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ORIGINAL ARTICLE

Consumer attitudes toward food crops developed by CRISPR/Cas9 in Costa Rica

Andrés Gatica-Arias[1,2] · Marta Valdez-Melara[1] · Griselda Arrieta-Espinoza[2] · Federico J. Albertazzi-Castro[2] · Johnny Madrigal-Pana[3]

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Abstract

Clustered regularly interspaced short palindromic repeats (CRISPR) technology has been used to confer crop resistance to biotic and abiotic stresses and to improve crop yields and nutritional quality. However, lack of consumer acceptance could potentially restrict the development and further commercialization of CRISPR crops. Therefore, a survey among 1018 adults in Costa Rica was conducted to analyze perceptions and attitudes toward the production and potential consumption of CRISPR/Cas9 crops. Regarding knowledge of gene editing via CRISPR/Cas9, 3.7% of the interviewees had heard or read a little (1.9%), some (1.2%), or a lot (0.6%) about the topic. In general, a high percentage of Costa Rican consumers would accept the use of gene editing for nature conservation (84.5%), curing diseases in animals (83.0%), crop improvement (80.9%) and curing human diseases (80.2%). Regarding potential benefits, interviewees agreed that CRISPR foods would increase crop production in the country (66.0%), improve the economy (63.7%), and bring benefits to their families (60.7%) and the environment (57.4%). Nearly half of the interviewees perceived low or no risk to the quality of life, health, and environment. A higher percentage would consume CRISPR foods if the nutritional quality were better (70.8%), if they were cheaper than conventional products (61.0%), and if they were available in the national market (59.4%). Finally, approximately half of the interviewees would be willing to purchase a kilo of rice or beans (traditional Costa Rican food products) if they were priced the same as conventional products.

Key message

Our survey among Costa Rica adults showed a little knowledge about gene editing via CRISPR/Cas9. Nevertheless, a high percentage of consumers would accept the use of gene editing for different purposes, and agree that CRISPR foods could bring potential benefits for crop production the economy, and the environment.

Keywords Genome editing · Agricultural biotechnology · New breeding technologies · CRISPR/Cas9 · Public perception

Introduction

The emergence of new plant breeding technologies (NPBTs) is revolutionizing plant biology and crop improvement (Liu et al. 2017; Yin et al. 2017; Mishra and Zhao 2018). Among these new technologies, clustered regularly interspaced short palindromic repeats (CRISPR)-associated endonuclease Cas9 (CRISPR/Cas9) is the most commonly used gene editing technique. CRISPR uses engineered nucleases (ENs) to generate double-stranded breaks (DSBs) in specific genes at desired locations in the genome. These DSBs then are repaired by either non-homologous end joining (NHEJ) or homologous recombination (HR) causing the insertion, deletion, or modification of DNA with increased specificity

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✉ Andrés Gatica-Arias
andres.gatica@ucr.ac.cr

[1] Laboratory of Plant Biotechnology, School of Biology, University of Costa Rica, San José, Costa Rica

[2] Research Center in Cellular and Molecular Biology (CIBCM), University of Costa Rica, San José, Costa Rica

[3] School of Statistics, University of Costa Rica, San José, Costa Rica

and efficiency (Mishra et al. 2018; Uchiyama et al. 2018). Detailed overviews of genome editing tools and mechanisms of action have been compiled by Mishra and Zhao (2018) and Modrzejewski et al. (2018a).

Since the first reports of applications of CRISPR/Cas9 in *Arabidopsis thaliana*, *Nicotiana benthamiana* and *Oryza sativa*, the number of published studies on CRISPR/Cas9 has increased from 30 in 2013 to more than 200 in May of 2018 (Zhang et al. 2017; Modrzejewski et al. 2018b). The main applications of CRISPR genome editing in agriculture are for crop yield improvement, biofortification, and biotic and abiotic stress tolerance (Ricroch et al. 2017). The main crop that has been studied using this new genome editing technology is rice (*O. sativa*), followed by other important crops such as maize (*Zea mays*), tomato (*Solanum lycopersicum*), potato (*S. tuberosum*), barley (*Hordeum vulgare*) and wheat (*Triticum aestivum*). Most of the research has come from China, followed by the USA, Europe, Japan, and Israel (Ricroch et al. 2017). A detailed overview of genome editing applications in plants has been compiled by Jung et al. (2018).

The CRISPR/Cas9 system is becoming an important tool for crop genetic improvement to counteract the impacts of climate change and ensure future food security in developing countries (Georges and Ray 2017; Haque et al. 2018). However, will consumers accept food crops developed using genome editing technologies? Since, advances in science and technology, including NPBTs, are influenced by public opinion and cause discussion among consumers (Malyska et al. 2016); the application of gene editing techniques like CRISPR/Cas9 could cause enthusiasm or reluctance in different sectors of the population, and could lead to controversy over the possible production and marketing of these types of agricultural products (Ishii and Araki 2016). For these reasons, understanding consumers' attitudes toward food products is a challenging task (Pranav et al. 2015; Zhang et al. 2016). This paper describes the perceptions and attitudes of the Costa Rican population toward the production and consumption of genetically edited crops, specifically those developed using CRISPR/Cas9 technology.

Materials and methods

Questionnaire development

A structured questionnaire consisting of 57 questions was developed to register respondents' socio demographic background, knowledge on genome editing (GE), consumer attitudes, confidence, and perception of benefits and risks regarding GE. The instrument was tested with 21 preliminary interviews in February 2018 and further refined into the final survey. The questionnaire and the resulting database for the statistical analyses are in Spanish and are not publicly available, but can be made available from the corresponding author on reasonable request.

Survey

Telephone interviews were conducted between February 2018 and April 2018 between 17:00 and 21:00 in a study population of people 18 years old or older who were residents of private homes with a landline phone. This type of housing represents 40% of the registered houses in Costa Rica, according to the National Housing Survey 2017 (ENAHO-2017, acronym in Spanish) carried out by the National Institute of Statistics and Census of Costa Rica. For this reason, it is important to point out, that even though the survey did not cover the entire population of the country it includes residents of all the provinces. Randomly generated telephone numbers were screened for active area codes in the telephone data base of the Costa Rican Electricity Institute using the Wasksberg technique (Waksberg 1978). In case of no response to the first attempt of the call, it was made up to 4 times in different days and times than the first call. The country was stratified in three zones. The number of telephone numbers selected per zone was proportional to the number of inhabitants: 55% in the Metropolitan region (urban area of San José, Alajuela, Heredia, and Cartago provinces), 25% in the Central Valley outside the Metropolitan Region (rural areas of San José, Alajuela, Heredia, and Cartago provinces) and 20% in the rest of the country (Guanacaste, Limón, and Puntarenas provinces). For each phone number selected, a resident of the household who was 18 years old or older was chosen at random using the Next-Birthday Method of Respondent Selection (Salmon and Nichols 1983). The obtained sample included 1018 persons, which corresponded to a response rate of 80%. Due to non-response, the sample was adjusted so that the distribution by sex, age, and educational level of the 18 years-old or older population of residents of homes with landline phones coincided with the distribution reported by the ENAHO-2017. A CATI (Computer-Assisted Telephone Interviewing) system was used to register information directly onto computers.

Statistical analysis

Exploratory factor analysis was used to determine the number of dimensions in the set of questions asked and to sum them up in scales (Bartholomew et al. 2002). The number of dimensions was established by the characteristic values (eigenvalues) that registered an explained variance higher than 10%. Given that there were four to six questions per topic, a single factor was expected for each set of questions. To test the reliability of the scales, Cronbach's Alpha tool (Cronbach 1951) was used, and reliabilities higher than 70% were expected. Cluster analysis, specifically the k-means

procedure (Dillon and Goldstein 1984), was used to classify respondents in three categories according to their attitudes toward consumption of genetically edited foods: negative, medium, and positive. The classification was designed to have the least possible variability within the constructed groups, and the highest possible variability between groups, so that each group was homogeneous. The objective of this procedure was to quantify attitudes toward the topic. Finally, multiple linear regression (Kutner et al. 2005) was used, in which the dependent variable was the attitude toward consumption of genetically edited foods and the independent variables were the six socio-demographic characteristics (sex, age, education, subjective income, religion, and zone of residence), the attitude toward the use of genetic editing for different purposes, and the perceptions of risks and benefits of consuming these products.

Results

Demographics

A higher percentage of respondents were women (53.3% women and 46.7% men). The age distribution was as follows: 50.2% of the interviewees were 50 years or older, 20.2% were 18 to 29 years old and 29.6% were 30 to 49 years old. Approximately one third of the population was represented at each educational level. Family income was subjectively measured through money saving ability; 27.9% of the interviewees had some or many difficulties for saving, 41.0% had no difficulties and 25.1% were able to save money. In terms of religion, 73.0% of the interviewees were Catholic, 14.6% were evangelical Christians, and 12.4% followed another religion or no religion. The distribution by area showed that 52.9% of the interviewees lived in the Metropolitan Region, 25.9% lived in the Central Valley outside of the Metropolitan Region, and 21.2% lived in the rest of the country (Table 1).

Table 1 Demographic characteristics of Costa Rican interviewees

	No.	%
Total	1018	100.0
Sex		
Male	476	46.7
Female	542	53.3
Age		
18–29	206	20.2
30–49	301	29.6
50 and over	511	50.2
Education		
Elementary school or less	338	33.2
High school	333	32.7
University	347	34.0
Subjective income		
Have great difficulties	57	5.6
Have difficulties	284	27.9
Have no difficulties	417	41.0
Can save	255	25.1
Not sure/no response	5	0.5
Religion		
Catholic	743	73.0
Evangelic	148	14.6
Other/no religion	126	12.4
Geographic zone		
Metropolitan region	538	52.9
Rest of the central valley	263	25.9
Rest of the country	215	21.2

Knowledge about gene editing

When asked "How much have you heard or read about gene editing via CRISPR/Cas9?", 3.7% of the interviewees responded that they had heard or read a little (1.9%), some (1.2%), or a lot (0.6%), whereas 96.3% had heard or read nothing about genome editing (data not shown). Knowledge of gene editing was not associated with socio-demographic characteristics, with the exception of education and subjective income. With higher levels of education and income, the percentage of respondents who had heard or read about the topic increased. Up to 6.7% of the consumers having university education knows about GE compare to 3.4% and 0.8% of the ones with high school and elementary or less education level showed by an association coefficient of 12.9%. In the case of subjective income, 5.7% of the interviewees who were able to save money, have knowledge about GE with an association of 8.3% compare to the others (Fig. 1).

Regardless of previous knowledge about the topic, all interviewees were then given the following statement: *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, or to improve yield and nutritional quality, to studying and healing genetic disease in humans and animals."* Afterwards, they were asked if they had any questions about the topic, if they needed to hear the description of gene editing again, or if they needed any clarifications. Once this statement was given, the interviewees continued with the survey.

Attitude toward gene editing

The respondents were asked "What do you think about the use of this technology for the conservation of nature, for curing diseases in animals, for improving agricultural crops, and for curing diseases in humans?" Responses showed high

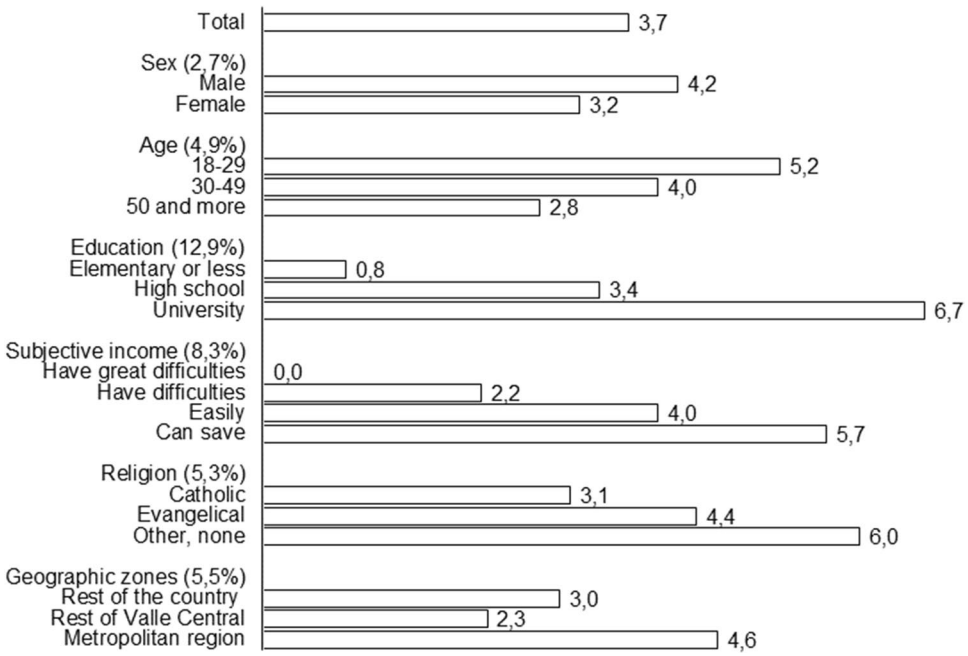

Fig. 1 Percentage of Costa Rican consumers who had heard or read about CRISPR/Cas9 genome editing according to sex, age, education level, subjective income, religion affiliation, and geographic zone. Eta association coefficient is shown in parentheses

acceptance of the use of gene editing for nature conservation (84.5% agreed or highly agreed) and for curing diseases in animals (83.0% agreed or highly agreed). A high percentage also agreed or highly agreed with gene edition for crop improvement (80.9%) and for curing disease in humans (80.2%) (Fig. 2).

Perceived benefits of genome editing

Interviewees were informed that genetically edited foods are not yet produced or marketed in Costa Rica. Respondents were then asked "Do you agree, strongly agree, disagree or strongly disagree, that if the products were available in

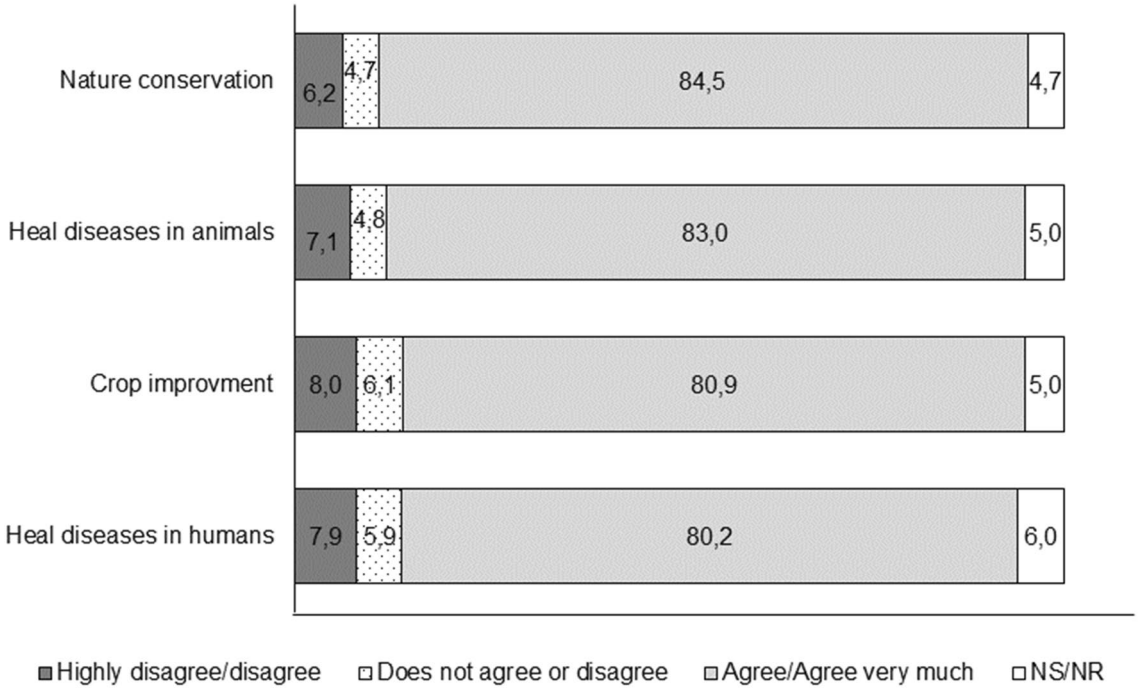

Fig. 2 Attitude of Costa Rican consumers toward the use of CRISPR/Cas9 technology for nature conservation, curing disease in animals, crop improvement, and curing diseases in humans. The numbers represent the percentage distribution

the country, they would increase crop production in Costa Rica, improve the Costa Rican economy, bring benefits for you and your family, improve the nutritional quality of food in Costa Rica, bring benefits to the Costa Rican environment, and their consumption would be morally acceptable to Costa Ricans?" The majority of the respondents agreed or highly agreed that genetically edited foods would increase crop production in the country (66.0%), improve the economy (63.7%), and bring benefits to the family (60.7%) and the environment (57.4%). A smaller percentage (47.0%) agreed that consumption of genetically edited foods would be morally acceptable to Costa Ricans (Fig. 3). The question regarding whether consumption of genetically edited foods would be morally acceptable received the highest number of negative responses (20% disagreed) and 15.2% of respondents were undecided or did not respond.

Perceived risks of genome editing

After being informed that genetically edited foods are not yet produced or marketed in Costa Rica, the interviewees were asked "would you say that the risk would be high, low or that there is no risk that these agricultural products will affect the quality of life of your family, have negative effects on the health of Costa Ricans or their descendants, or produce environmental damage to the country?" The perception of risk was similar for the different alternatives. Nearly half of the study population perceived low or no risk to the quality of life, health, and environment, while over one third of the respondents perceived a medium or high risk. Nearly 15% did not know or did not respond (Fig. 4).

Consumer attitudes toward genome editing

Questions about consumer attitudes toward the possible consumption of genetically edited foods were asked in terms of nutritional quality and cost. Interviewees were asked "Although there are no genetically edited agricultural products in the country, would you consume them if they were of better nutritional quality or if they were cheaper than conventional products?" A high percentage responded that they would consume genetically edited foods if the nutritional quality were higher (70.8%) and if they were cheaper than conventional products (61.0%) (Fig. 5).

Moreover, when asked "would you consume genetically edited agricultural products if they were available in the national market?", 59.4% responded positively (Fig. 5).

Finally, respondents were asked "would you consume genetically edited agricultural products if the price were equal to that of conventional products, and would you buy a kilo of genetically edited beans or rice if the conventional product cost the same?" Although 61.0% would consume

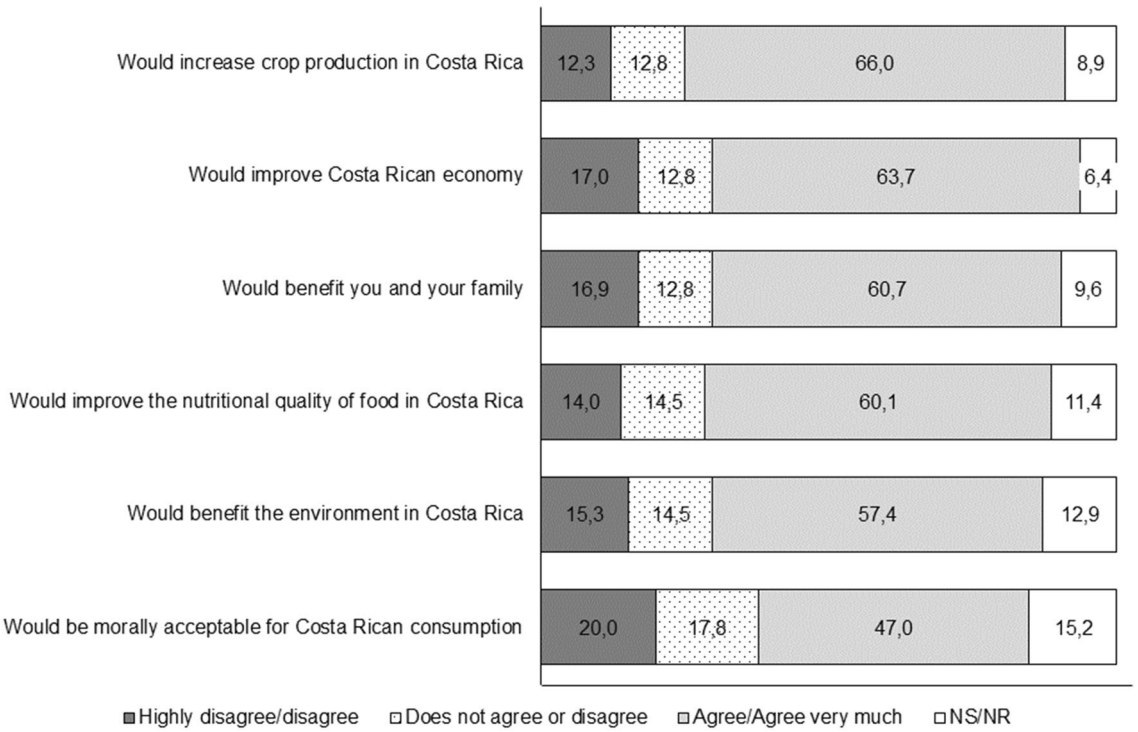

Fig. 3 Consumer perception of potential benefits of genetically edited food if it were produced or marketed in Costa Rica. The numbers represent the percentage distribution

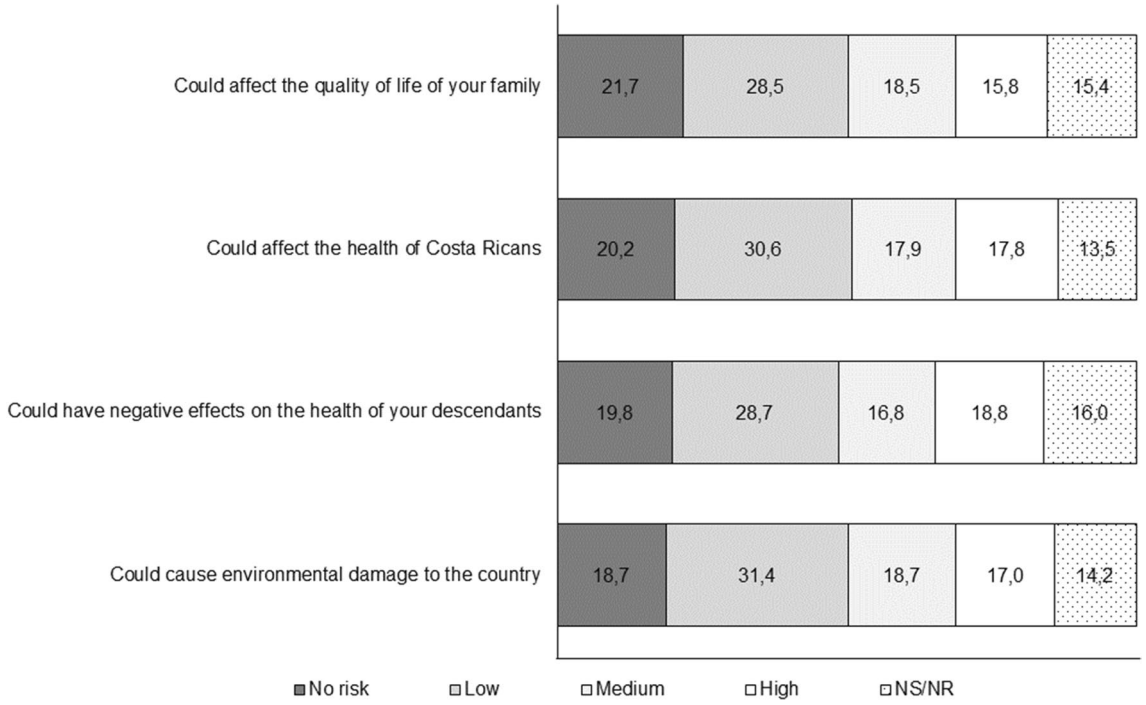

Fig. 4 Consumer perception of risks of genetically edited food if it were produced or marketed in Costa Rica. The numbers represent the percentage distribution

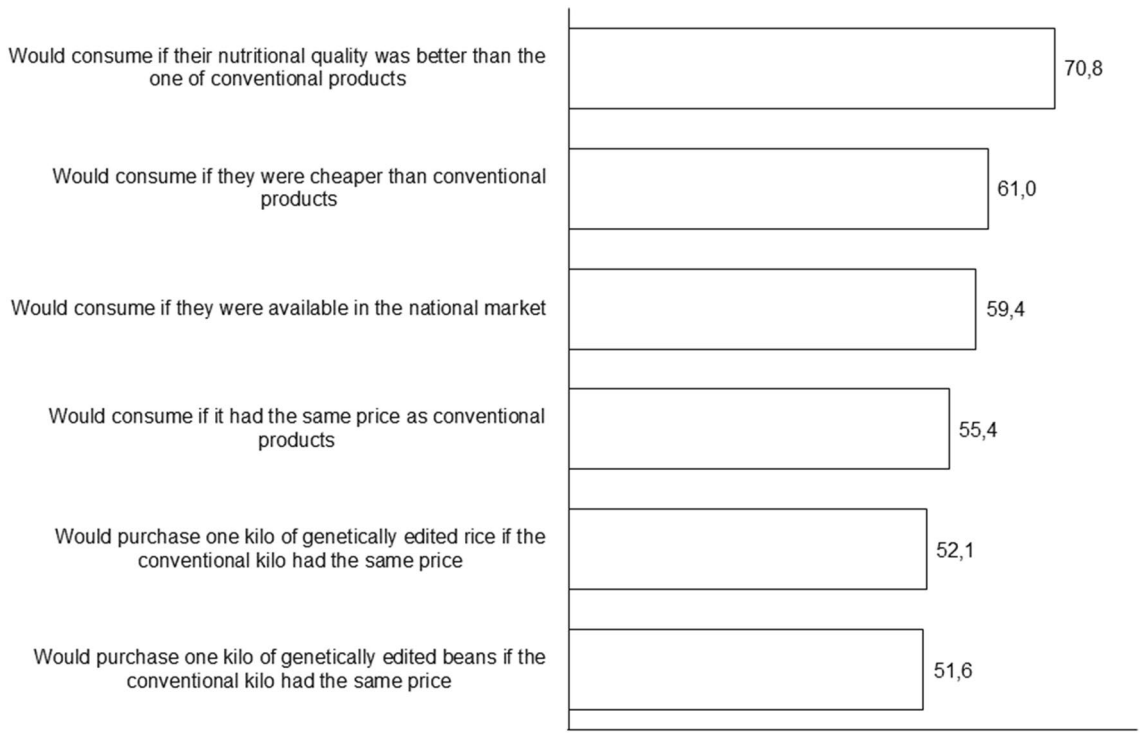

Fig. 5 Attitude of the Costa Rican consumers toward consumption of genetically edited foods. The numbers represent the percentage distribution

genetically edited products if they were cheaper than conventional products, if the price were the same as conventional products the number dropped to 55.4%. Furthermore, when referencing specific products in the traditional Costa Rican diet (rice and beans), approximately half of the interviewees would be willing to purchase genetically edited products if they cost the same as conventional products (Fig. 5).

Because consumer attitude toward genetically edited foods was the topic of this study, the answers to these questions were averaged to construct a consumer attitude scale. This scale was processed with the mathematical algorithm of cluster analysis using the k-means procedure to classify respondents into three groups according to their attitudes. Each group was as homogeneous as possible and as different as possible from the other groups. The three classifications revealed a clear distinction between negative (4.2), medium (50.0) and positive (96.4) attitudes (Table 2). Nearly half of the respondents showed a positive attitude toward consumption (48.5%), an important percentage was neutral (20.7%) and 30.9% showed a negative attitude toward consumption of gene-edited products (Table 2).

Table 2 Classification of interviewees according to their attitudes toward consumption of genetically edited food crops (K-means procedure)

Attitude toward consumption	Average	Sample	Percentage	Standard deviation
Negative	4.2	314	30.9	7.2
Medium	50.0	210	20.7	13.4
Positive	96.4	494	48.5	6.9
Total	58.4	1018	100.0	41.2

Attitude toward consumption of genetically edited food crops is shown as the average of responses to six questions, with values between 0 and 100. Reliability, measured by the Crombach's alpha was 91.9%

The questions used to evaluate attitude toward the use of gene editing for different purposes and the perception of benefits and risks were submitted to exploratory factor analysis to verify the formation of the answers in one single factor (one-dimension). This was achieved in the three cases, with explained variance percentages higher than 60%. The corresponding scales (Crombach's Alpha) were built, with a reliability higher than 85% (Table 3).

In a second analysis, a multiple linear regression model was constructed to determine which factors contribute to consumer attitude toward genetically edited food crops. Attitude toward genetically edited foods was the dependent variable. Independent variables were the six socio-demographic characteristics converted into dummy variables and the three scales (attitude toward the edition of genomes for different purposes, perception of benefits of production and commercialization of genetically-edited products and perception of risks of genetically edited agricultural products) (Table 4). The compliance of the scenarios of the model was analyzed and accepted in terms of homoscedasticity (distribution of constant residual errors), normalcy of the distribution of errors and their independence. Furthermore,

Table 3 Summary statistics of built scales regarding attitude toward the use of gene editing for different purposes and the perception of benefits and risks of genetically edited foods

Statistics	Scales			
	Attitude toward consumption of genetically edited foods[a]	Attitude toward gene editing for different purposes[b]	Perceived benefits of the production and marketing of genetically edited foods[c]	Perceived risks of genetically edited foods[d]
Number of cases	1018	1018	1018	1018
Missing values	0	0	0	0
Average	58.4	7.4	6.1	4.6
Mean	66.7	7.5	6.7	4.2
Trend	100.0	7.5	7.5	3.3
Standard deviation	41.2	1.7	1.7	3.0
Min.	0.0	0	0.0	0.0
Max.	100.0	10	10.0	10.0
Dimensions in factor analysis	NA	1	1	1
Variance explained in AF (%)	NA	73.3	63.4	79.7
Crombach's alpha (%)	91.9	87.7	88.1	91.5

[a]Information from Fig. 5

[b]Information from Fig. 2

[c]Information from Fig. 3

[d]Information from Fig. 4

the absence of multicollinearity (high correlations among independent variables) was verified. As a result, none of the socio-demographic characteristics were found to determine consumer attitudes toward genetically edited foods. This was observed in *t* values and their significance ($t < 1.96$ or significance higher than 0.05). Specifically, sex, age, education, subjective income, religious affiliation and geographical zone were not related to respondents' attitudes toward consumption of these products (Table 4). On the other hand, attitudes toward gene editing for different purposes, and perceptions of benefits and risks were statistically meaningful, as determined by *t* values and their significance (Table 4). The scale for perception of benefits had the most weight in the model, as shown by the standardized values of beta (0.349), whereas risk perception was second in importance (−0.270) (Table 4). The model confirmed that the perceived benefits and risks showed an inverse relation to consumer attitude. As the perception of benefits increased, the attitude toward consumption was more positive (+8.49 for each unit increase on the perceived benefits scale, according to the *B* coefficient). Conversely, as the perception of risks increased, the attitude toward consumption was more negative (−3.75 for each unit increase on the scale of perceived risks, according to *B* coefficient). These results suggested that perceptions of benefits and risks were inversely related, which was confirmed with the Pearson correlation coefficient of −0.524.

Discussion

Plant biotechnology plays an important role in crop breeding. The CRISPR technology is among the most innovative and vanguard tools. Several research studies have demonstrated the potential to confer crop resistance to biotic and abiotic stresses and to improve yields and nutritional quality. However, consumer acceptance could restrict the development and further commercialization of CRISPR crops (Shew et al. 2018). Previous plant biotechnology applications, specifically genetically modified (GM) technology, stimulated discussion around the world and many consumers reacted negatively to GM crops (Cui and Shoemaker 2018). Although CRISPR differs considerably from

Table 4 Multiple regression using attitude toward consumption of genetically edited foods as the dependent variable, and socio-demographic characteristics, attitude toward gene editing for different purposes, and perceptions of risks and benefits as independent variables

Independent variables	Non-standardized coefficients		Standardized coefficients	*t*	Sig[1]	Confidence interval of 95.0% for B	
	B	Standard error	Beta			Lower limit	Upper limit
Constant	16.44	9.48		1.73	0.083	−2.17	35.05
Sex							
Male	2.52	2.15	0.031	1.17	0.242	−1.70	6.74
Age							
Age_34–49	0.55	3.14	0.006	0.18	0.860	−5.61	6.71
Age_50 or more	−2.31	3.01	−0.028	−0.77	0.444	−8.22	3.61
Education							
High school	0.31	2.79	0.004	0.11	0.910	−5.17	5.80
University	1.72	3.04	0.020	0.57	0.572	−4.24	7.67
Subjective income							
With_difficulties	−7.65	4.80	−0.083	−1.59	0.112	−17.07	1.78
Without_difficulties	−6.49	4.77	−0.077	−1.36	0.174	−15.85	2.87
Can_save	1.26	5.16	0.013	0.24	0.807	−8.87	11.38
Religion							
Catholic	−1.74	3.31	−0.019	−0.53	0.600	−8.23	4.75
Evangelical	0.73	4.14	0.006	0.18	0.860	−.40	8.86
Geographic zone							
Metro_region	−1.31	2.75	−0.016	−0.48	0.634	−6.70	4.08
r_central_valley	−1.72	3.13	−0.018	−0.55	0.582	−7.86	4.42
Attitude_editing_diff_purp	1.80	0.67	0.075	2.66	0.008	0.47	3.12
Perceived_benefits	8.49	0.77	0.349	11.02	0.000	6.98	10.00
Perceived_risks	−3.75	0.42	−0.270	−8.86	0.000	−4.58	−2.92

The R value of 58.6 value of adjusted R^2 was 33.4%

[1]Significance

GM technology (Sharma et al. 2017), consumers may confuse both and could react negatively when buying or consuming CRISPR foods (Shew et al. 2018). To the best of our knowledge, no surveys have focused on how CRISPR technology in agriculture is perceived in developing countries. In this regard, Costa Rica is leading the way. This public opinion and perception survey to assess the level of awareness and support for CRISPR crops was performed as part of a strategic plan for the development of CRISPR rice lines resistant to drought and salinity in Costa Rica.

According to Cui and Shoemaker (2018), factors such as the knowledge of science, lifestyle and public perception are associated with complex consumer attitudes about GM crops. Regarding knowledge about gene editing via CRISPR/Cas9, similarly to our results, a high percentage of adults in Japan (67.2%) had never heard about genome editing (Uchiyama et al. 2018). In contrast, Canadian consumers were more familiar with the term genetic editing and only 20% had not heard about it (McFadden and Smyth 2018). One possible interpretation of these results is that gene editing is a relatively new technology and the information generated in scientific studies on CRISPR/Cas9 has not been communicated effectively though media sources to the general public. As mentioned by Wunderlich and Gatto (2015), the dissemination of knowledge from scientific studies is a crucial aspect of consumer education and ultimately could determine the successful implementation and acceptance of CRISPR technology. Precisely, the results of a survey 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), revealed that 34% of the participants believed that public perception was a social factor that could limit the success of NPBTs (Lassoued et al. 2018).

Despite the low level of knowledge about gene editing among Costa Rican citizens, our study showed an overall positive attitude toward CRISPR technology. Our results revealed a high level of acceptance of the use of gene editing for nature conservation (84.5%), healing diseases in animals (83.0%), crop improvement (80.9%), and healing disease in humans (80.2%). CRISPR technology offers potential applications in several fields, such as agriculture, human and animal health, and biodiversity conservation, and can be employed to afford important benefits to humankind. Nevertheless, acceptance by consumers, regulators, and non-governmental organizations can determine the success of innovations in the agriculture and food industry (Lassoued et al. 2018). Regional differences in acceptance and consumer attitudes toward plant biotechnology applications in agriculture, specifically GM technology, are known to exist between the United States and Europe. Many studies have shown that acceptance of agricultural biotech products is higher among United States citizens than Europeans (Frewer et al. 2013; Lassoued et al. 2018). In this sense, the opinion of Costa Ricans regarding GM crops is more in line with that of citizens of the United States (Sittenfeld and Espinoza 2002).

In general, acceptance of the applications of biotechnology can depend on a mixture of attitudes toward benefits, risks, and ethical concerns (Frewer et al. 2013; McFadden and Smyth 2018). In our study, more than half of the interviewees agreed that CRISPR foods would increase crop production in the country, improve the economy, and bring benefits to their families and the environment. Similarly, as indicated by McFadden and Smyth (2018), the majority of Canadian consumers considered that modern plant breeding technologies would increase production, but in contrast to our results they believed that NPBTs would lead to a loss of biodiversity. In the same way, the results of a survey of scientists and non-scientists in North America, Europe, and the rest of the world revealed that 70% of the participants believed that citizens from their country would perceive some benefits from products developed using NBTs (Lassoued et al. 2018). A panel of experts identified improvement of crop yield and nutritional quality, resistance to biotic and abiotic stress, and improvement of livestock health, welfare, and productivity as potential benefits of genome editing in plants and animals in agriculture. Moreover, they identified potential benefits to human health through the application of genome editing for better understanding of disease, for the discovery and development of new drugs, and for the treatment of genetic disorders (Fears and ter Meulen 2018).

On the other hand, innovations such as CRISPR technology have some associated risks and concerns regarding unintended, often undesirable, health, environmental and social side effects (Lassoued et al. 2018). In our study, nearly half of the interviewees perceived low risk or no risk to the quality of life, health, and environment. In contrast, as indicated by Lassoued et al. (2018), 90% of the participants believed that citizens from their country would perceive some risk from products developed using NPBTs. However, as mentioned by Fears and ter Meulen (2018), since NPBTs can be used to develop products that could not be imagined with other methods, it is necessary to clarify whether additional risks are conferred. In this regard, an international panel of experts in genome editing identified off-label applications of somatic editing for the improvement of humans as a potential security concern (Fears and ter Meulen (2018). This panel of experts recognized no new risk categories associated with the application of genome editing in plants and animals in agriculture, nevertheless, they mentioned that the relative lack of traceability in the editions presents a challenge for regulation and compliance (Fears and ter Meulen 2018).

In general, our results showed a positive attitude toward consumption of CRISPR crops under certain conditions of nutritional quality, price, and market availability. For

consumers, affordability and food security are important factors (McFadden and Smyth 2018). As indicated by Lassoued et al. (2018), 54% of the participants believed that citizens from their country think that NPBTs could improve food security. Moreover, a multi-country survey indicated that 15, 13, 10, 20, and 9% of the participants in USA, Canada, Belgium, France, and Australia would consume CRISPR food (Shew et al. 2018). As in our study, over half of the participants (68%) of the survey performed by Lassoued et al. (2018) believed that consumers from their country would buy products derived from NPBTs if available in the market. Our study showed that a high percentage of participants would consume CRISPR foods if the price were cheaper than that of conventional products (61.0%). This is in line with other results showing that North American citizens view low food prices as an important aspect of future crop innovation (McFadden and Smyth 2018). Moreover, consumers from the USA, Canada, Belgium, France, and Australia willing to pay for CRISPR produced rice would require a discount with respect to conventional rice (Shew et al. 2018).

Finally, in our study, approximately half of the interviewees would be willing to purchase a kilo of genetically edited rice or beans (traditional Costa Rican food products) if the price were the same as that of conventional products. Similarly, 40–50% of Costa Ricans who had heard about GM crops would buy them if the price were no different from conventional products (non-GM crops) (Sittenfeld and Espinoza 2002).

In the era of NPBTs, the academic and scientific community in Costa Rica faces a great challenge and must promote and engage in discussions about advantages, disadvantages, benefits, and risks of genome editing. Innovative ideas using media sources and educational programs at schools, high schools, and universities could be employed to facilitate the acceptance of agricultural products developed through CRISPR technology.

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Compliance with ethical standards

Conflict of interest The authors declared that they have no conflict of interests.

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