

FIGURE 2. Percent distribution of the attitude toward the use of CRISPR/Cas9 technology for different purposes.

TABLE 2. Percentage of respondents who approved of the use of CRISPR / Cas9 technology for different purposes by field of study

Area	Conservation of nature	Cure animal diseases	Improve crops	Cure human diseases
Humanities	86.7	83.8	76.0	85.8
Arts & Letters	79.6	67.9	67.0	75.4
Agriculture and Food Science	69.3	73.1	71.2	59.1
Basic Sciences	89.2	87.9	80.9	87.6
Social Sciences	84.4	84.0	74.6	81.3
Engineering	73.3	74.0	66.7	66.6
Health	83.5	85.3	80.6	87.4
Eta	13.4%	15.5%	10.8%	17.9%

A scale was constructed to measure students' attitudes towards genome edition. It included values from 1 to 10, with 10 indicating a positive attitude or support for genome edition. This scale was used later in the regression model. It is important to mention that the scale was unidimensional and the reliability measure satisfied the expected requirements (Cronbach´s alpha 87.8%).

Perception of benefits and risks

In the scope of the benefits, more than 60% of the students agreed that gene edition in agricultural products could increase crop production in Costa Rica. Approximately 45% of the

respondents agreed that this technology could improve the Costa Rican economy as well as improve the nutritional quality of food.

Students agreed that CRISPR foods would increase crop production in the country (62.1%), and bring benefits to their families (37.2%) and to the environment (36.1%). On the other hand, 22.3% of the students responded that gene edition of agricultural products would not be morally acceptable. Nevertheless, a high percentage of respondents answered "neither agree nor disagree" or did not respond (NR) to statements regarding perceived benefits (Table 3).

TABLE 3. Level of agreement about benefits of genome edition in agricultural products (Percentage distribution)

Benefits	Level of agreement			
	Disagree	Neither agree nor disagree	Agree	NR
Would improve the Costa Rican economy	10.6	32.5	46.0	10.8
Would benefit you and your family	13.5	39.5	37.2	9.8
Would increase crop production in Costa Rica	9.1	20.4	62.1	8.3
Would benefit the Costa Rican environment	18.6	34.0	36.1	11.3
Would improve the nutritional quality of food in Costa Rica	16.0	31.1	43.4	9.6
Consumption will be morally acceptable to Costa Ricans	22.3	33.4	34.3	9.9

Concerning perceived risks, students commonly selected answers in the middle range ("low" or "medium" risk), but not the extremes of "high" or "no risk". More than 40% of students responded that there was no risk or low risk that genetically edited products would affect their families' quality of life (Table 4). On the other hand, more than half of the respondents believed that these products would affect human health (62.4% medium or high risk), have a negative impact on the health of their descendants (54.9% medium or high risk) or cause environmental damage in the country (63.5% medium or high risk). As with the questions regarding benefits, a considerable percentage of students did not respond.

Table 4. Perception of risk of genome edition in agricultural products (Percentage distribution)

Risks	Level of perceived risk				
	No risk	Low	Medium	High	NR
These products would affect the health of Costa Ricans	5.2	20.1	47.8	14.6	12.2
These products would cause environmental damage to the country	3.3	22.2	43.0	20.5	11.0
These products would affect your family's quality of life	10.8	31.8	35.1	8.9	13.3
These products would have negative effects on the health of your descendants	6.4	22.6	36.1	18.8	16.1

Students' perceptions of both risks and benefits were very similar. In general, on a scale of 1 to 10, respondents rated both risks and benefits in the medium range (Table 5). Risks were perceived to be lower by students of Agricultural and Food Science than by students in the other areas of knowledge. Responses of students in other areas were very similar, with results between 5.6 and 6.2. In the case of benefits, results were very similar across all areas of knowledge, except for the engineering students who gave the lowest response (5.2). For both scales, the association between field of knowledge and perception of risks and benefits was not strong.

TABLE 5. Perception of benefits and risks by area of study. (Scale of 1 to 10, where 10 means a high or positive perception and 1 means a low or negative perception)

Area of knowledge	Benefits	Risks
Humanities	5.9	5.8
Arts and Letters	6.5	6.2
Agricultural and Food Science	6.4	3.8
Basic Sciences	6.3	5.6
Social Sciences	6.0	6.0
Engineering	5.2	6.2
Health	6.0	5.8
Mean (Standard deviation)	6.0 (1.92)	5.9 (2.14)
Eta coefficient	14.9%	20.4%
Cronbach´s alpha	88.7%	85.5%

Pearson coefficient between scales -5.10 ($p<0.05$). The unidimensional of the scales was corroborated

Attitude towards consumption of genetically edited agricultural products

Figure 3 shows cases in which students would buy a genetically edited agricultural product. Respondents were most likely to buy genetically edited products if they were nutritionally superior to conventional products (77.1% would buy in this case). The price of the product was an essential factor in deciding whether to buy a conventional or edited product; 60.4% of the respondents would consume edited products if they were less expensive than conventional ones, but if the price were equal, the percentage of possible consumers decreased to 46.5%.

When asked about traditional food products of the Costa Rican diet, such as rice and beans, the majority responded that they would not buy genetically edited rice (46.0%) or beans (45.8%) if conventional products were sold at the same price (Figure 3). There were no important differences in attitude towards consumption by gender, year of study, religion or area of study. However, there were differences between age groups. Younger students (less than 20 years old) were more likely to consume genetically edited products. For example, if genetically edited agricultural products were available in the market, 75.8% of students under 20 years old would consume them, in comparison with 38.9% of students older than 29 years. The same pattern was seen when students were asked if they would consume genetically edited products if they had better nutritional quality or if they were less expensive than conventional products. When asked if they would buy a kilogram of genetically edited rice or beans at the same price as traditional rice or beans, responses did not differ greatly between age groups (Table 6).

A scale was constructed to measure students' attitudes towards consumption of genetically edited agricultural products, where 1 represented a negative attitude and 10 a positive attitude towards consumption. The scale was used to rate six scenarios in which students would or would not consume genetically modified products (for example if the products were available in the national market, if they were nutritionally superior to conventional products, or if they were less expensive than traditional products). The unidimensional of the scale was confirmed and the measure of reliability satisfied the expected requirements (Cronbach´s alpha 90.1%).

Factors that influence attitudes toward consumption

Multiple regression was used to evaluate the influence of different factors on students' attitudes towards consumption of genetically edited agricultural products. Attitude towards consumption was the dependent variable, and gender, age group, year of study, area of knowledge, and religion were used as independent variables. Scales for rating perception of benefits, risks, and general attitude towards genome edition were also added to the model. Age group was a determining factor affecting attitude towards consumption of genetically edited products (Table 7). Younger people had a more positive attitude than older groups (under 20 years of age: 69.1; 20-24 years: 62.2; 25-29 years: 57.1; and over 29 years old: 43.6%). Perception of benefits, risks, and attitude in general toward the techniques also influenced attitudes towards consumption (p-value < 0.05). The other variables such as gender and field of study did not have a significant impact on attitude towards consumption. For this model, assumptions regarding the normality of the residues, homoscedasticity, collinearity and goodness of fit were validated. Additionally, the goodness of fit (adjusted R^2 = 48.5%) indicated that the variables used in the model explained the variance in attitude towards consumption in a moderate way.

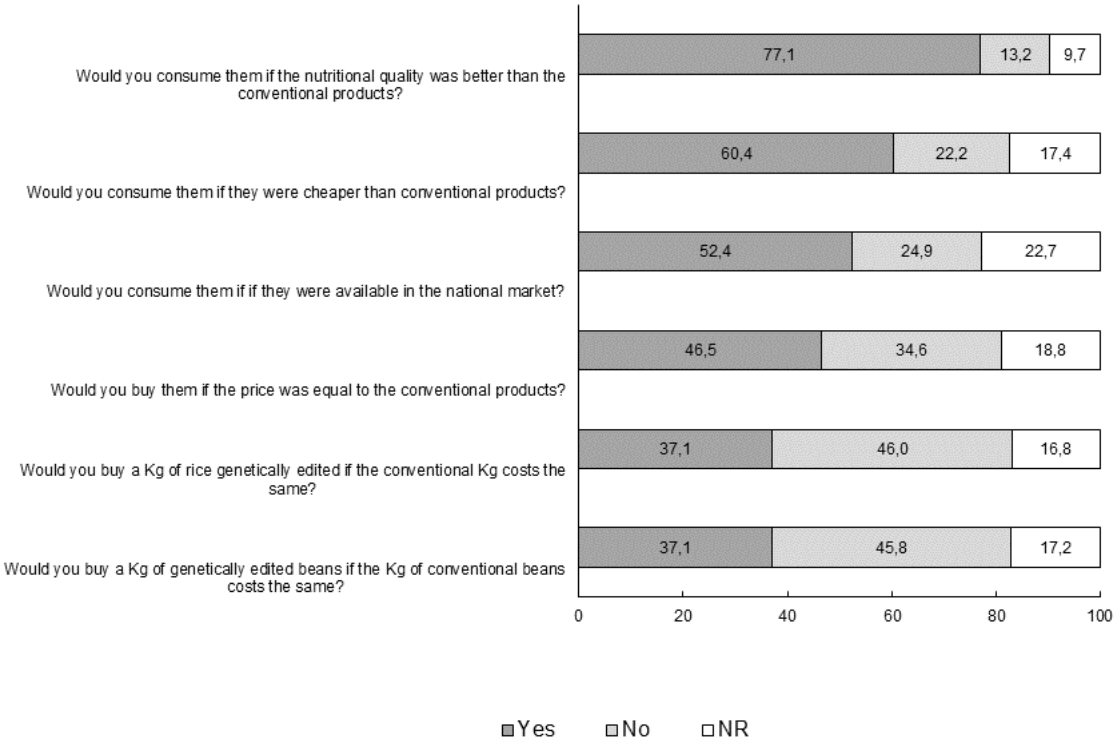

FIGURE 3. Percent distribution of the attitude towards consumption of genetically edited agricultural products.

TABLE 6. Percentage of respondents who would consume genetically edited agricultural products in different scenarios by age group

Scenarios of consumption	Age Group				Eta
	< 20	20 - 24	25 - 29	29 >	
If they were available in the national market	75.8	67.6	63.3	38.9	18.7
If they were nutritionally superior to conventional products	91.2	86.2	75.2	65.8	19.0
If they were cheaper than conventional products	81.3	71.0	65.1	63.6	13.9
If the price were equal to that of conventional products	62.3	58.2	47.3	47.6	10.7
I would buy a Kg of genetically edited beans if a Kg of conventional beans cost the same	48.4	44.8	38.9	39.1	6.8
I would buy a Kg of genetically edited rice if a Kg of conventional rice cost the same	49.4	44.1	38.3	39.1	7.9

TABLE 7. Multiple regression using attitude towards the consumption of genetically edited agricultural products as a dependent variable

	Independent variables	Unstandardized coefficients		Standardized coefficients	t	Sig.	95% Confidence interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
	(Constant)	-7.1	17.1		-0.4	0.6	-40.8	26.4
Sex	Male	-3.1	2.4	-0.0	-1.2	0.2	-7.9	1.6
Age	20-24	1.2	0.4	0.1	3.1	0.002	0.4	2.1
	25-29	1.5	0.6	0.0	2.4	0.015	0.2	2.7
	over 29	3.1	0.9	0.1	3.3	0.001	1.3	4.9
Year of university studies	Second year	0.6	3.5	0.0	0.1	0.8	-6.3	7.5
	Third year	4.8	4.5	0.0	1.1	0.2	-4.0	13.8
	Fourth year	3.0	4.5	0.0	0.6	0.5	-5.9	11.9
	Fifth year	8.8	6.6	0.05	1.3	0.1	-4.2	21.9
Religion	Protestant	-2.2	3.8	-0.018	-0.5	0.5	-9.8	5.3
	Other/non-religious	-0.0	2.5	-0.001	-0.02	0.9	-5.0	4.8
Field of study	Humanities	0.9	7.8	0.01	0.1	0.9	-14.3	16.3
	Arts and Letters	4.8	8.8	0.02	0.5	0.5	-12.4	22.1
	Basic Sciences	0.7	7.2	0.01	0.1	0.9	-13.4	14.8
	Social Sciences	1.4	6.8	0.02	0.2	0.8	-11.8	14.8
	Engineering	8.4	7.7	0.05	1.0	0.2	-6.8	23.6
	Health	2.9	7.4	0.02	0.3	0.6	-11.7	17.5
	Benefits	6.5	0.7	0.3	8.5	0.0	5.04	8.0
	Risks	-5.4	0.6	-0.3	-8.5	0.0	-6.7	-4.2
	Attitude toward editing	2.1	0.6	0.1	3.2	0.0	0.8	3.5

a. dependent variable: attitude toward consumption
Note: R = 70.9%; adjusted R^2= 48.5%

IV. DISCUSSION

This survey was part of a larger study about the knowledge of and attitudes towards genome edition of agricultural products in Costa Rica. Previously, a nationwide residential telephone survey was conducted in a study population of Costa Rican adults, 18 years or older, who were residents of private homes with a landline phone (Gatica-Arias, Valdez-Melara, Arrieta-Espinoza, Albertazzi-Castro, & Madrigal-Pana, 2019). Understanding students' perceptions regarding CRISPR agricultural products and their possible benefits and risks to health, the economy and the environment is fundamental in order to identify elements that could promote consumption of these products in the future and to develop an effective communication and education strategy.

Public perceptions about biotechnology applications are related to knowledge and understanding of fundamental concepts (Tegegne, Aziz, Bhavsar, & Wiemers, 2013). Regarding knowledge about gene editing via CRISPR/Cas9, 25.6% of Costa Rican university students had heard or read about the topic. In contrast, a nationwide residential telephone survey demonstrated that only 3.7% of the interviewees had knowledge about this technology (Gatica-Arias, Valdez-Melara, Arrieta-Espinoza, Albertazzi-Castro, & Madrigal-Pana, 2019). Similarly, the percentage of patients in Japan who had heard about genome editing (11.5%) was higher than the corresponding percentage in the general adult population (6.6%) (Uchiyama, Nagai, & Muto, 2018). This result indicated that university students in Costa Rica might be more aware than the general adult population. This finding was expected, as university students may be more informed and interested about gene editing since this topic is included in the curriculum of different areas of study. (Finke & Kim, 2003) also indicated that students may be more aware of agriculture biotechnology than the general population. This awareness may be acquired though science-based coursework, laboratory work, and interactions with professors and instructors (Laux, Mosher, & Freeman, 2010). Nevertheless, a better understanding of genome editing can be achieved through curriculum revision, dissemination of knowledge from scientific studies through public discussions with scientists and effective communication through media sources.

Our results demonstrated differences in the level of knowledge about gene editing via CRISPR/Cas9 among students in different areas of study. The percentage of students who had heard about genome editing using CRISPR/Cas9 was highest among Agricultural and Food Science majors. Differences in the degree of knowledge about biotechnology have also been detected between students in the social and biological sciences in United States of America (Tegegne, Aziz, Bhavsar, & Wiemers, 2013).

Students represent a subpopulation of the general public and their opinions concerning genetically modified food are of interest (Laux, Mosher, & Freeman, 2010). In our study, students had a positive attitude toward the application of CRISPR/Cas9 for nature conservation (79.4%), healing diseases in animals (78.5%), healing human diseases (76.5%), and for crop improvement (72.0%). These results are in accordance with the positive attitude toward CRISPR technology among the Costa Rican general population (Gatica-Arias, Valdez-Melara, Arrieta-Espinoza, Albertazzi-Castro, & Madrigal-Pana, 2019) and with results of an earlier survey which showed that the majority of university students in Costa Rica believed that biotechnology would improve the quality of life for humanity (Valdez, Rodríguez, & Sittenfeld, 2004). Similarly, university students in Turkey showed supportive attitudes toward the use of GMO and genetic engineering in agro industry, human medicine and decomposition of human sewage (Öztürk-Akar, 2016).

Attitudes toward benefits and risks, and ethical concerns can affect public acceptance of the applications of biotechnology (Frewer, y otros, 2013) (McFadden & Smyth, 2018). In our study, university students agreed that CRISPR foods would increase crop production in the country, improve the economy and bring benefits to their families and to the environment. Interestingly, the awareness of benefits among students from the University of Costa Rica was lower than that reported for the general population (Gatica-Arias, Valdez-Melara, Arrieta-

Espinoza, Albertazzi-Castro, & Madrigal-Pana, 2019). A possible explanation is that a high percentage of students answered "neither agree nor disagree" or did not respond to statements regarding benefits. This finding could allow us to infer that the university students had less information about potential benefits of this technology. Potential benefits of genome editing in plants and animals in agriculture include improvement of crop yield and nutritional quality, resistance to biotic and abiotic stress, and improvement of livestock health, welfare, and productivity. Potential benefits to human health, according to a panel of international experts, include understanding diseases, discovering and developing new drugs, and treating genetic disorders (Fears & ter Meulen).

Potential risks associated with agricultural innovations such as GM and CRISPR technology may include unintended and undesirable health or environmental side effects (Lassoued, Smyth, Phillips, & Hesseln, 2018). In our study, less than half of the respondents perceived no or low risk that genetically edited products would affect their quality of life, while more than half of the university students believed that these products would affect human health, have a negative impact on the health of their descendants or cause environmental damage. In contrast, in a prior study (Gatica-Arias, Valdez-Melara, Arrieta-Espinoza, Albertazzi-Castro, & Madrigal-Pana, 2019) nearly half of the interviewees perceived low or no risk to the quality of life, health, and environment.

Our results showed that perceptions of benefits and risks were similar among university students in different scientific and non-scientific areas of study. This is in line with other results showing that the percentage of scientists and non-scientists in North America (Canada and United States), Europe, and the rest of the world (Asia, Africa, Oceania, Central and South America) who perceived benefits of NPBTs differently. Both the risks and the benefits were perceived in a greater percentage by the scientist experts (Lassoued, Smyth, Phillips, & Hesseln, 2018). As mentioned by (Öztürk-Akar, 2016), differences between science and non-science students regarding knowledge of and attitudes toward scientific and technological issues are principally due to the manner in which these topics are presented.

For scientists currently working on genome edition, as well as for producers and sellers of agricultural products, it is vital to know what students think about the possibility of acquiring these products. This information can be used to better inform this subpopulation about these products, and to understand the possible scenarios in which students would accept or reject genetically edited products. In our study, a higher percentage of students would consume CRISPR foods if the nutritional quality were better, if they were cheaper than conventional products, and if they were available in the national market. This is in line with other results showing that a high percentage of the general population in Costa Rica would consume CRISPR foods if the price were lower than that of conventional products (Gatica-Arias, Valdez-Melara, Arrieta-Espinoza, Albertazzi-Castro, & Madrigal-Pana, 2019).

Finally, several studies have been conducted on attitudes toward genome editing among the general public, but to the best of our knowledge, no surveys have focused on how CRISPR technology in agriculture is perceived among university students. The population chosen in this study was drawn from a single university and may not be representative of Costa Rican university students in general. Therefore, it is recommended that future research include multiple universities in order to understand students' knowledge of and opinions on the topic of genome editing.

V. CONCLUSIONS

Few students had heard or read about CRISPR/Cas9 technology and most of those who had were students of the Basic Sciences, Social Sciences or Agri-Food Sciences. When asked their opinions about genome editing, most of the interviewees agreed with its use for nature conservation and to cure diseases in animals. A slightly smaller percentage approved the use of this technology to cure human disease and to improve agricultural crops. University students were cautious when commenting on the benefits of genome

editing. The benefit that was perceived by more students was the increase in crop production in the country. Students also considered that genome editing could improve the Costa Rican economy and improve the nutritional quality of food. On the other hand, an important percentage believed that consumption of foods produced using these technologies would not be morally acceptable to Costa Ricans, and some did not believe that this technology would be beneficial for the environment. The environmental issue stands out because the greatest risks perceived by the students were to the environment and to the health of Costa Ricans and their descendants. Although results were similar among students in different areas of study, students of Basic Sciences and Health perceived greater benefits of genome edition, while students of Engineering and Arts and Letters perceived greater risks. An interesting aspect regarding attitudes toward consumption of genetically-edited products was that the majority affirmed that they would consume these products if they were of better nutritional quality or if they were cheaper than traditional ones. However, if the price of basic foods such as rice and beans were the same, students would prefer conventional products over genetically modified foods. The group of "concerned" students or those pessimistic towards this technology would not consume genetically modified foods even if they were of better nutritional quality than conventional products.

VI. REFERENCES

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