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The future of protein feed: a case study of sustainable substitutes in the German livestock industry

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Abstract

The use of imported soybean/soybean meal is criticized in the context of the sustainability discussion in Germany. Imported soybean is often associated with deforestation and genetic modification, which is largely viewed critically by consumers. This study aims to forecast changes in future demand for imported soybean/soybean meal and its possible substitutes in the German livestock industry. The two-round Delphi method was used in the study by sending questionnaires to 28 experts from four groups: food retailers, livestock associations, animal nutrition manufacturers and research institutes. Our main result is that the total use of soybeans in German livestock farming will decrease from almost 4 million tons of soybean equivalents in 2018/19 to approximately 3.4 million tons by 2030/31. In contrast, the share of non-GM soybean is forecast to increase from 26 to 53%. Factors that influence the increased use of non-GM protein feeds most are “specifications from downstream processors” and “demand from the feed industry.” Experts forecast that about 36% of imported soybean/soybean meal (from non-EU countries) for German livestock farming could be replaced by protein feed produced in the EU. Rapeseed was considered to have a particularly high potential for production in the EU, followed by soybean and sunflower. Experts considered the factors: “requirements by the food retailers,” “reasonable price,” “political regulation” and “better profitability for the producer” as the most influential for extended use of regional protein feeds.

Keywords Non-GM soybean · Regional protein feeds · Food retailers · Two-round Delphi · Sustainability

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1 Introduction

The ban on using meat and bone meal in animal feed due to the BSE (bovine spongiform encephalopathy) crisis in 2000, was a turning point for the worldwide protein feed industry (Klohn, 2002). Since then soybeans have become the main source of protein in animal nutrition due to their high nutritional value and low production costs (Asbridge, 1995; Garret & Rausch, 2016; Jia et al., 2020). They can be used for many applications in the food and feed industry. About 87% of the global soybean output is processed into soybean oil and soybean meal, 6% is used for human consumption (e.g., tofu, soy milk, soy sauce, tempeh) and a further 7% is utilized as whole-bean animal feed (Fraanje & Garnett, 2020). The crushing of soybeans results in soybean oil (share approximately 18%) and soybean meal (share approximately 79%) (Oil World, 2019). The latter has become an important source of protein in animal feed. Additionally, the increase in global meat and milk consumption has led to an increased demand for protein feeds in livestock production. Consequently, global soybean acreage has expanded rapidly. In 2018/19, these areas covered approximately 126 million hectares (Oil World, 2019). In the leading producer countries in South America, soybean cultivation promoted economic development, especially in rural areas (IDH & IUCN, 2019). At the same time, however, increased negative impacts on the environment (e.g., greenhouse gas emissions, biodiversity loss, deforestation) (Ferreira et al., 2016; Gaitan-Cremaschi et al., 2015; He et al., 2019; IDH & IUCN, 2019; Raucci et al., 2015; Taherzadeh & Caro, 2019; Zortea et al., 2018) and elevated social tensions (e.g., food insecurity, rural conflicts) (Altenburg, 2007; McKay, 2018) also became evident.

In 2018/19, about 3.1 million tons of soybean meal (equivalent to four million tons of soybeans) were used for livestock farming in Germany (BMEL, 2019). The German demand for protein feeds, especially soybean meal, is covered almost exclusively by imports from Brazil, the USA, and Argentina, which had a share together of 75% of total imports of soybean equivalents in Germany in 2018/19. A discussion about imported soybeans has raised the questions as to what extend they can be linked to deforestation and loss of native vegetation in the Amazon and other areas of South America (Fraanje & Garnett, 2020; Gibbs et al., 2015; Kastens et al., 2017), and to what extent they can be replaced by regional feed production (European Commission, 2018b; Jouan et al., 2020; Kuepper & Steinweg, 2019). These sustainability problems related to the so-called protein deficit in Germany and the high share of imports of domestic demand, led to a political discussion in Germany with the goal of reducing imported soybeans and replacing them with regional alternatives (BMEL, 2016; BLE, 2018).

Furthermore, most of the imported soybean varieties are genetically modified. In Germany and other member states of the European Union (EU), while GM feed is generally allowed, consumer preferences are for products without genetically modified organisms (GMOs) (European Commission, 2018a; Jouan et al., 2020). Historically, the proportion of non-GM soybean consumption in livestock farming increased from 15% in 2012/13 to about 26% in 2018/19 in Germany (European Commission, 2018a; JRC, 2015).

Therefore, this study analyses future changes in demand for imported GM soybean/soybean meal and possible sustainable substitutes in the German livestock industry. Two alternatives are assessed: regionally produced alternatives or non-GM protein feeds. The study presents an outlook into future changes of demand in protein feeds from the point of view of stakeholders involved in the value chain.

In this study, the terms non-GM protein feeds and regional protein feeds are used in the following senses: (1) non-GM protein feeds are either produced locally or imported; and

(2) regional protein feeds are protein feeds (e.g., soybean, rapeseed, sunflower, legumes) only produced within EU territory, which are all non-GM. The EU and Germany aim to reduce external soybean imports by increasing regional protein feed production within the EU, which is guaranteed to be non-GM. However, the EU and Germany still have to rely on imports of non-GM protein crops. For this reason, it is necessary to study the factors affecting the increased use of non-GM protein feeds and regional protein feeds separately in order to better understand the supply possibilities leading to a sustainable substitution of imported GM soybean/soybean meal in the German livestock industry.

2 Background

Soybean markets are embedded in the oilseed markets, vegetable oil markets, and protein feed markets, of which the latter is the focus of this paper. Soybean meal dominates the protein feed market due to its high nutritional value and low prices compared to other protein feeds (Asbridge, 1995). Soybeans are one of the world's most important arable crops. Global soybean cultivation is concentrated in North and South America. Part of the production is exported directly and further processed in the importing countries, another part is exported in the form of soybean meal (Oil World, 2019). Together, Brazil, Argentina and the USA generated 82% of global production in 2018/19 (Oil World, 2019). Cultivation in Asia and in temperate European climate zones (especially in Ukraine, Russia, Italy, France) is significantly lower than in North and South America, but shows an increasing trend.

The current protein deficit in Germany and the EU is mainly due to the following four reasons: intensification of livestock farming, lower competitiveness of protein crops in comparison with other crops, European policy promotion of cereal production, and increasingly unfavorable climate conditions and pest infestations on protein crops (European Commission, 2018a). Lower production and increasing demand for protein feeds in the EU are therefore covered by imports.

After World War II, and before the establishment of the World Trade Organization (WTO) in 1995, American countries agreed to specialize in oilseed production while Europeans focused on grains as part of the general agreement on tariffs and trade (GATT) negotiations. As part of the Dillon round of GATT, which took place in 1960–1961, the European Commission reduced its import duties on oilseeds, oilseed products and other non-cereal feed ingredients. This gave the US and other exporters duty-free access to the European market (European Commission, 2018a). This agreement has had several implications for the EU agricultural sector, including making soybean imports more competitive than other substitutes. As a result, imported soybeans have become an important protein source for animal feed. In addition, due to the high demand for soybean, Argentina and Brazil have increased their production and have become the main soybean suppliers to the EU. In 1992, the US and the EU negotiated the Blair House agreement which limited the amount of oilseed area allowed to be subsidized in the EU. The deal favored soybean imports. However, since the 2008 European common agricultural policy (CAP) health check, special payments for energy crops and the restricting regulations have been abolished. Hence, the Blair House agreement is considered not to be restrictive under the current CAP but still remains in force (European Commission, 2018a). Currently, there are no restrictions on the cultivation of oilseeds in the EU, but neither are there any import duties on oilseeds, so soybeans and soybean meal can be imported duty-free (Kootstra et al., 2017).

After describing the political context and the origins of soybeans, we now analyze the question of final use in different animal sectors by employing data on compound feed in Germany (Table 1). Between 2018 and 2021, Germany produced with an average of approx. 23.6 million tons compound feed (BMEL, 2022). The demand for compound feed is mainly determined by the swine, cattle and poultry sectors. In 2018, more than 50% of the production of compound feed for poultry and dairy cow was non-GM, while the share of non-GM compound feed for the swine sector was much lower with only 3% (European Commission, 2018a). Soybean meal was mainly mixed into poultry feed, particularly 26% for broilers and 15% for laying hens. The proportion of soybean meal in dairy cow feed is also notably high at 12%, while it was only 9% in swine feed. The latter is subject to great uncertainty, with estimates of the soybean meal content in swine feed being between 7.5% (WWF, 2014) and 19% (VLOG, 2018).

Commercial compound feed production with non-GM soybeans varies greatly across EU countries and livestock sub-sectors. On the one hand, there are two EU Member States, namely Hungary and Sweden, which almost exclusively produce compound feed with non-GM soybeans (JRC, 2015). Both countries are rather small manufacturers of compound feed at EU level, but have developed a high level of specialization in the segment of non-GM feed production. On the other hand, Belgium, the Netherlands, Portugal and Spain, use practically no non-GM soybeans in the production of compound feed. These countries are relatively large producers of compound feed in the EU (JRC, 2015). For the rest of the EU countries, the production of compound feed containing non-GM soybeans is variable and depends on the livestock sub-sectors. Non-GM soybean is least used in the production of compound feed for the swine sector and most used in the poultry sector (JRC, 2015).

Since the main suppliers of soybeans or soybean meal for the EU countries are in North and South America, where the cultivation of GM varieties in agriculture is very high, there are concerns about the ability of EU operators to secure demand for non-GM soybean in future. In 2018/19, 77% of the soybean area was used for GM varieties (ISAAA, 2018). Soybean cultivation in the three main producing countries is dominated by GM varieties: In 2018, the proportion of GM varieties was 100% in Argentina, 97% in Brazil and 96% in the USA (ISAAA, 2018; USDA, 2019). At the same time, these countries are also the main exporters of soybeans or soybean meal. As a result, most soybeans and soybean meal traded on world markets are GM varieties. Demand for non-GM soybeans is relatively high in the EU compared to other parts of the world. With the increase in local non-GM variety

Table 1 Industrial compound feed production and shares in Germany of soybean meal and non-GM feed used in livestock production by animal species

Sector/Year	Compound feed (million tons)		% Soybean meal content	% Non-GM feed
	2018	2021	2018	2018
Dairy cow	6.5*	6.2*	12	50
Swine	9.5	9	9	3
Broiler	4.1	4	26	60
Laying hen	2.2	2.3	15	70
Others	1.5	1.3	–	–
Total	23.8	22.8		

**Estimation*

Source: FEFAC (2022); BMEL (2022); IDH (2016) production, these main producing countries have the opportunity to export more soybeans or soybean meal to the EU market.

The production and sourcing of protein feeds for the agri-food sector has repeatedly raised political debates at German and EU level. As a result of the protein deficit in the German livestock industry and the increased demand for regional protein feeds, Germany has set itself the goal of reducing its dependency on imports of protein feeds, especially soybeans (BMEL, 2016). However, the substitution of imported GM soybeans in the German livestock industry is currently limited by diverse influencing factors relating to alternative non-GM and regional protein feeds. From an animal nutrition perspective, soybean alternative proteins (e.g., broad beans, peas, lupins) can be substituted only in limited amounts depending on animal species and growth phase (Bellof et al., 2020). The change of feed rations with more soybean alternatives at commercial level requires both scientific evidence and demand from the animal nutrition industry (Zerhusen-Blecher et al., 2016). Additionally, production of these alternative proteins needs to increase considerably in the EU to be competitive with GM soybeans and other imported alternatives (Zimmer & Böttcher, 2021). This will decide whether more protein sources from the EU are used in feed rations, and thus imports from outside EU countries, especially from South American countries could be reduced to avoid long transport routes and protect the local environment. Another alternative is the import of non-GM protein feeds from different destinations such as rapeseed/rapeseed meal from Australia or oilseeds/oilseed meal from Ukraine.

An increase in regional soybean cultivation in Germany or within the EU could contribute to many ecological, economic and social sustainability benefits. These include lower GHG emissions (Hortenhuber et al., 2011; Sasu-Boakye et al., 2014) and better social standards (Garret & Rausch, 2016; Sojafördering, 2023). The biological nitrogen fixation ability of soybeans could reduce the use of fertilizers and can be used in crop rotation which revitalizes the soil and solves crop rotation problems (Watson et al., 2017). In addition, soybean cultivation is profitable for many farmers in different regions of Germany and the EU (Zimmer & Böttcher, 2021). However, as Germany/the EU need to produce more oilseeds this comes at the cost of lower grain production. This grain has then to be imported from elsewhere. The associated global land-use changes could indeed be detrimental (Freund et al., 2023).

Several studies have looked at the ability of the EU to produce regional protein feeds and the possibility of substituting its GM soybean imports. The European Commissions (2018a) reviewed the supply and demand situation for protein feeds, such as rapeseed, sunflower seeds or legumes. It shows that in 2016/17 almost 95% of soybeans were imported for food and feed industry. This is mainly due to the lower competitiveness of regional protein crops compared with imported GM soybeans. To this end, the EU has proposed policies to support the production of regional protein crops through the CAP in order to boost its regional production and reduce future imports. Jouan et al. (2020) studied the cultivation of legumes as a substitute for external imports in animal husbandry in France. It was discovered that although support for regional protein crop production increased, the level of self-sufficiency could not be raised sufficiently. Another factor is that regional legumes in feed rations are of low quantity and quality compared to imported protein feeds which do not meet the requirements for animal feeds, especially in swine nutrition. Another study on market structure of regional legume production in Germany by Sepngang et al. (2018) found that the market is non-transparent and fragmented, which constitutes a major barrier for increasing production. Zerhusen-Blecher et al. (2016) have studied influencing factors on the use of regional proteins feed identified by experts from animal feed production companies. The results showed that the availability of regional protein feeds and the willingness to change to feed rations with more regional protein feeds were important factors in increasing regional production. While Zimmer and Böttcher (2021) studied the feasibility of growing soybeans in the EU to increase self-sufficiency, they found that in southern Germany climate and market conditions promoted long-term soybean cultivation, but that this is difficult in the northern region. The above studies clearly showed that the European protein crop production is not sufficient to cover growing demand. Imported GM soybean substitution with regional protein feeds produced in the EU is to some extent possible because of a variety of market and climatic factors. However, there is still a lack of long-term studies on how much imported GM soybeans could be substituted with regional protein feeds and other alternatives as well as which factors will contribute to sustaining such reductions in future. In order to achieve a better balance in the supply and demand of protein feeds, this study provides a model case for studying the future substitution of GM soybean imports from outside the EU with regional protein feeds. In addition, influencing factors contributing to this development will be identified through opinions from a panel of experts from different groups directly involved in the livestock industry. This study could be a guideline for other EU member states or other countries who need to reduce their long-term sustainable GM soybean imports.

3 Methodology

3.1 The Delphi method

Dalkey and Helmer (1969) define the Delphi method as a technique for collecting and refining group judgments on subjects where detailed information or knowledge is lacking. In addition, it is used to gather different expert opinions and reach a consensus on the different unknown factors (Green et al., 1990). The Delphi method was developed in the USA at the end of the 1940s and since the 1970s has also been increasingly used in German research.

Its main features are anonymity, iteration, controlled feedback, and statistical group response (Rowe et al., 1991). *Anonymity* is achieved through the use of formal questionnaires in which independent opinions can be freely expressed without being influenced by others. *Iteration* and *controlled feedback* are performed during the Delphi process. The survey is conducted in at least two or more rounds so that the experts have the opportunity to revise their previous answers. *Statistical group response* is generated at the end of each round, where group judgments can be expressed as means, medians, interquartile ranges, or standard deviations based on the numerical ratings of each item. In the course of the study, the individual statements are more and more similar to the mean values from all individual answers. A consensus is generated and from this relatively reliable forecast, values and future scenarios can be created (Vollstädt, 2003). In the final round, the group opinions are aggregated and presented as a simple statistical summary. These four basic features are seen as the strength of the Delphi study (Linstone & Turoff, 1977) since they minimize the biasing effects of dominant individuals, irrelevant communications, and group pressure toward conformity.

The Delphi study is used extensively in information management, decision science, risk analysis, supply chain management, and related fields to identify, assess and prioritize factors (Akkermans et al., 2003; Chen et al., 2020; Flostrand et al., 2020; Jäger & Piscicelli, 2021; Lummus et al., 2005; Soisontes, 2017). In addition, this method is often used to make forecasts (Culot et al., 2020; Jiang et al., 2017; Kluge, et al., 2020; Markmann et al., 2013; Melander et al., 2019; Peppel, et al., 2022; Roßmann et al., 2018). In the field of agricultural science, Veahthier and Windhorst (2011) applied the Delphi method to forecast future poultry production and its affecting factors. The Delphi technique was used to identify sustainability factors in the poultry industry (Soisontes, 2017) and milk production systems (Munyaneza et al., 2019). The study on non-regulatory animal health issues facing the Irish livestock industries (More et al., 2010) and future agricultural production structures within the cross-border region of the Netherlands, North-Rhine Westphalia,and Lower Saxony by 2020 (Hop et al., 2014) also used the Delphi method. Detailed information and discussion of the Delphi method can be found in Häder (2002), Von der Gracht (2012), Soisontes (2017), Flostrand et al. (2020), and Barrios et al. (2021).

It can be concluded that the Delphi technique is best used in fields of study where knowledge is limited or where no historical data is available (Gupta & Clarke, 1996). However, it should be noted that the Delphi method might be unsuitable for more complex issues where the theme cannot be reduced or simplified, and for studies with the key objective of inspiring reflection and discussions on the theme (Eto, 2003). With the growing use of the Delphi method, there has also been a growing impact of the methodology on both corporate planning and government policy-making. Because the results are generated from judgments it is important that the methodology is used properly and the outcomes are interpreted carefully (Story et al., 2001). Since in each succeeding round of questionnaires in the Delphi process the range of responses will presumably decrease, maintaining participant interest in the Delphi study is a challenge (Beech, 1999). Thus, in order to apply the Delphi method successfully, the questionnaire design and expert selection process need to be done carefully.

3.2 Study design

In this study, the Delphi method was used to identify the possibilities of substituting imported GM soybean/soybean meal with non-GM protein feeds or regional protein feeds produced in the European Union (EU) in 2030/31. In addition, the use of non-GM and regional protein feeds in German livestock farming was forecasted up to 2030/31 and their affecting factors identified. The target year 2030/31 represents a long-term development and tangible future, i.e., it is not so far in future for it to be unimportant for the respondents of the questionnaire and their businesses. But it is far enough into the future that short-term development should not play a disproportionately large role for the respondents when answering the questionnaire.

Figure 1 shows the process of the conducted Delphi study. It consisted of four steps: selection of an expert panel, questionnaire design and validation, survey and data analysis. The Delphi study is a group decision mechanism requiring qualified experts who are specialists on the issues being researched. Thus, choosing the panel members is a crucial prerequisite for a successful Delphi study (Martino, 1993; Rowe & Wright, 1999; Welty, 1972). The experts were identified through browsing organization websites and journal databases, as well as recommendations from institutions and other experts. In the first step, experts were selected based on the guidelines of Delbecq et al. (1975) and Okoli and Pawlowsky (2004). The variety of relevant expert groups involved in the supply chain is necessary to combine knowledge representing all relevant perspectives (Gill et al., 2013; Rowe & Wright, 2001). The experts' professional experiences in the German livestock industry include publications in the field, project references,

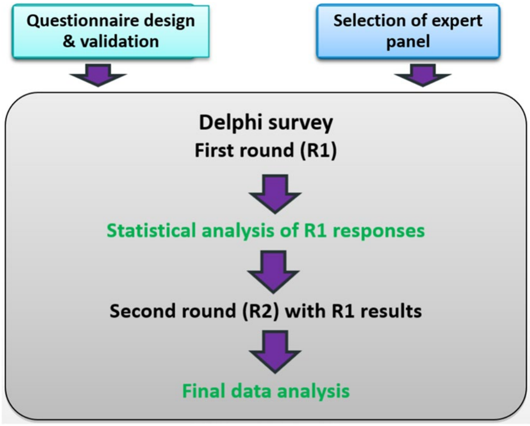

Fig. 1 The process of the Delphi study

conference participation, or years of experience in academia, government, NGOs, or the private sector. The literature is divided on the issue of the optimal size of a Delphi panel (Linstone & Turoff, 1977; Williams & Webb, 1994). Adler and Ziglio (1996) suggest 20–30 participants for each issue. The reliability of group responses can be increased by a higher number of participants (Dalkey et al., 1972).

A literature review and expert recommendations were carried out for questionnaire design and validation. The results discussed the possibility of substituting imported GM soybean/soybean meal with non-GM and regional protein feeds for livestock farming in Germany. As recommended by Belton et al. (2019) and Frewer et al. (2011), this investigation focused on peer-reviewed articles, books, magazines, conference papers, and reports published in English and German. The factors related to the use of non-GM and regional protein feeds for livestock production in Germany were considered when creating the Delphi questionnaire. Copies of this questionnaire were distributed to seven experts as a pre-test to validate the composition and structure of the questionnaire and the comprehensibility of the individual questions. Necessary adjustments were made based on their comments, and a final version of the Delphi questionnaire was developed. This was followed by two rounds of surveys, in which the questionnaire was sent to the experts by e-mail. An evaluation took place after the first round (*R*1), and in the second round (*R*2) of the survey, the experts were given feedback on the results of *R*1 in the form of statistical mean values. The final results were analyzed after the end of *R*2.

This study was conducted over a period of six weeks from September to November 2020, with the individual survey rounds lasting 15 days each. *R*1 was sent to 28 participants. They were asked to: (a) forecast the share of non-GM protein feeds required by livestock farming in Germany by 2030/31; (b) project the total demand of soybeans for livestock farming in Germany by 2030/31 with the share of non-GM variety; (c) suggest and rate the level of influence of factors affecting the increased use of non-GM protein feeds in Germany by 2030/31; (d) estimate the long-term possibilities for Germany to substitute imported GM soybean/soybean meal with regional protein feeds by 2030/31; (e) rank the most promising substitutes produced in the EU by 2030/31; and (f) suggest and rate the level of influence of factors affecting the increased use of regional protein feeds in Germany by 2030/31. Table 2 shows the description of influencing factors and how they might affect the increased use of non-GM and regional protein feeds in Germany.

Table 2 Description of influencing factors for the increased use of non-GM and regional protein feeds in Germany

Influencing Factors	Description
Policy support measures*,**	Agricultural policy support measures, e.g., the national protein crop strategy, could lead to an increasing use of non-GM and regional protein feeds
Political regulation*	Political regulation to support regional protein feeds has a direct impact on the increased use of regional protein feeds
Social acceptance*,**	Social acceptance plays an important role in the use of non-GM and regional protein feeds such as non-GM soybeans
Better availability*,**	More availability of regional protein feeds on the EU market, e.g., soybean, rapeseed, grain legumes, could increase the use of non-GM and regional protein feeds
Reasonable price*,**	With a cheaper price for non-GM and regional protein feeds compared with imported GM products, farmers can reduce their production costs for livestock production resulting in an increasing use of non-GM and regional protein feeds
Expansion of regional protein crop cultivation*,**	Greater regional production of protein feeds would increase the availability and use of non-GM and regional protein feeds
Expansion of the regional value chain*,**	Increased cooperation between stakeholders involved in the value chain is necessary for the increased use of non-GM and regional protein feeds such as soybeans
Improvement in breeding (protein crops)*	The improvement of plant breeding for regional protein crops adapted to local conditions such as weather or soil structure, is necessary for the production of regional protein feeds
Better profitability for the producer*	More profits for the producers who produce regional protein feeds could promote regional protein feed production and thus increase its use
Improvement in protein quality (e.g., soybean)*,**	At present, the protein quality of regional protein feeds such as soybeans is still lower than that of imported soybeans produced in Brazil. It is therefore necessary to improve the protein quality of regional feeds in order to increase competitiveness
Changed feeding concepts (e.g., climate-friendly)*	Changing in feeding concepts by using regional protein feeds to reduce environmental impact, for example through lower greenhouse gas emissions, could be an important factor for livestock farming in future
Demand for deforestation-free by actors in the value chain*	Soybean cultivation, particularly in Brazil, has been heavily criticized for its impact on local forests. The support of the actors in the value chain for deforestation-free, e.g., protein feed production within the EU could therefore increase the use of regional protein feeds
Expansion of labels such as VLOG (Non-GMO Food Association)*	The development of more labels for regional products such as VLOG can promote the use of regional protein feeds

Table 2 (continued)

Influencing Factors	Description
Requirements by the food retailers*	Food retailers are increasingly focusing on the marketing of regional and non-GM products and are using the "Ohne Gentechnik (without GMO)" label on many of their own products, especially eggs, meat and dairy products. The food retailer therefore has an influence on the use of regional protein feeds
Demand from the feed industry**	The animal feed industry plays a central role in animal production. Its demand for non-GM protein feeds for animal production has a direct impact on the increased use of non-GM protein feeds
Better certainty of origin**	Better traceability of non-GM soybean products can ensure consumer confidence in non-GM protein feeds
Positive image**	Non-GM products have a relatively positive image, particularly in the EU, which could influence the increased use of non-GM protein feeds
Specifications from downstream processors (e.g., dairy factories, food retailers)**	The demand for non-GM products, particularly from dairy and food retailers, has a direct impact on the increased use of non-GM protein feeds for livestock production
Adjustment of the legal framework for non-GM labeling**	Adjusting the legal framework for "Ohne Gentechnik (Without GMO)" labeling in favor of the manufacturer could increase the use of non-GM protein feeds

*Influencing factors for regional protein feeds, **Influencing factors for non-GM protein feeds

The respondents were asked to state volumes and shares freely. The rating questions used a 5-point Likert scale rating system, which is based on Vagias (2006): 1 = not at all, 2 = slightly, 3 = moderate, 4 = strong/high, and 5 = particularly strong/particularly high. For each factor, mean values (MV) and standard deviations (SD) were calculated. $R2$ was based on the responses from $R1$giving the respondents the chance to revise their answers given in $R1$. In this study, MV were used to identify the level of potential or influence. They were selected in order to include all opinions regarding the purpose of the Delphi method. Based on the definition of the five-point Likert scale used in this Delphi study, the MV is interpreted following the guidelines of Wrench (2013) and Soisontes (2017): 1.00–1.80 = not at all, 1.81–2.60 = slightly, 2.61–3.40 = moderate, 3.41–4.20 = strong/high, and 4.21–5.00 = particularly strong/particularly high.

There is variation in measuring consensus for the Delphi method depending on the purpose of each study (Barrios et al., 2021; Boulkedid et al., 2011; von der Gracht et al., 2012). This Delphi study evaluated the change in MV and SD between $R1$ and $R2$ to measure consensus for quantitative forecasting numbers based on Veauthier and Windhorst (2011). In addition, SD values were used to measure the level of consensus among expert panels in identifying factors or issues in this Delphi study based on Grobbelaar (2007), Giannarou and Zervas (2014), and Soisontes (2017): $0.00 \leq SD < 1.00$ = high level, $1.00 \leq SD < 1.50$ = reasonable and $SD \geq 1.50$ = no consensus.

3.3 Composition of the Delphi panel

A total of 28 experts were invited to participate in this study, 27 experts agreed to participate in the first round. Of these 27 experts, one person was no longer willing to participate in the second round of the survey due to time constraints during the survey. In Delphi studies, it is quite common for the number of participants to decrease from round to round. However, a number of 26 experts is considered sufficient for the achievement of relevant results due to the nature of the subject of investigation.

The Delphi panel consisted of the following four expert groups: food retailers, livestock associations, animal nutrition manufacturers, and research institutes with the composition as presented in Table 3. The response rate of this Delphi study was over 96% in both survey rounds.

4 Results

4.1 Use of non-GM protein feeds for livestock farming in Germany

4.1.1 Forecast of the use of non-GM protein feeds required by German livestock farming by 2030/31

In the Delphi study, the experts were asked to estimate the total amount of non-GM protein feeds required by German livestock farming by 2030/31. According to the predictions of the experts in the second round of the survey, the use of non-GM protein feeds for laying hen husbandry will increase from 70% in 2018/19 to 88% in 2030/31 (see Fig. 2). The demand for broiler will also rise from 60% and for dairy cattle from 50% in 2018/19 to 80% in 2030/31. Although the use of non-GM protein feeds in swine husbandry was only 3% in 2018/19, an increase to 34% in 2030/31 is projected. In comparison with poultry and cattle, the use of non-GM protein feeds is lower in swine production. Important reasons given by the experts are cost effectiveness and organizational form in the swine industry.

As expected, the range of answers was reduced in the second round, so that the minimum and maximum values were adjusted to the average. The standard deviation values (SD) were also significantly lower than in the first round of the Delphi study. This shows that consensus among experts is developed.

Table 3 Response rates across the panelists and rounds

	Round 1 (*R*1)	Round 2 (*R*2)
Total questionnaires sent	28	27
Total responses	27	26
Expert groups		
Food retailers	4	4
Livestock associations	5	5
Animal nutrition manufacturers	15	15
Research institutes	3	2
Response rate (%)	96.4	96.3

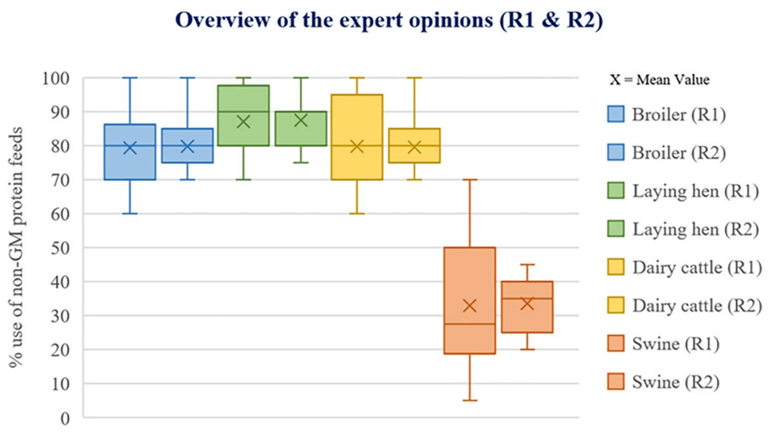

Fig. 2 Share of non-GM feed in animal ratios based on expert opinions in $R1$ and $R2$ of the Delphi study

The Delphi study predicted a decrease in the total use of soybeans in German livestock farming: starting from almost 4 million tons of soybean equivalents in 2018/19, dropping to around 3.4 million tons in 2030/31. In contrast, the share of non-GM varieties is expected to increase from 26 to 53% (see Fig. 3). Experts stated that the total requirement of soybeans depends heavily on how price synthetic amino acids are and how much they can be used to reduce the protein content in animal feed. By lowering the protein content, regional protein feeds such as rapeseed extraction meal have a high potential to be used as a substitute which are also non-GM feed. Another uncertainty

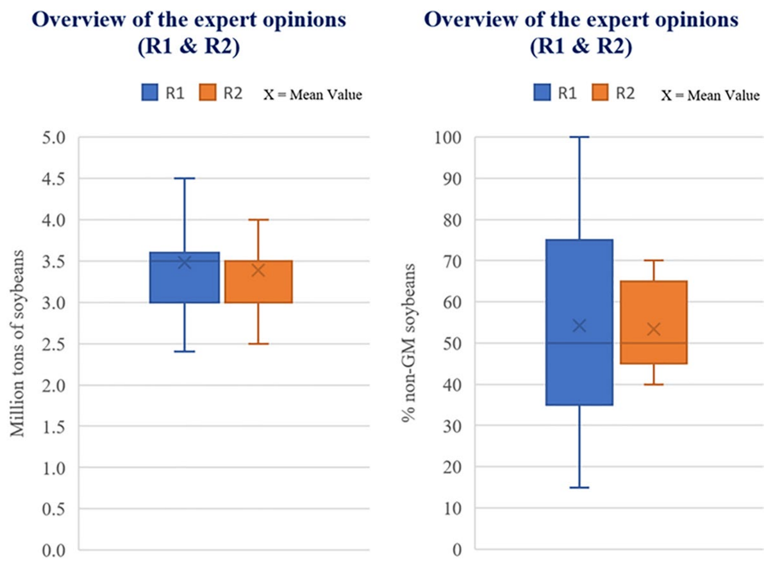

Fig. 3 Overview of the expert opinions in $R1$ and $R2$ of the Delphi study on the total demand of soybeans (left) and share of non-GM protein feeds (soybeans) (right)

regarding the total requirement of protein feeds is the possible enhanced reduction in livestock production in Germany in future.

The range of answers decreased in the second round of the survey, which resulted from an adjustment of the maximum and minimum values. The SD values were also significantly lower, showing increasing consensus.

4.1.2 Factors affecting the increased use of non-GM protein feeds in Germany by 2030/31

Another question in the Delphi study was to identify factors that have a particular influence on the long-term increase in the use of non-GM protein feeds in Germany by 2030/31. The 11 influencing factors regarding the use of non-GM protein feeds in Germany listed in the initial surveys are based on a literature review and expert recommendations. An additional factor was proposed by the experts in the first round of surveys. A total of 12 factors were identified and rated. Table 4 summarizes the *R*1-/*R*2-Delphi results and *R*2 results by stakeholder groups, including the sample size (*N*), MV and SD for each factor. Based on the SD values in *R*2, the consensus among experts is achieved.

As shown in Table 4, it can be seen that the experts identified *specifications from downstream processors (e.g., dairy factories, food retailers)* and *demand from the feed industry* as the most influential factors in the increased use of non-GM protein feeds in Germany. This clearly shows that the demand for non-GM products, particularly from dairy factories, food retailers and animal feed industry, has a direct impact on the increased use of non-GM protein feeds. Experts identified *reasonable price* for non-GM protein feeds as a strong influencing factor. With a cheaper price for non-GM protein feeds compared with imported GM varieties, farmers could reduce their production costs for livestock resulting in an increasing use of non-GM protein feeds. Other strong influencing factors include *social acceptance, positive image* and *adjustment of the legal framework for non-GM labeling*. While the factors: *expansion of regional protein cultivation, better availability, policy support measures, better certainty of origin, expansion of the regional value chain,* and *improvement of in protein quality,* were considered by the experts to have only moderate influence on the increased use of non-GM protein feeds in Germany.

As animal nutrition manufacturers and food retailers play an important role in the use of non-GM protein feeds for livestock farming in Germany, the Delphi study was also able to provide the results identified by these two stakeholder groups in order to see their attitudes on the use of non-GM protein feeds clearer than before. As presented in Table 4, animal nutrition manufacturers and food retailers agreed that the factor *specifications from downstream processors (e.g., dairy factories, food retailers)* has a particularly strong influence on the increased use of non-GM protein feeds in Germany, which corresponds to the Delphi result identified by all experts. Food retailers also considered the factor *demand from the feed industry* as a particular strong influence, while animal nutrition manufacturers rated this factor as a strong influence. This confirms that the demand from these two stakeholder groups is an important factor for the increased use of non-GM protein feeds in the German livestock farming. Non-GM products have a relatively *positive image*, particularly in the EU as well as the *adjustment of legal framework for non-GM labeling* in favor of the manufacturers and *reasonable price* for non-GM protein feeds could increase the use of non-GM protein feeds. Thus, both expert groups assessed these three factors as a strong influence.

Table 4 Summary of *R*1-/*R*2-Delphi results and *R*2 results by stakeholder groups for factors affecting the increased use of non-GM protein feeds in Germany

Factors	*R*1			*R*2 (*N*=26)	
	N	MV	SD	MV	SD
Total Delphi result					
Specifications from downstream processors (e.g., dairy factories, food retailers)	27	4.69	0.46	4.85	0.36
Demand from the feed industry	27	3.92	1.07	4.23	0.70
Social acceptance	27	3.54	1.08	3.77	0.89
Reasonable price	27	3.73	1.13	3.73	0.81
Positive image	27	3.46	1.08	3.65	0.73
Adjustment of the legal framework for non-GM labeling	1	4.00	–	3.62	0.96
Expansion of regional protein crop cultivation	27	3.35	1.04	3.35	0.87
Better availability	27	3.35	1.25	3.12	1.05
Policy support measures	27	3.19	1.07	3.00	0.83
Better certainty of origin	27	3.23	1.01	2.92	0.78
Expansion of the regional value chain	27	2.92	1.00	2.88	0.89
Improvement in protein quality	27	2.88	1.19	2.85	0.86

*R*2-Results by stakeholder groups	Animal nutrition manufacturers		Food retailers	
	N=15		*N*=4	
	MV	SD	MV	SD
Specifications from downstream processors (e.g., dairy factories, food retailers)	4.80	0.40	5.00	0.00
Demand from the feed industry	4.07	0.68	4.25	0.83
Adjustment of the legal framework for non-GM labeling	3.93	0.93	3.50	0.87
Social acceptance	3.80	0.91	3.25	1.09
Reasonable price	3.67	0.87	4.00	0.71
Positive image	3.60	0.71	4.00	0.71
Expansion of regional protein crop cultivation	3.53	0.88	2.75	0.83
Policy support measures	3.27	0.93	2.50	0.50
Better availability	3.00	0.89	2.25	0.83
Expansion of the regional value chain	2.93	0.99	2.50	0.87
Improvement in protein quality	2.93	0.99	2.75	0.43
Better certainty of origin	2.60	0.80	3.25	0.43

Although the higher *social acceptance* for non-GM protein feeds and greater *expansion of regional protein crop cultivation* would increase the use of non-GM protein feeds, animal nutrition manufacturers and food retailers had different opinions on these two factors. Here, animal nutrition manufacturers weighted both factors as having a strong influence, while food retailers considered them as only having a moderate influence. Their opinions were also different for the factors *policy support measures, better availability* and *expansion of the regional value chain* which were viewed by animal nutrition manufacturers as having a moderate influence, but by food retailers as only having a slight influence. On the other hand, food retailers rated the factor *better certainty of origin* as having more influence on the increased use of non-GM protein feeds than the animal nutrition manufacturers.

Overall results clearly show that the demand from dairy factories, food retailers and the feed industry post a strong influence on the increased use of non-GM protein feeds in German livestock farming.

4.2 Possibilities of substituting imported GM soybean/soybean meal with regional protein feeds

4.2.1 Long-term substitution possibilities by 2030/31

In the Delphi study, the experts were asked to estimate the long-term possibilities of substituting imported GM soybean/soybean meal with regional protein feed produced in the EU by 2030/31. In 2018/19, around 4 million tons of soybean equivalent were used for livestock farming in Germany, almost 100% of this amount was imported. Experts predict that around 36% of imported soybean/soybean meal (from non-EU countries) for German livestock farming can be replaced by regional protein feed produced in the EU by 2030/31 (see Fig. 4).

The mean values decreased slightly in the second round of surveys. Between 10 and 90% of substitution were predicted in the first round. However, the range of answers was narrowed to 20% and 50% in the second round. The standard deviation was also lower in the second round, it can be assumed that the consensus of the expert opinions has developed. Some experts who predicted the higher possible substitution of imported soybean/soybean meal with regional protein feeds named the following reasons (a) the possibility that more synthetic amino acids could also be used in animal feeds and (b) an expected reduction in livestock production in Germany in future.

4.2.2 Main potential for regional protein feed produced in the EU by 2030/31

As part of the Delphi study, the potential of regional protein feed produced in the EU was estimated up to 2030/31 (Table 5). In addition to the regional protein feeds already specified, *corn gluten feed, insect protein* and *alfalfa*, were named as further protein feeds by the

Fig. 4 Overview of the expert opinions in the 1st (*R*1) and 2nd (*R*2) round of the Delphi study

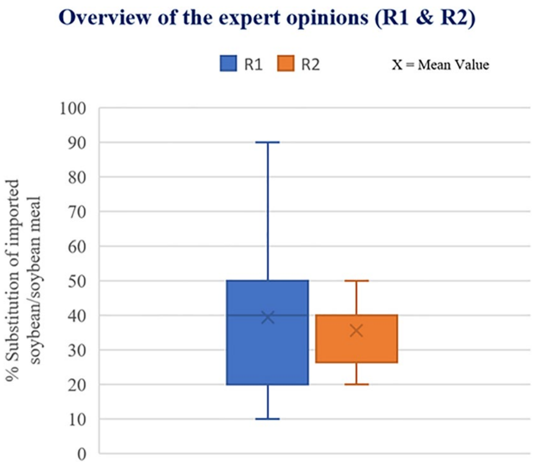

Table 5 Evaluation of regional protein feed with the highest potential produced in the EU by 2030/31

Main regional protein feed produced in the EU	*R*2 (*N*=26)	
	MV	SD
Rapeseed/rapeseed meal	4.58	0.63
Soybean/soybean meal	3.96	1.06
Sunflower/sunflower meal	3.65	0.73
Peas	3.31	0.87
Broad beans	3.15	0.77
Dried distillers' grains with solubles (DDGS)	2.81	0.68
Lupins	2.65	0.83
Wheats	2.62	0.96
Corn gluten feed	2.58	0.88
Insect protein	2.46	1.01
Alfalfa	2.35	0.83

experts in *R*1 and added to in *R*2. All SD values were lower than 1.50, which means that consensus is achieved. Based on the results of *R*2, *Rapeseed/rapeseed meal* was considered to have the highest potential for production in the EU, followed by *soybean/soybean meal* and *sunflower/sunflower meal* (see Table 5).

Replacing imports with regionally grown grain legumes such as *peas, broad beans* and *lupins* was only rated as having a moderate potential in the long term. *Corn gluten feed, insect protein* and *alfalfa* were ranked as protein feeds with the lowest potential to be produced in the EU.

4.2.3 Factors affecting the increased use of regional protein feeds in Germany by 2030/31

This Delphi study also identified factors that have an impact on the long-term increase in the use of regional protein feeds in Germany by 2030/31. The seven influencing factors regarding the use of regional protein feeds in Germany listed in the initial surveys are based on a literature review and expert recommendations. The seven additional factors were proposed by the experts in the first round of surveys. A total of 14 factors were identified and rated. Table 6 summarizes the *R*1-/*R*2-Delphi results and *R*2 results by stakeholder groups, including the sample size (*N*), MV and SD for each factor. Based on the SD values in *R*2, consensus among experts is achieved.

Based on Table 6, it can be noted that the experts identified *requirements by the food retailers, reasonable price, political regulation,* and *better profitability for the producer* as factors with a particularly strong influence on the increased use of regional protein feeds in Germany. This is especially in line with food retailers who are currently focusing on the marketing of regional and non-GM products and using non-GM labeling on many of their own products such as eggs, meat and dairy products. This campaign has clearly had a direct impact on the increased use of regional protein feeds. In addition, political regulations that support regional protein feeds and provide more profits for producers could result in an enormously positive development in using regional protein feeds for livestock farming.

At present, the protein quality of regional protein feeds such as soybeans is still lower than that of imported soybeans produced in Brazil. The improvement of plant breeding

Table 6 Summary of *R*1-/*R*2-Delphi results and *R*2 results by stakeholder groups for factors affecting the increased use of regional protein feeds in Germany

Factors	*R*1			*R*2 (*N*=26)	
	N	MV	SD	MV	SD
Total Delphi result					
Requirements by the food retailers	1	5.00	–	4.65	0.73
Reasonable price	27	4.30	0.97	4.62	0.84
Political regulation	2	5.00	0.00	4.58	0.63
Better profitability for the producer	1	4.00	–	4.31	0.61
Improvement in protein quality (e.g., soybean)	1	4.00	–	4.00	0.62
Improvement in breeding (protein plants)	27	3.92	0.92	3.92	0.78
Changed feeding concepts (e.g., climate-friendly)	1	5.00	–	3.92	0.87
Better availability	27	3.67	1.09	3.88	0.75
Expansion of regional protein crop cultivation	27	3.96	0.92	3.81	0.83
Policy support measures	27	3.70	1.08	3.77	0.97
Expansion of labels such as VLOG (Non-GMO Food Association)	1	4.00	–	3.58	0.93
Demand for deforestation-free by actors in the value chain	1	4.00	–	3.46	0.89
Expansion of the regional value chain	27	3.30	1.08	3.35	0.87
Social acceptance	27	2.96	0.96	3.19	0.79

R2-Result by stakeholder groups	Animal nutrition manufacturers		Food retailers	
	N=15		*N*=4	
	MV	SD	MV	SD
Political regulation	4.67	0.47	5.00	0.00
Reasonable price	4.60	0.80	5.00	0.00
Requirements by the food retailers	4.60	0.88	4.50	0.50
Better profitability for the producer	4.47	0.62	4.00	0.00
Policy support measures	3.93	0.99	3.00	0.71
Improvement in protein quality (e.g., soybean)	3.93	0.68	4.00	0.71
Changed feeding concepts (e.g., climate-friendly)	3.93	1.06	4.00	0.71
Better availability	3.87	0.88	3.75	0.83
Expansion of regional protein crop cultivation	3.80	0.91	3.25	0.83
Improvement in breeding (protein plants)	3.80	0.83	3.50	0.50
Expansion of labels such as VLOG	3.60	0.95	3.75	1.09
Demand for deforestation-free by actors in the value chain	3.40	1.02	3.25	0.83
Expansion of the regional value chain	3.27	0.68	3.25	0.83
Social acceptance	3.00	0.73	3.50	0.87

for regional protein crops adapted to local conditions such as weather or soil structure is necessary for the production of regional protein feeds. The importance of factors' *improvement in protein quality (e.g., soybean)* and *improvement in breeding* were therefore considered as a strong influence on the increased use of regional protein feeds by experts. Other strong influencing factors include *changed feeding concepts, better availability, expansion of regional protein crop cultivation, policy support measures, expansion of labels such as*

VLOG, and *demand for deforestation-free by actors in the value chain*, while *expansion of the regional value chain* and *social acceptance* were only rated as having a moderate influence.

We now focus on the result identified by two stakeholder groups, namely animal nutrition manufacturers and food retailers. They both agreed on the factors of *political regulation, reasonable prices,* and *requirements by the food retailers* as having a particularly strong influence on the increased use of regional protein feeds. This is consistent with the results identified by all experts in the Delphi study. The current trends of climate-friendly feeding gain importance in the development of feeding concepts for the livestock industry. Substituting imported GM feed with regional protein feeds in feed ration in order to reduce environmental impacts such as greenhouse gas emissions could be an important factor for livestock farming in future. In addition, greater availability of regional protein feeds on the EU market, e.g., soybean, grain legumes, and stronger development of labels for regional products could also promote the use of regional protein feeds in Germany. Thus, both animal nutrition manufacturers and food retailers identified the factors *changed feeding concepts (e.g., climate-friendly, better availability* and *expansion of labels such as VLOG* as strong influences on increasing the use of regional protein feeds. However, both expert groups also had different opinions on *policy support measures* and *expansion of regional protein feed cultivation*. Animal nutrition manufacturers considered that both factors could have a strong influence, while food retailers saw them as having only a moderate influence. The issue of *social acceptance* was seen as a strong influence by food retailers but only as a moderate influence by animal nutrition manufacturers. This is because food retailers are directly affected by consumers purchasing end-products on their shelves. But this not the case for animal nutrition manufacturers, as they do not deal directly with consumers, thus this factor is rated less influential.

Overall results, should the *political regulation* and *requirements by the food retailers* support more regional protein feed production so that a better and more continuous availability of regional protein feeds at a *reasonable price* is guaranteed, the animal nutrition manufacturers can imagine considering regional grain legumes in their compound feed recipes on a permanent basis. Stronger market demand for compound feed with regional protein feeds can also trigger a corresponding reaction from feed-producing companies resulting in an increasing use of regional protein feeds.

5 Discussion

5.1 Using the Delphi method for this study

The main advantage of the Delphi method is that it employs group decision-making techniques by involving experts in the field. It helps to overcome the shortcomings of either sole reliance on just one expert's opinions or on round table discussions that can be biased and dominated by opinionated leaders (Soisontes, 2017). The technique guarantees anonymity because responses will never be publicly attributed to each individual. Since the interviews are done by e-mail, there is no need to travel during the study, which eliminates the complications of organizing a meeting, reducing the cost of research, and removing geographic boundaries. The method forces participants to think about possible future scenarios and provides respondents with the opportunity to re-evaluate certain points and collect further information between the two rounds (Grobbelaar, 2007). This study used the two-round Delphi method as the Delphi results are most accurate after round two and become less precise during additional rounds (Dalkey et al., 1970; Soisontes, 2017).

However, the Delphi process requires time for the panelists to respond to the questionnaire between rounds, it is a fairly time-consuming method and it is difficult to convince people to answer a questionnaire twice or more often. The questionnaire design and selection of expert panelists have to be carefully prepared and the researcher needs to be very familiar with this method. This Delphi study overcame this disadvantage and achieved a response rate of more than 96% in the second round of surveys, which ensured the accuracy of the results. A shift in opinion toward the group opinion between Delphi rounds confirms the influence of feedback on individual responses and the achievement of consensus in Delphi studies (Barrios et al., 2021; Makkonen et al., 2016). Barrios et al. (2021) explain that opinion shift is linked to the feedback given, whereas the sociodemographic and professional profile of experts had no significant effect. It is important to note that even if the consensus is unlikely, the quality of Delphi results depends on the proper identification and selection of qualified experts.

The majority of the experts were from the animal nutrition manufacturers' group. Because of this concerns about bias and self-interest could be raised. However, experts working on sustainability were carefully selected based on their experiences from all groups and the content in the questionnaires is not directly related to any business benefits. In addition, the overall findings of the study and the comparison between two expert groups (animal nutrition manufacturers and food retailers) showed similarities and no significant difference. This is consistent with Schmid (1997), Schmid et al. (2001) and Soisontes (2017)'s conclusions that there was no need to have the same number of panelists between expert groups since the expert opinions were not affected by the panel size.

The Delphi method is a sound and effective instrument for identifying and forecasting issues and providing potential opportunities for improving sustainability (Blackburn, 2007). As a result, the findings provide basic information and highlight which factors should be taken into further consideration in order to shift protein feed supply toward more regional and non-GM feed. However, this study still has limitations. The focus year for the study was 2030/31 which represents a long-term development. Consequently, it does not consider short-term and unforeseeable factors such as a global economic crisis, wars, price peaks, new policies, and laws. These factors could alter the results of the current projection study and in the case of short-term factors even have higher effects at specific times in future.

5.2 Future demand for non-GM and regional protein feeds in Germany

As some processors and consumers in Germany and the EU tend to prefer more non-GM and regional products in future (European Commission, 2018a), the livestock industry has to adapt its production systems from the most current use of imported GM feeds, especially soybean/soybean meal, to using more non-GM and regional protein feeds.

The Delphi study shows that the consumption of non-GM protein feeds in Germany is mainly determined by the poultry sector. It is estimated that more than 60% of poultry feed is GM-free, followed by the dairy sector (50%) in 2018/19. Their GM-free shares are estimated to increase to 80% by 2030/31. This would be due to shifts in consumer preferences toward more non-GM and regional products in future (European Commission, 2018a). In addition, the poultry sector in Germany and the EU is mainly vertically integrated, which could lead to a better adaptation of its production to changes in consumer demand (Soisontes, 2017). The poultry sector also encourages the production of non-GM feeds in the United Kingdom (UK), Denmark and Ireland (European Commission, 2018).

In 2018/19, about 1.04 million tons of non-GM protein feeds (soybean) (26% of total soybean consumption) were consumed by German livestock farming, an increase of 11% compared to 2012/13 (JRC, 2015; European Commission, 2018a). This Delphi study predicts that the required amount of non-GM soybeans will increase to 1.80 million tons or 53% of total soybean consumption in German livestock farming by 2030/31. This means the share of non-GM soybeans will double in the projection year due to the increasing consumer demand for non-GM products. To promote the use of non-GM protein feeds in German livestock farming, experts identified the factors *demand from the feed industry* and *specifications from downstream processors (e.g., dairy factories, food retailers)* as particularly strong influencing factors. The first factor was also identified by Zerhusen-Blecher et al. (2016). The study by JRC (2015) also shows that the factor *specifications from downstream processors (e.g., dairy, food retailers)* is the most important aspect of the decision to use non-GM protein feeds. In particular, the role of food retailers in the non-GM value chain is important, as they decide which products are on their shelves. They also oblige all actors in the supply chain to adapt their processes to their requirements, which was also identified in this Delphi study. The purchase conditions of non-GM protein feeds are important factors in the use of non-GM and regional protein feeds in the EU (BLE, 2018; Castellaria et al., 2018; European Commission, 2018a; Venus, et al., 2018). The supply of non-GM soybeans is currently limited on the world market. So far, Brazil has been the most important producer (BLE, 2018). Although there are no technical barriers to expand non-GM soybean cultivation in Brazil (Peter & Krug, 2016), it must be remembered that the long transport route and long processing chain make the separation between GM and non-GM product lines complex in practice (BLE, 2018). In addition, the higher costs incurred along the supply chain of non-GM goods compared to GM products can also limit the demand for non-GM soybeans in the EU and Germany and the supply on the world market, especially from Brazil (Peter & Krug, 2016).

The Delphi study also shows that the German imported soybean/soybean meal (from non-EU countries) could be replaced by regional protein feed produced in the EU by around 36 % by 2030/31. As only German experts and the German demand was considered, production constraints were rated as having only a moderate influence on the provision of local protein feed to satisfy the German demand. Hence the experts judged that the German demand can be satisfied by local protein feed production. Consequently, an EU wide aim to substitute imports by domestic production might result in lower estimates due to increased production constraints.

Rapeseed/rapeseed meal is expected to have the highest potential followed by soybeans and sunflower seeds produced in the EU as identified by the Delphi panel. However, it can be assumed that the production of rapeseed will tend to decline in future in the EU and Germany. This is due to restrictions on phosphorus and nitrogen application, which are anchored in the new fertilizer and material flow balance regulations in the EU (BLE, 2018). Also, imported rapeseed is competitive with domestically produced rapeseed as a rapid increase in rapeseed imports from non-EU countries to the EU occurred in recent years. Imports increased from 0.3 million tons in 2005 to 5.6 million tons in 2019 with the main suppliers being Ukraine, Australia and Canada (UN Comtrade, 2022). Contrary to this claim, the most recent developments of Russia invading Ukraine, restricts Ukraine's ability to produce and export its agricultural products. In the short-term, destroyed harvests, blocked ports, and ongoing fighting hinder production and exports. In the long term, mined fields could lead to abandoned land and, consequently, lower production. This is especially pronounced for sunflower seed production which mainly takes place in the middle, southern and eastern parts of Ukraine but less for rapeseed and soybeans which are mostly cultivated in the western and southern parts of Ukraine (State Statistics Service of Ukraine, 2022). In addition, it can be assumed that the demand for rapeseed oil will increase less than in previous years since the expansion of biofuel production based on rapeseed oil has been limited by the European biofuel policy. Consequently, less rapeseed meal will be available and the use of rapeseed meal as animal feed might possibly decline.

The experts assessed the cultivation of soybeans in the EU and Germany as having a high potential for substituting imports. The study by Zimmer and Böttcher (2021) shows that soybean cultivation in southern Germany is competitive with the cultivation of other arable crops, while climatic conditions and lack of marketing structures in the northern regions currently make them less competitive. Similar to rapeseed, sunflower seeds might be an alternative to GM soybeans but their production predominantly takes place in non-EU countries, i.e., Russia and Ukraine. Consequently, the aim of more non-GM feed might result in partial substitution of soybean meal in feed rations but not necessarily with feed produced in the area of the EU. Again, in light of the war between Russia and Ukraine, this might change and increase sunflower area in the EU as seen in 2022 when the sunflower area increased by more than 17% (European Commission, 2022).

The experts assessed the long-term potential of replacing imports with regionally grown grain legumes such as peas, broad beans, and lupins as only moderate since there are currently still limitation on changing feed concepts for livestock farming due to current low availability and cost effectiveness (Jouan et al., 2020; Zerhusen-Blecher et al., 2016). Although corn gluten feed, insect protein and alfalfa are feasible to replace soybean meal as an alternative source of protein, experts considered these alternatives as only having low potential. This is due to their limitations including cost consideration for corn gluten feed (Ash, 1992; Hasha, 2002), anti-nutritional factors for alfalfa (Sen et al., 1998), and currently limited technological development for the mass production of insect protein (Moon & Lee, 2015; Patra, 2021).

To promote the use of regional protein feeds, the experts identified the factors, *improvement in breeding, requirements by the food retailers*, *reasonable price,* and *better profitability for the producer* as strong to particularly strong. These factors are also confirmed by Zerhusen-Blecher et al. (2016), Venus et al. (2018) and Trewern et al. (2021). The experts predicted that the *expansion of the regional value chain* will have a moderate influence on the increased use of regional protein feeds. However, this is an important factor in producing the required amount of regional protein feeds, as shown in the case study of soybeans by Zimmer and Böttcher (2021). While the factor *improvement in protein quality* has a strong influence on the increased use of regional protein feeds in this Delphi study, it is only of minor importance in the study by Zerhusen-Blecher et al. (2016).

The experts identified the factor *political regulation* as the most important to increase regional protein feeds. This can be interpreted in the following way: few if any economic incentives exist to expand regional protein crop production in Germany and the EU and, hence, an increase will not occur without political support. In the EU and Germany, policies and strategies exist to promote the cultivation of protein crops, especially legumes. However, these have not yet led to major increases in protein crop cultivation. Within the greening policy instruments of the CAP (period 2015–2022), protein crops were eligible to fulfill the requirements of ecological focus areas (Haß et al., 2022) which increased their areas in Germany (0.2 million ha from 2014 to 2020) and the EU (1.6 million ha from 2014 to 2020) but the overall share of protein crop area in arable land is still low (in 2020: Germany 4.8% and EU 7.5%) (Eurostat, 2022). In the new CAP period (2023–2027), the cultivation of protein crops does not account for the "enhanced conditionality" (the successor of the greening requirements) in Germany anymore (Haß et al., 2022). Hence, support for protein crops within the CAP has only been possible via the agri-environment-climate measures in Germany since 2023. The German protein strategy does not have any instruments or policies which actively encourage protein crop production besides the instruments of the CAP. The strategy focuses more on supporting research, e.g., breeding programs, advertising the benefits of protein crops in the crop rotation, and supporting projects along the whole value chain for demonstration purposes (BMEL, 2020).

6 Conclusion

Germany is almost 100% dependent on imports of soybean/soybean meal, mainly from North and South American countries, where genetically modified varieties dominate the production. In Germany, there is a trend toward non-GM feeding, especially in poultry farming and the dairy industry, and a possible trend toward using more regional protein feeds. Against this background, this study tries to shed light on the question: How much imported soybean could reasonably be substituted by non-GM and regionally produced protein feeds in future?

The results of this study are based on the evaluations by several expert groups involved in the value chain of the German livestock industry as well as researchers using the two-round Delphi method. A total of 26 experts took part in both rounds, which consisted of the following four expert groups: food retailers, livestock associations, animal nutrition manufacturers and research institutes. There was a high overall consensus of the expert opinions in this Delphi study. Due to the current "protein deficit" in Germany, this study helps to estimate future potential demand for non-GM and regional protein feeds in the German livestock industry by 2030/31. Experts predict that around 36% of the imported soybean/soybean meal (from non-EU countries) can be replaced by regional protein feed produced in the EU for German livestock farming. A decrease in the use of soybean is expected from almost 4 million tons of soybean equivalents in 2018/19 to around 3.4 million tons by 2030/31. In contrast, the share of non-GM soybeans is forecast to increase from 26 to 53%. An increase in the proportion of non-GM soybean is expected for all types of livestock farming.

The experts rate the current existing substitutes, i.e., oilseed meals, as most likely to partially replace imported GM soybean/soybean meal. As these oilseeds are often imported, local production might only contribute toward replacing GM soybean meal to a small extent. Consequently, locally produced protein crops might continue to play a minor role in livestock feed ratios in Germany.

The current substitution of GM soybean meal is driven mainly by the demand side as the requirements of processors and retailers need to be fulfilled. The experts also judged this to be the case for the future as the factor *specifications from downstream processors* is rated as the most significant. Interestingly, retailers rate *social acceptance* as having only a moderate influence on a further increase in non-GM feedstuff despite a strong demand. Consequently, other unknown motives might be the reason for retailers to push in this direction which are, however, not identified in this current study.

To what extent the political aim of reducing the "protein deficit" by cultivating local protein crops in the EU can be achieved, remains a major challenge and would require political interventions such as financial support a) to encourage breeding of higher yielding and climatic adapted varieties; b) to produce protein crops; and c) to strengthen the supply chain. Alternatively, a stronger reduction in livestock production in the EU might contribute to reaching this goal (WBA, 2015). However, economic and ecological consequences need to be carefully considered before advocating increased regional protein feed crop production, which is beyond the scope of this study and leaves room for further research.

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Declarations

Conflict of interest The authors have no competing interests to declare that are relevant to the content of this article.

References

Adler, M., & Ziglio, E. (1996). *Gazing into the oracle: The Delphi method and its application to social policy and public health*. Jessica Kingsley Publishers.

Akkermans, H. A., Bogerd, P., Yücesan, E., & van Wassenhove, L. N. (2003). The impact of ERP on supply chain management: Exploratory findings from a European Delphi study. *European Journal of Operational Research, 146*, 284–301. https://doi.org/10.1016/S0377-2217(02)00550-7

Altenburg, T. (2007). *Donor approaches to supporting pro-poor value chains. Report prepared for the donor committee for enterprise development working group on linkages and value chains*. German Development Institute.

Asbridge, D. D. (1995). Soybeans vs. other vegetable oils as source of edible oil products. In D. R. Erickson (Ed.), *Practical handbook of soybean and utilisation* (pp. 1–8). AOCS Press.

Ash, M. S. (1992). *Animal feeds compendium*. USDA.

Barrios, M., Guilera, G., Nuño, L., & Gómez-Benito, J. (2021). Consensus in the Delphi method: What makes a decision change? *Technological Forecasting and Social Change, 163*, 120484. https://doi.org/10.1016/j.techfore.2020.120484

Beech, B. (1999). Go the extra mile—use the Delphi technique. *Journal of Nursing Management, 7*, 281–288. https://doi.org/10.1046/j.1365-2834.1999.00125.x

Bellof, G., Halle, I., & Rodehutscord, M. (2020). *Ackerbohnen, körnerfuttererbsen, Süßlupinen und sojabohnen in der geflügelhaltung. UFOP - Praxisinformation*. UFOP.

Belton, I., MacDonald, A., Wright, G., & Hamlin, I. (2019). Improving the practical application of the Delphi method in group-based judgment: A six-step prescription for a well-founded and defensible process. *Technological Forecasting and Social Change, 147*, 72–82. https://doi.org/10.1016/j.techfore.2019.07.002

Blackburn, W. R. (2007). *The sustainability handbook. The complete management guide to achieve social, economic, and environmental responsibility*. Environmental Law Institute.

BLE. (2018). *Bericht zur markt- und versorgungslage futtermittel 2018*. BLE.

BMEL. (2016). *Die Eiweißpflanzenstrategie des BMEL zur förderung des leguminosenanbaus in Deutschland*. BMEL.

BMEL. (2019). *Statistisches jahrbuch über ernährung landwirtschaft und forsten*. BMEL.

BMEL. (2020). *Ackerbohne, Erbse & Co. Die eiweispflanzenstrategie des BMEL zur förderung des leguminosenanbaus in Deutschland*. BMEL.

BMEL. (2022). *Tabellen zur landwirtschaft*. BMEL.

Boulkedid, R., Abdoul, H., Loustau, M., Sibony, O., & Alberti, C. (2011). Using and reporting the Delphi method for selecting healthcare quality indicators: A systematic review. *PLoS ONE, 6*(6), e20476. https://doi.org/10.1371/journal.pone.0020476

Castellaria, E., Soregarolia, C., Venus, T. J., & Wesseler, J. (2018). Food processor and retailer non-GMO standards in the US and EU and the driving role of regulations. *Food Policy, 78*, 26–37. https://doi.org/10.1016/j.foodpol.2018.02.010

Chen, K., Ren, Z., Mu, S., Sun, T. Q., & Mu, R. (2020). Integrating the Delphi survey into scenario planning for China's renewable energy development strategy towards 2030. *Technological Forecasting and Social Change, 158*, 120157. https://doi.org/10.1016/j.techfore.2020.120157

UN Comtrade (2022). *Comtrade database*. UN. Retrieved March 18, 2022, from https://comtrade.un.org/data/

Culot, G., Orzes, G., Sartor, M., & Nassimbeni, G. (2020). The future of manufacturing: A Delphi-based scenario analysis on industry 4.0. *Technological Forecasting and Social Change, 157*, 120092. https://doi.org/10.1016/j.techfore.2020.120092

Dalkey, N. C., & Helmer, O. (1969). *The Delphi method: An experimental study of group opinion*. The Rand Corporation.

Dalkey, N. C., Rourke, D. L., Lewis, R., & Snyder, D. (1972). *Studies in the quality of life*. Lexington Books.

Dalky, N., Brown, B., & Cochran, S. (1970). Use of self-ratings to improve group estimates. *Technological Forecasting and Social Change, 1*(3), 283–291. https://doi.org/10.1016/0099-3964(70)90029-3

Delbecq, A. L., van de Ven, A. H., & Gustafson, D. H. (1975). *Group techniques for program planning: A guide to nominal group and Delphi processes*. Scott, Foresman and Company.

Eto, H. (2003). The suitability of technology forecasting/foresight methods for decision systems and strategy. A Japanese view. *Technological Forecasting and Social Change, 70*, 231–249. https://doi.org/10.1016/S0040-1625(02)00194-4

European Commission. (2018a). *Market developments and policy evaluation aspects of the plant protein sector in the EU*. European Commission.

European Commission. (2018b). *Feasibility study on options to step up EU action against deforestation*. European Commission.

European Commission. (2022). *Short-term outlook for EU agricultural markets in 2022*. European Commission.

Eurostat. (2022). *Dataset: Crop production in EU standard humidity (APRO_CPSH1)*. Eurostat.

FEFAC. (2022). *Compound feed production 1989–2022*. FEFAC.

Ferreira, M. E., Ferreira, L. G., Jr., Latrubesse, E. M., & Miziara, F. (2016). Considerations about the land use and conversion trends in the savanna environments of Central Brazil under a geomorphological perspective. *Journal of Land Use Science, 11*, 33–47. https://doi.org/10.1080/1747423X.2013.845613

Flostrand, A., Pitt, L., & Bridson, S. (2020). The Delphi technique in forecasting: A 42-year bibliographic analysis (1975–2017). *Technological Forecasting and Social Change, 150*, 119773. https://doi.org/10.1016/j.techfore.2019.119773

Fraanje, W., & Garnett, T. (2020). *Soy: Food, feed, and land use change*. Food Climate Research Network.

Freund, F., Soisontes, S., Laquai, V., & Banse, M. (2023). *Global land-use implications of more GMO-free and regional protein feed in Germany and the EU*. Unpublished Manuscript.

Frewer, L. J., Fischer, A. R. H., Wentholt, M. T. A., Marvin, H. J. P., Ooms, B. W., Coles, D., & Rowe, G. (2011). The use of Delphi methodology in agrifood policy development: Some lessons learned. *Technological Forecasting and Social Change, 78*(9), 1514–1525. https://doi.org/10.1016/j.techfore.2011.05.005

Gaitan-Cremaschi, D., Kamali, F. P., van Evert, F. K., Meuwissen, M. P. M., & Lansink, A. G. J. M. O. (2015). Benchmarking the sustainability performance of the Brazilian non-GM and GM soybean meal chains: An indicator-based approach. *Food Policy, 55*, 22–32. https://doi.org/10.1016/j.foodpol.2015.05.006

Garret, R. D., & Rausch, L. L. (2016). Green for gold: Social and ecological tradeoffs influencing the sustainability of the Brazilian soy industry. *The Journal of Peasant Studies, 43*, 461–493. https://doi.org/10.1080/03066150.2015.1010077

Giannarou, L., & Zervas, E. (2014). Using Delphi technique to build consensus in practice. *International Journal of Business Science and Applied Management, 9*, 65–82.

Gibbs, H. K., Rausch, L., Munger, J., Schelly, I., Morton, D. C., Noojipady, P., Soares-Filho, B., Barreto, P., Micoland, L., & Walker, N. F. (2015). Brazil's soy moratorium. *Science, 347*, 377–378. https://doi.org/10.1126/science.aaa0181

Gill, F., Leslie, G. D., Grech, C., & Latour, J. M. (2013). Using a web-based survey tool to undertake a Delphi study: Application for nurse education research. *Nurse Education Today, 33*, 1322–1328. https://doi.org/10.1016/j.nedt.2013.02.016

Green, H., Hunter, C., & Moore, B. (1990). Assessing the environmental impact of tourism development: Use of the Delphi technique. *Tourism Management, 11*, 111–120. https://doi.org/10.1016/0261-5177(90)90026-6

Grobbelaar, S. S. (2007). *R&D in the national system of innovation: A system dynamics model*. Dissertation. University of Pretoria.

Gupta, U. G., & Clarke, R. E. (1996). Theory and application of the Delphi technique: A bibliography (1975–1994). *Technological Forecasting and Social Change, 53*(2), 185–211. https://doi.org/10.1016/S0040-1625(96)00094-7

Häder, M. (2002). *Delphi-befragungen*. Springer.

Hasha, G. (2002). *Livestock feeding and feed imports in the European Union: A decade of change*. USDA.

Haß, M., Deblitz, C., Freund, F., Kreins, P., Laquai, V., & Offermann, F. (2022). Thünen-baseline 2022–2032: Agrarökonomische projektionen für Deutschland. *Thünen Report*. https://doi.org/10.3220/REP1667811151000

He, R., Zhu, D., Chen, X., Cao, Y., Chen, Y., & Wang, X. (2019). How the trade barrier changes environmental costs of agricultural production: An implication derived from China's demand for soybean caused by the US-China trade war. *Journal of Cleaner Production, 227*, 578–588. https://doi.org/10.1016/j.jclepro.2019.04.192

Hop, G. E., Mourits, M. C. M., Lansink, A. G. J. M. O., & Saatkamp, H. W. (2014). Future structural developments in Dutch and German livestock production and implications for contagious livestock disease control. *Technological Forecasting and Social Change, 82*, 95–114. https://doi.org/10.1016/j.techfore.2013.05.011

Hortenhuber, S. J., Lindenthal, T., & Zollitsch, W. (2011). Reduction of greenhouse gas emissions from feed supply chains by utilizing regionally produced protein sources: The case of Austrian dairy production. *Journal of the Science of Food and Agriculture, 91*(6), 1118–1127. https://doi.org/10.1002/jsfa.4293

IDH, & IUCN. (2019). *European soy monitor*. IDH and IUCN.

IDH. (2016). *Soy footprint of animal products in Europe*. IDH.

ISAAA. (2018). *Global status of commercialized biotech/GM crops in 2018: Biotech crops continue to help meet the challenges of increased population and climate change*. ISAAA.

Jäger, J. K., & Piscicelli, L. (2021). Collaborations for circular food packaging: The set-up and partner selection process. *Sustainable Production and Consumption, 26*, 733–740. https://doi.org/10.1016/j.spc.2020.12.025

Jia, F., Peng, S., Green, J., Koh, L., & Chen, X. (2020). Soybean supply chain management and sustainability: A systematic literature review. *Journal of Cleaner Production, 255*, 120254. https://doi.org/10.1016/j.jclepro.2020.120254

Jiang, R., Kleer, R., & Piller, F. T. (2017). Predicting the future of additive manufacturing: A Delphi study on economic and societal implications of 3D printing for 2030. *Technological Forecasting and Social Change, 117*, 84–97. https://doi.org/10.1016/j.techfore.2017.01.006

Jouan, J., Ridier, A., & Carof, M. (2020). Legume production and use in feed: analysis of levers to improve protein self-sufficiency from foresight scenarios. *Journal of Cleaner Production, 274*, 123085. https://doi.org/10.1016/j.jclepro.2020.123085

JRC. (2015). *Markets for non-genetically modified, identity preserved soybean in the EU*. European Union.

Kastens, J. H., Brown, J. C., Coutinho, A. C., Bishop, C. R., & Esquerdo, J. C. D. M. (2017). Soy moratorium impacts on soybean and deforestation dynamics in Mato Grosso, Brazil. *PLoS ONE, 12*(4), e0176168. https://doi.org/10.1371/journal.pone.0176168

Klohn, W. (2002). *Strukturen der produktion und des handels von sojabohnen und sojaprodukten*. Institut für Strukturforschung und Planung in agrarischen Intensivgebieten.

Kluge, U., Ringbeg, J., & Spinler, S. (2020). Door-to-door travel in 2035: A Delphi study. *Technological Forecasting and Social Change, 157*, 120096. https://doi.org/10.1016/j.techfore.2020.120096

Kootstra, A. M. J., Schoorlemmer, H. B., & de Visser, C. L. M. (2017). *Fostering sustainable legume-based farming systems and agri-feed and food chain sin the EU*. Retrieved on March 10, 2023, from https://www.legvalue.eu/media/1190/legvalue-d51-report.pdf

Kuepper, B., & Steinweg, T. (2019). *Feed and livestock in Brazil, China, EU consume most cerrado soy*. Chain Reaction Research.

Linstone, H. A., & Turoff, M. (1977). *The Delphi method: Techniques and applications*. Addison–Wesley.

Lummus, R. R., Vokurka, R. J., & Duclos, K. L. (2005). Delphi study on supply chain flexibility. *International Journal of Production Research, 43*, 2687–2708. https://doi.org/10.1080/00207540500056102

Makkonen, M., Hujala, T., & Uusivuori, J. (2016). Policy experts' propensity to change their opinion along Delphi rounds. *Technological Forecasting and Social Change, 109*, 61–68. https://doi.org/10.1016/j.techfore.2016.05.020

Markmann, C., Darkow, I. L., & von der Gracht, H. (2013). A Delphi-based risk analysis: Identifying and assessing future challenges for supply chain security in a multi-stakeholder environment. *Technological Forecasting and Social Change, 80*(9), 1815–1833. https://doi.org/10.1016/j.techfore.2012.10.019

Martino, J. P. (1993). *Technological forecasting for decision making* (3rd ed.). McGraw-Hill.

McKay, B. M. (2018). Control grabbing and value-chain agriculture: BRICS, MICs and Bolivia's soy complex. *Globalizations, 15*, 74–91. https://doi.org/10.1080/14747731.2017.1374563

Melander, L., Dubois, A., Hedvall, K., & Lind, F. (2019). Future goods transport in Sweden 2050: Using a Delphi-based scenario analysis. *Technological Forecasting and Social Change, 138*, 178–189. https://doi.org/10.1016/j.techfore.2018.08.019

Moon, S. J., & Lee, J. W. (2015). Current views on insect feed and its future. *Entomological Research, 45*(6), 283–285. https://doi.org/10.1111/1748-5967.12138

More, S. J., McKenzie, K., O'Flaherty, J., Doherty, M. L., Cromie, A. R., & Magan, M. J. (2010). Setting priorities for non-regulatory animal health in Ireland: Results from an expert policy Delphi study and a farmer priority identification survey. *Preventive Veterinary Medicine, 95*, 198–207. https://doi.org/10.1016/j.prevetmed.2010.04.011

Munyaneza, C., Kurwijila, L. R., Mdoe, N. S. Y., Baltenweck, I., & Twine, E. E. (2019). Identification of appropriate indicators for assessing sustainability of small-holder milk production systems in Tanzania. *Sustainable Production and Consumption, 19*, 141–160. https://doi.org/10.1016/j.spc.2019.03.009

Oil World. (2019). *Oil world annual 2019*. ISTA Mieke GmbH.

Okoli, C., & Pawlowsky, D. S. (2004). The Delphi method as a research tool: An example, design considerations and applications. *Information and Management, 42*, 15–29. https://doi.org/10.1016/j.im.2003.11.002

Patra, A. K. (2021). Potential utilization of insect meal as livestock feed. *Intechopen*. https://doi.org/10.5772/intechopen.101766

Peppel, M., Ringbeg, J., & Spinler, S. (2022). How will last-mile delivery be shaped in 2040? A Delphi-based scenario study. *Technological Forecasting and Social Change, 177*, 121493. https://doi.org/10.1016/j.techfore.2022.121493

Peter, G., & Krug, O. (2016). *Die verfügbarkeit von nicht-gentechnisch verändertem soja aus Brasilien*. Thünen Institut.

Raucci, G. S., Moreira, C. S., Alves, P. A., Mello, F. F. C., de Almeida Frazao, L., Cerri, C. E. P., & Cerri, C. C. (2015). Greenhouse gas assessment of Brazilian soybean production: A case study of Mato Grosso State. *Journal of Cleaner Production, 96*, 418–425. https://doi.org/10.1016/j.jclepro.2014.02.064

Roßmann, B., Canzaniello, A., von der Gracht, H., & Hartmann, E. (2018). The future and social impact of big data analytics in supply chain management: Results from a Delphi study. *Technological Forecasting and Social Change, 130*, 135–149. https://doi.org/10.1016/j.techfore.2017.10.005

Rowe, G., & Wright, G. (1999). The Delphi technique as a forecasting tool: Issues and analysis. *International Journal of Forecasting, 15*(4), 353–375. https://doi.org/10.1016/S0169-2070(99)00018-7

Rowe, G., & Wright, G. (2001). Expert opinions in forecasting: The role of the Delphi technique. In J. S. Armstrong (Ed.), *Principles of forecasting* (pp. 125–144). Springer.

Rowe, G., Wright, G., & Bolger, F. (1991). Delphi: A reevaluation of research and theory. *Technological Forecasting and Social Change, 39*, 235–251. https://doi.org/10.1016/0040-1625(91)90039-I

Sasu-Boakye, Y., Cederberg, C., & Wirsenius, S. (2014). Localising livestock protein feed production and the impact on land use and greenhouse gas emissions. *Animals, 8*(8), 1339–1348. https://doi.org/10.1017/S1751731114001293

Schmidt, R. C. (1997). Managing Delphi surveys using nonparametric statistical techniques. *Decision Science, 28*(3), 763–774. https://doi.org/10.1111/j.1540-5915.1997.tb01330.x

Schmidt, R., Lyytinen, K., Keil, M., & Cule, P. (2001). Identifying software project risks: An international Delphi study. *Journal of Management Information Systems, 17*(4), 5–36. https://doi.org/10.1080/07421222.2001.11045662

Sen, S., Makkar, H. P. S., & Becker, K. (1998). Alfalfa saponins and their implication in animal nutrition. *Journal of Agricultural and Food Chemistry, 46*(1), 131–140. https://doi.org/10.1021/jf970389i

Sepngang, B. K., Stauss, W., Stute, I., & Mergenthaler, M. (2018). *The market of grain legumes in Germany*. Fachhochschule Südwestfalen.

Soisontes, S. (2017). Concerns about sustainability in the poultry industry: A comparative Delphi study in Germany and Thailand. *World's Poultry Science Journal, 73*, 886–903. https://doi.org/10.1017/S0043933917000800

Sojafördering. (2023). *Informationen rund um Soja*. Retrieved on July 10, 2023, from https://www.sojafoerderring.de/

State Statistics Service of Ukraine. (2022). *Statistical information*. State Statistics Service of Ukraine. Retrieved on March 6, 2023, from https://ukrstat.gov.ua/druk/publicat/kat_u/publ7_u.htm

Story, V., Hurdley, L., Smith, G., & Saker, J. (2001). Methodological and practical implications of the Delphi technique in marketing decision-making: A reassessment. *The Marketing Review, 1*, 487–504.

Taherzadeh, O., & Caro, D. (2019). Drivers of water and land use embodied in international soybean trade. *Journal of Cleaner Production, 223*, 83–93. https://doi.org/10.1016/j.jclepro.2019.03.068

Trewern, J., Chenoweth, J., Christie, I., Keller, E., & Halevy, S. (2021). Are UK retailers well placed to deliver 'less and better' meat and dairy to consumers? *Sustainable Production and Consumption, 28*, 154–163. https://doi.org/10.1016/j.spc.2021.03.037

USDA. (2019). *Database*. USDA. Retrieved February 23, 2021, from https://apps.fas.usda.gov/psdonline

Vagias, W. M. (2006). *Likert-type scale response anchors*. Clemson International Institute for Tourism & Research Development.

Veauthier, A., & Windhorst, H. W. (2011). *Die wettbewerbsfähigkeit der deutschen und niedersächsischen geflügelfleischerzeugung: Gegenwärtige strukturen und prognosen bis 2020*. ISPA.

Venus, T. J., Drabik, D., & Wesseler, J. (2018). The role of a German multi-stakeholder standard for livestock products derived from non-GMO feed. *Food Policy, 78*, 58–67. https://doi.org/10.1016/j.foodpol.2018.02.009

VLOG. (2018). *Verfütterung von sojaschrot in Deutschland 2018*. VLOG.

Vollstädt, W. (2003). Zur zukunft der lehr- und lernmedien in der schule. Eine Delphi-studie in der diskussion. In B. Asbrand, M. Hummrich, T.-S. Idel, & A. Moldenhauer (Eds.), *Reihe Schule und Gesellschaft.* Springer.

Von der Gracht, H. A. (2012). Consensus measurement in Delphi studies: Review and implications for future quality assurance. *Technological Forecasting and Social Change, 79*, 1525–1536. https://doi.org/10.1016/j.techfore.2012.04.013

Watson, C. A., Reckling, M., Preissel, S., Bachinger, J., Bergkvist, G., Kuhlman, T., Lindström, K., Nemecek, T., Topp, C. F. E., Vanhatalo, A., Zander, P., Murphy-Bokern, D., & Stoddard, F. L. (2017). Chapter four - grain legume production and use in European agricultural systems. *Advances in Agronomy, 144*, 235–303. https://doi.org/10.1016/bs.agron.2017.03.003

WBA. (2015). *Wege zu einer gesellschaftlich akzeptierten nutztierhaltung*. Bundesministerium für Ernährung und Landwirtschaft.

Welty, G. (1972). Problems of selecting experts for Delphi exercises. *Academy of Management Journal, 15*(1), 121–124. https://doi.org/10.5465/254805

Williams, P. L., & Webb, C. (1994). The Delphi technique: A methodological discussion. *Journal of Advanced Nursing, 19*, 180–186. https://doi.org/10.1111/j.1365-2648.1994.tb01066.x

Wrench, J. S. (2013). *Workplace communication for the 21st century: Tools and strategies that impact the bottom line*. Praeger.

WWF. (2014). *Der futtermittelreport: Futtermittel und fütterungsstrategien für Deutschland zur verminderung des verbrauchs von importierten sojaerzeugnissen in der schweinefütterung*. WWF.

Zerhusen-Blecher, P., Kramps-Alpmann, D., Rohn, S., Braun, J., & Schäfer, B.C. (2016). *LeguAN – Innovative und ganzheitliche Wertschöpfungskonzepte für funktionelle Lebens- und Futtermittel aus heimischen Körnerleguminosen vom Anbau bis zur Nutzung (Arbeitspakete 2 und 7)*. Forschungsberichte des Fachbereichs Agrarwirtschaft Soest, Nr. 41. Fachhochschule Südwestfalen.

Zimmer, Y. & Böttcher, T. (2021). Mit Sojaanbau profitabel Fruchtfolgen erweitern. *Thünen Working Paper*, 169.

Zortea, R. B., Maciel, V. G., & Passuello, A. (2018). Sustainability assessment of soybean production in Southern Brazil: A life cycle approach. *Sustainable Production and Consumption, 13*, 102–112. https://doi.org/10.1016/j.spc.2017.11.002