What do societal stakeholders in the Middle East, North Africa, and Turkey (MENAT) region think about genetically modified (GM) crops, feed, and food products? A systematic literature review

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1. Introduction

1.1. Background

Genetic modification or engineering is a scientific method where modern biotechnology and biological techniques are applied to manipulate and affect alterations in the genetic machinery of living organisms (Zhang *et al.*, 2016). The World Health Organization (WHO, 2014) has defined Genetically Modified Organisms (GMOs) as: *"Organisms (i.e., plants, animals, or microorganisms) in which the genetic material (DNA) has been altered in a way that does not occur naturally by mating and/or natural recombination".* That is similar to GM products, which are defined by the Food and Agriculture Organization of the United Nations (FAO) as *"a product that doesn't occur naturally by mating and/or natural recombination"* (FAO, 2021). These definitions present a clear distinction between modern direct genetic manipulation techniques and the classical practices of genetic stock improvement for both plants and animals over consecutive generations through traditional selective breeding (Zhang *et al.*, 2016). An advantage of modern genetic engineering techniques over selective breeding, is that they enable scientists to transfer the genes of desirable characteristics and traits (e.g., resistance to diseases, insects and pests, or unfavourable environmental stresses) in a more precise, predictable, and controllable way (Harlander, 2002). Moreover, these approaches must be subject to rigorous food and environmental safety tests before their introduction to the marketplace, which is not necessarily the case for organisms improved using conventional genetic manipulation methods (Harlander, 2002). Food products that are produced or derived from genetically modified organisms are usually referred to as "GM foods".

Modern biotechnology and associated genetic modification techniques can help tackle several global challenges including rising pollution levels, biodiversity loss, water and land scarcity, and climate change (Dupont-Inglis & Borg, 2018). Genetic modification can help improve food security for the growing population (Georges & Ray, 2017) by improving crop yields from currently cultivated land, given the FAO predictions of a dramatic decrease in the amount of arable land for food production per person from 0.242 ha to 0.18 ha by 2050 (Alexandratos & Bruinsma, 2012) and that there is currently a limited ability to increase the amount of land under cultivation (Oliver, 2014). Furthermore, genetic engineering techniques can assist in the breeding of plants and crops with traits that can help to resist the negative impacts of climate change and global warming (e.g., drought-tolerant, and heat-tolerant crops). Conventional breeding can yield the same results; however, it is typically slower, and it can take several years before the desired traits are successfully expressed and for the organism to be ready for commercial use (Scott *et al.*, 2018). Advancements in biotechnology and GM techniques can therefore help to accelerate this process (Ford, 2004), and dramatically reduce food production timelines. Given those arguments, it can be concluded that achieving sustainable global food security can be accomplished through various options that the development of GM foods and the introduction of biological technology can offer (Zhang *et al.*, 2016).

Undeniably, novel GM technologies offer several benefits that cannot be ignored or discounted (Ford, 2004). These benefits can be observed in many fields such as medicine and health care, agriculture and food production, industry, and environment and bioremediation. They extend to include a range of benefits across different categories such as ecological and environmental benefits; welfare gains and improved health benefits for farm workers and households (Qaim & Kouser, 2013; Kathage & Qaim, 2012); economic benefits and farm income growth (Douris *et al.*, 2020; Shi *et al.*, 2017; Zhang *et al.*, 2016); benefits for manufacturers and retailers that are relevant to improving food processing (Zhang *et al.*, 2016) and offering longer shelf life for fresh fruit and vegetables (Harlander, 2002); as well as a variety of potential advantages to consumers. Like the vast majority of new scientific discoveries and novel technologies, genetic modification technologies are not risk-free and are expected to have some drawbacks. It is therefore important to estimate the costs and benefits of such new technologies in order to choose the best course of action for society (Ford, 2004). Because of their potential risks, there is widespread opposition, especially in Europe, to genetically modified foods and crops (Scott *et al.*, 2016; Frewer *et al.*, 2013); however, much of this resistance stems from uncertainties about potential unknown ecological or health implications of genetic modification technology, as well as the possible detrimental effects of GM foods on the environment (Scott *et al.*, 2016; Zhang *et al.*, 2016).

Notwithstanding the potential threats from GM crops and foods, the scientific consensus is that GM crops are no more hazardous or harmful than their conventional equivalents (Badghan *et al.*, 2020; Scott *et al.*, 2016; Chang & Huang, 2010). For instance, as stated by the American Association for the Advancement of Science (AAAS), the consumption of foods with ingredients derived from genetically modified crops has not been found to pose a greater risk than the consumption of similar foods produced using conventional methods of plant improvement. This conclusion has been corroborated by a variety of other respected organisations (e.g., the World Health Organization (WHO), the American Medical Association, the U.S. National Academy of Sciences, and the British Royal Society) that have examined the evidence (American Association for the Advancement of Science, 2012).

Besides, in terms of environmental concerns, no additional significant environmental risks from genetically modified crops beyond those associated with traditional agricultural production, have been identified by independent scientific reviews (National Academies of Sciences, Engineering, and Medicine, 2016; Nicolia *et al.*, 2014; Sanvido *et al.*, 2007; Harlander, 2002) apart from some evidence of gene flow, but again, with no recorded adverse effects on relevant wild species, health, or food safety (National Academies of Sciences, Engineering, and Medicine, 2016; Harlander, 2002).

Nowadays, use of genetically modified foods is widespread in several countries around the world, especially in Northern America and some Asian countries. However, this is not the norm, particularly when considering the global picture. Given the various benefits of genetically modified food and crops, as well as their potential risks and uncertainties, there is a great deal of global controversy among various stakeholder groups regarding whether it is prudent to produce and consume them (Valente & Chaves, 2018; Scott *et al.*, 2018; Linnhoff *et al.*, 2017; Wunderlich & Gatto, 2015; Costa-Font *et al.*, 2008). According to a large body of research literature, societal acceptance of innovative food technologies (such as GM technology and its applications) is essential for their proliferation and for their products to be successfully commercialized (Li *et al.*, 2020; Siegrist & Hartmann, 2020; Jin *et al.*, 2019; Bearth & Siegrist, 2016; Horlick-Jones *et al.*, 2007). Therefore, over the last two decades there has been extensive research on societal perceptions of GM applications in the agriculture and food sectors, medicine and pharmaceutical production, and various other applications (Gupta *et al.*, 2012; Costa-Font *et al.*, 2008) as social and consumer resistance has been widely regarded as one of the main barriers to the diffusion of genetically modified crops and foods (Lucht, 2015). Utilising various qualitative and quantitative research approaches, previous research has sought to explore public and societal concerns about GM crops and food products (Frewer *et al.*, 2013) including perceptions, attitudes and their formulation factors, acceptance and resistance, intentional behaviours, as well as actual behaviours. According to Frewer et al. (2013), much of research in this field has focused on benefit and risk perceptions; ethical, religious, or value-related concerns (e.g., unnaturalness or the notion that using genetic modification is “playing god”); the role of trust in information about GM and in those who develop and deliver such information (e.g., governments and regulatory bodies); and the role of knowledge.

1.2. The need for the review: review’s main aim and objectives

Despite extensive recent research on societal perceptions and attitudes towards genetic modification applications in general, and genetically modified crops and food products in particular, most of this research has focused on European, North American, and some Asian countries, with little research conducted from a developing and Middle Eastern countries’ perspective (Frewer *et al.*, 2013). According to Frewer *et al.* (2014), there is a lack of research on the attitudes of consumers from emerging economies and developing countries towards GM foods, especially GM animal-based foods. Similarly, a more recent review study by Beghin and Gustafson (2021), that had no geographical limitations to its search, concluded that research coverage of consumer valuation and attitudes for NPET-based foods (New Plant Engineering Techniques) was predominantly focused on two regions, Europe and North America. Hence, the aims of this systematic review were threefold: first, it aimed to collate existing knowledge and available evidence on societal perceptions and attitudes towards GM crops and foods in the Middle East, North Africa, and Turkey (MENAT) region to support both existing and future research, as well as to identify existing knowledge gaps and poorly covered aspects of GM perceptions and attitudes for the purpose of research prioritisation. Second, it aimed to contribute to the growing body of academic literature in this research area and provide necessary insights for further research. Finally, the findings were expected to inform an empirical study on Egyptian consumers’ perceptions and attitudes towards GM foods. This review is the first of its kind since no other systematic literature reviews on attitudes towards GM foods in the MENAT region have been conducted.

In light of the above, this review’s main focus was to establish the perceptions and attitudes of stakeholders (e.g., consumers, farmers, scientists, students, etc.) in the MENAT region towards genetically modified crops, feed, and food products. Heterogeneity within the data will be explored in relation to a number of secondary objectives, specifically to determine: 1) the factors that influence and form perceptions and attitudes towards genetically modified food products, crops, and feed; 2) whether cultural and, specifically, religious factors play a significant role in social acceptance of genetically modified foods in the MENAT region; 3) the primary risks stakeholders associate with genetic modification applications in food and feed production; and 4) the perceived benefits that drive the acceptance of genetically modified crops, feed, and food products.

2. Material and methods

Since systematic reviews are literature reviews that closely follow a set of transparent and rigorous scientific methods designed in an effort to minimize synthetic errors (bias) by attempting to identify, appraise, and synthesize all relevant research to address a particular question (Petticrew & Roberts, 2008; Greenhalgh et al., 2004), a series of steps should be followed to guarantee that the process is conducted with the necessary rigour and transparency (Sargeant *et al.*, 2006). Therefore, following the development of the research question and the identification of the target population to be investigated, a review protocol was compiled prior to commencing the search process to act as a guideline and a framework that to be followed while developing the review. In the footsteps of most of systematic review studies in social sciences (e.g., Bearth & Siegrist, 2016; Giles *et al.*, 2015; Frewer *et al.*, 2013), reporting of the review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (see **figure 1** – PRISMA flow diagram).

2.1. Literature search and information sources

A two-stage identification and search strategy was employed to identify relevant literature while minimising publication biases and ensuring that all relevant studies are included. First, a literature search was conducted in three online databases (Web of Science, Scopus, and CAB Abstracts) between 18th February and 11th March 2022 utilising a compound search string that was refined in a multistep process and trialled over several rounds of paper identification. Meanwhile, face validity was assessed through picking up key papers in the area of interest using the search string. **Table 1** shows the final search string used to retrieve the studies to be considered for closer inspection.

As research on societal perspectives of genetically modified crops and food products in developing countries and the MENAT region is relatively recent, no publication year limitations were applied during the literature search process in an endeavour to gather as much evidence as possible. Search was limited to studies published in English but inclusive of studies completed in any geographic location within the MENAT region, and it was also limited to peer-reviewed studies to ensure that all of the returned studies demonstrate an appropriate level of academic rigour. In an attempt to capture any further relevant studies that were not identified in the database search, the second stage of the two-stage identification and search process involved screening the reference lists of all studies that met the eligibility criteria.

Table 1: Final search string

Population	(Consumer* OR public* OR Social OR societ* OR stakeholder* OR people* OR citizen* OR student* OR Farmer* OR Scientist* OR laypeople* OR layperson* OR buy* OR purchas*)
	AND
Outcome	(perception* OR intention* OR accept* OR preference* OR behavio?r OR knowledge OR willingness OR attitude* OR "subjective norms" OR reject* OR understanding OR readiness)
	AND
Technology/ treatment	(genetically-modified OR genetically-engineered OR "genetically engineered" OR "genetically modified" OR bioengineered OR bio-engineered OR GMO* OR GM OR modern-biotechnology OR "modern biotechnology" OR transgenic OR "gene edit*" OR gene-edit* OR ingenic OR xenogenic OR frankenfoods OR franken-foods OR frankenstein)
	AND
Product	(crop* OR plant* OR organism* OR food* OR animal* OR "food product*")
	AND
Geographical scope[1]	(MENA OR "middle east" OR middle-east OR "north Africa" OR north-Africa OR MENAT OR Arab* OR Egypt OR Algeria OR Bahrain OR Iran OR Iraq OR Israel OR Jordan OR Kuwait OR Lebanon OR Libya OR Morocco OR Oman OR Qatar OR KSA OR "Saudi Arabia" OR Syria OR UAE OR Tunisia OR "United Arab Emirates" OR Yemen OR Sudan OR "Western Sahara" OR Turkey OR Cyprus OR Palestine OR Malta)

[1] Where search sensitivity was low, geographical location terms were used to increase specificity.

2.2. Eligibility criteria for studies selection

Studies identified by database search were subject to a predefined eligibility criteria (**Table 2**) to help identify studies that are consistent with the aim and objectives of the review. Only studies that met the inclusion criteria were included for further inspection. Differences of opinion between the authors regarding the eligibility of any study for inclusion were resolved through discussion and consensus. Considering the PICO tool (Population, Intervention, Comparison, and Outcome) and given the nature of the topic of the review, the "Comparison" element was not applicable.

Table 2: Summary table of eligibility criteria

Criteria	Inclusion	Exclusion
Type of study	Empirical (qualitative, quantitative, or mixed)	Non-empirical (review article, book chapter, etc.)
Topic	Social perspectives such as perceptions, attitudes, risk-benefit perceptions, acceptance, preferences, etc.	Other non-social aspects such as technical or legal aspects as well as general challenges and opportunities or safety assessments.
Products	Genetically modified crops, feed, and food products.	Any other genetically modified products.
Type of population and geographical scope	Studies with participants from any country in the MENAT region.	Studies with participants from other countries than MENAT countries.
Type of intervention	Studies with both real or hypothetical scenarios, products, or reactions to real world events.	N/A
Language	Studies published in English language.	Studies published in languages other than English.

2.3. Search outcomes and screening phases

Using the final version of the search string (**Table 1**), the literature search process resulted in a total of 2,248 studies returned from the three databases comprising 1,584 studies returned from Scopus, 444 studies from Web of Science (WoS), and 220 studies from CAB Abstracts. Primary title screening was applied in each database separately against initial inclusion/exclusion criteria. Studies were considered eligible for further screening if their titles showed clear relevance to the review research topic, if they included the MENAT region or any of its countries, or if they didn't state any geographical focus. A total of 136 studies (40 from Scopus, 45 from WoS, and 51 from CAB Abstracts) were identified following the primary title screening and were eligible for subsequent screening stages. Upon duplicates removal, 95 studies (30 from Scopus, 20 from WoS, and 45 from CAB abstracts) were eligible for the following two-stage screening process that was independently conducted by a lead (Medani) and secondary (Neill) reviewer:

2.3.1 Abstract screening

Titles and abstracts of all 95 papers were screened by both reviewers, independently, against the predefined eligibility criteria (**Table 2**). Throughout the process, both reviewers utilised a Microsoft Excel spreadsheet with a traffic light system to indicate whether each paper matches the inclusion criteria, is unclear and needs further investigation, or meets the exclusion criteria. Upon completion, verdicts from each researcher were consolidated and compared while any disagreements over inclusion or exclusion were reported and resolved through face-to-face discussions. This screening stage resulted in the exclusion of 30 articles while 65 articles were found eligible to proceed to full-text screening. Those 65 articles not only included studies that were relevant and eligible for further analysis but also included studies where titles and/or abstracts did not provide sufficient clarity to either confirm or disconfirm their inclusion. Hence, a decision to consider them for full-text screening was made for further investigation and confirmation.

2.3.2 Full-text screening

Full-text screening was the final stage of the screening process. In this stage, the 65 eligible articles were divided between the two reviewers (where the lead reviewer reviewed 70% of them and the secondary reviewer reviewed 30%) to independently examine whether they are eligible for analysis. Accordingly, each article was read in full and assessed against the predefined eligibility criteria. Then, following the completion of full-text screening, a backward snowballing screening of the reference lists of the remaining 65 articles was conducted by both reviewers. This procedure aimed to enhance the theoretical validity of the review as suggested by Petersen *et al.* (2015) by capturing any additional relevant studies and ensuring that no relevant studies were discarded or omitted. The snowballing process led to the detection of four additional articles that seemed to be relevant based on title screening. As a result of the screening process 30 articles were excluded, while the remaining 35 articles plus three of the four articles identified by backward snowballing, progressed to the final analysis. **Figure 1** (PRISMA flow diagram) provides an overview of the search process and inclusion strategy in full.

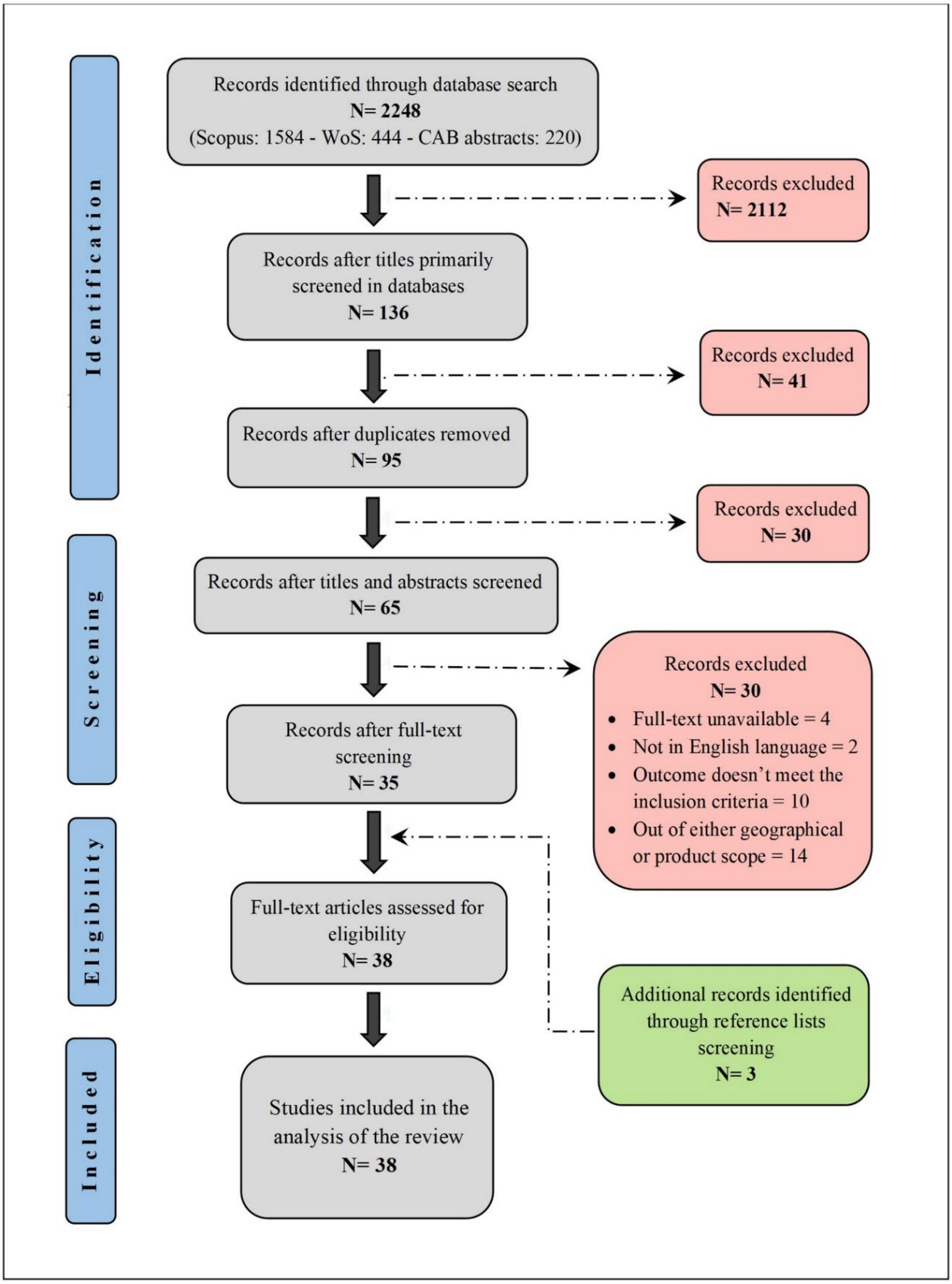

Figure 1: PRISMA flow diagram of the search process and inclusion strategy

2.4. Data extraction and analysis

Upon completion of the screening phases, a data extraction form was collaboratively designed, based on the review's aim and secondary objectives, by both reviewers in a Microsoft Excel spreadsheet and used to extract pertinent data from the included studies. The final data extraction form included information on author and journal details; research aims, theoretical and methodological approach including participants' information and study geographical scope; GM foods/products under examination; main factors found to be significant and/or insignificant; cultural factors; perceived risks and perceived benefits; as well as any other study information of note. A pilot extraction was initially conducted before full data extraction for all included studies was performed. Upon completion, and following guidance from Petersen *et al.* (2015), both reviewers independently audited a random sample of one another's extracts to ensure a minimised risk of selection bias and an improved theoretical validity of the review.

According to Petticrew and Roberts (2008), meta-analysis should only be applied when a series of studies has been identified for review that address an identical conceptual hypothesis, while it is inappropriate for studies that address different hypotheses, or that address the same hypothesis in very different manners. Here, a combination of large variance of measurements and scales used in the studies included, a lack of homogeneity among their findings, and the heterogeneity of data extracted, made it inappropriate to conduct a meta-analysis. Therefore, following guidance from Petticrew and Roberts (2008) and the Economic and Social Research Council narrative synthesis in systematic reviews guidelines (Popay *et al.*, 2006), a narrative synthesis with theoretical thematic analysis tools was instead conducted. According to Popay *et al.* (2006), narrative synthesis is an approach to the systematic review and synthesis of findings from multiple studies that should be used when statistical meta-analysis or another specialist form of synthesis is not feasible. Data were analysed in a single stream as most of the studies were quantitative in nature with a few mixed-method studies that included some qualitative data.

A summary table with an overview of included studies was created to allow the researcher to become acquainted with the data prior to commencing the coding process. Using open-coding, codes were initially generated based on the review's aim and objectives, while additional codes emerged throughout the coding procedure in an iterative way. This coding framework was further developed by reorganising codes and/or breaking some codes down into multiple subcodes to allow for more detailing. Generated codes and subcodes were grouped into themes which then formed the basis for a thematic analysis that was carried out afterwards.

3. Results

3.1. Overview and descriptive results

In total, 38 peer-reviewed journal articles were included in the analysis. They were published between 2000 and 2021, where the number of published articles peaked in 2013 and has subsequently declined. Most of the studies (n=36) were quantitative, one was qualitative, and another was a mixed-methods study that employed qualitative in-depth interviews in addition to a structured-questionnaire survey. All the quantitative studies employed questionnaire-based surveys, with most of them (n=34) using a single questionnaire, one used two questionnaires, and another used sex different questionnaires.

Regarding the geographical context of the studies analysed, most of the studies included were conducted in Iran, Turkey, the Kingdom of Saudi Arabia, or Israel, representing over 87% of the studies included. **Figure 2**. Shows the geographical distribution of the studies included in the review and reflects a poorer focus of research on perceptions and attitudes towards GM feed, food, and crops in most of the MENAT countries.

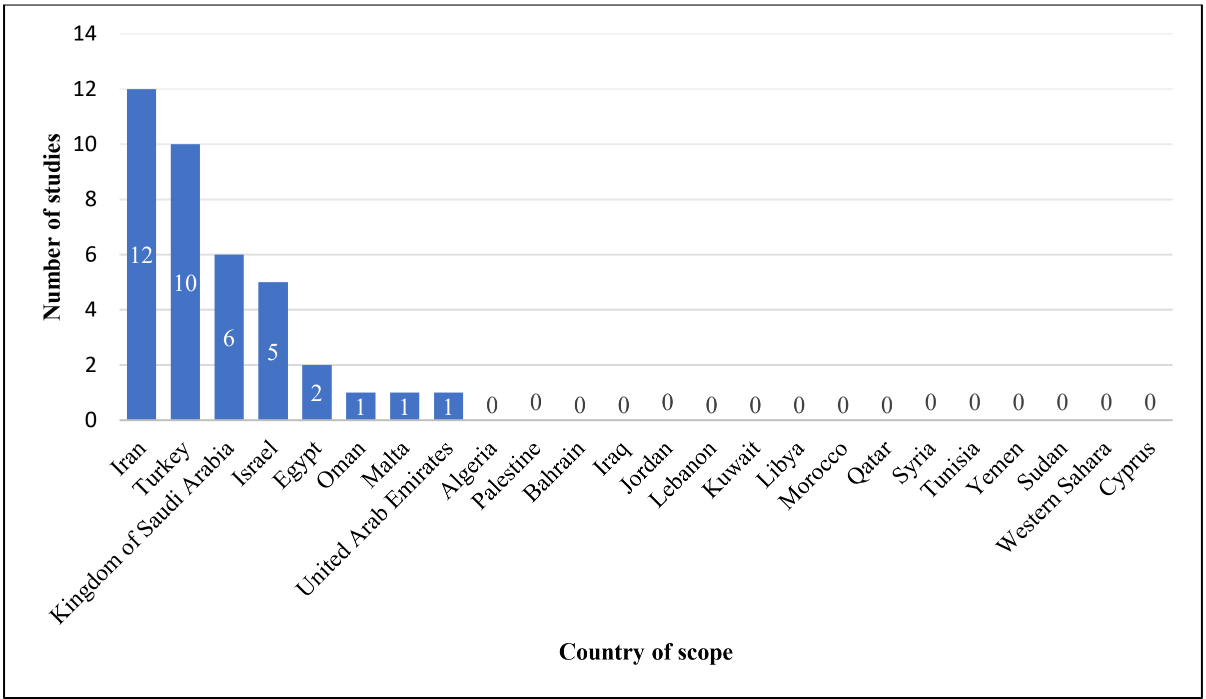

Figure 2: Geographical scope of the studies included in the review

In terms of research scope, most of the included studies (n=29) examined the acceptance, perceptions, and attitudes towards GM crops and foods in general, with no greater focus paid to any specific food or crop categories. By contrast, the remaining nine studies were more specific about the GM products under examination (e.g., GM chicken and beef meat; Bacillus

Thuringiensis (BT) rice; Golden rice; GM oil; GM vegetables - hypothetical bell peppers; GM plants and animals; tomatoes, canola oil, and cotton). It is noteworthy that none of the studies examined genetically modified crops or products for use in animal feeds.

Results have shown that the included studies surveyed various categories of stakeholders. Over half of the studies (n=22) focused on examining participants from educational institutions of different levels, seven studies examined food consumers, four studies examined agricultural experts and researchers, and three studies examined the general public (see **Figure 3**). Most of the studies failed to provide sufficient justification for the recruitment and selection of participants which, in most cases, was probably for convenience unless otherwise stated.

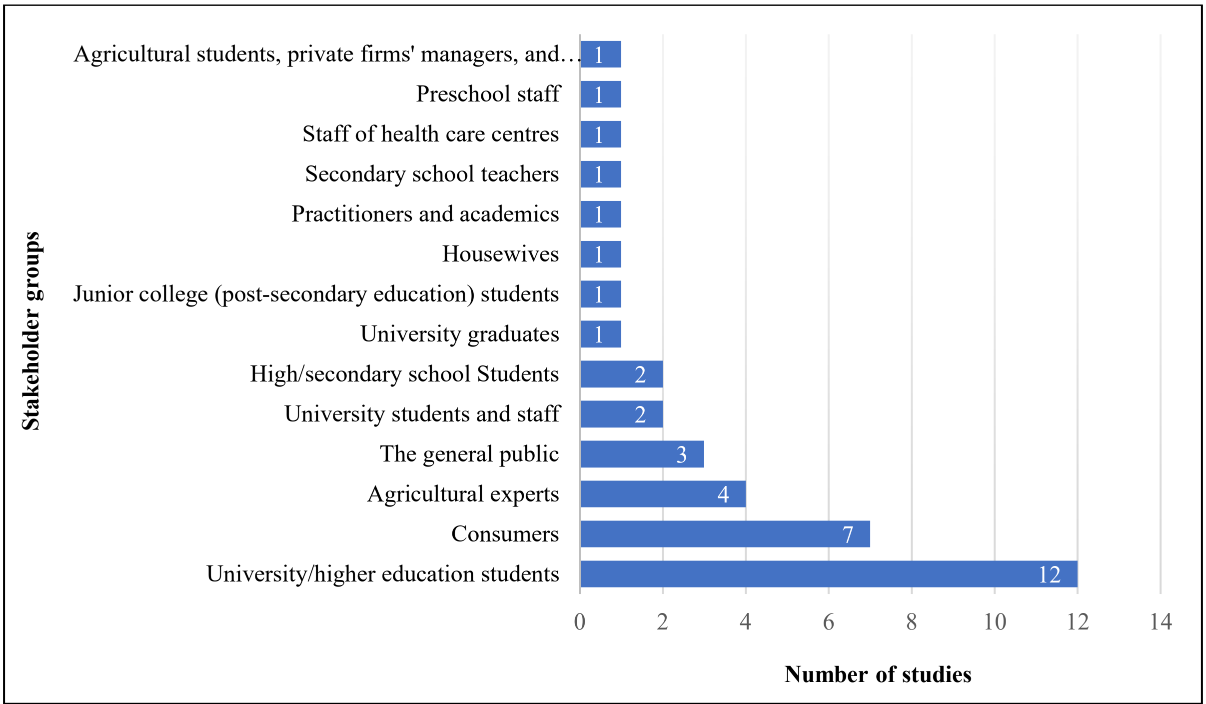

Figure 3: Societal stakeholder groups participated in the studies included in the review

Studies were also appraised for overall quality against a number of quality assessment criteria, including study aims and/or main objectives, study design, recruitment of participants, data collection, data analysis, ethical considerations, and the discussion of the study findings, as suggested by Clark (2017) and Yin (2009). In this respect, most of the included studies properly stated their aims, either in the form of a clear declaration of study aim/purpose or objectives, suggesting some hypotheses that the study attempts to test, or by expressing research questions for which the study sought to find answers. Also, most of the studies employed a research design that was adequate for the study aims; nevertheless, the majority of studies did not justify the utilisation of the methods applied. In contrast, several studies lacked sufficient and clear information on both participant recruitment and sampling methods, as well as response rates and sample size justification. Sufficient detail on data collection tools and data analyses were provided by most of the studies; nonetheless, few studies reported the reliability and validity of the measurements and instruments used. Most studies failed to provide appropriate discussion of their findings in regard to their original research aims and questions, while study limitations were reported on relatively few occasions and ethical considerations pertaining to research design and participants' recruitment were seldom reported. Finally, the majority of studies did not provide evidence of any theoretical background/underpinning of the research. It is noteworthy that no studies were discarded based on that quality appraisal; rather, findings were kept in mind throughout the analysis for the purpose of evaluating the overall strength of evidence (Clark, 2017).

3.2. Thematic analysis

This subsection demonstrates the outcomes of the thematic analysis including all themes and subthemes that emerged from the analysis and were included in the review. An overview of all generated themes and their relevant subthemes can be found in **Table 3**.

3.2.1 Existing perceptions and attitudes

Results of the analysis revealed that stakeholders' perceptions and attitudes were mixed and varied among the studies included and, in many cases, varied within the same study. Consequently, two major subthemes can be derived from that theme based on overall attitudes and perceptions expressed by participants in each study, namely: positive perceptions and attitudes (n=9 studies), and negative perceptions and attitudes (n=15 studies).

- **Positive perceptions and attitudes**

In several cases (n=9), participants showed positive perceptions and attitudes, as well as considerable levels of acceptance towards genetically modified foods and crops (e.g., Ghoochani *et al.*, 2018; Ghanian *et al.*, 2016; Prokop *et al.*, 2013; Zammit-Mangion *et al.*, 2012; Heiman *et al.*, 2011). These positive perceptions ranged from the general use of gene technology to the use of genetic modification applications for specific purposes (addressing environmental and health issues, drug production, diseases treatment, etc.), or for specific crops and/or products (GM oil, GM rice, GM tomatoes, GM cotton, GM apples, etc.), or GM plants and crops in general. Furthermore, positive attitudes extended, in some cases, to reflect willingness to purchase GM vegetables and products as an alternative to their non-GM equivalents if they were offered at the same price (e.g., Zammit-Mangion *et al.*, 2012) and to support national investments in research on genetic modification technologies (e.g., Basaran *et al.*, 2004). Moreover, some consumers perceived GM food products (e.g., GM canola oil) to be healthier than their conventional counterparts (Heiman, 2014), while others preferred GM foods over chemically treated food products when they were offered the choice (Heiman *et al.*, 2001).

Most of time, these positive attitudes were encouraged by the participants' beliefs and perceptions of the broad benefits of genetic modification technologies, such as their positive contributions to production and economic performance, their potential to solve food issues that cannot be addressed with traditional plant breeding methods (a view of agricultural experts), improved quality of life, increased yields, reduction of pesticide use, and reduction of water used for agricultural production; as well as product-specific benefits such as improved product taste and extended shelf life (Ghanian *et al.*, 2016; Heiman, 2014; Ismail, 2013; Heiman *et al.*, 2011; Heiman & Zilberman, 2011). It is worth noting that lower levels of acceptability towards animal-based GM products was a common pattern that was observed across several studies. Applying genetic modification on animals for food production purposes was less acceptable, and even firmly rejected in some studies, compared to plant-based GM products (e.g., Tas *et al.*, 2015; Ismail, 2013; Zammit-Mangion *et al.*, 2012; Tuna & İncekara, 2011; Sheikhha *et al.*, 2006).

- **Negative perceptions and attitudes**

As is the case with positive perceptions and attitudes, negative perceptions and unfavourable attitudes towards GM foods constituted a pattern that was prevalent among many of the studies (n=15) that are included in the review, regardless of the stakeholders' group under examination. For instance, there was a consistent pattern of general negative attitudes towards, and adoption disapproval of, GM foods across students at different educational stages, consumers, the public, and housewives. These negative attitudes and rejection tendencies were mostly driven by various health, environmental, and ethical concerns, as well as worries about any potential unknown long-term consequences relevant to the consumption of such products (Akbari *et al.*, 2019; Ismail, 2013).

For instance, participants from the studies of Ghasemi *et al.* (2020), Yıkmış & Çöl (2019), Utkualp *et al.* (2016), Bakr & Ayinde (2013a), Ozer *et al.* (2009), and Demİrcİ (2008) had several health and environmental concerns about GM foods and crops as they thought that such products, as well as their relevant production technologies, are harmful and unsafe, detrimental to health, and a cause of various human diseases such as cancer, congenital organism anomalies, and infertility. Additionally, they believe that GM foods and crops are dangerous to the environment and many of them perceived them as unnatural and/or man-made.

Another driver that was found to be a stimulus of negative attitudes towards GM foods were the social risks and ethical concerns relevant to GM production and consumption. In some studies (e.g., Ghasemi *et al.,* 2020; Ismail, 2013; Heiman *et al.,* 2011; Demİrcİ, 2008), participants revealed their views that GM foods are unethical, immoral, and risky. They were concerned about their social risks and believed that they could conflict with their socio-ethical principles and values, while some respondents declared that GM foods violated their religious beliefs. Additionally, lack of trust in GM foods was observed amongst respondents from various studies (e.g., Ardekani *et al.*, 2021; Akbari *et al.*, 2019; Al-Rabaani & Al-Shuaili, 2014; Al-Khayri & Hassan, 2012). This lack of trust extended to biotechnology and the safety of GM foods, as well as the information concerning GM foods generated by scientists and commercial production companies. Hence, many participants refrained from buying, consuming, serving (to school children), or encouraging their students to eat GM food products, irrespective of the purpose for their modification (e.g., taste, appearance, or productivity improvements), and expressed their desire for companies producing GM foods to clearly label them as genetically modified. Furthermore, some others supported the imposition of strict laws to prevent genetic manipulation (e.g., Al-Rabaani & Al-Shuaili, 2014). In some of these cases, this lack of confidence was based on inadequate knowledge of biotechnology and GM foods and limited awareness of their benefits.

Table 3: Summary table of themes and subthemes generated from included studies (n=38)

Themes	**Subthemes**
Existing perceptions and attitudes	Positive perceptions and attitudes
	Negative perceptions and attitudes
Knowledge about GM foods and awareness of their existence in local markets	
Factors affecting perceptions and attitudes towards GM foods	Familiarity, knowledge, and educational background
	Risk and benefit perception
	Socio -demographic and -economic factors
	Ethical concerns, beliefs, and religiosity
Perceived benefits and perceived risks	Perceived benefits
	Perceived risks

3.2.2 Knowledge about GM foods and awareness of their existence in local markets

As many of the studies included (n=18) examined participants' levels of GM and biotechnology knowledge, most of these studies reported low levels of knowledge about GM food products and biotechnology applications. According to these studies, participants demonstrated low levels of knowledge in regard to what GM foods are, their production, and their associated benefits and risks. In some cases, participants were confused or lacked awareness about whether GM food products are present in their local food markets and were uncertain about previous or current experience of the consumption of GM products (Tas *et al.*, 2015; Ismail, 2013; Bakr & Ayinde, 2013a; Sheikhha *et al.*, 2006). As a result, respondents were sometimes unclear about the differences between GM foods and other applications of biotechnology in food production (e.g., foods containing hormones, Ozer *et al.*, 2009), were unable to articulate well-considered arguments on the topic of GM foods, or found it difficult to make an educated decision about whether or not to purchase or consume such products. In contrast, in a few studies participants were found to have greater levels of knowledge about GM applications and food products; however, the depth of that knowledge was still relatively low.

In addition, some of the studies examined the relationships that might exist between levels of GM knowledge and other relevant factors. For instance, Mehmetoglu and Demirkol (2007) found that some sociodemographic characteristics, such as higher income and educational levels, were positively associated with increased levels of GM knowledge. Furthermore, GM awareness was found to be significantly and positively associated with the consumption of GM foods and risk perceptions, while knowledge of gene technology was found to be a good predictor of awareness of benefits and risk perceptions, with a significant negative relationship sometimes observed between levels of knowledge and risk perceptions (Mostafa, 2021; Bakr & Ayinde, 2013b). Additionally, a study by Al-Rabaani & Al-Shuaili (2014) noted statistically significant differences in students' knowledge of GM food products, based on their educational backgrounds and the colleges to which they belonged.

When it comes to information sources, broadcast and written media (e.g., television, radio, newspapers, and magazines), as well as the internet and other informal information sources (e.g., social media, blogs, podcasts, personal websites), were the most cited sources of information by participants across many of the studies included in the review (e.g., Marzban *et al.*, 2020; Yıkmış & Çöl, 2019; Utkualp *et al.*, 2016; Tas *et al.*, 2015; Ghasemi *et al.,* 2013; Zammit-Mangion *et al.*, 2012; Ozer *et al.*, 2009; Mehmetoglu & Demirkol, 2007; Basaran *et* *al.*, 2004). Moreover, TV and radio were repeatedly mentioned as the main information source from which participants first, and frequently, heard of GMOs and GM foods and from which they gained their GM knowledge. Other sources that were much less frequently mentioned are books and teachers in the school, scientific journals, and friends and relatives, and these were mainly cited by students, agricultural professionals, and housewives, respectively (Marzban *et al.*, 2020; Yıkmış & Çöl, 2019; Ghasemi *et al.,* 2013; Zammit-Mangion *et al.*, 2012). From a reliability and trustworthiness perspective, scientists, researchers, academics, as well as universities and research institutes, were, repeatedly, the most trustworthy sources of knowledge about GM reported by the respondents.

3.2.3 Factors affecting perceptions and attitudes towards GM foods

Of the studies examined, several have paid greater attention to investigating the factors and constructs that influence participants' attitudes to genetically modified crops and food products. Hence, this theme includes a group of subthemes that organise and further discuss these factors in more detail as follows:

- **Familiarity, knowledge, and educational background**

In some studies, familiarity with GM foods was found to have an impact on respondents' attitudes and concerns towards them (Akbari *et al.*, 2019). For instance, in some cases familiarity was found to be positively associated with attitudes towards GM foods (e.g., Basaran *et al.*, 2004), as participants were found to be more likely to support GM foods if they had higher levels of familiarity and knowledge. In contrast, agricultural experts from a study by Hosseini et al. (2011), reported high levels of unfamiliarity with GM crops, which led to less optimistic and unclear perceptions towards biotechnology and GM products. This lack of familiarity was ascribed to the fact that the study was conducted in a small province in Iran where the production and consumption of GM crops is uncommon. However, it reflects on the role that familiarity plays in the formation of participants' attitudes and perceptions towards GM foods and crops.

In addition to GM familiarity, educational background and level of knowledge about GM foods were found to influence attitudes and perceptions towards GM foods. In some cases, this influence extended to affect their choices, acceptance, and willingness to purchase GM food products. In this context, educational background refers to participants' study area/domain, the college to which each participant belonged, or the level of biology in their educational background. Overall, participants from science domains and scientific colleges tended to have more positive attitudes towards GM foods, compared to participants from other educational backgrounds such as social sciences and administration (AbuQamar *et al.*, 2015; Al-Rabaani & Al-Shuaili, 2014; Zammit-Mangion *et al.*, 2012; Basaran *et al.*, 2004). They were also more familiar with biotechnology applications and their potential environmental impacts (AbuQamar *et al.*, 2015). In the study by Zammit-Mangion *et al.* (2012), exposure to biology was found to be correlated with a stronger willingness to purchase GM food products. Exceptionally, only one study found students in the social sciences to have more positive attitudes towards GM foods, compared to students from natural sciences and other disciplines (Tuna & İncekara, 2011).

Levels of GM knowledge were found to affect attitudes and perceptions towards GM foods; however, the direction of the effect differed between studies. Having a good knowledge of biotechnology and GM increased respondents' rate of acceptance, decreased negative perceptions (e.g., overall and perceptions of immorality) towards GM foods, whilst a lack of knowledge was linked to higher perceptions of both human and environmental health related risks (Heiman & Zilberman, 2011; Demİrcİ, 2008). Conversely, several studies have indicated that the more knowledge participants had about GM foods, the more likely they were to reject them (e.g., Ghasemi *et al.*, 2013; Al-Jebreen, 2010). This variation in the effects of GM knowledge on attitudes and perceptions towards GM foods, suggests a need for further thorough examination of the existing relationship between both constructs.

- **Risk and benefit perception**

Risk perceptions were found to have significant negative effects on attitudes and behavioural intentions towards the production and consumption of GM foods and crops which, in turn, in many cases, led to their rejection (Akbari *et al.*, 2019; Ghoochani *et al.*, 2018; Al-Rabaani & Al-Shuaili, 2014; Bakr & Ayinde, 2013a; El-Nakhlawy *et al.*, 2013; Ismail, 2013). For instance, Akbari *et al.* (2019) and El-Nakhlawy *et al.* (2013) found that consumers' concerns about GM foods such as possible future detrimental health effects and environmental, ethical, and equity-related concerns, are a significant predictor of their attitudes and intentions. Furthermore, while participants across most of the studies were most concerned about GM health-related risks, participants who might have closer links to the production of GM crops (agricultural experts and extension specialists) were less concerned about GM crops' health-related risks. Instead, they paid more attention to potential unintentional environmental risks such as adverse effects on biodiversity, cross-pollination of GM crops, and the creation of super weeds (Ghanian *et al.*, 2016; Hosseini *et al.*, 2009).

In contrast, benefit perceptions were found to be positively associated with, and directly affect, attitudes towards GM foods and crops, leading to higher rates of acceptance of such food products (Ghoochani *et al.*, 2017; Ghanian *et al.*, 2016). They also have both direct and indirect positive impacts on participants' behavioural intentions towards GM crops (Ghoochani *et al.*, 2018; Ghasemi *et al.,* 2013). For example, GM food acceptance rates tended to be higher when participants perceived genetically modified crops as being produced using less pesticides (Ghoochani *et al.*, 2018; Heiman *et al.*, 2011). As reported by Sheikhha *et al.* (2006), participants perceived GM foods to be of better quality, to improve farmers' economic situation and offer them better profits, to improve yields and productivity, and to reduce pesticide usage.

- **Socio -demographic and -economic factors**

Across most of the studies included in the review, gender was the most common socio-demographic factor to correlate with and affect attitudes towards GM foods. For instance, male participants were always more receptive to, had more positive attitudes, and reported higher levels of approval towards GM foods, than females. Conversely, female participants had more negative attitudes, were less likely to approve and accept GM foods, and tended to believe in the harm that GM foods may cause (Al-Rabaani & Al-Shuaili, 2014; Prokop *et al.*, 2013; Zammit-Mangion *et al.*, 2012; Tuna & İncekara, 2011). In addition, females were more concerned about the health hazards of GM and its morality, and they perceived GM foods to be less ethical and less healthy than their conventionally grown non-GM counterparts. They were less willing to purchase GM foods, even if offered at a discounted price.

Also, a relationship was found to exist between education level and perceptions and attitudes towards GM foods (Ismail, 2013; Al-Khayri & Hassan, 2012); however, the direction of the effect varied across different studies. For instance, as observed by Heiman *et al.* (2000; 2001), the relationship between the level of education and attitudes towards GM foods was significant and positive as individuals with higher education levels tended to hold more favourable attitudes towards GM foods than those with lower educational levels. Contrarily, the findings of Marzban *et al.* (2020) and Ismail (2013) demonstrated a negative correlation, as respondents with higher education and graduate degrees were better informed about the potential drawbacks of GM foods, held more negative attitudes towards them, and were most likely to disapprove of them, compared to those with primary and secondary education who were more likely to approve of them. Overall, higher levels of education were found to positively influence knowledge about GM foods which, in turn, had an impact on attitudes and perceptions towards them (Al-Khayri & Hassan, 2012).

Another two attributes that were found to be related to attitudes towards and acceptance of GM foods are age and income level (Tas *et al.*, 2015). According to Ismail (2013) and Al-Khayri and Hassan (2012), older people were more concerned about, and less approving of, biotechnology and GM foods than people from younger age groups. Likewise, middle- and higher income consumers were more accepting and more in favour of GM foods than those in lower income bands who were less accepting and more suspicious towards them (Al-Khayri and Hassan, 2012; Heiman *et al.*, 2000).

- **Ethical concerns, beliefs, and religiosity**

In many of the studies reviewed, cultural factors such as ethical values and concerns, beliefs, and religion were found to influence attitudes and perceptions towards GM foods and crops. According to Akbari *et al.* (2019) and Ghoochani *et al.* (2017), GM food related ethical concerns were found to be a significant predictor of consumers' attitudes towards GM foods and to negatively affect their behavioural intentions towards them, indirectly, through their attitudes. Similarly, Ghasemi *et al.* (2020) found that moral and ethical beliefs about GM foods significantly and positively influence social risk perceptions of GM foods through general attitudes towards the use of novel technologies, as respondents with stronger moral beliefs were found to have more negative general attitudes and higher risk perceptions of GM foods. Participants in several studies (e.g., Zammit-Mangion *et al.*, 2012; Heiman *et al.*, 2011; Demİrcİ, 2008; Sheikhha *et al.*, 2006; Heiman *et al.*, 2000) consistently opposed GM foods in general, and animal-based GM foods particularly, on the grounds of moral and ethical considerations. These individuals believed that GM foods are immoral, unethical, and, in some cases, they considered ethical problems as the primary drawback of GM foods.

Religious beliefs and religiosity intensity were also shown to be a good predictor of attitudes towards and acceptance of GM crops and food products. As reported by Akbari *et al.* (2019), religious concerns about GM foods have always been a key barrier to their adoption, making it a challenging task to build trust in such products among consumers in developing countries. This viewpoint was corroborated by the findings of Heiman *et al.* (2000; 2001) who observed that orthodox participants were the strongest opponents to GM foods, followed by conservatives, while secular participants were mostly in favour of them. Similarly, Ghasemi *et al.* (2020) found that individuals with intense religious beliefs had more negative attitudes towards using genetic modification in food production than those who were less religious. Those more religious individuals believed that GM crops violated their religious beliefs and ethical principles (Ghasemi *et al.,* 2020; Ismail, 2013). Oppositely, participants from some studies (e.g., Ghasemi *et al.,* 2013), who were assumed to be Muslims, didn't regard GM foods as conflicting with their religious beliefs.

3.2.4 Perceived benefits and perceived risks

Since attitudes and perceptions were found to be influenced by risk and benefit perceptions, this theme summarises the different categories of benefits and risks that participants perceive to be associated with the production and consumption of GM foods and crops. This involves two major subthemes as discussed below.

- **Perceived benefits**

Participants believed that GM foods could deliver several benefits on various levels. For instance, increased agricultural yields, agricultural development acceleration, resistance to pests and plant diseases, drought resistance, and better seed quality were all among the production-related benefits listed by participants from many of the studies included (Ghasemi *et al.,* 2020; Ghoochani *et al.*, 2018; Ghanian *et al.*, 2016; Utkualp *et al.*, 2016; Tas *et al.*, 2015; Ghasemi *et al.,* 2013; Heiman *et al.*, 2011; Hosseini *et al.*, 2009; Sheikhha *et al.*, 2006). Sustainability and environmental benefits included food security, starvation and malnutrition alleviation, quality of life improvements, less irrigation water, reduced need for pesticides and other chemical inputs and, consequently, reduced environmental pollution and higher environmental protection (Ghasemi *et al.,* 2020; Ghoochani *et al.*, 2018; Ghanian *et al.*, 2016; Tas *et al.*, 2015; Heiman, 2014; El-Nakhlawy *et al.*, 2013; Ismail, 2013; Ghasemi *et al.,* 2013; Heiman *et al.*, 2011; Sheikhha *et al.*, 2006).

From an economic perspective, many participants believed that GM foods are good for the national economy, boosting farmers' incomes through better profits, and helping to lower food prices because of reduced production costs (Heiman *et al.*, 2011; Hosseini *et al.*, 2009; Sheikhha *et al.*, 2006). In many cases, participants were additionally convinced that genetic modification can offer various product-attributes-related benefits such as extended shelf life, improved physical appearance, increased quality and nutritional values, as well as improved taste (Ghasemi *et al.,* 2020; Utkualp *et al.*, 2016; Tas *et al.*, 2015; Heiman, 2014; Heiman & Zilberman, 2011; Sheikhha *et al.*, 2006). Finally, some participants listed a few health-related benefits such as the use of GM ingredients in medicines, and some believed that GM foods reduce health risks and provide higher quality nutrients (Ghasemi *et al.,* 2020; Heiman, 2014; El-Nakhlawy *et al.*, 2013; DemİrcĪ, 2008). **Figure 4** provides a graph of the GM foods benefits network that has been created by the authors based on the findings of the perceived benefits analysis.

- **Perceived risks**

Many participants also believed that genetically modified foods have potential disadvantages, and their use might pose certain risks. Most of the reported risks and concerns were relevant to human health and the environment (e.g., Yıkmış & Çöl, 2019; Ghoochani *et al.*, 2018; Al-Rabaani & Al-Shuaili, 2014; Heiman, 2014; Bakr & Ayinde, 2013a; El-Nakhlawy *et al.*, 2013; Ghasemi *et al.,* 2013; Tuna & İncekara, 2011; Ozer *et al.*, 2009; Hosseini *et al.*, 2009; Demİrcİ, 2008; Mehmetoglu & Demirkol, 2007; Sheikhha *et al.*, 2006). For instance, from a human health perspective, some study participants considered GM foods to be unhealthy and unsafe to consume, with the potential to have a negative impact on human health. Such hazards may range from allergenicity, antibiotics resistance, or gene mutation, to infertility, congenital organ anomalies, and carcinogenicity. Participants also perceived GM foods to be dangerous to the natural environment with the potential to generate negative environmental impacts such as biodiversity loss, disturbing natural genetic diversity and balance, as well as undesirable cross-pollination. These adverse environmental impacts can further extend to include creating new and unsafe species such as super weeds, new bacteria or viruses, and potentially creating new diseases; causing the unintended loss of beneficial insects; and leading to greater environmental pollution. In the studies of Ghoochani *et al.* (2017), Utkualp *et al.* (2016), Ghanian *et al.* (2016), and Tas *et al.* (2015), participants highlighted some political risks of GM foods such as reducing the economic power of the agricultural sector, making national governments dependent on foreign countries, threatening national genetic resources, and leading to production-exclusivity or monopolisation by seed companies. In a few cases, participants also reported ethical risks such as immorality, interfering in god's creation, animal welfare issues caused by gene manipulation, threats to the availability of natural resources for future generations, and expanding the gap between rich and poor people (Ghasemi *et al.,* 2020; Ismail, 2013; Heiman *et al.*, 2011).

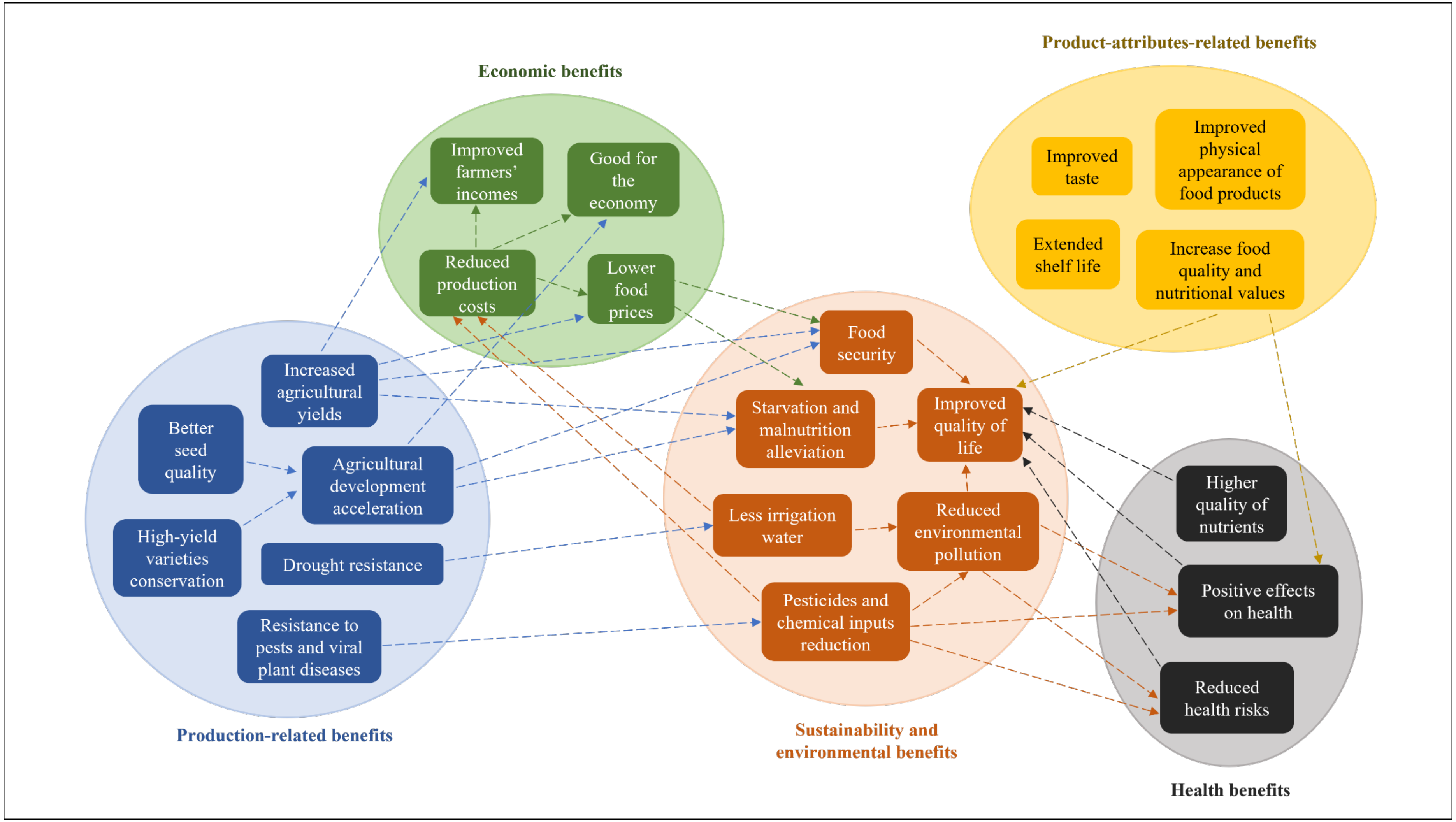

Figure 4: GM foods benefits network

4. Discussion

This review identifies and investigates societal perceptions and attitudes towards genetically modified crops and food products in the MENAT region. The review employed a two-stage search process which resulted in the identification of 38 studies eligible to be included in the review. Most of the studies included were quantitative, and are, supposedly, at lower risk of bias than qualitative studies. However, appraisal of the overall quality of the studies included indicated a moderate overall strength of evidence, which suggests the need for a cautious interpretation of the review's results. Many of the studies included in the review lacked sufficient information on methodological aspects such as sampling methods, ethical considerations, response rates, and the validity and reliability of results. Additionally, most of the studies failed to provide evidence of any theoretical underpinning of their empirical research.

Geographical distribution of the studies included in the review showed a clear imbalance, with 87% of the studies conducted in only four out of the 24 countries in the MENAT region. This geographical underrepresentation implies that there has been little research on attitudes and acceptance of GM foods in most MENAT countries. In addition, most of the studies were generic in terms of their focus. They examined attitudes and perceptions towards the generic notion of genetic modification in the agriculture and food sectors without prioritising any particular crop or food categories. Moreover, none of the included studies investigated perceptions or attitudes towards genetic modification for animal feed purposes. This lack of depth suggests that social research of GM application in food and agriculture sectors in the Middle East and North Africa is still in its early stages and that future and more targeted research in this area should be encouraged.

Results of the thematic analysis showed that societal stakeholders in the MENAT region are both concerned and uncertain about the presences of GM crops and foods in their lives, while holding a mixture of positive and negative attitudes towards them. Overall, negative perceptions and attitudes were found to be more prominent than positive ones. That aligns with the results of a review study that was conducted by Costa-Font *et al.* (2008), which revealed that over 58% of European consumers were generally pessimistic and 17% were undecided about GM foods. The study also suggested that opinions on GM foods from the US were not significantly different from those found in Europe. The confusion that participants felt about GM foods, as well as their doubts about whether to consume GM foods or not, was primarily attributed to inadequate levels of knowledge about GM products among study participants, that was underlined by the review's findings.

According to the review's findings, levels of knowledge about genetic modification had an impact on perceptions and attitudes towards GM food products. The review also reported very limited levels of knowledge about GM foods and what are they, whether they are beneficial or harmful, as well as a lack of awareness about their availability in local food markets. These findings align with the results of other review studies (Siddiqui *et al.,* 2022; Beghin & Gustafson, 2021; Wunderlich & Gatto, 2015; Costa-Font *et al.,* 2008) which found that knowledge, both subjective and objective, is one of the main contributors to the development of attitudes and responses to GM foods; and that, generally speaking, consumers' knowledge about gene technology application in food processing is relatively low. While these studies revealed that higher levels of knowledge promoted acceptance and more positive attitudes, they only partially support the findings of the current review, where in some cases, higher levels of knowledge about GM foods were associated with a higher likelihood of refusing them.

Likewise, familiarity with GM foods was found to play an important role in shaping attitudes and promoting acceptance. That is, the more the respondents were familiar with biotechnology and GM applications, the more likely they were to accept and support GM foods and crops. In a similar vein, Beghin and Gustafson (2021) argued that, in 2019, EU consumers were not as worried about GM foods as they had been in 2010, a finding which was attributed to the effect of increasing familiarity. Unexpectedly, none of the studies included in this review examined the influence of food neophobia, which is closely linked to unfamiliarity, on perceptions and attitudes towards GM foods. According to Siegrist *et al.* (2013), food neophobia is the fear of, or reluctance to eat, new foods, and it is well established that it can affect attitudes about novel food products.

The review's finding also revealed that risk and benefits perceptions were found to constitute a major driver of attitudes towards GM foods and crops and that the nature of the effect on attitudes was clear and consistent. This corresponds to the conclusions of Costa-Font *et al.* (2008) who found that risk and benefit perceptions, along with individual values and attributes, and knowledge, are, *inter alia*, the main factors that drive consumer attitudes towards GM foods. According to their results, while consumers in most European countries believe that the benefits of GM foods are insufficient to overcome their costs, US consumers think that these benefits outweigh the associated risks. In the current review, perceptions of the general benefits of the application of genetic modifications in agriculture and the food sector (e.g., productivity, environmental, and economic benefits) and product-oriented benefits (e.g., improved taste, shelf life, physical appearance, etc.) stimulated positive attitudes towards them; however, unfavourable attitudes were often associated with various health, environmental, social, and ethical concerns that participants perceived to be linked to GM foods.

Individual characteristics, such as socio-demographic and socio-economic attributes, were found to be associated with perceptions and attitudes to GM foods. Similar findings in the review by Costa-Font *et al.* (2008) suggested that age, ethnicity, residence, and income level were directly related to consumers' attitudes towards GM foods. Overall, male, younger, and middle- and upper-income participants held more favourable attitudes than female, elderly, and low-income individuals. The former also demonstrated greater acceptance and approval towards GM food products. Consistent with the findings of Frewer *et al.* (2014), females expressed more health concerns and negative opinions about GM foods, with lower levels of willingness to purchase than males. That could be attributable to the fact that females usually assign greater weight to health, than males, when making food choices (Heiman et al., 2011). Likewise, older participants were less accepting of biotechnology and novel food technologies than younger people, that is possibly because they are less familiar with novel food products and GM technologies due to more limited access to information, compared to young participants who might have greater access to information through multiple sources and channels (e.g., Internet, social media platforms, Artificial Intelligence, etc.). Also, participants with lower income levels tended to reject GM foods, which can be explained by the observed relationship between income and willingness to pay for most goods, especially since GM foods can be more expensive, at least in niche markets and at the early stages of diffusion, compared to their conventional rivals.

Ultimately, findings of the review argued that cultural factors including, *inter alia*, ethical and moral concerns, and religiosity, play an undeniable role in shaping attitudes and perceptions towards GM foods. In their systematic literature review, Frewer *et al.* (2013) emphasized that moral and ethical concerns should be taken into consideration when communicating about GM food applications, given their significance in attitude formation. In line with the findings of an overview study by Scott *et al.* (2018), participants from many of the studies included in our review were opposed to GM foods on moral grounds and, for many of them, GM foods constituted a moral contravention. Some even considered ethical problems to be the main drawback of GM foods. In a similar manner, religious beliefs and levels of religiosity were found to be, in some cases, predictive of opposition to genetic modification which could be thought of as being against God’s will (Scott *et al.*, 2018). For instance, participants with greater religiosity intensity demonstrated more negative attitudes towards applying genetic modification in food production; however, an exception to this finding was discovered in a few studies where religious participants declared that there was no conflict between GM foods and their religious beliefs.

5. Conclusion and research implications

Given the existing global debate on the production and consumption of GM foods and the fact that there is a lack of research on perceptions and attitudes towards GM foods in emerging economies and developing countries, this research aimed to collate available evidence on societal perceptions and attitudes towards GM crops and foods in the MENAT region to support both existing and future research. The findings of the systematic review suggest that people in the MENAT region generally tend to hold negative attitudes towards GM foods as well as demonstrating poor levels of knowledge about them and their existence in local food markets. Risk and benefit perceptions, GM knowledge and educational background, socio-demographic attributes, as well as culture and moral beliefs were all found to contribute to the formation of attitudes towards GM foods and crops.

The review also identified a few research gaps in the existing literature and highlights the need for further research. In light of these gaps, the review suggests some relevant points for future research to take into account to help enhance the reliability of research on attitudes towards GM foods in the MENAT region. First, from a research quality perspective, future studies need to provide clear and sufficient detail on both their methodological underpinning, as this was a commonly missing element throughout most of the studies analysed that affects their quality scores on quality appraisal scales. Second, given the geographical diversity of attitudes, there is a clear need for future research studies to direct greater focus on underrepresented MENAT countries, cultural regions, and stakeholder groups. The latter can be achieved through conducting qualitative research studies that facilitate the exploration of deeper and more detailed insights into the attitudes and preferences of consumers and other stakeholders. Third, since the authors observed that most of the existing literature has examined generic classifications of GM applications, it could be worthwhile conducting further case study research that considers specific GM food and/or crop categories in different MENAT countries, whilst taking into consideration any existing variations in the uptake and development of GM foods between the countries under examination. This could help to better capture existing attitudinal differences between various GM applications and food categories.

Additionally, there was an observed discrepancy in relation to the effect of religiosity on attitudes that necessitates further investigation of the link between cultural factors in general, and religious beliefs in particular, on attitudes towards GM food production; especially in the case of middle eastern and developing countries where such considerations play a vital role in people's daily lives and food shopping decisions. Finally, since many participants reported that they relied mainly on media and informal information sources, which may serve as a fertile environment for misleading, biased, or inaccurate information, further research on information provision and communication strategies for GM foods is required. To this end, policy and decision makers, along with scientists, need to contribute to, and supervise, the information communicated to the public and try to ensure its accuracy and validity. This would help to enhance people's understanding of GM foods and allow them to make more reasoned purchase decisions.

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