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A Report on Breeding Priorities for the High-Value Pea Processing Sector in Western Canada

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Executive Summary

This research investigates the plant breeding priorities of high-protein pea processors and explores the market potential of climate-smart certification programs and gene-edited pea varieties. Stakeholders in the higher-value pea processing sector were engaged to identify important pea breeding traits and assess potential premiums for high-protein pea varieties. An online survey and semi-structured interview were used to understand valued pea attributes and price premiums for high-protein peas and gather opinions on gene-editing and climate-smart certification. The findings provide insights into processor priorities and the dynamics of the high-protein food market.

High Value Pea Ingredient Market

Canadian exports of protein concentrates, and plant protein ingredients is growing, with the U.S. being the largest consumer of pea protein. The high-value pea processing sector is competitive and price-sensitive, with processors focusing on technology innovations and product differentiation to develop functional pea ingredients. As processors and food manufacturers learn more about the functional properties of peas, the market demand for new pea ingredients has grown. The pea protein processing sector in Canada faces challenges such as limited access to capital, slower-than-expected growth in consumer demand for plant-based foods, and economic factors including inflation and high interest rates.

Gene-Editing

Processors generally supported the use of gene-editing to improve desired pea attributes. While the value in addressing production issues and enhancing the sustainability and palatability of peas was acknowledged by those interviewed, most fear the use of gene editing might have negative implications for the growing food ingredient market and the broader pulse industry. They express concerns about consumer acceptance, the image of pulses, and potential trade implications.

Protein Composition, Quality & Content

The current industry standard for peas purchased for processing is 23% protein. While higher protein was very important to dry fractionators, it was not considered the highest priority for most processors. In general, processors are currently able to meet their buyers' protein content requirements with existing varieties, and there is no significant market pull for higher protein content. The composition and quality of pea protein were cited by respondents as important attributes for further development through breeding. As the application of peas as a replacement and

value-add ingredient expands, the versatility of peas as a functional ingredient has become an important marketing advantage.

Climate-Smart Certification Programs

While the idea of an industry-wide climate-smart certification program received support from processors, a lack of market demand and the potential administrative burdens of such a program make it unlikely to be implemented in the near future. There is agreement that industry standards are necessary, but achieving consensus on definitions and measurement is a significant barrier.

Yield & Price

Breeding programs need to include a strong emphasis on yield to ensure a consistent supply of high-quality peas at an affordable price for the processing sector. In the competitive food ingredient market where price is the driving factor in the purchase decision, pea processors are under pressure to keep costs low for their customers. While some processors pay premiums for high-protein peas, yield drag limits profitability for new varieties.

Breeding Priorities

Plant breeding priorities focused on improving yield and attributes that enhance processing efficiency and product quality. The functionality of peas as a food ingredient was identified by processors as a key strength, especially given the recent price inflation of other ingredients. Plant breeding for the pea protein processing sector should focus on attributes that improve processing efficiency, consistency, and specific protein qualities.

Protein Extraction

Improving protein extraction technology is a priority for processors, who view it as a competitive advantage in continuing to innovate to meet market demands. The industry's focus on functionality and efficiency is putting pressure on processors to better utilize the protein within existing pea varieties. Improvements in the ability to separate protein from starch have the potential to significantly enhance processing efficiency and product quality.

Taste/Flavor

Pea protein taste was considered to be a limiting factor in the use of peas as a functional ingredient in food manufacturing. Taste improvement is a top consumer concern and will allow for higher pea protein content in food products.

Other Breeding Priorities

Overall, the plant breeding priorities of processors varied, reflecting the diverse processing technologies and specialized products continuing to be developed for the food ingredient market. The application of pea ingredients as a replacement for other ingredients is expanding as food manufacturers look to improve the value to customers without compromising on any of the product qualities that consumers expect. When used to replace other ingredients like wheat flour or corn

starch, manufacturers are looking for a white color, a breeding trait of value to processors. The solubility and digestibility of protein were other desired variety improvements from pea breeding.

New Variety Development

Processors emphasized the importance of aligning plant breeding priorities with market needs to maintain and grow the competitive advantage of the Canadian pea processing sector. Interviewees identified improved communication and collaboration among supply chain stakeholders as crucial for ensuring the quality and marketability of new varieties. Policy issues that if addressed could facilitate sector growth included financial support and an enabling regulatory environment for start-ups, industry standards for climate-smart programs, consumer understanding and acceptance of gene editing and a stable global regulatory environment for gene-edited peas. The need for improved communication and collaboration is heightened by the fact that the food industry is constantly adopting innovative technologies that disrupt what is possible in ways that continuously move the frontier of product innovation. The plant breeding priorities identified through the interviews were acknowledged to be reflecting the needs of the market today, not necessarily five to ten years in the future. The future demands of the market are difficult to predict.

Introduction

PEA^{CE} is an interdisciplinary plant-breeding project employing state-of-the-art genomic technologies to increase the quality, profitability and resilience of peas grown in Canada. The GE^{3}LS portion of this research examines the potential constraints to the expansion of pea cultivation and associated markets.

A recent market report provided by Pulse Canada indicates that globally, over 4,500 new food products containing pea and pea protein ingredients were launched in 2023 alone (Der, 2024). While overall the plant-based food sector growth has slowed below projections, the potential of the market has continued to attract new entrants into the Canadian pulse processing space resulting in what processors describe as a highly competitive and price sensitive market. China has been accused of dumping pea protein into the North American market at below market prices, adding to the competitive pressure on domestic processors. Despite these challenges, the food industry continued to drive growth in the demand for pea protein in 2023, with the pet food sector dominating the global demand for pea protein at 83% while packaged food made up the balance at 17% (Der, 2024). To support this growth, the sector is focused on product and process innovation necessary to capture and create market share in the food ingredient industry.

The high-value pea ingredient market is evolving rapidly, driven by significant product innovation and specialization in response to market demands and economic pressures. The competitive nature of the Canadian pulse processing industry necessitates constant innovation to meet customer specifications and enter new markets. Despite the traditionally higher cost of pulse protein ingredients, their non-GMO status and lower carbon footprint are opening new opportunities in food manufacturing. The industry has been working on improving processing technology to enhance efficiency and product quality, but faces challenges such as limited capital, competitive pressures, and

slow market growth. Processors are continually refining their technology and processes to enhance the desirable attributes of pea products and versatility in food applications. Additionally, processors are focusing on maximizing the value of the entire pea, including fiber and starch, to improve sustainability and profitability. The sector is beginning to explore the potential of faba beans and chickpeas as alternative plant-based protein sources.

The high-protein pea processor interviews and survey reported on here investigate processors' plant breeding priorities and begins to explore the market potential of climate-smart certification programs and gene-edited pea varieties. We engaged stakeholders in higher-value pea markets to identify the traits most important to this industry and assess the marketing potential of specific attributes. While producers have voiced an interest in genome edited crops, industry leaders believe Canadian processors have not been formally consulted on this issue (T. Stephenson, personal communication, January 29, 2024). This research looks to address this by gathering input from pea processors on the use of gene-editing in pea plant breeding. We also present our results in a shorter briefing note (here) as well as a more detailed report that provides an in-depth description of the survey and results (here).

Methods

Prior to undertaking this research, we conducted a review of the Canadian pea and pulse industry literature to obtain a comprehensive description of both the domestic and international markets for field peas. Meetings to discuss the research objectives were held with the Canadian Pulse Association, Saskatchewan Pulse Growers Association, Alberta Pulse Growers, Manitoba Pulse and Soybean Growers, and Protein Industries Canada. Based on the meetings and the literature review, a short online SurveyMonkey survey and semi-structure interview instrument were developed to explore the pea attributes that processors value, and price premiums for high protein peas. The anonymous survey included nine questions that asked about processing capacity, the pea attributes that were important to processors, and premiums paid for pea protein (**Appendix 1**: Online SurveyMonkey questions). Open-ended, multiple choice, and Likert scale questions were used in the survey. The 10-question interview guide (**Appendix 2**: Qualitative interview questions) asked respondents their thoughts on the plant-based food market, the pea attributes of value to processors, the use of gene-editing in pulse breeding, and the marketing potential of a climate-smart certification program. The research project was approved by the University of Saskatchewan Behavioral Research Ethics Board on April 10, 2024.

Introductory emails and follow-up reminders were sent to 34 prospective participants. Primary processors, food ingredient processors and food manufacturers were invited to participate. Of those invited, 12 agreed to participate and were sent a follow-up email providing additional information about the project, a copy of the consent form and a link to the online survey. Virtual interviews were conducted using Zoom between May and November 2024. Interviews took between 45 and 90 minutes to complete. Zoom's recording feature was employed to create a transcript of the conversation with participants. Of the 12 interview participants, six completed at least some of the

online survey questions. Two respondents stated that processing volumes and capacity at their facilities was proprietary information, and we believe this may explain the low survey response rate.

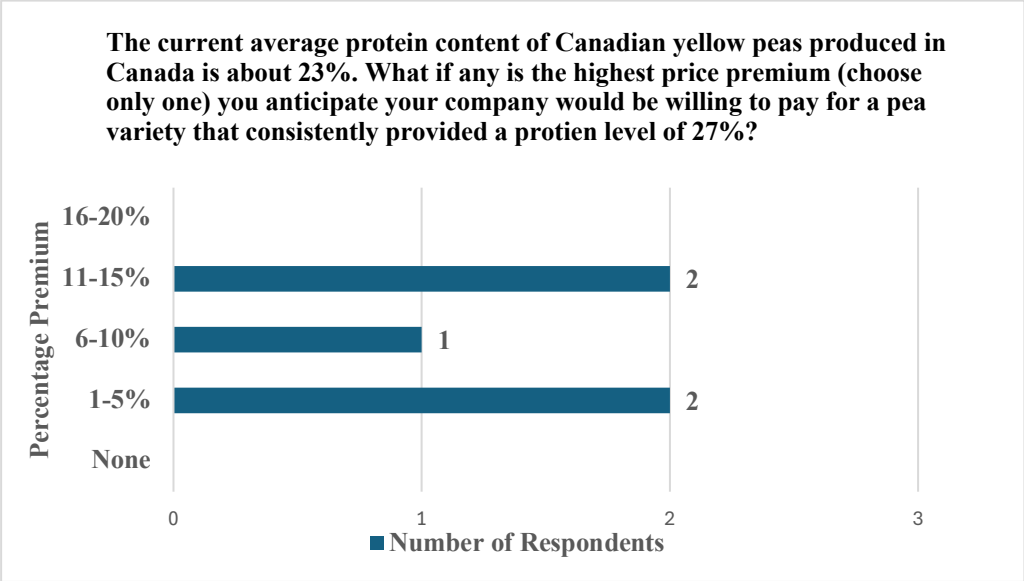
A semi-structured interview format was used to allow respondents to offer their opinions on the high value pea market and information relevant to pea plant breeding. Before beginning the interview, respondents were asked if they had read the consent form and to give their verbal consent to participate in the interview. Participants were also asked if they had completed the online survey, their willingness to have the interview recorded, and if they agreed to be quoted either by name or anonymously. At the end of the interview, respondents were asked if there was anything else relevant to the project not already covered in the interview they thought breeders should know.

The high protein pea ingredient products produced by processors participating in the study included protein flour, concentrates, and isolates. The specific interview questions asked varied depending on the participant's job within the company, the company's role in the supply chain, and the type of products produced. Participants held a variety of roles within the companies they represented including export sales, procurement, CEO, operations, and R&D, adding to the diversity of perspectives and responses gathered through the interview process.

Canadian Pea Processing Sector

The Canadian pulse processing sector employs two primary methods for extracting pea protein: dry and wet fractionation. Dry fractionation is more cost-effective as it does not use chemicals or water, but it yields lower protein purity compared to wet fractionation. Dry fractionation typically results in product protein content between 50-65%, whereas wet fractionation can achieve over 80% protein purity. The processors interviewed often contract peas directly from producers within a 100–200-kilometer radius of their facilities. Their stated willingness to pay premiums for higher protein levels was limited and varies based on the availability of suitable peas. The survey responses to willingness to pay a price premium for peas that consistently provided 27% protein are provided in **Figure 1** and suggest a premium for higher protein may be possible but is likely dependent on the suitability for processing and composition of the protein.

Figure 1: Price premium for higher protein content



Most processors reported they do not have minimum protein level requirements for the peas they process, typically expecting an average protein content of 23% in Canadian grown peas. The survey asked respondents to indicate the importance of protein content when purchasing peas (**Appendix 3**: Importance of attributes when buying peas). Five respondents rated it as either important or very important, while one respondent indicated it was not important at all. Genetics and environment are the biggest influencers on the level of protein found in pea seed (Barker,2023). The Canadian Grain Commission reported that the mean protein content of western Canadian No.1 green peas tested in 2023 was 25.3% compared to 25.5% in 2022 (Wang, 2023). Western Canadian No.1 grade yellow peas had a mean protein content of 23% in 2023 compared with 23.8 in% in 2022.

> *"…there's competition in the area. Generally, if we're buying in the area, we're all paying the same amount. Whoever sets the first buying, that's where you're at for that week."*

The pea protein processing sector in Canada currently faces a number of challenges such as limited access to capital, slower-than-expected growth in consumer demand for plant-based foods, and macro-economic factors including inflation and high interest rates. To remain competitive, processors aim to improve efficiency, reduce costs, and increase sales through product and process innovations. The presence of multinationals in the sector adds competitive pressure on independent processors who have limited access to capital. Buyer price sensitivity is a significant challenge, with most processors prioritizing cost-effectiveness to remain viable in the market. Respondents talked about adapting to the evolving environment by layering on additional technology to create products that are of greater value to buyers.

The survey asked respondents to indicate the importance of price when sourcing and purchasing peas for processing (**Appendix 3**: Importance of attributes when buying peas). Four of five respondents to this question indicated it was either very important or the highest priority. During the interview, several respondents described themselves as price takers, required to pay the current market rate when buying peas.

High-Value Pea Ingredient Market

The Canadian pea protein processing sector has experienced significant innovation and specialization in response to market demands and economic pressures. Companies are refining their technology and processes to improve the desirable attributes of their pea products. This constant innovation is driven by the competitive nature of the industry and the evolving demands of the food market. Processors are leveraging the versatility of pea protein to develop innovative products and entering new markets.

> *"…we have to be very cautious when we do innovation. If we want to come up with some kind of cutting-edge technology that's going to require a large investment on our end, then obviously we need to recoup that in the cost of the ingredient that we sell. And so, our customers need to be confident that the consumers will also help to recoup. And so, I think it's still quite sensitive right now."*

Customization of products to meet specific buyer needs is a growing trend. As processors and food manufacturers learn more about the functional properties of peas, the demand for new pea ingredients has increased. This demand often arises from requests by existing customers for solutions to specific problems, leading to the development of made-to-order ingredients. The goal is often to reformulate products to make them more affordable without losing perceived value. The rising cost of traditional ingredients like eggs and dairy, combined with a non-GMO status and lower carbon footprint, has made pulse ingredients more attractive to food manufacturers.

> *"We're always trying to solve problems. So, somebody is trying to make something or do something. We try to give them the best solution for them."*

The perception of pea ingredients as a healthy alternative rather than a filler is creating a competitive advantage in the ingredient market. Consumers view pulses as nutritional, which is helping pea ingredients gain traction over alternatives like wheat flour or corn starch. As technology evolves and processors gain more experience, the high-protein pea ingredient market is poised for expansion. The

combination of improved affordability and perceived health benefits is driving this growth. One processor suggested the healthy image of pulses has led to pea ingredients being perceived positively by consumers as a value-add rather than a filler when used by food manufacturers to replace higher priced ingredients in products.

> *"…clean label is really important to consumers. …that comes back to the ingredient manufacturer. So how do we take out, say methyl cellulose in a plant-based burger? How do we make a clean label milk alternative that doesn't have any hydrocolloids for suspension to overcome some solubility issues that plant-proteins have."*

Processors are also focusing on maximizing the value of the entire pea, including fiber and starch. Many are using these components in their own products or selling them to other food manufacturers. This strategy not only addresses sustainability concerns but also helps processors achieve the greatest return from their processing efforts. The growing demand for pea fiber ingredients is believed to represent a significant future opportunity for the processing sector.

> *"…we are in fact, not eating the recommended levels of fiber and a lot of companies are investing in that right now. We have a pretty hardy portfolio of fibers available for different applications, and it's because we recognize that this is going to be the next topic that everyone's talking about."*

> *"The whole world is getting enough protein. They're not getting enough fiber.... Fiber is a train that is coming into the station. ...If you taste our pea fiber, there's no taste to it because it's clean, all the pea is cleaned out of it."*

The beneficial attributes of pea starch for analog products include the ability to gel, hold water, develop viscosity, and contribution to the texture of final products. Pulse starches are also being used in various applications including gluten-free baking, snacks, sauces, batter and breading products, and beverages. However, the most widely adopted food use for pulse starches is in noodles and pasta, with pea starch gaining popularity in this application. Non-food applications include industrial, cosmetic, and pharmaceutical products, as well as animal and pet feed.

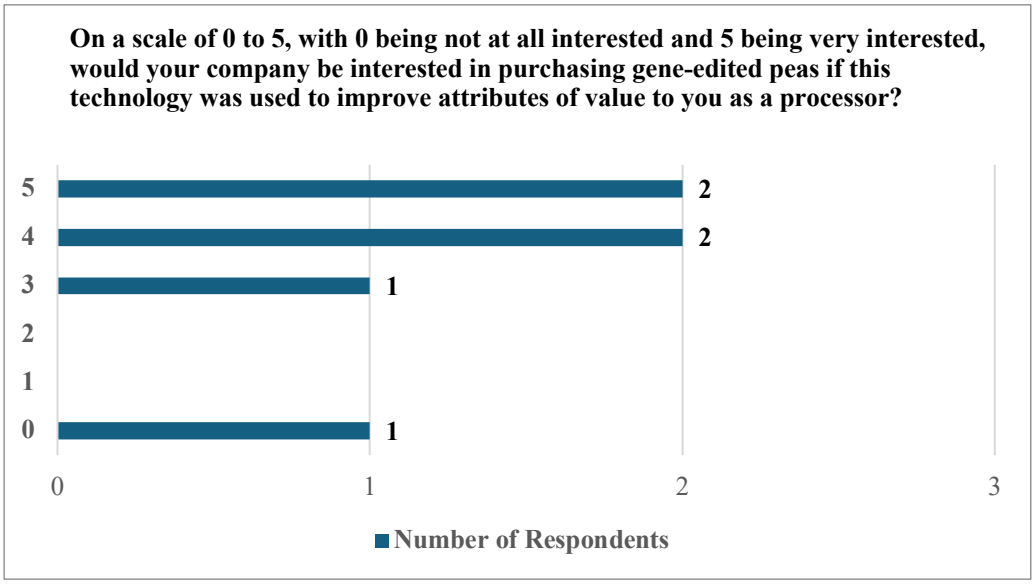
Pulse Canada announced in 2023 a focus on finding high-value and high-volume end uses for pea starch as a by-product of pea protein processing, exploring industrial applications such as bioplastics (Chorney, 2023). Research into patent filing and grants for pulse starches shows a significant increase in activity beginning in 2017 and peaking in 2019 at just over 30 applications, with most starch-

related innovation occurring in China, the US, and to a lesser extent Europe (Pulse Canada, n.d.). Of the 190 patents evaluated, 136 were for pea starch and 25 for lentils. Of 190 filings evaluated, 105 were for food end-use market applications, with many looking to address the functionality of pulse starch that makes it challenging to use as a direct replacement for other starches.

Gene-editing

Processors were asked about their views on using gene-editing in plant breeding to address specific pea attributes. Processors supported the potential of gene-editing to enhance desired attributes in peas, such as improved resistance to root rot and drought which affect the yield variability and profitability of growing peas. The survey asked respondents whether they would be interested in purchasing gene-edited peas if the technology improved attributes of value to processors. The results are shown below in **Figure 2**. Consistent with the interviews, respondents indicated they were interested in gene-editing to improve desired pea attributes.

Figure 2: Interest in purchasing gene-edited peas



While respondents recognized the potential future benefits of gene-editing in addressing sustainability, palatability, and production issues, they expressed concerns about current consumer acceptance of the technology. Issues such as the image of pulses, segregation of gene-edited varieties, regulatory considerations, and implications for international trade and commodity markets were raised. Most respondents believed that consumers acceptance of gene editing technology in major markets could be an issue and as a result, introducing gene-editing at this time could be detrimental to the food ingredient market and the pulse industry as a whole in Canada.

The image of the industry was a significant concern for several processors. They viewed the current consumer perception of non-GMO pulses as a marketing advantage over other plant-based ingredients, describing pulses as “natural”, “clean”, and “healthy”. Many felt that consumers did not

distinguish gene-editing from GMOs. Some processors anticipated a negative response from consumers, while others were unsure and advocated for significant consumer research and education if needed before adopting the technology.

The implications of gene-editing for accessing international pulse ingredient food markets and the larger Canadian commodity export market were also discussed. If the value-added ingredient market is to grow it will require growing export sales and processors indicated that they are starting to export to Europe and Asia including South Korea and Japan. Some processors felt that gene-editing could become a trade barrier for commodity sales, the mainstay of the Canadian pea market. Concerns were raised about the ability to test for and segregate gene-edited products once introduced, with the metaphor of "Pandora's box" being used to describe the potential unknown negative implications. Participants noted that regulatory environments, both domestically and internationally, are unstable and subject to change based on political and public will rather than scientific evidence. While Japan, like Canada, has exempted gene-edited crops from regulation, a 2019 study revealed Japanese consumers define naturalness as the lack of artificial manipulation and consumer perceptions of gene editing and naturalness differ from the view of scientific experts in that country (Otsuka, 2021). Europe regulates gene-edited crops the same as GMOs while South Korea does not currently have specific regulations for gene-edited products (Vora et al., 2023). This uncertainty adds to the caution surrounding the adoption of gene-editing technology in the pulse industry.

The survey asked respondents to indicate the importance of non-GMO when purchasing peas for processing (**Appendix 3**: Importance of attributes when buying peas). The importance ratings varied. Survey respondents were asked a similar question about the importance of purchasing peas bred using conventional methods (non-GE) (**Appendix 3**: Importance of attributes when buying peas). The responses to this question were more polar with three respondents indicating it was not at all important and three respondents rating it either very important or of the highest priority.

High Protein

The importance of developing pea varieties with higher protein content was discussed during the interview. Respondents indicated that their current product offerings met the protein content requirements of their customers, which varied depending on the buyer. While new varieties that offered more protein were welcomed, protein content was not the highest breeding priority for most processors (**Appendix 4**: Importance of improving attributes through plant breeding). The interest in more protein was tempered by a lack of market demand, market price sensitivity, and concerns over the trade-offs associated with growing existing high-protein pea varieties. For most processors, there was no strong market pull to increase the protein content of their pea ingredient products.

Processors more often voiced an interest in the functionality and accessibility of the protein within the pea as breeding priorities rather than the amount of protein content itself. To remain competitive, processors have been focusing on improving their technology and processes to increase protein extraction efficiency, reduce costs, and enhance product quality. Developing proprietary technologies and processes that improve the functionality of pea ingredients can provide a competitive edge. As

the market evolves, processors are increasingly interested in the specific types of proteins being increased through plant breeding. The survey ratings of the importance of protein quality, functionality, and micronutrients varied among respondents, reflecting the diversity of products being produced (**Appendix 3**: Importance of attributes when buying peas).

The competitive nature of the market and the price sensitivity of the food industry were recurring themes in the interviews. The trade-offs involved in breeding for higher protein content have included the undesirable attribute of yield drag in some varieties necessitating a price premium to entice producers to grow them. Processors noted that buyers were extremely sensitive to any price increases in pea protein ingredients, leading to the speculation that customers would not be willing to pay more for higher protein content products.

Climate-Smart Certification

Processors were asked about their interest in a climate-smart certification program and the development of an industry-wide framework and standards for such a program. While there was general agreement that a sustainability initiative was beneficial, most processors felt that developing a climate-smart certification program at this time was premature. The idea of an industry-wide program was seen as valuable and potentially essential for the long-term success of the sector but achieving consensus on definitions and standards was viewed as a significant hurdle.

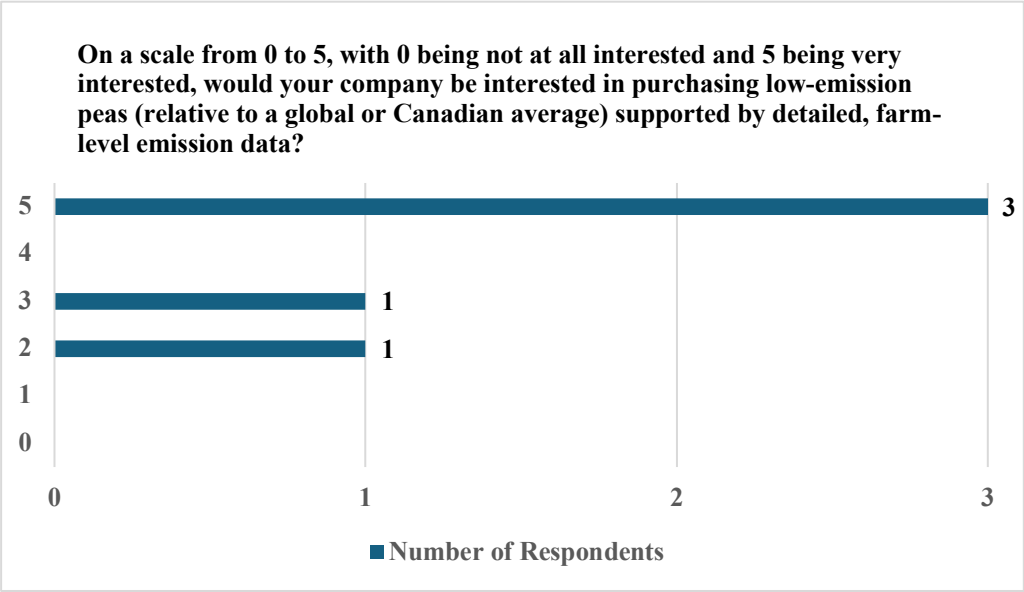
While respondents acknowledged potential benefits for the industry and farmers, they noted that buyers were not currently demanding this certification and would likely resist any cost increases associated with establishing and supporting such a program. Conversations with customers about sustainability and ESG initiatives revealed that protein ingredient buyers remain focused on price and were not currently willing to pay more for such designations. However, processors did not rule out the possibility of future price premiums if there was sufficient consumer pressure. Some processors suggested integrating the climate-smart certification with existing programs to reduce the administrative burden.

There was debate about whether producers would financially benefit from a climate-smart certification program. While one processor was aware of a producer who received a substantial payment from a private company for participation in a sustainability program, others believed that such certification would eventually become a market participation requirement without compensation. Many processors felt that producers were already implementing practices that would meet certification standards, with the main barrier being the additional administrative cost to producers in providing the necessary documentation of these practices.

Despite these concerns, almost all processors expressed interest in sustainability initiatives for their companies. Many envisioned a potential competitive advantage in such designations, even if they did not expect immediate market value in the form of price premiums. Some processors believed that the industry might eventually support a climate-smart certification program, but for now, companies were focusing on internal environmental and sustainability projects. Participant responses to the online survey question regarding their company's interest in purchasing low-emission peas is shown

in **Figure 3**. Survey responses indicated a strong interest in purchasing low emission peas, aligning with the interview findings that companies value ESG and sustainable practices. Respondents were not asked about their willingness to pay a premium for peas with this certification.

Figure 3: Interest in purchasing low-emission peas



Plant Breeding Priorities

Processors were asked questions in the interview to first ascertain what attributes they valued in current pea varieties, and then what their priorities were for improving existing varieties through breeding as they looked to the future of the high protein pea ingredient market. To gather information on processors plant breeding priorities, respondents were asked about what attributes were most important when purchasing peas for processing, what constraints current varieties available posed for the processing sector, and what attributes they believed plant breeders needed to focus on now to meet the future needs of the pulse food industry. To say that increasing the protein content of peas was not a priority would be misleading, but it was not the top priority coming out of the interviews. While there were some consistent themes, the plant breeding priorities of processors were varied and reflect the diversity of processing technology being employed and the specialized nature of the products that processors are continually developing in response to the evolving demands of the food ingredient market. In general yield and price were top breeding priorities followed by taste, protein separation, and protein content. The solubility of protein and color were other attributes mentioned by multiple respondents as a focus for future pea breeding.

While higher protein content is desirable, those interviewed have found it often comes at the cost of lower yields in newer pea varieties, necessitating a premium to compensate growers. Processor supply concerns focused on the need to have a consistent quality and volume of peas to meet operational

needs at an affordable price. Yield was most consistently cited as a priority for plant breeding of pea varieties, as it directly impacts the economic viability and adoption of new varieties by farmers. Processors understood that from the producer's perspective peas compete for seeded acres with other crops, so it was important that the per acre return be sufficient to persuade the producer to grow them. Additionally, there was agreement that continuous year-over-year yield growth was essential for growing the high protein ingredient sector and maintaining export competitiveness.

The global commodity market for yellow peas is highly price-driven, with minimal emphasis on protein content or other quality standards, making cost the primary concern for exporters. Speculation in the market has led to situations where imported peas are cheaper than locally sourced ones, complicating the economics for processors. Processors face pressure from their customers to keep costs low, as even minor price increases can be untenable in the competitive food market. Low profit margins in processing generated further pressure to minimize costs. Despite the potential benefits of higher protein content, the market's reluctance to pay premiums for this desired attribute underscores the dominance of price as the driver in the purchase decision. As a result, processors are sensitive to any cost increases associated with new pea varieties, as it significantly influences market dynamics and farmer cropping decisions. When asked in the survey about the significance of price as a priority in plant breeding, all respondents indicated it was important, with three rating it as the highest priority (**Appendix 4**: Importance of improving attributes through plant breeding).

> *"My most expensive cost are my peas going in right, and the food manufacturers on the other end are pushing down on me, saying, oh, you can't cost (more), you know I can't then pass it on as easily as we think. I can't just raise my price, right?... I did this whole calculation. I'm like, it's going to cost you a tenth of one penny per liter (to add our protein) and that's too much money for them. So, I'm looking all the way down at the end of the supply chain. …So, whatever I pay my farmers, I'm just going to take the hit on it right. I will just take the hit because I can't pass that on."*

While yield and price are essential considerations, taste was identified as an important plant breeding priority, as it directly affects consumer acceptance and market versatility. The inherent "beany" taste of pea is a significant drawback, making flavor something most agreed should be addressed through breeding. Ongoing efforts to apply various technological treatments to pea protein to enhance flavor and mouthfeel have had some success. Masking the strong, often bitter flavor of pea protein with salt or sodium is a common but suboptimal solution, making it a priority for breeding improvements. Starting with a neutral-tasting pea protein can eliminate the need for chemical flavorings, simplifying the production process for products like plant-based burgers. Enhancing the taste of pea varieties through plant breeding is essential for their broader acceptance and use in various food products. One respondent stated that the industry's growth hinged on improving taste, as "taste is king."

The survey asked respondents to indicate the importance of improving flavor through plant breeding (**Appendix 4**: Importance of improving attributes through plant breeding). Consistent with the comments made about taste in the interviews, five of the six respondents rated this as very important or highest importance. One respondent indicated this was not at all important and this low prioritization may be an indication that flavor is not a concern for the products produced by that processor or that technologies are being employed that address flavor issues through processing.

"…improvements to taste. …It's always something that consumers come back to us about, it's a number one concern. So, if there is anything that can be done from the breeding side of that it would be great."

Breeding varieties that made it easier to extract more of the protein was mentioned by several processors. The ease of dehulling is considered a desired plant breeding trait, as it directly impacts processing efficiency and product quality. Production efficiency was improved by reducing the time and effort required to dehull the peas and value gained through the ability to remove the hull cleanly such that none of the usable pea was wasted. The need for exhaustive dehulling to maximize efficiency was emphasized.

Consistent seed size is important for dehulling because uniformity simplifies the cleaning process and subsequent processing stages. Larger seeds are easier to dehull, leading to greater efficiency. Described as the first step in the fractionation process, proficient dehulling is crucial for splitting efficiency and minimizing by-products. Varieties with thicker or tougher skins require different machine settings, complicating and slowing the processing. The need to balance between ease of dehulling and hull thickness to protect against splitting during harvest was recognized.

"Certainly, the efficiency at which we can de-hull dried peas and making sure that is as efficient and as exhaustive as it can be."

Improving the ability to separate the protein from other elements within the pea during processing was identified as a current technological focus for the sector. Processing would be simplified if the protein and starch molecules could be easily separated. Improving protein-starch separation through breeding would support advancements in processing technologies and improve the overall quality of the pea-based ingredients produced. It was noted that some private breeding companies have reportedly developed pea varieties that allow for improved protein-starch separation, making milling and separation more efficient.

"…we are constantly monitoring the process to make sure that the individual components are being separated and going into the highest valued stream that they can go into."

Participants were asked specifically about their thoughts on the breeding of pea varieties that would provide more protein. Increasing the amount of protein in pea varieties was a desired outcome of plant breeding as it directly impacts both market demand and processing efficiency. However, protein levels in peas do not generally drop below 23%, ensuring a consistent quality of peas for processing. One respondent stated maintaining a target protein range of 21-25% is important but current protein levels are sufficient to achieve this. Some varieties can achieve protein levels as high as 28-29%, offering potential benefits to processors in terms of efficiency and output if yields are also favorable. Securing premiums for higher protein content can be a challenge for both producers and processors as the market is not yet willing to pay extra for this attribute. Nevertheless, there is an ongoing push for higher protein peas to improve processing efficiency and expand product offerings.

"You're on the right course looking at protein. Why wouldn't we grow more protein if we can get more protein in our peas?"

Manufacturers are using pea products to substitute for other ingredients in their food products. When used as a replacement for other ingredients like cornstarch and wheat flour, it was considered desirable that the pea ingredient does not disrupt consumers' expectations of the food item it is being used in. Color was raised as something that would expand the adoption of pea ingredients as a substitute in food manufacturing. The color of pea protein is expected to impact market acceptance and consumer preferences for food products containing these ingredients. The yellow color of pea protein is often undesirable, with buyers favoring a whiter pea to produce a less yellow protein. One respondent recalled a past attempt to introduce an orange pea variety in commodity markets that failed solely due to the color, despite their excellent yield and size. This example underscores how even the most promising varieties can be rejected if the color does not align with consumer expectations.

"The yellow color of protein is an issue for many, and buyers want a whiter pea. Something that would produce a whiter, less yellow protein would be good. …"

The types and functional properties of the proteins in the pea were identified by processors as attributes to be improved through plant breeding. Desired breeding outcomes included more soluble,

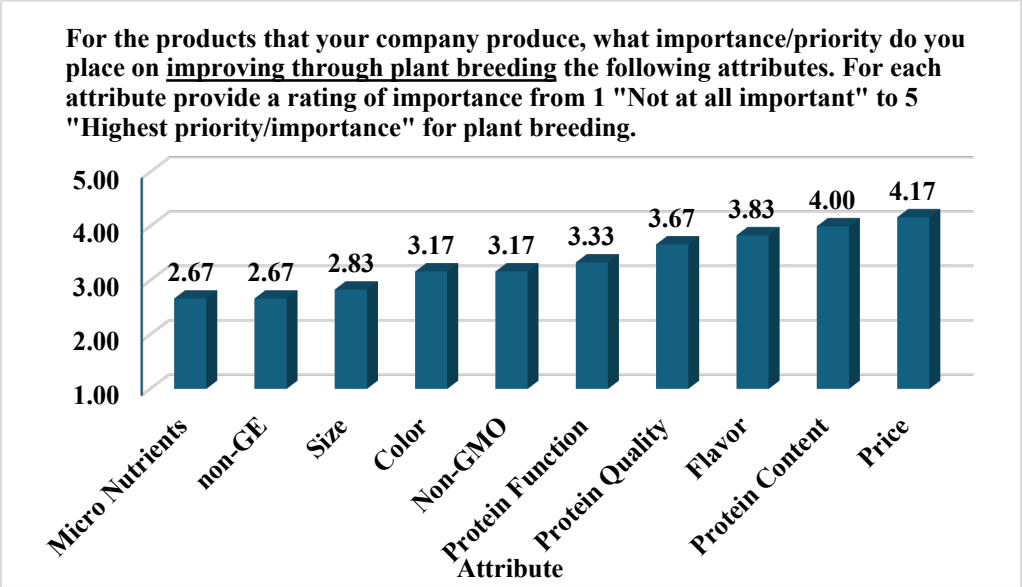
digestible, and complete protein, improved protein quality, and the ratio of the various types of proteins within the pea. These requests arise from the market demand for specific functions from pea ingredients within food products. In the survey, respondents were asked about the importance of protein quality, functionality, and micronutrients as priorities for plant breeding (**Appendix 4**: Importance of improving attributes through plant breeding). Overall protein quality and functionality received high importance ratings. Micronutrients had a slightly lower rating with three individuals indicating it was only somewhat important.

"I think, from the protein side, as we understand more how the protein profile influences its functionality, I think that we could then lean on the breeders, if possible, to produce peas with different ratios of the globulins that are present. …Pea protein, but it's a collection of proteins. It's not just one protein. And so, understanding how each one of those fractions of proteins contribute to its performance in an application. That's probably the biggest thing that comes to my mind from an R&D side in terms of how we could really leverage the breeding."

"Let's make it more soluble by gene editing. Let's make the pea plant produce more albumins than globulins and make it more digestible. Let's say if you can make a plant that's producing protein that's 90% digestible versus the 70% that we digest now… so you don't have to focus on protein being 25, if you can get a 20% pea that is 100% protein digestible to the average human."

Figure 4 provides the online survey average importance rating of improving specific pea attributes through breeding. It is important to remember that only six of the 12 interview participants completed the survey. For those that did complete the survey, protein content was an important priority.

Figure 4: Importance of improving attributes through breeding



New Variety Development and Adoption

To better understand the requirements of the high value pea market, processors were asked about the constraints they faced in the industry and what role they felt plant breeders could play in helping to maintain and grow the competitive advantage of the Canadian pea processing sector. Several respondents referred to the growing competition in global markets and felt plant breeding had the potential to play a role in helping Canada maintain its competitive advantage by continuing to supply the quality of peas needed to meet market demands and be the preferred supplier in global trade arenas.

Participants talked about the importance of understanding and focusing on the needs of the market in setting priorities. Processors felt it was important to understand the needs of the entire supply chain and be aware that those needs were becoming increasingly specialized. Past breeding efforts that have focused on attributes of value to producers had occasionally led to the release of varieties that proved difficult to process or market because of undesirable traits. Processors noted the attributes of most benefit to producers were not necessarily the same as those that food manufacturers and final consumers valued. Several examples of varieties developed in the past that did not meet the needs of end users were identified. If new varieties were to be successful in the market, it was important to consider whether the attributes developed to address production issues could be delivered in varieties that also meet the needs of the entire supply chain.

Almost all processors interviewed contract directly with producers to supply peas and have the potential to influence the decision to adopt new varieties. Factors thought to affect grower adoption include the cost of new seed, regional accuracy of trial information, crop planning considerations, perceived risk and uncertainty associated with growing new varieties, and the economic importance of peas to the farm's income. Risk aversion and familiarity with existing varieties weigh into the

producers' decision of which variety to grow. Stable yields, earlier maturity, and regional growing conditions encourage producers to stick with known varieties. Producers have become skeptical that new varieties will perform as promoted, preferring to observe the experience of others before trying new varieties. Historically, planting pulses has been more about soil health and crop rotation than profit, with peas being a small percentage of crop planting each year due to disease pressures. This results in a tendency to return to familiar varieties and minimal grower effort into researching new varieties. Economic drivers for change have been limited, but this may shift if pea prices remain high, and a larger portion of the farm can be seeded to peas. Some processors have included seed retention in contracts to promote the adoption of new varieties.

Processors felt improved communication and collaboration amongst the supply chain stakeholders would be beneficial in ensuring the quality and marketability of future pulse varieties. Several participants indicated a willingness to be more involved in the plant breeding process, offering input and feedback as varieties are being developed. As a more informed participant in varietal development, processors felt they could also play a role in promoting new varieties for adoption by growers.

Conclusion

The high-value pea processing sector was described by those interviewed as competitive and very price sensitive. Many processors indicated they compete based on technology and product differentiation, focusing on developing functional pea ingredients that add value to the products food manufacturers want to create for their markets. The competitive nature of the industry helps explain the interview findings that processors value pea attributes that improve the efficiency of processing or the functional value of peas as a food ingredient, and the importance processors place on improving yield through plant breeding.

While processors saw the value of gene-editing in advancing pea breeding for desired attributes such as flavor and disease resistance, they had concerns about the consumer response to employing this technology in pulses that are currently marketed as non-GMO. The image of pulses as being natural and healthy was important to the sector, and any technology that might jeopardize this branding would be resisted. Research into consumer acceptance both domestically and in international markets, along with an assessment of the implications for the pea commodity market, would be needed before processors would feel confident in endorsing gene-editing.

Through the conversations with processors, several explanations for why increasing protein content was not the highest priority were identified, including a lack of demand from the market, price sensitivity, the current industry focus on functionality and product innovation, and concerns related to the attributes of existing high protein pea varieties. While more protein was not the top concern, the attributes of the protein within the pea were of interest to some processors.

Some processors are paying small price premiums to producers for high-protein peas, but there were concerns that some of the newer high-protein varieties have been associated with yield drag, limiting

the profitability of growing these varieties. One buyer who dealt in the export of commodity pea indicated that the entrance of larger processors into the Canadian market seemed to have raised the basis price slightly, suggesting a supply and demand price effect for all pea producers associated with the growth in the pea processing sector.

Processors identified climate-smart certification as something their customers might be interested in but were not willing to pay a premium for in the current market environment. There was disagreement on whether there might be a future price premium for producers from developing a climate-smart program or whether participation in these kinds of programs will simply become a requirement to sell in the market. It was clear that an industry-wide program was not something that had economic value right now, and until consistent global industry standards and definitions for sustainability and climate-smart were established, not attainable.

Processors viewed the functionality of peas as an important strength that could be exploited in the ingredient market. The ease of dehulling peas is crucial for processing efficiency, as it impacts the time and effort required to process and ensures minimal waste. Taste is another important attribute with several processors noting it currently limits the applications of pea ingredients. Processors generally agreed that consistent pea size was desirable for processing efficiency, though it was not currently a top priority for breeding.

As a functional ingredient, peas may have benefited from the recent price inflation of other food ingredients, making pea a more affordable alternative as well as one that is perceived by consumers as creating "health" value in the final food products it is added to. Processors are anticipated to continue to focus on exploiting this unique positioning of pea in the food ingredient market into the foreseeable future. However, faba beans and chickpeas are already emerging as contenders in the protein ingredient market, and only time will tell if they eclipse pea as the functional pulse ingredient of choice in food manufacturing.

The takeaway message for plant breeders regarding high-protein peas was that although more protein is always welcome and is a priority for those engaged in product differentiation based on this attribute, most processors are focused on improving attributes that facilitate the separation of the protein from other elements of the pea, increase processing efficiency and consistency in the final products, or enhance specific elements of the pea such as a particular protein desired for product development. The challenge in breeding for specialized protein attributes is that they are often product and processor-specific and so not necessarily of benefit to the industry in general. As processors readily admit, product innovation and market focus are evolving very quickly. What is of value today may not be tomorrow.

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Appendix 1: Online SurveyMonkey questions

1. How many tonnes of peas does your company currently purchase and process in a year?
   - In Canada
   - Globally (excluding processing in Canada)

2. How many tonnes of peas does your company currently have the capacity to process in a year?
   - In Canada
   - Globally (excluding processing in Canada)

3. How many tonnes of peas does your company plan to have the capacity to process in Canada per year?
   - 5 years from now
   - 10 years from now
   - 15 years from now

4. Based on your company's projected market/demand growth for products containing peas, what, if any, percentage increase in the amount of peas processed do you project for the next 10 years (we are looking for the average annual increase)? [% increase each year over 10 years (2024-2035)]

5. The current average protein content of Canadian yellow peas produced in Canada is about23%. What if any is the highest price premium (choose only one) you anticipate your company would be willing to pay for a pea variety that consistently provided a protein content of 27%?

1-5%	6-10%	11-15%	16-20%	None

   - Other. Please indicate both (1) what percentage of protein content would be required for your company to consider offering a price premium (relative to the price paid for peas offering 23% protein) and (2) what that percentage price premium would be

6. For the products that your company produce, what importance/priority do you place on the following attributes when sourcing peas to buy and process. Provide a rating of importance from "Not at all important" to "Highest priority/importance". If the attribute is not one you consider when purchasing peas give it a rating of "Not at all important".

Attribute	Not at all Important	Somewhat Important	Important	Very Important	Highest priority/ Importance

Flavor					
Size					
Color					
Seed Weight					
Protein Content					
Protein Quality					
Price					
Functionality					
Micronutrients					
Non-GMO					
Non-GE					

7. For the products that your company produce, what importance/priority do you place on improving through plant breeding the following attributes. For each attribute provide a rating of importance from "Not at all important" to "Highest priority/importance" for plant breeding. If you believe the attribute does not need to be improved (current quality is sufficient or it is not important to you) give it a rating of "Not at all important".

Attribute	Not at all Important	Somewhat Important	Important	Very Important	Highest priority/ Importance
Flavor					
Size					
Color					
Seed Weight					
Protein Content					
Protein Quality					
Price					
Functionality					

Micronutrients					
Non-GMO					
Non-GE					

8. On a scale of 0 to 5 with 0 being not at all interested and 5 being very interested, would your company be interested in purchasing gene-edited peas if this technology was used to improve attributes of value to you as a processor?

9. On a scale from 0 to 5, with 0 being not at all interested and 5 being very interested, would your company be interested in purchasing low-emission peas (relative to a global or Canadian average) supported by detailed, farm-level emission data?

Appendix 2: Qualitative interview questions

1. What types of innovations are you seeing in the industry?

2. What constraints do the current pea varieties available pose for the processing sector?

3. What are the most important attributes you consider when purchasing peas for processing?

4. Are you considering or interested in a Climate-smart certification program for any of your products? What are your thoughts about the development of an industry -wide framework/standards for a certification program? What do you think would be the issues/barriers in developing these programs? Is there market value in such a program and who do you think would benefit from it? What are your thoughts on the MRV framework that PIC is looking to develop for the industry?

5. Do you foresee gene-editing being used to address specific attributes of pea ingredients being used in the food market such as flavor? Israeli Plantae Biosciences has used CRISPR to remove the bitter taste from yellow peas. Do you anticipate the plant-based food sector will be quick to adopt gene-edited technology?

6. Going forward as pulse breeders look to address various production and market issues, do you anticipate there is a willingness to trade-off gene-editing for highly desirable attributes related to sustainability and palatability?

7. What percentage of pea protein does processing allow you to extract? Is improving the extraction technology a focus for your company? Is the fractionation process/technology an important source of competitive advantage in the pulse processing industry?

8. Considering that it takes seven to ten years for new pea varieties to reach the market, what attributes do you think plant breeders need to focus on now to address the future needs of the pulse food industry (2030)?

9. What do you think is Canada's current competitive advantage for global marketing of pulses and pulse products, specifically peas? What role if any does/can plant breeding play in maintaining /growing that competitive advantage?

10. What are the biggest issues/constraints the processing sector is currently facing in Canada?

This information gathering is to support the work of plant breeders so is there anything else you would like them to know?

Appendix 3: Importance of attributes when buying peas

Only 6 of 12 interview participants completed the anonymous online survey. Respondents were asked to rate the importance of specific attributes when **purchasing** peas for processing. The number of responses for each attribute importance rating is shown in the table below.

For the products that your company produce, what importance/priority do you place on the following attributes **when sourcing peas to buy and process**. Provide a rating of importance from **"Not at all important"** to **"Highest priority/importance".** If the attribute is not one you consider when purchasing peas give it a rating of "Not at all important".

Attribute	Not at all important	Somewhat important	Important	Very important	Highest priority/ importance	Total Responses
Flavor	1	1	1	3	-	6
Size	-	3	2	1	-	6
Color	-	3	1	1	1	6
Seed weight	-	4	1	1	-	6
Protein content	1	-	2	3	-	6
Protein quality (amino acid provide and digestibility)	1	1	2	1	1	6
Price	0	1	0	2	2	5
Functionality (viscosity, gelation, fat and water absorption, solubility)	1	1	2	1	1	6
Micronutrients (fiber content, vitamin and mineral content, amino acid profile, fatty acid profile)	1	2	2	1	0	6
Non-GMO	1	1	1	2	1	6

Bred using conventional methods (non-GE)	3	-	-	2	1	6

Appendix 4: Importance of improving attributes through plant breeding

Only 6 of 12 interview participants completed the anonymous online survey. Respondents rated the importance of specific attributes for **improvement through plant breeding**. The number of responses for each attribute importance rating is provided in the table below.

For the products that your company produce, what importance/priority do you place on **improving through plant breeding** the following attributes. For each attribute provide a rating of importance from **"Not at all important"** to **"Highest priority/importance"** for plant breeding. If you believe the attribute does not need to be improved (current quality is sufficient or it is not important to you) give it a rating of "Not at all important".

Attribute	Not at all important	Somewhat important	Important	Very important	Highest priority/ importance	Total Responses
Flavor	1	-	-	3	2	6
Size	-	3	1	2	-	6
Color	1	1	1	2	1	6
Seed weight	-	5	-	1	-	6
Protein content	-	-	1	4	1	6
Protein quality (amino acid provide and digestibility)	-	-	3	2	1	6
Price	-	-	2	1	3	6
Functionality (viscosity, gelation, fat and water absorption, solubility)	1	-	2	2	1	6
Micronutrients (fiber content, vitamin and mineral content, amino acid profile, fatty acid profile)	-	3	2	1	-	6
Non-GMO	2	-	-	3	1	6

Bred using conventional methods (non-GE)	3	-	-	2	1	6