# Poison to Protein:
# The Case for Edible Cottonseed

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## Executive Summary

The United States cotton production market generated 7 billion dollars in 2017, with cottonseed making up about 1 billion dollars of that amount. Although cottonseed accounts for nearly 14% of revenues earned by farmers, its value is limited by its toxicity. It has only a few end markets, namely the markets for cattle feed and cottonseed oil. Removing the toxin from the seed would increase the consumptive potential of cottonseed beyond ruminant animals or ultra-processed oils.

The project client, Cotton Incorporated, is an industry group that represents the interests of United States cotton farmers and importers. Cotton Incorporated has been researching Ultra low Gossypol Cottonseed (ULGCS), a seed variety with exceptionally low levels of the toxin gossypol, since the early 1990s. Cotton Incorporated now holds the exclusive rights to license the technology to produce ULGCS. If adopted globally, ULGCS varieties would produce 9.125 trillion grams of protein annually, enough to meet the daily protein needs of half a billion people. The ULGCS trait can also be added to high-yielding, pesticide-resistant seed varieties. ULGCS was deregulated in October 2019 by the USDA and deregulation from the FDA
is pending.

ULGCS has the potential to transform aquaculture, pet food, and alternative snack and dairy markets and to deliver value to actors all along the cottonseed supply chain, including farmers and ginners, oil mills, seed companies, and food & feed companies. With ULGCS, farmers will be able to access a wide variety of higher-value markets, while seed companies could generate more revenue by charging a “technology fee” for seeds that include the ULGCS trait. Farther down the value chain, food and feed companies will benefit from this additional source of high-protein meal to serve as an input for various products. Beyond this, ULGCS may also be beneficial from a humanitarian and an environmental standpoint. In the humanitarian realm, ULGCS may serve as a protein source for malnourished populations worldwide. On the environmental front, ULGCS may be a sustainable feed for growing aquaculture operations, and an alternative to soy products, which contribute to deforestation.

This study relies on market research, industry expert interviews, and a life cycle assessment to understand the business outlook and potential environmental and social impacts of ULGCS. Findings suggest that the most promising end markets for ULGCS are aquaculture, pet food, and some human food products. In addition, while there is exciting market potential for ULGCS in international markets, strict GMO regulations in major cotton-producing countries such as India and China are currently prohibitive to expansion beyond the United States.

Recommendations include strategies for a business launch, funding access, and future areas of study. They include suggestions for additional economic modeling to understand how ULGCS will affect current cottonseed markets, as well as nutrition studies to explore the effects of ULGCS on human and animal performance. Lastly, targeted marketing and communications efforts supported by a dedicated ULGCS staffer will help build product demand across the value chain, from farmer to consumer. While barriers exist, we believe ULGCS offers a robust market opportunity for both cotton farmers and the aquaculture, pet food, and human food markets.

# Background

## Project Objective

**Cotton Incorporated** (the client), is a cotton industry group that generates research to promote the United States cotton industry. It is funded by the Cotton Board which assesses a $1 per bale fee on all cotton harvested and ginned in the United States as well as on cotton imports. Given that Cotton Incorporated is indirectly funded by growers, Cotton Incorporated aims to build an industry that supports the environmental, social and economic needs of cotton growers, manufacturers and producers.

Stemming from its mission to support cotton growers, Cotton Incorporated, in partnership with Texas A&M, has been researching ULGCS since the early 1990s. Cotton Incorporated holds the exclusive rights to license and sublicense the technology used to produce ULGCS which could transform the cotton industry by making cottonseed a more valuable byproduct. A team from Duke University's Nicholas School of the Environment collaborated with Cotton Incorporated to understand the potential value chains and end markets for ULGCS as well as avenues by which Cotton Incorporated can disseminate this technology both throughout the United States and globally.

This project aims to understand the following:

- What is the business outlook for ULGCS?
- How will the adoption of ULGCS impact stakeholders along the supply chain?
- What might the environmental impacts of a market for ULGCS cotton be?
- What is needed to bring ULGCS to market?

Ultimately, this research aims to better position Cotton Incorporated to attract the interest of a major seed company that can add the ULGCS trait to mainstream, high-yielding and pest resistant varieties of cottonseed.

## Introduction to Ultra-low Gossypol Cottonseed

ULGCS is cottonseed that has been modified to have extremely low levels of the naturally occurring toxin gossypol. The glands within traditional cotton pants contain gossypol in the seeds, stems and leaves, while a variety of cottonseed known as glandless cottonseed has no gossypol in the plant. ULGCS is distinct from both of these in that the toxin within the cottonseed is reduced to ultra-low levels while gossypol in the stem and leaves of the plant is retained to serve as a natural insect deterrent. Removing the toxin from the seed makes it possible for cottonseed to be consumed by a wider variety animals and humans. Cottonseed is primarily consumed for its high protein content. As such, adoption of the ULGCS technology will allow cottonseed to become a valuable protein source without diminishing the cotton plant's yields or resistance to pests.

## Technology Overview

**ULGCS is produced using RNA-interference (RNAi).** RNA interference, also referred to as gene silencing, stops the expression of the naturally occurring toxin gossypol in cottonseed. The technology allows gossypol to be left in the stem and leaves of cotton plants while removing the toxin almost entirely from the seed. This is an improvement on glandless cotton, a seed that emerged in the 1950s. Glandless cotton does not contain gossypol in any part of the plant leaving the plant vulnerable to pests, affecting yields.

The ULGCS event maintains the plant's natural defense mechanism while also creating the opportunity for cottonseed to be eaten by a wide variety of animals and humans. Furthermore, this trait can be added to any variety of seeds, meaning it can enhance existing seeds that have been modified to be high-yielding, herbicide or pest resistant.

RNA-interference is a reliable and well-understood technology. It became a popular biotechnology in the early 2000s. Prior to applying the technology to cottonseed, Texas A&M scientists studied glandless cotton to identify the critical enzyme for gossypol production. Around 2001, scientists blocked the enzyme using RNA-interference, diminishing gossypol production in the kernel, but preserving its production in the rest of the plant.

**Backcrossing is used to introduce the ULGCS trait in to higher-yielding cottonseeds.** Backcrossing is a traditional plant breeding method that involves a donor parent that has a gene of interest and a recurrent parent that could be made better by adding a gene of interest[1]. The donor is crossed with the recurrent parent, and the offspring of this cross is then 'crossed back' to the recurrent parent. The 'event' of the silenced gossypol-producing gene can be backcrossed into conventional varieties or stacked with other GM traits such as the Bt event. The technology, however, faces time constraints: it takes about 5 years to backcross the ULCGS trait into conventional varieties. There is currently only a small quantity of seed available to grow and it will be some time before ULGCS can be produced on a large scale, due predominantly to the slow nature of the backcrossing process. There will not be a substantial volume of seed available for selling, testing and marketing for at least 2 to 3 years.

## Deregulation and Field Testing

ULGCS is a genetically engineered organism, also known as a genetically modified organism (GMO). In the United States, federal laws specific to genetically engineered organisms are lenient relative to other major potential markets like China and India, who have strict regulations on GMOs.

The United States Animal and Plant Health Inspection Service (APHIS) approves and supervises field testing, planting, and importation of genetically modified crops. The three available routes to introduce a regulated article to the US are i) notification procedure; ii) permit application; and iii) determination of nonregulated status. The FDA regulates GMOs like it regulates all food. GE plant developers must explain their products to the FDA, receive feedback, and submit a safety assessment and summary.[2]

**The new ultra-low gossypol seed was officially deregulated by the U.S. Department of Agriculture (USDA) in October 2018.** The news generated press across the internet from NPR,[3] Vox,[4] and Politico.[5]

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[1] Plant & Soil Sciences eLibrary. (2019). Advanced Backcross Breeding. *Plant & Soil Sciences eLibrary*. http://passel.unl.edu/pages/informationmodule.php?idinformationmodule=959723462&topicorder=2&maxto=7

[2] Federation of American Scientists. (2011). U.S. Regulation of Genetically Modified Crops. *Case Studies in Agricultural Biosecurity*. https://fas.org/biosecurity/education/dualuse-agriculture/2.-agricultural-biotechnology/us-regulation-of-genetically-engineered-crops.html

[3] Charles, Dan. (October 17, 2018). Not Just For Cows Anymore: New Cottonseed Is Safe For People To Eat. *The Salt*. https://www.npr.org/sections/thesalt/2018/10/17/658221327/not-just-for-cows-anymore-new-cottonseed-is-safe-for-people-to-eat

[4] Sugar, Rachel. (October 19, 2018). Edible cottonseed is now a thing — and it could have big implications for world hunger. *Vox*. https://www.vox.com/future-perfect/2018/10/19/17995544/edible-cotton-science-gmo-texas

[5] McCrimmon, Ryan. (October 17, 2018). Edible cottonseed review shifts to FDA. *Politico: Morning Agriculture*. https://www.politico.com/newsletters/morning-agriculture/2018/10/17/edible-cottonseed-review-shifts-to-fda-376654

Deregulation was a critical step because it signals legitimacy to seed companies who may be interested in the technology. Additional field-level experiments with ULGCS will take place in 2019.[6]

**Deregulation by the Food and Drug Administration (FDA) is pending, but expected.** RNAi technology and gossypol are both well understood by the FDA. Since Cotton Incorporated and Texas A&M have simply blocked the production of toxin as opposed to inserting an unfamiliar protein, the deregulation process for the USDA was relatively straightforward and the same is expected for the FDA process.

**Field tests have shown no evidence of negative impacts of the ULGCS technology on the cotton plant.** Deregulation of ULGCS by the USDA required the submission of 8 field tests. In total, 12 ULGCS field trials have been completed over a three-year period in different soils and geographical locations. Four were completed in North Carolina, 4 in Mississippi, and the remainder were in Texas. The field trials involved a variety of measurements, from height, growth, bug damage and yield. The results of these tests reveal that the lack of gossypol does not affect the performance of the cotton plant. The oil and protein content of the seed do not change as a result of gossypol removal, and essential fiber properties and total yield are equal to non-ULGCS varieties. Moreover, trials of seedling ULGCS plants show that the trait is stable across five generations.

ULGCS has not yet been grown outside of small field testing plots. Cumulatively, ULGCS has been planted on approximately half an acre of land. For liability purposes, special precautions have been taken to ensure that the seed is not disseminated beyond test plots until full deregulation has occurred. There are plans to plant 19 additional acres in 2019. Cotton Incorporated aims to have half a million acres of ULGCS cotton in production within 5 to 6 years. By 2021-2022 there should be approximately 2,000 tons of ULGCS available.

Aside from the ULGCS cotton testing, glandless cotton has been extensively tested. Some human food studies were completed in the 1970 by Texas Woman's University. More recently, glandless cotton has captured the attention of organic cotton growers. In fact, approximately 200 acres of glandless cotton are currently being grown with the possibility of 500 acres next year.[7] Processing and selling glandless cotton could be a method by which to begin normalizing the consumption of cottonseed by a wider variety of animals and by humans. It could also complement the ULGCS market for companies who wish to use cottonseed in both conventional and organic product lines.

Animal feeding studies to date have been rare because of the large number of permits required. Nevertheless, two feeding studies—one for flounder and one for shrimp—have been completed. In addition, Cotton Incorporated is planning to fund a $75,000 - $125,000 project researching the nutritional effects of ULGCS on dogs.

**Deregulation may be difficult to achieve in non-US cotton producing countries.** Although there are regulations governing agricultural genetically modified organisms, China has not yet enacted any national laws against genetically modified organisms. The Ministry of Agriculture (MOA) outlines the regulatory framework for research, testing, production, processing, marketing, import and export of agricultural GMOs. In the Twelfth Five-Year Plan for National Economic and Social Development from 2011 to 2015,

[6] Holt, Greg. (January 2018). I*mplications of Ultra-Low Gossypol Cottonseed*. Beltwide Cotton Conferences. http://www.cotton.org/beltwide/proceedings/2005-2018/data/conferences/2018/papers/18139.pdf

[7] Personal communication, Tom Wedegaertner, January 28, 2019.

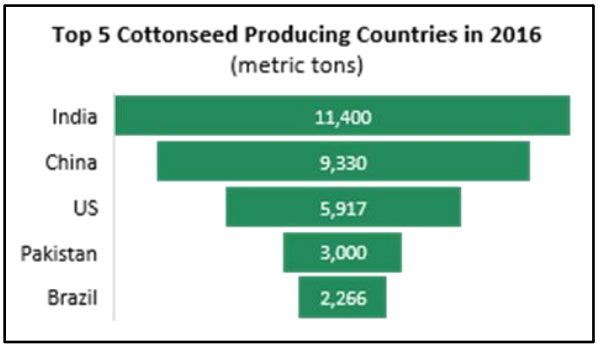
the Chinese government expressed its ambition to accelerate the innovation and application of agricultural biotechnology breeding and to cultivate large modern seed industries. Despite the highly accommodative policies and rich research funding, the commercial outlook for GM crops is not optimistic due to the public's negative perception of GMOs. As for imports, Bt cotton is currently the only GM cotton that can be imported into China. Commercial planting and marketing of genetically modified crops requires at least four licenses: a biosafety certificate for human and environmental safety certification, a crop variety certificate for successful registration of new crop varieties, a production license crop for the production of genetically modified crops, and a marketing license for genetically modified crops.[8]

In India, Rules 1989 covers the areas of research and large scale application of GMOs and products made throughout India. Two main agencies involved in the implementation of the Rules 1989 are i) the Ministry of Environment and Forests and the Department of Biotechnology (DBT), Government of India and ii) Section No. 6 of The Seed Policy, 2002 on transgenic plant varieties. Per the regulation on guidelines of the EPA, 1986, all genetically engineered crops/varieties must be tested for environment and biosafety before their commercial release. After commercial release of a transgenic plant variety, its performance in the field must be monitored for at least 3 to 5 years.[9]

Even though there is the potential for a market for cottonseed-protein products in China and India, it will be difficult to achieve legal status for ULGCS in these two markets due to the strict GMO regulations in both countries.

## The Market for Cottonseed

### Global Market for Cottonseed




In 2018, cotton farmers produced 1.24 million bales of cotton fiber and 44.15 million metric tons of cottonseed globally.[10] The United States produced 17% of the global total, and India and China produced 25% and 21% respectively.[11] China boasts the highest yield per planted acre, with a record 1,520 lbs. of cotton fiber and 2,128 lbs. of cottonseed per planted acre.[12] US cotton farmers typically yield about 794 lbs. of cotton fiber and 1,285 lbs. of cottonseed per planted acre.[13] India trails both countries at 454 lbs. of cotton fiber per

[8] Zhang, L. ( June 9, 2015). Restrictions on Genetically Modified Organisms: China. Retrieved April 16, 2019, from https://www.loc.gov/law/help/restrictions-on-gmos/china.php

[9] Biotechnology Regulatory Authority of India. (2018, November 09). Retrieved April 16, 2019, from https://en.wikipedia.org/wiki/Biotechnology_Regulatory_Authority_of_India

[10] United States Department of Agriculture Foreign Agricultural Service. (2019). *Cotton Supply and Distribution by Country 2017/2018*. Retrieved from https://apps.fas.usda.gov/psdonline/reportHandler.ashx?fileName=Table%2006A:%20Cotton%20Supply%20and%20Distribution%20by%20Country%202014/2015&reportId=855&templateId=3&format=html

[11] ibid.

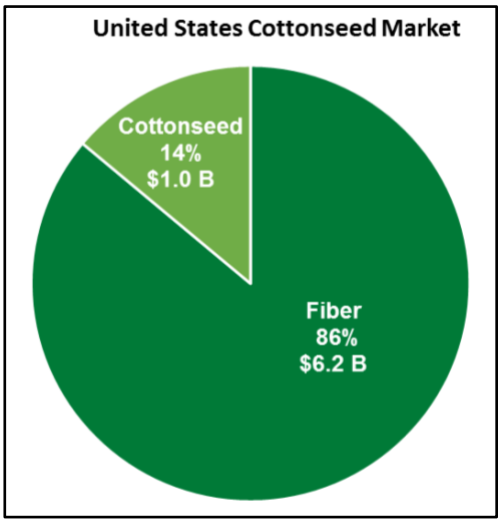
[12] USDA. (August 11, 2017). Commodity Intelligence Report. China: 2017/18 Cotton Production Outlook. Retrieved form: https://ipad.fas.usda.gov/highlights/2017/08/china/index.htm

[13] National Cotton Council. (August 2, 2018). Cotton Production Costs and http://www.cotton.org/econ/cropinfo/costsreturns/usa.cfm

planted acre, but plants more acreage of crops than both the United States and China, accounting for 37.5% of the global planted acreage.[14]

Although all three of these major producer countries represent potential markets for ULGCS, the trait has only been deregulated by the United States Department of Agriculture as of October 2018. At this point, adoption in the US market is most realistic and poses the lowest barrier to entry. Thus, this study focuses on the value proposition for ULGCS in the US market.

## The Market for Cottonseed in the United States




The projected revenue from US cotton production in 2019 is $7.2 billion, with cottonseed accounting for about $1.0 billion of revenues.[15] US cotton farmers, on average, generate $637.81 in revenue per planted acre, with only 14% coming from cottonseed.[16] Since cotton fiber is a commodity crop, the value US cotton farmers get from its production is linked to the global commodity pricing, which is currently $0.73/lb. cotton fiber.[17] This price is by no means stable, and is heavily influenced by the global supply of cotton, demand for fiber by textile industries, and competing commodities. Increased global competition and production, declining subsidies, and foreign tariffs all put future profitability of the cottonseed market at risk.[18] In light of price volatility and potential decreased profitability, cotton farmers are seeking new ways to add value to production.

**Increasing the revenue stream from cottonseed is a feasible and attractive option.** At $0.07/lb., cottonseed is currently a low-value oil seed whose production is driven entirely by the demand for cotton fiber.[19] While this relationship is not expected to change, ULGCS offers the opportunity to generate greater revenue from the cottonseed byproduct by expanding the options for the use and sale of cottonseed. Demand for cottonseed is currently sustained by two primary end markets: i) the market for dairy cattle feed and ii) the market for cottonseed oil. Cottonseed prices in these markets is affected by the supply and price of other close substitutes such as grapeseed, corn, and canola cooking oils, and soy-based , corn-based, and fish-based animal feed.[20] If cottonseed uses were not limited by the toxicity of gossypol, farmers would be able to fetch a higher price per pound for cottonseed, as higher-value end products incorporate whole cottonseed or high-protein cottonseed meal. ULGCS can help deliver this

[14] Chockalingham, S.M.M. (n.d.). *A Profile of Indian Cotton: At a Glance*. Retrieved from https://cotcorp.org.in/Writereaddata/Downloads/Article-ICAC-DM-CCI.pdf

[15] IBISWorld. (2018). *IBISWorld Industry Report 11192, Cotton Farming in the US*. Jack Curran. Retrieved from https://clients1-ibisworld-com.proxy.lib.duke.edu/reports/us/industry/industryoutlook.aspx?entid=37

[16] National Cotton Council. (October 2nd, 2018). Cotton Production Costs and Returns: United States. Retrieved from: http://www.cotton.org/econ/cropinfo/costsreturns/usa.cfm

[17] Markets Insider Cotton Price Commodity. (April 2019). Retrieved from https://markets.businessinsider.com/commodities/cotton-price

[18] ibid.

[19] National Cotton Council. (October 2, 2018). Cotton Production Costs and Returns: United States. http://www.cotton.org/econ/cropinfo/costsreturns/usa.cfm

[20] IBISWorld. (2018). *IBISWorld Industry Report 11192, Cotton Farming in the US*. Jack Curran. Retrieved from https://clients1-ibisworld-com.proxy.lib.duke.edu/reports/us/industry/industryoutlook.aspx?entid=37

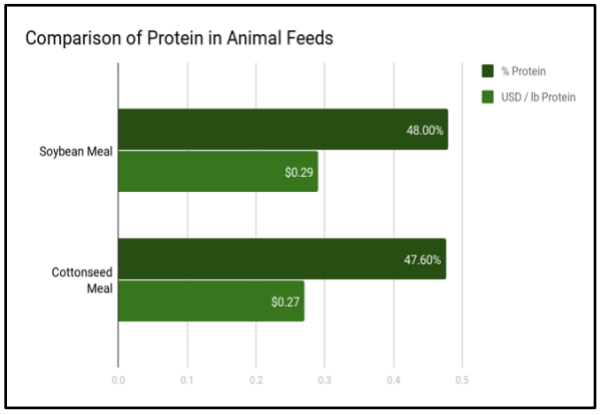
higher value to farmers, which would further translate into overall market growth from the current $1 billion attributed to cottonseed.

### Major Industry Players

**In order to be widely adopted, ULGCS must be integrated into seed varieties produced by a select few major seed and biotechnology companies in the United States.** Nearly all of the cotton in the United States is grown from genetically engineered seeds, with a few brands dominating the market. Deltapine, Americot, and Phytogen were grown on 37%, 30%, and 15%, of planted US acres in 2018, respectively.[21] Each of these brands contain a variety of traits to protect against pests, increase yield, or resist herbicides, just to name a few. While seed companies such as Americot remain independent, Bayer Crop Sciences (formerly Monsanto) and Dow AgroSciences dominate the rest of the marketplace. Any seed not produced directly by these industry giants most likely contains traits they own that are licensed for production for a set "technology fee." As such, ULGCS must be back-crossed into one of the commonly grown brands mentioned above, which means gaining the buy-in of at least one of very few powerful market players.

There are both pros and cons to only a few major industry players dominating cottonseed and trait production in the United States. The international market for cottonseed is less monopolistic than the US market. In India, for example, there are currently 619 hybrid varieties of cottonseed available that contain the Bt trait.[22] If ULGCS deregulation were pursued in India or other countries with a wide variety of seed hybrids, backcrossing the ULGCS trait into a few varieties for small-scale testing may prove easier than in the United States. That being said, if one seed or biotechnology company were to integrate ULGCS into all of its varieties, the trait would more rapidly gain access to a majority of the US cottonseed market than if it were tested with a small company. It also means that the marketing of ULGCS can be directed towards a few key customers rather than hundreds of smaller seed companies.

## Value Proposition




**The addition of the ULGCS trait to existing cotton varieties will realize value across the supply chain, to humanity, and to the environment.** In the supply chain for cottonseed, farmers will achieve a higher harvest value per acre. Animal agriculture entities will gain access to a competitively-priced protein and fat rich feed. Seed companies will realize increased profits by adding this trait to existing product offerings. Plus, ULGCS has humanitarian benefits. Cotton production overlaps with food insecure regions all over the world and, if ULGCS were widely adopted, cottonseed could meet the protein needs of half a billion people annually. ULGCS can help feed a growing population with plant-based protein sources without the need to convert additional land to agriculture, preserving the environment and improving lives globally.

[21] USDA. (October 4, 2018). *Cotton Varieties Planted 2018 Corp*. Retrieved from: https://www.ams.usda.gov/mnreports/cnavar.pdf

[22] Chockalingham, S.M.M. (n.d.). *A Profile of Indian Cotton: At a Glance*. Retrieved from https://cotcorp.org.in/Writereaddata/Downloads/Article-ICAC-DM-CCI.pdf

## Value along the Supply-Chain

ULGCS is high in protein at a time when human food and animal feed industries are continuously seeking out plant-based protein inputs. In fact, cottonseed meal has nearly same percentage of protein but a more cost-effective price per unit of protein than soybean meal. This makes ULGCS an exciting product for multiple end markets. ULGCS has many end-use market applications in both the animal feed and human food markets. It offers a nutritionally-equivalent animal feed component at a lower cost per gram of protein or fat relative to current market offerings. ULGCS can be a sustainable protein substitute that can generate added value across the supply chain, which includes farmers and ginners, oil mills, seed companies, and food & feed companies. See **Exhibit I** for a further explanation of the cottonseed supply chain.

***Benefits to Cotton Farmers and Ginners***

ULGCS has the potential to deliver increased production value to farmers relative to the status quo of cotton fiber and non-edible seed. The cotton market will always be driven by the demand for and price of cotton fiber. However, this does not mean farmers cannot realize additional revenue from value-added cottonseed end markets. Since ULGCS has so many uses beyond traditional cottonseed, farmers will have more customers to choose from when it comes to selling their seed. In addition, they could fetch a higher price for ULGCS going into aquaculture feed production relative to traditional end markets such as oil extraction. With more customers willing to pay a higher price, cotton farmers will see more money per acre of their production and will no longer be reliant on fiber commodity market prices alone. ULGCS is a differentiated crop with novel market opportunities. Since, ideally, the trait would be available in many existing seed varieties, farmers would not have to change any aspect of production. Adoption of ULGCS by farmers would, however, require them to pay an additional technology fee to seed companies in order to gain access to the trait. This fee for trait exchange is common in the agricultural industry.

***Benefits to Oil Mills***

ULGCS can lower costs and increase efficiency for cottonseed oil producers. According to Holt and Wedergartner, oil mills would benefit from ULGCS under the current market structure because, in order to increase their profitability, oil mills need to either 1) gain more value for the products produced, or 2) reduce processing costs.[23] Lower levels of gossypol in ULGCS would minimize the amount of processing needed to produce cottonseed oil. [24]

***Benefits to Seed Companies***

Cottonseed production has few market players: the most commonly grown seed varieties produced are licensed by only a handful of companies. Bayer Crop Sciences (who acquired Monsanto last year), Deltapine (via Bayer), Americot, and Pioneer (via Dow AgroSciences) produced the four most widely planted cottonseed varieties for the 2018 season. Agriculture biotechnology divisions within Bayer Crop Sciences, Pioneer, Syngenta, and BASF generate additional revenue from technology fees applied to seed for certain desirable traits. ULGCS would be licensed to a seed production company, who would then make the ULGCS option available for inclusion in all produced varieties.

ULGCS offers an opportunity to inject growth into the domestic cotton market. The planted acreage of cotton in the United States is heavily dependent on global supply and demand and the relative price for

[23] Holt, G., & Wedegaertner, T. (2018, May 31). *Implications of ultra-low gossypol cottonseed.* Retrieved from https://www.ars.usda.gov/research/publications/publication/?seqNo115=350721

[24] *Ibid.*

other crops. Acres in production have decreased from 15 million in 2006 to 13 million in 2016.[25] Through that same time period, planted acres have been volatile year-to-year, fluctuating from 15 million acres in 2011 to as low as 8.5 million in 2015.[26] Utilizing a new, innovative trait such as ULGCS will generate additional revenues from cotton even in years where overall purchase volume decreases.

ULGCS has gone through the early and middle stages of crop trait development. RNAi technology has proven effective for silencing the gene controlling gossypol production.[27] Trials of seedling ULGCS plants showed that the trait was stable across five generations.[28] Field trials further demonstrated that the trait was stable over three years and that yield and fiber quality were no different than traditional cotton plants,[29] further proving the commercial viability of ULGCS. Any seed company who wants to begin the backcrossing process of the ULGCS trait with existing seed varieties would face few of the costly research barriers that usually plague new seed technologies.

With the market nearly saturated with current biotech cottonseed offerings, there is much room to spur additional profit from innovation.[30] Seed companies that offer the ULGCS trait could see an increase in revenue for very little input cost. A firm who were to purchase the right to produce the ULGCS trait from Cotton Incorporated, or sub-license from a potential private spin-off, could charge a higher price for any variety containing ULGCS. There is no trait like ULGCS on the market. It represents a total different class of revenue from traditional genetically engineered traits that are associated with increased yield or pest control. Any firm who were to insert the ULGCS trait into existing seed varieties would gain competitive advantage in the market by being able to offer farmers access to new sources of revenue. In this way, the technology fee charged can be higher than those charged on other genetically engineered cotton traits. This opportunity for innovation could make any firm producing ULGCS a market leader as demand pulls the new seed into the market.

Lastly, ULGCS comes with significant humanitarian and environmental implications that could bolster the reputation of seed companies. The 44 million metric tons of cottonseed produced globally each year could satisfy the annual protein needs of 500 million people if fit for human consumption.[31] As world population and human food needs grow, cottonseed could serve as an important plant-based protein option, or as an animal feed input. In both cases, since cotton is already widely grown on land dedicated to agriculture, any substitution of ULGCS for existing human or animal food inputs would be associated with fewer resource requirements and land area conversion than comparable crops. A new major food source could arise without having to expand production into new lands. These facts could serve as compelling additions to the humanitarian reach or sustainability plan of any major seed company or biotechnology firm.

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[25] USDA. (March 29, 2019). All Cotton Acres in United States. Retrieved from: https://www.nass.usda.gov/Charts_and_Maps/graphics/cotnac.pdf

[26] ibid.

[27] Sunilkumar, G. et al. (2006). Engineering cottonseed for use in human nutrition by tissue-specific reduction of toxic gossypol. *Proceedings of the National Academy of Sciences, 103*(48).

[28] Rathore, K. et al. (2012). Ultra-low gossypol cottonseed: generational stability of the seed-specific, RNAi-mediated phenotype and resumption of terpenoid profile following seed germination. *Plant Biotechnology Journal, 10*, 174-183. doi: 10.1111/j.1467-7652.2011.00652.x

[29] Palle, S., Campbell, L., Pandeya D. (2013). RNAi-mediated Ultra-low gossypol cottonseed trait: performance of transgenic lines under field conditions. *Plant Biotechnology Journal, 11*, 296-304. doi: 10.1111/pbi.12013.

[30] IBISWorld. (2018). *IBISWorld Industry Report 11192, Cotton Farming in the US*. Jack Curran. Retrieved from https://clients1-ibisworld-com.proxy.lib.duke.edu/reports/us/industry/industryoutlook.aspx?entid=37

[31] Sunilkumar, G. et al. (2006). Engineering cottonseed for use in human nutrition by tissue-specific reduction of toxic gossypol. *Proceedings of the National Academy of Sciences, 103*(48).

***Benefits to Food and Feed Companies***

ULGCS has a nutritional content similar to other oil seeds, with 22.5% crude protein. United States consumers are seeking high protein food items, including plant-based proteins. Traditionally, soy-based high protein meals have served as a manufacturing input for food companies. Recent consumer concerns about soy have motivated companies to seek alternative protein sources, such as pea protein. Cottonseed protein meal produced from ULGCS could serve as a cost-competitive alternative to existing market options, or could even fit into the high-end snacking segment as a clean, high quality, plant-based protein input.

Since no additional land or resources are required to grow ULGCS, it could serve as an environmentally friendly product, generating an important competitive advantage for firms. A Cone Communications 2017 survey highlighted that consumers are increasingly aware of how businesses are contributing to social and environmental issues, and shift purchasing decisions based on such information.[32] By producing ULGCS, any food or feed company could demonstrate commitment to humanitarian hunger relief efforts and sustainable agriculture.

## Value to Society and the Environment

**Beyond the business opportunities, ULGCS poses positive impacts for sustainable fisheries, food security, nutrition, and deforestation**. These benefits may be viewed favorably by philanthropic funders and companies looking to further their environmental and humanitarian goals. Such applications of cottonseed can have both positive impacts and establish cottonseed as a mainstream product. A life cycle analysis of environmental impacts allocated between the seed and fiber as ULGCS changes the economic value of cottonseed can be found in **Exhibit II** of the Appendix**.** This section details more general environmental and humanitarian benefits of ULGCS.

***Combating malnutrition and food insecurity***

According to Texas A&M scientist Keerti Rathore, many of the world's 80 cotton-producing countries have populations that are malnourished, including India and China, the largest cotton producing countries.[33] Edible cottonseed can play a role in solving this challenge with its protein content. Protein in cottonseed is underutilized. Cottonseed meal contains 23% of a high-value protein, and can be processed to any protein concentration. Rathore claims that dedicating all cottonseed currently produced worldwide to human nutrition could meet the daily protein needs of approximately 575 million people.

In addition, the threat to food security may be augmented as the impacts of climate change persist. A 2017 study from the Harvard T.H Chan School of Public Health states that populations in 18 countries may lose more than 5% of their dietary protein due to a decline in the nutritional value of staple crops such as rice and wheat because of elevated levels carbon dioxide in the atmosphere.[34] Forbes India (2018) says that protein levels in beans/ legumes and whole brown lentils have dropped over the past two decades.

[32] CONE. (2017). 2017 Cone Communications CSR Study. Retrieved from: http://www.conecomm.com/2017-cone-communications-csr-study-pdf

[33] Dunham, Will. (October 17, 2018). *Modified cotton could be human food source after U.S. green light*. Reuters. Retrieved from https://af.reuters.com/article/commoditiesNews/idAFL2N1VX1CX

[34] Harvard T.H. Chan School of Public Health. (August 2, 2017). *Millions face protein deficiency as a result of human-caused carbon dioxide emissions*. Retrieved from https://www.hsph.harvard.edu/news/press-releases/climate-change-carbon-emissions-protein-deficiency/

Given that 76% of the global population derives their daily protein from plants, it will be important to take advantage of the protein content in edible cottonseed.[35]

Cottonseed protein could be highly impactful in India, where nearly 195 million undernourished people represent 25% of the world's hunger burden. It has one of the highest child undernutrition rates with one out of every ten children, or 40% of children under 5 years old, experiencing stunted growth.[36] An October 2018 Forbes India article draws attention to the urgency of the issue with its title: "Indians are protein deficient, and it needs immediate attention".[37] The article references a 2017 report from The Indian Market Research Bureau which says that more than 80 percent of Indians are protein deficient. It also references The Indian Consumer Market 2020 report which suggests that Indians spend only one-third of their food budget on protein-rich foods. Authors speculate this may be because nutritional food is prohibitively expensive. Edible cottonseed could be an affordable protein supplement. Protein intake during the first thousand days—from conception to two years of age—has shown to be particularly important for development. The Ministry of Health and Family Welfare has worked with the Food Safety and Standards Authority of India to advocate for a national food fortification policy.

***Growing sustainable fisheries***

Cottonseed has the potential to be a more nutritious and affordable source of fish feed while reducing the negative environmental impacts of aquaculture. There is concern that, at current catch levels, the harvest of pelagic fish harms ecosystem functions. Currently, small, open ocean fish are used to produce 70% of fishmeal and oil. The other 30% comes from scraps from fish processed for human consumption. Small wild fish are an important source of food for larger fish, marine mammals, and birds in the wild in addition to being primary protein sources for low-income communities worldwide.[38] Reducing the amount of wild fish used in fish feed would thus have positive environmental benefits.

At the same time, aquaculture is projected to grow faster than fishmeal production. Finding a source of sustainable feed is among the challenges that researchers see standing in the way of aquaculture development. In fact, a researcher from the University of California Santa Barbara said that more protein is needed for growing fish populations and, "we have pretty much tapped out wild fish as protein sources".[39] The National Oceanic and Atmospheric Administration (NOAA) also identified that the aquaculture industry will soon require more protein than current levels of fishmeal production can satisfy.[40] As such, many government-backed sustainability initiatives and environmental advocates are seeking fish feed input alternatives.[41]

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[35] Forbes India. (October 31, 2018). *Indians are protein deficient, and it needs immediate attention*. Forbes India. Retrieved from http://www.forbesindia.com/blog/giving/indians-are-protein-deficient-and-it-needs-immediate-attention/

[36] United Nations (2019). *Nutrition And Food Security*. United Nations in India. Retrieved from http://in.one.un.org/un-priority-areas-in-india/nutrition-and-food-security/

[37] Forbes India. (October 31, 2018). *Indians are protein deficient, and it needs immediate attention*. Forbes India. Retrieved from http://www.forbesindia.com/blog/giving/indians-are-protein-deficient-and-it-needs-immediate-attention/

[38] Food & Water Watch. (August 2010). *What Does Soy Have to Do with Fish?*. Food & Water Watch. Retrieved from https://www.foodandwaterwatch.org/sites/default/files/Soy%20Fish%20FS%20Aug%202010.pdf

[39] Holmyard, Nicki. (August 31, 2017). *Aquaculture can feed the world, new report claims*. SeafoodSource. Retrieved from https://www.seafoodsource.com/features/aquaculture-can-feed-the-world-new-report-claims

[40] NOAA Fisheries. (April 6, 2018). *Feeds for Aquaculture*. NOAA Fisheries. Retrieved from https://www.fisheries.noaa.gov/insight/feeds-aquaculture

[41] Rubicon Resources. (January 29, 2018). *3 Promising Alternative Feeds for Aquaculture*. Rubicon Resources. Retrieved from https://medium.com/sustainable-seafood/3-promising-alternative-feeds-for-aquaculture-2742c011e3cc

In response to over-harvesting of pelagic fish, regulation and careful fishery management including quotas and catch limit systems has in some instances been successful in preventing the harvest of pelagic fish beyond a maximum sustainable yield – the maximum amount of extraction that can occur without causing biomass depletion. Under these circumstances, prices for fishmeal and oil have increased, which is a substantial cost increase for the sector given that feed for farmed fish makes up about 60% of the cost of growing fish. In order to ensure pelagic-fish harvesting does not surpass unhealthy levels and keep aquaculture operations affordable, more high-protein-content alternatives to fishmeal are being explored[42].

According to the U.S. Soybean Export Council, vegetable proteins and oils can replace from one-third to one-half of the fishmeal in feeds for many farmed species, reducing the need for wild-caught fish for fishmeal. Traditionally, diets for carnivorous fish contain 30-50% fishmeal and oil, but these ingredients are not a requirement, according to NOAA. In fact, some carnivorous species are fed no fishmeal or oil. In a study that looked at substituting vegetable proteins for fish proteins, no significant differences were observed between diets of 25.00% to 62.50% substitution.[43] Meanwhile, a study by published by cottonseed scientist Tom Wedegaertner found that replacing 100% of fishmeal with ULGCS resulted in no meaningful change in fish growth and performance for several fish species[44].

To date, the most common alternative fish feed has been soy. While historically soy has posed digestive challenges to some fish species, products such as fermented soy and soybean protein concentrate have reduced anti-nutritional factors in soy, making them more digestible. Most farm-raised fish and shellfish can easily digest soymeal, which helps the fish efficiently transform ingested protein into body weight. Soymeal has also proven to be a much cheaper alternative to fishmeal. A South Dakota State University fisheries scientist, Mike Brown who is developing a soy protein quoted traditional fish feed as costing between $1,450 and $2,000 a ton whereas soybean meal costs approximately $425 per ton, as of 2015.

Despite some success of soy as an alternative feed, sceptics of replacing fishmeal with soymeal point to the need to consider the soy production system in the equation[45]. Soy is a primary driver of deforestation in certain parts of the word, as will be discussed in the next section. Given that the ULGCS proposition is to substitute ULGCS on land where cotton is currently being grown rather than to grow it in new areas, the use of ULGCS to produce cottonseed meal could prevent more land from coming under soy cultivation without increasing the land dedicated to cotton farming, making it a more sustainable option.

Cottonseed meal can serve as either a replacement or a complement to soy-based feeds. Even if cottonseed meal does not entirely replace soymeal, having another relatively inexpensive vegetable-based alternative to fish-meal can improve the efficiency and sustainability in aquaculture operations. In

[42] NOAA Fisheries. (April 6, 2018). *Feeds for Aquaculture*. NOAA Fisheries. Retrieved from https://www.fisheries.noaa.gov/insight/feeds-aquaculture

[43] Xu, Q.Y., Wang, C.A., Zhao, Z. G., Luo, L. (November 2011). *Effects of Replacement of Fish Meal by Soy Protein Isolated on the Growth, Digestive Enzyme Activity and Serum Biochemical Parameters for Juvenile Amur Sturgeon*. Asian-Australian Journal of Animal Sciences. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4093030/

[44] Wedegaertner, T. & Rathore, K. (2015). Elimination of gossypol in cottonseed will improve its utilization. *Procedia Environmental Sciences, 29*, 124-125.

[45] Associated Press. (November 25, 2016). *Scientists say feeding fish soy, not fish, more sustainable*. Fox News. https://www.foxnews.com/food-drink/scientists-say-feeding-fish-soy-not-fish-more-sustainable

addition, some fish feed scientists have pointed out that including multiple ingredients in feed blends can balance out the anti-nutritional factors of any one component, and lead to better growth rates.[46]

***Reducing deforestation from soy products***

Cottonseed has the potential to replace both animal and other plant-based proteins. Two large drivers of deforestation and thus of climate change are beef production and soy production. If cottonseed protein could replace some of the meat and soy protein in diets, perhaps some of the deforestation and land-footprint could be reduced.

While the likelihood of cottonseed replacing humanity's affinity for meat is low, it is a plausible replacement for soy. Soy is a legume that fixes atmospheric nitrogen in the soil. It is not as responsive to fertilizer as other crops and must use a portion of its metabolic energy to fix nitrogen. This leaves the soy plant with less energy to produce seed and makes raising its yield difficult. As such, growing more soybeans means increasing land area under soy cultivation. Since the mid-twentieth century, the land area dedicated to soy cultivation has grown nearly seven times while soy yields have only doubled. [47]

According to the World Wildlife Fund, the global soybean production has increased 15 times since the 1950s and is the second largest agricultural driver of deforestation behind beef. Today the United States produces 80 million tons of soybeans while Brazil and Argentina produce 70 million and 45 million tons, respectively. Soybean expansion has played a substantial role in the loss of nearly half of the savannah in southern Brazil. In fact, in Mato Grosso, Brazil, a moratorium was adopted by major soybean buyers on purchasing soybeans produced on deforested land.[48]

China imports the most soy: 60% of all soybeans entering the international market in 2011 went to China. Last year China imported 95.5 million tons of soybeans, including 32.9 million from the United States. The majority of soybeans imported to China are used for pig feed. China is the world's largest pork producing nation. Historically, China has included more soy containing protein and amino acids than needed to keep their hogs healthy. However, given the recent trade wars between China and the United States where levies by the US resulted in a retaliatory 25% tariff on US soybeans, China reportedly has plans to reduce the amount of soy in its hog feed from 20% to 12%—an amount equal to 82% of Chinese soy imports from the United States last year. That being said, China has bought record amounts of soybeans from South America over the past number of months. Mu Yan Kui, an executive from one of China's biggest soybean crushers said that, in addition to importing more soy from Brazil and Argentina, alternative protein sources such as rapeseed or cottonseed are part of the countries plan to reduce soybean imports from the US. As China consumes more meat, milk and eggs, its need for protein sources is expected to continue to grow.[49]

While China imports copious amounts of soy, the country is simultaneously the second largest cotton producer. If the ULGCS technology could be proven and adopted by Chinese producers, imports of soy and thus the destruction of South American savannas and forests could be reduced. It could replace the

[46] Rubicon Resources. (January 29, 2018). *3 Promising Alternative Feeds for Aquaculture*. Rubicon Resources. Retrieved from https://medium.com/sustainable-seafood/3-promising-alternative-feeds-for-aquaculture-2742c011e3cc

[47] Brown, Lester R. (November 6, 2013). *China and the Soybean Challenge*. Earth Policy Institute. Retrieved from https://permaculturenews.org/2013/11/06/china-soybean-challenge/

[48] World Wildlife Fund. (December 14, 2016). *The story of soy: As soy production expands, our ecosystems feel the pressure*. World Wildlife Fund. Retrieved from https://www.worldwildlife.org/industries/soy

[49] Mason, Josephine, Gu, Hallie and Plume, Karl. (December 27, 2018). *Inside China's strategy in the soybean trade war*. Reuters. Retrieved from https://www.reuters.com/article/uk-usa-trade-china-soymeal-insight/inside-chinas-strategy-in-the-soybean-trade-war-idUSKCN1OQ0D2

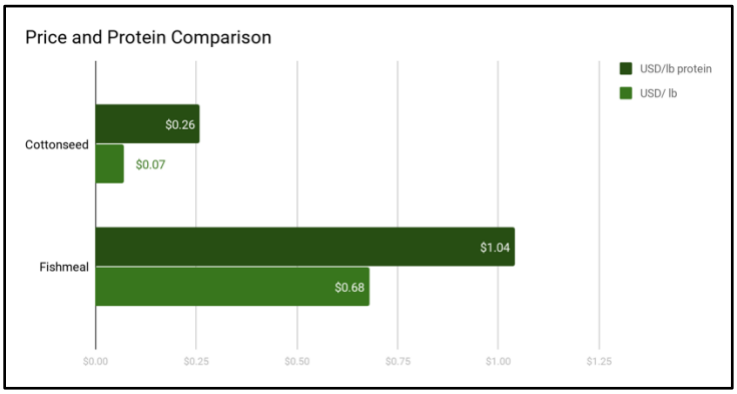
soybean meal that is widely used in animal feed as it has similar nutritional benefits and is a less controversial feed in terms of an ecological footprint.

## New End Markets

Proving the use of the ULGCS products in high-value markets could help move the needle towards commercializing the product. Based on market research and industry expert interviews, the markets for aquaculture feed, pet food, and human food products appear to be the best potential markets for ULGCS. The following section discusses these markets as well as other potential end markets that were researched.

### Aquaculture

**Aquaculture feed offers a robust market opportunity for ULGCS.** According to the most recent FAO State of World Fisheries and Aquaculture report, eighty million tons of fish were produced via aquaculture in 2016, with first-sale value estimated at $231.6 billion.[50] The FAO also noted that aquaculture grew an annual 5.8% over the past 15 years, faster than other food production sectors[51]. This growth is expected to continue, and will be driven primarily by an increased demand for fish and a subsequent increase in aquaculture production. Cottonseed meal, due to its protein content and fatty acid profile, has the potential to replace costly and unsustainable fishmeal in farm-raised fish diets. Fishmeal, produced almost entirely from small, wild-caught fish species is nearly ten times more expensive than cottonseed per pound.




This significant price differential presents an exciting market opportunity. Even a modest increase in the price of cottonseed could translate to large increases in profit for cotton farmers, and significant cost reductions for fish feed producers. Feed accounts for 40-50% of production costs in aquaculture, meaning changes in the price of fishmeal can significantly affect the profitability of operations.[52] In addition, as global concerns regarding overfishing and human rights on fishing vessels increases, animal feed producers may seek opportunities to remove risk from their supply chains. Cottonseed meal provides a low-risk, low-price alternative to fishmeal.

[50] FAO. (2018). The State of World Fisheries and Aquaculture 2018 - Meeting the sustainable development goals. Rome. Retrieved from www.fao.org/state-of-fisheries-aquaculture

[51] ibid.

[52] Craig, S. & Helfrich, L. (2017). Understanding Fish Nutrition, Feeds,and Feeding. *Virginia Cooperative Extension.* Retrieved from https://www.pubs.ext.vt.edu/content/dam/pubs_ext_vt_edu/FST/fst-269/FST-269.pdf

The US aquaculture production value was $1.45 billion in 2016,[53] with 444 thousand metric tons of fish produced.[54] The most commonly farmed species are carps, barbels, and other cyprinids, tilapia, and other miscellaneous freshwater fish.[55] However, the US does not make the top ten countries for aquaculture production, and China far outpaces all other countries in production value and volume, producing 49 million metric tons valued at $144 billion.[56]

While some informed consumers may prefer wild-caught fish over farmed fish if given the option, total volume from traditional capture fishing has remained stable since the late 1980s.[57] Many global fish stocks are already overfished or tightly regulated based on maximum sustainable yield. Thus, the only way total fish production can expand is through increased aquaculture operations, especially for the most popular fish species such as freshwater whitefish and salmon. Between 1961 and 2016, fish consumption grew faster than the global population rate.[58]

Soybeans can serve as inputs to fish feed, but nutrition studies note that soy lacks the essential amino acid methionine and as a result, extra methionine must be added to support growth and health.[59] Methionine accounts for only 1-2% of cotton seed's amino acid profile, so fish diets that rely on ULGCS may also require additional supplementation.[60] Commonly-produced freshwater fish require linolenic acid fatty acids in the diet, which is one of the major fatty acids in cottonseed.[61]

ULGCS may face competition from fishmeal by-products that were previously underutilized or wasted given that 25 to 35 percent of fishmeal and fish oil are produced from by-products.[62] Year-over-year variations in fishmeal and oil price and supply have slowly decreased their inclusion in farmed fish feeds. However, they are still considered the most nutritious and digestible ingredients. A nutrition comparison of fish by-products and ULGCS is necessary to determine which is nutritionally superior and the subsequent effects on fish performance.

ULGCS is still pending deregulation by the US Food and Drug Administration, which would allow for human and animal consumption of the seed and its products. China has not yet made any move to deregulate the production or consumption of ULGCS. Primary test markets for utilizing ULGCS in fish feed must

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[53] US Department of Agriculutre. (n.d.) Aquaculture production value in the United States from 2010 to 2016 (in million U.S. dollas). In *Statista – The Statistics Portal.* Retrieved February 6, 2019, from htpps://www-statista-com.proxy.lib.duke.edu/statistics/230292/us-aquaculture-production-since-2001/

[54] World Bank (n.d). Aquaculture production in the United States from 2001 to 2016 (in 1,000 metric tons). In *Statista – The Statistics Portal.* Retrived February 6, 2019, from https://www-statista-com.proxy.lib.duke.edu/statistics/240291/us-aquaculture-production-since-2001/

[55] FAO. (n.d.). Leading species groups in global aquaculture production in 2016 (in 1,000 metric tons). In Statista - The Statistics Portal. Retrieved February 6, 2019, from https://www-statista-com.proxy.lib.duke.edu/statistics/240284/major-species-in-aquaculture-production-worldwide-2010/

[56] FAO. (n.d.). Leading countries based on aquaculture production value in 2016 (in million U.S. dollars). In *Statista - The Statistics Portal.* Retrieved February 6, 2019, from https://www-statista-com.proxy.lib.duke.edu/statistics/240279/top-global-aquaculture-producing-countries-2010/.

[57] 18). The State of World Fisheries and Aquaculture 2018 - Meeting the sustainable development goals. Rome. Retrieved from www.fao.org/state-of-fisheries-aquaculture

[58] ibid.

[59] https://www.fishwild.vt.edu/extension/fiw/fisheries/fishfarming/Nutrition.pdf

[60] He Z, Zhang H, Olk DC. Chemical Composition of Defatted Cottonseed and Soy Meal Products. PLoS One. 2015;10(6):e0129933. Published 2015 Jun 16. doi:10.1371/journal.pone.0129933

[61] NCBI.(April 12, 2018). Analysis of Fatty Acid Composition in Cottonseed by Gas Chromatography with On-line Pyrolytic Methylation. Retrieved from: https://www.ncbi.nlm.nih.gov/pubmed/30251522

[62] ibid.

happen where its use is deregulated, even though the US is not a large player in the aquaculture space. With that said, India, Indonesia, Vietnam, and Bangladesh follow China in aquaculture production volume. Investigating those countries' stance on the use of genetically engineered feeds for fish production may prove useful in expanding the market for ULGCS.

## Pet Food

**ULGCS may be an attractive pet food input that can increase the competitive advantage of pet food companies.** The US animal and pet food market is valued at $61.4 billion with dog and cat food representing a sizeable share of the market, comprising 31% and 13.8% respectively.[63,64] The market is projected to increase by roughly 2% over the next 4 years. The industry is generally concerned with price increase and scarcity of pet food inputs, such as corn, grains and other commodities. The price volatility and the availability of these products puts pet food suppliers at risk. The industry is fragmented with top companies—Cargill, Mars, and Nestle—maintaining between a 6 to 8.5% market share. The industry operates in the traditional service economy space, where revenue gain or increase in market share may be reached through innovations in technology or improvement in capital efficiency.

Since the 2008 recession, there has been a steady increase in consumer spending on pet food, partially driven by increasing US pet ownership. The recent trend of the "humanization of pets" has caused consumers to weigh pet health higher and has driven a greater willingness to spend on improved quality pet food.[65] Thus, there has been a marked switch in companies concentrating on the pet food industry specifically. The dry pet food industry, which concentrates on dogs and cats, is valued at $14.9 billion, with a projected annual growth rate of 1.9%. Increased consumer willingness to spend on quality pet foods has the potential to lead to revenue increases which can drive growth in annualized profit.[66] This sector of the animal food market is less fragmented, with Nestle and Mars leading the pack at 22.6% and 17.5% market share, respectively. The dry food pet industry operates at the intersection of the "old economy" and the "investment economy." This intersection places the industry in a unique position in needing to innovate rapidly and improve manufacturing capabilities while holding costs level. ULGCS addresses this need directly by offering an opportunity to leverage innovative nutritional technology at an affordable cost. The processing of ULGCS or organic glandless cottonseed may require the implementation of new manufacturing equipment, which could fall under the capital improvements that pet food companies are likely to make.

Overall, ULGCS and organic glandless cottonseed could serve as a high-protein input for dog food mixes. The steady supply of the cottonseed in the US market makes it appealing: not only can ULGCS cottonseeds be used in pet food mixes, but the burgeoning organic glandless cottonseed varieties provide feed companies the opportunity to utilize the nutritional superiority of cottonseed in both sectors of their markets—traditional pet food and premium pet food. This would speak to pet owners who are concerned with cost, as well as those who are concerned with feeding their pets genetically engineered products—a smaller, but important consumer sector to consider.

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[63] IBISWorld. (November 2018). *IBISWorld Industry Report 31111, Animal Food Production in the US*. John Madigan. Retrieved from https://clients1-ibisworld-com.proxy.lib.duke.edu/reports/us/industry/ataglance.aspx?entid=213

[64] The animal food industry is inclusive of both pet and livestock feed.

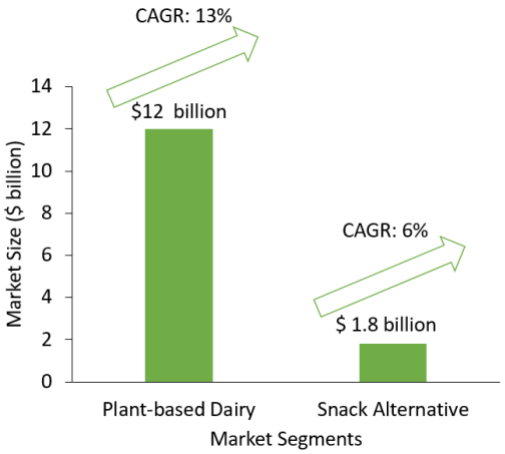
[65] Forbes, S.L., Trafford, S., Surie, M. (2018). Pet Humanisation: What is it and Does it Influence Purchasing Behaviour? *Journal of Dairy & Veterinary Sciences, 5*(2). doi: 10.19080/JDVS.2018.05.555659

[66] IBISWorld. (2018). *IBISWorld Industry Report OD4348, Dry Pet Food Production in the US*. Jonathan DeCarlo. Retrieved from https://clients1-ibisworld-com.proxy.lib.duke.edu/reports/us/industry/ataglance.aspx?entid=4348

Integrating ULGCS into pet food products could occur in a variety of forms, the predominant one being a protein powder or paste that could be processed through extrusion. Extrusion is the most popular method used to manufacture dry pet food; thus, the raw material made from ULGCS or glandless cottonseed should be processed into something that can be used in extrusion such as a flour. The flour can go directly into an extrusion machine, or can be mixed with other components, as the product demands. Since cottonseed is not a grain, it can be marketed as a grain-free pet food.

## Human Food Markets

**ULGCS could serve as a potential input for plant-based dairy and snack alternatives, two rapidly growing market segments that currently utilize crops such as nuts, seeds, and protein extracts.** The market is ripe for innovation and open to new sources of plant-based protein, driven in part by growing public concern about how diet impacts health, sustainability, and animal welfare. The U.S. market size of plant-based dairy is projected to be $12 billion in 2021 with CAGR of 13%,[67] while the U.S. market size of snack alternative is predicted to be $1.8 billion in 2019 with CAGR of 6%.[68]




***Alternative snack food market***

Under the healthier-for-you trend, the alternative-ingredient snack market increased from $1,369 million in 2015 to $1,439 million in 2016 with an increase of 5.2% and is projected to be $1,724 million in 2019 with a compound annual growth rate (CAGR) of 6.2%. In the sub-categories of alternative-ingredient snacks, salty snacks is the largest one, with a market more than three times that of the crackers segment. Within the salty snacks segment, alternative vegetable snacks are the most popular category, with 45% of sales. Alternative grain-based snacks follows, accounting for 40% of the salty snacks segment. Pulse-based snacks account for 15% of alternative ingredient salty snack sales, while it is experiencing fast growth in the past two years. Within the cracker segment, grain-based snacks dominate, with 93% of sales, followed by vegetable (5%) and pulses (2%).[69] The two major drivers of growing the alternative-ingredient snacks market are 1) increased health awareness among snackers, and 2) a higher percentage of eating snacks in young families with children. First, the growing trend of health awareness has a dual impact on the alternative ingredient snack market. On the one hand, more and more people are shifting from traditional snacks to alternative snacks. On the other hand, no matter what the ingredients, some people will not eat snacks at all. Second, families with children are one of the most important population groups to promote the sale of alternative snacks.

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[67] Packaged Facts. (2017). Snack Food Nutrition Trends: Pulses, Vegetables, and Grains in Salty Snacks & Crackers. Retrieved from: http://academic.marketresearch.com.proxy.lib.duke.edu/product/display.asp?productid=10588600&curl=&surl=%2Fsearch%2Fresults%2Easp%3Fprid%3D1280991939%26query%3DSnack%2BFood%2BNutrition%2BTrends%253A%2BPulses%252C%2BVegetables%252C%2Band%2BGrains%2Bin%2BSalty%2BSnacks%2Band%2BCrackers%26cmdgo%3DGo&prid=1280991939

[68] Packaged Facts. (2017). Dairy and Dairy Alternative Beverage Trends in the U.S., 4th Edition. Retrieved from: http://academic.marketresearch.com.proxy.lib.duke.edu/product/display.asp?productid=11000293&curl=&surl=%2Fsearch%2Fresults%2Easp%3Fprid%3D1280991939%26query%3DDairy%2Band%2BDairy%2BAlternative%2BBeverage%2BTrends%2Bin%2Bthe%2BU%2ES%2E%252C%26cmdgo%3DGo&prid=1280991939

[69] Packaged Facts. (2017). Snack Food Nutrition Trends: Pulses, Vegetables, and Grains in Salty Snacks & Crackers. Retrieved from: http://academic.marketresearch.com.proxy.lib.duke.edu/product/display.asp?productid=10588600&curl=&surl=%2Fsearch%2Fresults%2Easp%3Fprid%3D1280991939%26query%3DSnack%2BFood%2BNutrition%2BTrends%253A%2BPulses%252C%2BVegetables%252C%2Band%2BGrains%2Bin%2BSalty%2BSnacks%2Band%2BCrackers%26cmdgo%3DGo&prid=1280991939

Even if health issues prompt customers to choose alternative snacks, the taste/texture is still the main reason they choose to buy.

PepsiCo is the largest marketer of alternative-ingredient salty snacks and crackers by dollar sales for IRI multi-outlet (MULO) tracked sales. Hain Celestial Group is the largest dedicated alternate ingredient marketer, and the second largest marketer overall. Within the alternative-ingredient salty snacks segment, the top 3 marketers are PepsiCo Inc., Hain Celestial Group Inc., and Calbee North America LLC. The top 3 marketers within the alternative-ingredient crackers segment are Mondelez International, Kellogg, and Campbell Soup. The alternative-ingredient cracker segment is very consolidated, with the top 5 marketers and private label holding 82.5% market share of IRI's InfoScan Multi-Outlet (IRI MULO) tracked sales.[70]

***Dairy alternative market***

With the steady decline in dairy milk consumption, the US market share of dairy is stagnant. However, the market share of dairy alternatives has increased from $3,800 million in 2012 to $6,075 million in 2016 and is projected to increase to $11,175 million in 2021.[71] The dairy industry is mature, but the plant dairy industry is still in the early stages of development, meaning this segment is ripe for a ULGCS entry. The expansion of the dairy alternative beverage market is caused by concerns regarding health problems, animal welfare issues and sustainability issues. First, more and more consumers believe that plant foods are healthier than animal foods. In addition, the harsh conditions of dairy cows on factory farms have prompted consumers to choose plant products rather than animal products. Finally, plant-based milk substitutes are positioned to be more environmentally friendly than dairy products given that dairy products require more land, water and energy to produce.

Although the expansion of non-dairy milk is caused by health, animal welfare and sustainability issues, taste is a decisive factor in whether customers will continue to buy alternative dairy products. Therefore, a formula that is sweet or accurately representative of the popular nut flavor of a non-dairy milk source is necessary. Texture and taste are also key to success. According to the packaging facts of the National Consumer Survey in September 2017, 26% of consumers drink non-dairy milk (refrigerated) and 6% of consumers drink non-dairy milk (shelf life). The proportion of US-based consumption of plant-based milk varies by region, employment status, income, education level, and age. For example, plant-based milk has a significant increase in penetration among people over the age of 65 and those who earn between $50,000 and $99,999. Therefore, when launching a new botanical milk brand, it is highly recommended to treat these people as target customers.

In the plant-based dairy replacement market, major players include: Blue Diamond, Califia Farms, CytoSpot, Hain Celestial and Pacific Foods. Campbell Soup and DanoneWave have operations in the dairy and vegetable dairy markets. They are primarily focused on positioning products to be more nutritious and/or more delicious than dairy products. The plant-based dairy market is an emerging market with relatively low internal brand competition, but this is changing as new entrants begin to highlight nutrients (per protein content) and environmental differences from various plant sources. With the growth in plant-based milk replacement

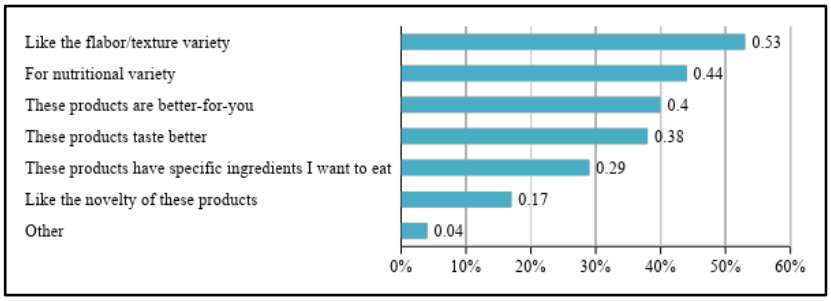
[70] Packaged Facts. (2017). Snack Food Nutrition Trends: Pulses, Vegetables, and Grains in Salty Snacks & Crackers. Retrieved from: http://academic.marketresearch.com.proxy.lib.duke.edu/product/display.asp?productid=10588600&curl=&surl=%2Fsearch%2Fresults%2Easp%3Fprid%3D1280991939%26query%3DSnack%2BFood%2BNutrition%2BTrends%253A%2BPulses%252C%2BVegetables%252C%2Band%2BGrains%2Bin%2BSalty%2BSnacks%2Band%2BCrackers%26cmdgo%3DGo&prid=1280991939

[71] Packaged Facts. (2017). Dairy and Dairy Alternative Beverage Trends in the U.S., 4th Edition. Retrieved from: http://academic.marketresearch.com.proxy.lib.duke.edu/product/display.asp?productid=11000293&curl=&surl=%2Fsearch%2Fresults%2Easp%3Fprid%3D1280991939%26query%3DDairy%2Band%2BDairy%2BAlternative%2BBeverage%2BTrends%2Bin%2Bthe%2BU%2ES%2E%252C%26cmdgo%3DGo&prid=1280991939

sales, dairy marketers may increasingly seek to acquire companies that offer these products or develop their own plant alternatives.

***General human food inputs***

Generally speaking, ULGCS has a competitive strength in high-value plant-protein content. Cottonseed flour contains nearly 50g protein per 100g, and many consumers perceive plant-protein as a healthier option compared to animal-protein. With both internal competency and external opportunities, ULGCS has great potential in both the dairy alternative beverage market and the alternative-ingredient snacks market. However, partnerships with major players who are interested in diversifying their products are necessary to integrate ULGCS into existing product offerings.




Reasons for Buying Alternative-Ingredient Snacks, 2016[72]

## Other Farm Animal Markets

The ruminant animal feed industry, particularly the cattle and dairy cow industry, have been the main outlets for non-ULGCS cottonseed thus far. Ruminant animals are the only animals that have been able to digest the toxin gossypol without detrimental effects. The removal of gossypol from the kernel allows for all livestock to be able to digest cottonseeds and access their robust nutritional profile.

***Animal Feedstock Wholesale***

The corn, wheat and soy feedstock industries that typically dominate animal feed input options have seen a decline in revenue and producer price index after the commodity bubble burst in 2014.[73] There has been excess supply on the market, driving revenue down for wholesalers.[74] However, projections expect revenues to increase over the next four years, implying that feed input costs will likely increase as the market re-adjusts. A main driver in this industry is the animal feed market. Demand for animal products has been on the rise in both developed and developing countries and is projected to continue growing,[75] which can draw higher prices for wholesalers and create additional competition for inputs. The number of poultry and hogs in meat production worldwide is expected to increase by 64% and 21%, respectively, by 2030. In comparison, ruminant animal production is expected to increase by 24%.[76]

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[72] Packaged Facts. (2017). Dairy and Dairy Alternative Beverage Trends in the U.S., 4th Edition. Retrieved from: http://academic.marketresearch.com.proxy.lib.duke.edu/product/display.asp?productid=11000293&curl=&surl=%2Fsearch%2Fresults%2Easp%3Fprid%3D1280991939%26query%3DDairy%2Band%2BDairy%2BAlternative%2BBeverage%2BTrends%2Bin%2Bthe%2BU%2ES%2E%252C%26cmdgo%3DGo&prid=1280991939

[73] U.S. Bureau of Labor Statistics. (April 24, 2019). *Producer Price Index by Commodity for Processed Foods and Feeds.* Retrieved from FRED, Federal Reserve Bank of St. Louis, https://fred.stlouisfed.org/series/WPU02

[74] IBISWorld. (April 2019). *IBISWorld iExpert Industry Summary 42451, Corn, Wheat & Soybean Wholesaling in the US*. Retrieved from https://clients1-ibisworld-com.proxy.lib.duke.edu/reports/us/iexpert/default.aspx?entid=981

[75] FAO. (2003). *World agriculture: towards 2015/2030, An FAO perspective*. Rome, Italy: FAO Publishing Management Service. Retrieved from http://www.fao.org/docrep/005/y4252e/y4252e07.htm

[76] *Ibid.*

Entering the wholesale market does present a financial hurdle. The wholesale market operates by purchasing in bulk quantities due to the low margins typical of the industry.[77] Thus, entering the market may cause ULGCS growers to operate without additional profit during the market growth phase. Cotton Incorporated could offer support to ULGCS growers at this time either through subsidization of seed cost or inputs in order to balance out the farmers' expenses. Once enough ULGCS reaches the wholesale market, the farmers should see increases in revenue. However, the nature of the wholesale industry requires product to pass through middlemen before it reaches an end market. As such, the initial seller of the product may retain only a small portion of the profit from growing ULGCS. Partnering with wholesalers who also operate animal feedstuffs operations may combat this issue by removing a least one transaction.

***Existing Dairy Cattle Markets***

Our team received feedback from a farmer in North Carolina who was concerned about the effects of the increasing cost of cottonseed as a dairy cow feed.[78] While a valid concern, the market for ULGCS should not entirely offset the market for cottonseeds containing gossypol. Since those seeds can only be utilized as an input for dairy cows or other ruminant animals, the price should remain relatively stable, so long as supply does not collapse. It is partially for this reason that exploring the wholesale and feed industry for other livestock is an appealing option for ULGCS—it opens up a market that is unique to ULGCS that is unavailable to gossypol-containing seeds. While utilizing cottonseed as an input for dairy farmers remains an incredibly viable, simple option for ULGCS, the poultry and hog industry offers potential for ULGCS to garner a higher price on the wholesale market.

***Poultry***

Poultry protein requirements are far lower than those of ruminant animals. Crude protein needs vary throughout the lifespan of a chicken, but typically fall below 20%.[79] The nutrient profile of ULGCS offers far higher levels of crude protein and, as such, may not be ideal as a whole seed feed.[80] ULGCS, instead, may act as a substitute protein additive in feed, taking place of soy or corn. Cottonseeds also contain a high level of lysine which is essential for poultry growth.[81] Utilizing them in feedstuffs offers a way to introduce additional lysine in a product without having to add an additional input. A downside to the poultry feed market is the variety of feeding methods poultry operations employ. Common practice notes that "high daily feed consumption permits low nutrient concentrations and low daily feed consumption demands high nutrient concentrations," though many chickens are given free access to food.[82] Without a clear feed practice, it can be difficult to anticipate how ULGCS may affect poultry growth. Additional nutrient testing with specific regard to poultry feed must be done in order to properly assess the viability of this market category.

[77] U.S. Bureau of Labor Statistics. (April 24, 2019). *Producer Price Index by Commodity for Processed Foods and Feeds.* Retrieved from FRED, Federal Reserve Bank of St. Louis, https://fred.stlouisfed.org/series/WPU02

[78] Personal conservation via email with anonymous farmer, 5 February 2019

[79] Subcommittee on Poultry Nutrition, Committee on Animal Nutrition, Board on Agriculture (1994). Nutrient Requirements of Chicken. In *Nutrient Requirements of Poultry, Ninth Revised Edition*. Washington, DC: National Academy Press. Retrieved from https://www.nap.edu/read/2114/chapter/4#21

[80] @ALLISON FIND THIS TABLE

[81] Subcommittee on Poultry Nutrition, Committee on Animal Nutrition, Board on Agriculture (1994). Nutrient Requirements of Chicken. In *Nutrient Requirements of Poultry, Ninth Revised Edition*. Washington, DC: National Academy Press. Retrieved from https://www.nap.edu/read/2114/chapter/4#21

[82] ibid.

***Swine***

Hogs can have extremely flexible diets, but typically receive a majority of their caloric needs through fats and carbohydrates.[83] Full-fat soybeans utilized as the sole protein source for hogs offer optimal fat additives.[84] ULGCS could potentially replace full-fat soybeans due to their high protein and high fat nutritional profile. Cottonseed is consistently lower in price than soybeans, which tend to be a competitive commodity and input for feedstuff.[85] ULGCS could enter the market at a price slightly lower than the rate for full-fat soybeans in order to establish itself. Similar to the poultry segment, nutritional testing must be done in order to ensure that ULGCS provides appropriate energy to hogs.

## Go-to-Market Strategies

### Standalone company option

As an alternative to internally working to bring ULGCS to market, Cotton Incorporated should consider launching a spin-off company that can dedicate more time and resources to attracting partners, customers, and funding. An independent company can focus entirely on ULGCS in a way that Cotton Incorporated cannot, given the volume and scope of their other programs.

***Business model***

As the sole sub-licenser of the ULGCS technology, a start-up model will require Cotton Incorporated to transfer their ULGCS licensing rights to this spin-off company. The spin off company will approach major seed companies that produce the most widely-grown cottonseed varieties such as Bayer Crop Sciences or Americot with a value proposition: the potential to generate additional revenue via a ULGCS technology fee charged per bag of seed. Seed companies would add the ULGCS trait to their existing varieties through the backcrossing process. The seed companies who sublicense the product could charge a price premium to farmers purchasing the seed, and would then pay royalty fees to the spin-off company. The business case is strengthened by the fact that trait development typically requires years of investment in both research time and costs, as well as deregulation activities. Since ULGCS has already been tested at the field-level and achieved deregulation status within the United States, seed companies will be able to generate sales relatively quickly.

***Execution***

The ULGCS start-up approach will require strong business development skills to convey the value of ULGCS to potential seed company customers. Their support is vital, as they alone have the capability to back-cross the ULGCS trait into their seed varieties that contain other patented traits that farmers seek for optimal growth. ULGCS will not be widely adopted until it is available in the most popular, best growing cotton varieties.

Cotton Incorporated should seek talent to operate this venture who can develop and communicate a compelling value proposition to seed companies. Those driving the launch of ULGCS must be able to create demand from farmers to pull ULGCS into the market by demonstrating its end market uses. This means communicating with animal and food production companies in an effort to find customers for whole

[83] University of Nebraska and South Dakota State University. (2000). *Swine Nutrition Guide*. Nebraska and South DakotaL Reese, D.E. et al. Retrieved from https://animalscience.unl.edu/Extension/Swine/swinenutrition.pdf

[84] Ibid.

[85] Markets Insider Soybeans Price Commodity. (April 2019). Retrieved from https://markets.businessinsider.com/commodities/soybeans-price

cottonseed or high-protein cottonseed meal. A private company can also attract grant and venture funding to conduct additional field trials in partnership with farmer and seed companies, in addition to looking further into deregulation in other countries. A sample operations plan can be found in **Exhibit III** of the Appendix, while a sample marketing and communications plan can be found in **Exhibit IV** of the Appendix.

**Table 1** and **Table 2** on the following pages summarize the current state of a ULGCS standalone venture in terms of the level of resources currently dedicated to the ULGCS project. By this evaluation, there is high confidence in the technology this opportunity rests upon as it has been tested and proved successful in the field, has exhibited generational stability essential for production, and is ready to begin backcrossing as soon as customers sign on to work with Cotton Incorporated. The market opportunity is also promising as ULGCS can provide key inputs to growing aquaculture, farm animal, and human protein markets.

Building out a team dedicated to bringing ULGCS to market and obtaining a better gage on what it will take for customers to purchase this trait are currently the weakest areas, and are thus the top priorities.

The seed production industry is somewhat of an oligopoly in the United States, with a few key players dominating sales with their cottonseed varieties. There are smaller firms that Cotton Incorporated could approach for continued proof of concept, and to secure buy-in from farmers. However, this opportunity will not reach full potential unless Cotton Incorporated secures large Bayer Crop Sciences (formerly Monsanto) or Syngenta as a customer and gets ULGCS into their widely-grown varieties. This feeds into the ability to execute problem. Cotton Incorporated cannot "execute" (i.e. get the ULGCS trait into the most widely-grown seed varieties) until it secures the large seed companies as customers. Even then, the lengthy backcrossing process delays proof of concept, adoption by farmers, and sale of cottonseed to end markets. Ultimately, adoption and subsequent growth and profitability of ULGCS will most likely be slow. Lastly, uncertain and costly foreign GMO deregulation may impede international adoption of ULGCS.

The cottonseed market is less monopolistic in other countries. Even though 95% of planted acres of cotton in India grow Bayer Crop Sciences-owned Bt cotton, there are currently 619 hybrid varieties available that contain the trait.[86] If ULGCS deregulation were pursued in India or other countries with a wide variety of seed hybrids, backcrossing the ULGCS trait into a few varieties for small-scale testing may prove easier than in the United States, where a few hybrids dominate the marketplace. However, if one seed or biotechnology company were to integrate ULGCS into all of its varieties, the trait would then gain access to a majority of the US cottonseed market. Thus, there are both pros and cons to only a few major industry players dominating cottonseed and trait production in the United States. It also means that ULGCS can pursue targeted marketing and communications on a few key customers rather than having to pursue business development with hundreds of smaller seed companies.

[86] Chockalingham, S.M.M. (n.d.). *A Profile of Indian Cotton: At a Glance*. Retrieved from https://cotcorp.org.in/Writereaddata/Downloads/Article-ICAC-DM-CCI.pdf

**Table 1: Assessment of market readiness of a standalone company**

| Metric | | Description | Scale | | | | |
|---|---|---|---|---|---|---|---|
| | | | Poor | | Good | | Best |
| Team | Quality of the team | World-class, diverse skills is best; single, skilled inventor is good | ○ | ○ | ○ | ○ | ○ |
| Technology | Uniqueness of Technology | Unprecedented, patented is best; highly competitive is good | ○ | ○ | ○ | ○ | ○ |
| Market | Size of market opportunity | >$1B is best; smaller niche market is good | ○ | ○ | ○ | ○ | ○ |
| Customers/Revenue | Are there customers? | Commercial customers/revenue is best; government customers are good | ○ | ○ | ○ | ○ | ○ |
| Ability to Execute | Can team deliver? | Ability to deliver product immediately is best; prototype is good | ○ | ○ | ○ | ○ | ○ |

**Table 2: Analysis of metrics for market readiness of a standalone company**

| | Rating | Positive | Negative | Recommended Actions |
|---|---|---|---|---|
| Team | Good | • Subject matter expertise | • Lack of business development experience<br>• Exclusively US market focused/understanding | • Bring in external expertise<br>• Consider spin-off into commercial venture to expand market potential |
| Technology /Innovation | Excellent | • Concept proved, field-tested, ready for backcrossing | • Untested on commercial scale | • Continue to test with different seed varieties at larger scales |
| Market | Good | • Large, billion-dollar markets for end use of cottonseed | • Public stigma against GMOs<br>• Steep competition, many animal and human food close substitutes<br>• Dealing with commodity pricing | • Market potential end uses to farmers, ginners, animal feed producers to create demand and pull ULGCS into market |
| Revenue/ Customer Base | Poor | • Huge size of potential customers allows for large scale-up after licensing, ULGCS will go into most common/widely sold varieties | • Oligopoly, only a few very big players who dominate the market<br>• Large seed companies fear international regulatory landscape<br>• Large seed companies see cotton as a minor market<br>• Seed companies may not be able to generate enough revenue to cover increased costs associated with producing ULGCS<br>• Value add to farmers depends on sales, not cost savings in production (output dependent, not input dependent) | • Develop convincing value proposition for large seed companies |
| Ability to Execute/ Operations | Poor to Good | • The event ready to be backcrossed<br>• Some field studies completed<br>• Cotton Incorporated position within US provides multiple touchstones with industry<br>• No regulatory hurdles in USA (brink of deregulation) | • Cannot produce in mass<br>• Backcrossing takes a long time<br>• International regulatory environment not clear | • Focus efforts on attaining customers with ability to backcross<br>• Gain access to popular, patented varieties<br>• Clarify low regulatory hurdle end markets |

***Market exclusivity***

Since ULGCS is a novel product, animal and human food industries are unfamiliar with how to utilize cottonseed. Market uncertainty for a new product, coupled with upfront investment, will make most firms wary to proceed, even if ULGCS proves promising. As such, significant upfront research and development will likely be necessary to optimize the nutritional, taste, and textural properties of ULGCS. Cotton Incorporated, or the company vehicle that forms around ULGCS, should consider how to support ULGCS commercial activity.

If ULGCS or the protein isolate meals manufactured from it become a branded product, firms who invest in R&D for cottonseed products could be granted exclusive access to ULGCS for the first few years of its production. This model was suggested by a food industry expert with previous experience in R&D for novel food products.[87] Guaranteeing initial exclusivity would help incentivize human food or animal feed companies to invest in cottonseed product development because it would differentiate them from competitors. It would also provide some degree of assurance that upfront investment would be paid back via the exclusive sale of ULGCS products. As ULGCS production scales up, exclusivity contracts could time out.

***Economic support program***

Growing ULGCS poses some risk to farmers. Seed companies will likely charge a higher technology fee for the trait, and farmers risk losing profitability if they cannot then sell ULGCS for a higher price. This scenario may arise if ULGCS production scales faster than end markets for its use. As such, an economic support program, developed by Cotton Incorporated or the ULGCS start-up, could undertake activities to remove some of the risk inherent in growing, selling, or utilizing ULGCS. This program, designed to facilitate integration of ULGCS into the market while supporting everyone who plays a part in its production, could include ULGCS growers, processors, animal feed manufacturers, or human food companies. Ideally, ULGCS will be able to add value to all actors along the supply chain. Cotton Incorporated, or the ULGCS start-up, will be uniquely positioned to engage in collaborative activities between and provide support to those actors.

## Key Considerations

Realization of the ULGCS value proposition rests on the notion that markets will purchase and utilize ULGCS, whether for animal or human feed. It also assumes that adequate infrastructure will be in place to deliver value to stakeholders along the supply chain. ULGCS success also depends on expansion into international markets. Uncertainties surrounding ULGCS and necessary development activities are explored in this section.

***Economic considerations***

Farmers initially may be able to sell ULGCS at a price premium given access to new end markets. However, if the supply of ULGCS were to increase sharply relative to low demand, or if the price of close substitutes were to fall too low, farmers would have to sell ULGCS for a lower price. Thus, it becomes riskier for them to invest in more costly seed if prices are too volatile. All other genetically engineered seed traits offer guarantees for production: higher yield, fewer pests, fewer resource inputs. ULGCS, however, offers a less direct benefit, as the return it promises to the farmer is highly dependent on global market prices and the

[87] Personal communication with food industry expert on November 9, 2018

creation of value-added end markets, not on field-level results. This is perhaps more risk than the farmer is willing to undertake.

In addition, end-market competition exists in alternative animal feed and human plant-based protein markets. Other feed crops, such as widely-used corn and soy, may make it difficult for ULGCS to gain market share. While ULGCS is comparable or superior from a nutritional perspective, it may not have the same economy of scale and infrastructural support to remain price competitive. Globally, 50.7 million acres of cotton are planted each year, which gives an extremely large serviceable market into which ULGCS could grow. Channeling enough effort toward market scaling will be key in achieving price competitiveness.

***Nutritional and field-testing considerations***

Each market segment identified will likely require additional rigorous research to affirm that ULGCS performs as well or better than existing options. While preliminary studies have compared ULGCS with fishmeal and have shown no decrease in performance, cattle, chicken, and hogs all require different nutrient profiles for their feed.[88] Before animal agriculturalists are willing to adopt a new type of feed, research and trials will need to prove that performance will remain stable.

Even more rigor may be necessary for human food markets. An interview with a food industry veteran revealed that decisive research on the nutritional value of cottonseed, and its protein, is necessary before any food company will be willing to take on the risk of trying it out in its product offerings.[89] Consumers care about the ingredients in the food they are eating, and may even have negative associations with cottonseed if they know about non-ULGCS toxicity. Consumer demand will not simply appear if ULGCS has not been proven safe, effective, and desirable to consumers. While human food may be the most desirable market option for ULGCS, accessing this market will require the most upfront research, marketing, and overall investment.

***Infrastructure considerations***

The United States currently has a fixed number of cottonseed processing facilities. If applications require high-protein meals instead of whole seeds, harvested ULGCS must first be sent to a nearby oil mill to extract the oil and meal. This could potentially create a bottleneck and limit the amount of ULGCS products available for end-market uses.

Processing cottonseed may also require sophisticated and expensive technologies. Cottonseed has a durable seed coat that does not have a seam on it. Existing infrastructure could have trouble removing this seed coat, which may pose a problem to processing cottonseed into high protein meal or a shelled whole snacking seed. Since toxicity has prevented cottonseed from being used in human and animal food products, machinery may not have been designed with the seed's unique shape in mind. If this proves true, the production process will have to be built from the ground up and will be expensive.

In the past, cryogenic technology with dry ice has been used to crack the seed coat and retain an intact kernel, but it is a costly process. Other options include using sophisticated processing equipment such as optical sorters, which can be expensive. Sorting will be necessary to avoid processing seeds that have elevated, yet minute, levels of gossypol. While these elevated levels of gossypol pose no threat to animal

[88] Wedegaertner, T. & Rathore, K. (2015). Elimination of gossypol in cottonseed will improve its utilization. *Procedia Environmental Sciences, 29*, 124-125.

[89] Personal communication, Food industry expert, November 9, 2018.

or human health, they can create a bitter taste. This could decrease the appeal of the product, particularly in a human food market. That being said, once processing infrastructure is in place there is the possibility of making end products such as flours and meals with any concentrate of protein, as well as whole seeds.

Since these complications could be cost-prohibitive or bring about logistical issues as the market for ULGCS grows, Cotton Incorporated must investigate the gaps in processing infrastructure that exist on a national scale. This includes oil mills that are both currently operational, as well as those sitting idle due to lack of supply or demand. If insufficient facilities exist, capital infusions may be required to ensure that ULGCS can be processed at the scale and speed necessary for profitability. At the very least, Cotton Incorporated should assess whether equipment commonly used to manufacture target end-products can handle cottonseed effectively.

Tom Wedegaertner, director of Cottonseed Research at Cotton Incorporated, recommends using optical sorting in order to remove any seeds containing gossypol from the production line since gossypol glands tint the seeds a slightly darker color. Investing in this technology at the oil mill level may prove most effective in guaranteeing pure ULGCS supply chains for manufacturers, but may represent too large of an investment for mill operators. Cotton Incorporated should investigate optical sorter price and need at the oil mill level, and discuss with potential end-market customers whether they would be interested in, or require, a 100% pure ULGCS supply.

Lastly, a low-tech problem for farmers may be the need for a critical mass of ULGCS seed at the ginner level to motivate him to process an entirely separate run of boll. The ginner may have to sacrifice time and profitability if he has to hold up large volumes of non-ULGCS seed to run a small batch of ULGCS boll. Further surveying of ginning facilities may be necessary to tease out how much ULGCS a ginner would need to make a separate processing run financially and logistically possible. If not enough ULGCS seed is being grown in a given region to meet that critical level, Cotton Incorporated may have to investigate alternative program support it could provide to incentivize ginners to make these ULGCS-specific runs.

***Funding and partner considerations***

Additional financial resources will be necessary to get ULGCS off the ground. Given that ULGCS is still such a new product produced at a very small scale, it is not yet considered to be a viable product offering for venture funding. To make ULGCS a robust market opportunity, the end uses of ULGCS must be proven. A demonstrated market need would encourage investors to consider funding the expansion of ULGCS. In order to reach this point, Cotton Incorporated will need to conduct additional research regarding the applications of edible cottonseed which would reduce the risk perceived by investors.

Initially, Cotton Incorporated may explore funding opportunities from foundations or philanthropic organizations. This funding could support the sort of research that can help prove the ULGCS concept and demonstrate its viability to more mainstream investors and customers. Grant funding or other concessionary financing will likely also be needed to support the salary of someone who is focused on getting the ULGCS in to markets.

In addition to funding, it will be important for Cotton Incorporated to develop research partnerships. Research may be conducted in partnership with Universities such as Texas A&M and UC Santa Barbara where faculty have a vested interest in the cotton industry and in aquaculture, respectively. There are also NGOs and research institutes that focus on the issue areas of sustainable fisheries, food security and deforestation that may be willing to partner with Cotton Incorporated to conduct research that helps

bring ULGCS to market. A full list of potential partners and funders can be found in **Exhibit V** of the Appendix.

***Funding for nutrient supplements and food security***

There are a number of programs past and present under the US Department of Agriculture that provide grant funding for projects related to food security. For example, the USDA's Specialty Crop Research Initiative explores methods to improve crop productivity and profitability by funding research related to plant breeding and genetics.[90] In addition to government funding sources, foundations such as the Bill & Melinda Gates Foundation and the Global Alliance for the Future of Food have dedicated resources for health and agricultural development efforts in developing countries.

***Funding for sustainable fisheries***

Many government programs and non-government funders may take interest in sustainable aquaculture. Notably, the National Oceanic and Atmospheric Administration (NOAA) has listed fisheries as one of its focus areas and has an initiative with the US Department of Agriculture (USDA) dedicated to identifying alternative feeds for aquaculture (Alternative Feeds Initiative).[91] In addition, the National Marine Aquaculture Initiative has been supporting alternative feeds research and nutrition projects for a variety of fish species since 1998. Non-government research institutes study aquaculture feed as well. For example, the Hubbs-SeaWorld Institute conducted a study with the goal of minimizing the use of fish meal and fish oil in diets for carnivorous marine finfish. Hubbs-SeaWorld Institute receives funding from Rising Tide Conservation, an organization that attempts to reduce the collection of wild fish through the promotion of aquaculture in order to protect fish populations and coral reefs.[92]

***Funding to combat deforestation***

The 2006 moratorium on soy produced in the Amazon has put the spotlight on soy as a driver of deforestation for both NGOs and corporations. While securing funding to combat deforestation by replacing soy feed with cottonseed may seem like a peculiar niche, Cotton Incorporated can reach out to participants in the soy moratorium and the Roundtable for Responsible Soy for support. This includes members in industry and trade such as Archer Daniels Midland Company (ADM), Bunge, and Dupont, financiers such as the International Finance Corporation, and NGOs such as World Resources Institute and Conservation International.[93]

As ULGCS is further developed, it is critical to draw on the skills of professionals with expertise that Cotton Incorporated does not have in house. Specifically, funding can be dedicated to hiring an economist who is able to develop economic models that predict the impacts of introducing ULGCS to aquaculture and pet food markets, which appear to be the most promising end-markets for ULGCS.

As Cotton Incorporated continues to build the proof of concept and investment case for ULGCS, there should be some focus on gauging the interest of venture capitalists and end-market customers. While both these groups require more confidence that the product will succeed, it will be good to familiarize them will the product and update them with monumental achievements, such as securing grant funding,

[90] National Institute of Food and Agriculture. (November 2018). *Speciality Crop Research Initiative*. USDA. Retrieved from https://nifa.usda.gov/funding-opportunity/specialty-crop-research-initiative-scri

[91] National Oceanic and Atmospheric Administration. (2019). *NOAA USDA Alternative Feeds Initiative.* NOAA. Retrieved from https://www.fisheries.noaa.gov/noaa-usda-alternative-feeds-initiative

[92] Rising Tide Conservation. (2019). *Saving the Ocean One Fry at a Time*. Retrieved from https://www.risingtideconservation.org/

[93] Roundtable for Responsible Soy. (2014). *About RTRS.* RTRS. Retrieved from http://www.responsiblesoy.org/about-rtrs/about-us/?lang=en.

research results, and the expansion of land under cultivation. In terms of investors, it may be worthwhile to start by engaging impact investors that focus on the fisheries and agriculture sectors. Having a pipeline of potential investors and customers will make it easier for a company licensing the ULGCS technology to ramp up when the time comes.

## Recommendations

As a result of our research and analysis, our team has generated the following recommendations for activities that will help bring ULGCS to market. They are ranked one through six in terms of recommended order of completion:

1. Conduct additional economic research
2. Develop strategic partnerships & seek funding
3. Conduct additional nutritional testing
4. Conduct feeding trials
5. Implement marketing activities
6. Explore international markets and regulations

### 1. Conduct additional economic research

Further exploration of economic impact is needed, as the greater economic landscape for ULGCS is still relatively unknown and will likely shift as production increases. As such, Cotton Incorporated should partner with an agricultural economist to understand the implications of ULGCS entering the US market. More specifically, modeling to show the impacts of introducing ULGCS to markets as related to i) price; ii) nutrition tradeoffs; iii) market share and value allocation; iv) land use; and v) feasibility with or without subsidy could be helpful for developers of ULGCS going forward. Sample research questions under each of these themes are detailed in **Exhibit VI**.

Economic studies can help Cotton Incorporated understand the market price of ULGCS relative to other options, and how that price will affect actors along the value chain. This includes the value farmers will ultimately get for their seed, and how the price of traditional cottonseed and its products will change as a result. Second, further insight is needed as to how land use and cotton market share will change as ULGCS gains popularity. An economist could map out whether higher prices for ULGCS would drive land conversion to agriculture or crop switching from corn and soy to cotton. Lastly, given the price and value-added results, the economist can provide insight as to any financial support cotton farmers may require in order to successfully grow the market for ULGCS cotton.

### 2. Develop strategic partnerships & seek funding

***Secure Research Partners and Funders***

Developing nutritionally-balanced, effective animal feeds and human food products that consumers want to buy will require significant research and development activities. The nutrient needs of each target animal species will require different fortifications and mixes of other raw materials. Funding will be need to carry out these activities.

Given that the benefits of ULGCS can appeal to a variety of audiences, Cotton Incorporated should cast a wide net when seeking partnerships and sources of funding to carry out nutrition and feed studies

expounded on later in the recommendations. A list of potential funders and their associated issue areas can be found in **Exhibit V** of the Appendix.

***Promote Product Development via Company Partnerships***

Nutrition studies and small-scale trials can prove the case for ULGCS, but it will not be widely adopted until it is readily available in major market offerings. Testing, integrating, and scaling ULGCS feeds will require some upfront investment from animal feed companies. This introduces market risk for companies trying to create products from cottonseed, given the novelty and lack of consumer awareness of ULGCS.

As a result, Cotton Incorporated should consider partnering with a select brand or company in each of the animal feed end markets to develop ULGCS fish feed, and then giving that entity exclusive access to ULGCS for a predetermined amount of time. Given the upfront investment required to develop and test new ULGCS feed products, such a contract will ensure the partner company return on investment via guaranteed access to ULGCS as it is produced at scale.

Such a model may also apply to human food products. However, since there are more diverse end-market applications for ULGCS in human food, niche applications may not compete with one another (plant-based milks and protein powders are not in the same product category). As a result, Cotton Incorporated could explore granting exclusive access to ULGCS for a product/firm in each category. This will allow ULGCS use to spread to many products that utilize plant-based proteins, and will promote consumer awareness of cottonseed, all while assisting invested firms in achieving ROI on ULGCS research and development.

## 3. Conduct additional nutritional testing

Safety, efficacy, and nutritional benefits for ULGCS applications in animal and human food remain relatively unknown. Further nutrition research is necessary to understand how ULGCS affects animal growth and performance. Cotton Incorporated should fund additional nutrition research in all viable end markets, beginning with those identified in this report. ULGCS should also undergo independent testing. This will ensure both consumers and investors that cottonseed can deliver on its promises without question of bias. See below for recommendations specific to each end market.

***Aquaculture***

As outlined previously in this report, feed costs represent the most expensive input for aquaculture operations, and fishmeal produced from wild-caught species is an inherent supply chain risk due to cost and sustainability concerns. If fish feed were produced partially or entirely from ULGCS, aquaculture facilities' operational costs would decrease, and cotton farmers' production value would increase. One promising paper, published by cottonseed scientist Tom Wedegaertner, found that replacing 100% of fishmeal with ULGCS resulted in no meaningful change in fish growth and performance for several fish species.[94] However, one study is insufficient proof of concept that will not convince the industry to adopt ULGCS. As such, Cotton Incorporated should allocate additional research funds towards studies that test the nutritional fit and efficacy of ULGCS in fish feed.

In the past, plant-based fishmeal replacements have proved nutritionally insufficient or too difficult to digest for certain fish species. Aquaculture feed requires a specific balance of macro and micronutrients, amino acids, and fatty acids. If ULGCS can, as preliminarily demonstrated, replace 100% of fishmeal used

[94] Wedegaertner, T. & Rathore, K. (2015). Elimination of gossypol in cottonseed will improve its utilization. *Procedia Environmental Sciences, 29*, 124-125.

in feed, it will have a distinct advantage over other crops tested and used in fish feed. At present, further research must be conducted to tease out the optimal percentage of fishmeal replaced with ULGCS, and the required level of additional supplementation given cotton's nutrient and amino acid profile.

In addition, carnivorous fish (ex. salmon and rainbow trout) have different nutritional needs than herbivorous species that, if ignored, could lead to decreases in performance or even outright harm. Cotton Incorporated should augment general ULGCS nutrition research with species-specific research, especially for those most often produced in target markets. This is necessary to demonstrate proof of concept and develop a list of best-performing species on a ULGCS diet.

***Pet Food***

The US pet food market is highly regulated; however, once ULGCS has been deregulated by the FDA it can be used in pet food products. Further research on the nutritional acceptability of ULGCS as an ingredient for different pet species is necessary. Cotton Incorporated should sponsor a nutritional testing study to order to analyze the effects of ULGCS on dogs and cats. They should also put ULGCS through rigorous nutritional profiling in order to update previous research completed on the topic. This will help provide clarity about how to integrate ULGCS into existing pet food options where certain amino acids may be lacking, and can demonstrate how it compares to other plant-based proteins used. If tests result in positive findings indicating that cottonseed supports the nutritional needs of cats and dogs, they can be used as an important proof point in assuring manufacturers and pet owners that cottonseed is safe, effective, and nutritionally viable.

***Human Food Applications***

Human markets will require extensive research to understand cotton's nutritional benefits, as well as taste and flavor profiles. Personal preference, taste, and price still drive most consumer food purchases. Even though ULGCS is an exciting, plant-based, protein-rich product, it must still perform as well or better than existing market offerings in those areas in order for manufacturers to utilize it. Our conversations with food industry experts indicated that human consumers often seek some nutritional benefit if they are choosing to add a new product to their diets. Utility and validity are necessary to prove each ingredient has a purpose in a food product, especially among younger, more discerning consumers who care deeply about what is in their food.

Cotton Incorporated should fund its own research in human food nutrition and safety, but independent and in-house R&D at a large food company will prove equally as important in this end-market. Such companies will have a much better understanding of consumer preferences, trends, and best uses of raw materials such as whole cottonseed and high-protein meals. Thus, Cotton Incorporated should divert the majority of nutrition testing resources to animal feeds, and cover the bare minimum of understanding nutritional benefits and safety of ULGCS as it pertains to human food.

## 4. Conduct feeding trials

Nutrition research alone will not convince feed producers or farmers to adopt ULGCS. It must also demonstrate equivalent performance at a larger scale. Cotton Incorporated should pursue partnerships with aquaculture facilities and farms who are willing to be early adopters of ULGCS feed. This is the next best step, following laboratory nutrition studies, in working to bring ULGCS to market. Successful completion of small scale trials and production of animals that are well nourished and grow as fast as they do on traditional feeds will demonstrate to other producers that ULGCS is a viable, attractive alternative.

Small-scale trials will also help tease out the operational cost advantage ULGCS can offer to producers, and will help determine a fair market price for ULGCS feed.

***Aquaculture***

Key partnerships with individual producers as well as larger research facilities will be instrumental in demonstrating the viability of ULGCS to aquaculture producers. The US Fish and Wildlife Service operates seven Fish Technology centers which "provide leadership in development of new concepts, strategies, and technologies for science-based conservation and management of aquatic resources"[95]. For example, the facility in Bozeman, MT collaborates with the USDA in a program focused specifically on the "development of plant-based fish feeds to reduce reliance on ocean forage fish for fish feed protein" [96]. Partnering with such a facility, could prove invaluable in integrating ULGCS into aquaculture feed and testing that feed at scale.

Once a specific formula has been developed, Cotton Incorporated can also partner with individual producers who have the facilities to test ULGCS feed on a small portion of their fish stock. This is an opportunity to do a larger scale side by side comparison with ULGCS and traditional fishmeal-based feed. This step is necessary to demonstrate whether or not ULGCS is indeed equally as effective for fish production compared to other options. ULGCS feed cannot be produced or adopted at scale unless positive results are proven on a small scale with an actual fish producer.

***Pet Food***

It will be important to begin small-scale feeding trials with common pet species. The decentralized nature of the pet food market makes small-scale trials more difficult. However, concentrated populations of dogs do exist at municipal kennel and animal shelter facilities. If ULGCS-containing dog foods are proven safe, effective, and digestible in the laboratory, Cotton Incorporated should consider forming a mutually beneficial, ethical partnership with such shelters to test new food formulas.

***Farm Animal Feed***

The plant-based nutritional needs of farm animals such as hogs and poultry and how whole ULGCS or high-protein meal may fit into their feed will require further nutritional testing. Given that most animal feed relies on low-priced commodity farm products such as corn and soy, farm-scale testing is necessary to determine if using ULGCS for animal feed represents a viable financial opportunity for both the cotton and animal farmer. The goal of ULGCS is to deliver greater return to the cotton farmer via access to higher-value end markets. Determining the price animal agriculture operators are willing to pay for feed containing ULGCS will help tease out the price cotton farmers could hope to achieve for their seed.

Cotton Incorporated should seek partnerships with hog and poultry farmers to test the effects of adding ULGCS to their feed on animal growth and health. After such trials, researchers should then discuss with animal farmers the value they place on ULGCS feed given the results generated. This will further test whether the animal farm feed market is a viable option for ULGCS.

[95] US Fish and Wildlife Service, Fish and Aquatic Conservation Mountain Prairie Region, About Us. (n.d.). Retrieved from https://www.fws.gov/mountain-prairie/fisheries/

[96] ibid.

## 5. Implement marketing activities

***Targeted Marketing Activities***

Cotton Incorporated can help generate demand to pull ULGCS food applications into the market via specific marketing actions. If nutrition research and small-scale trials generate positive results, communicating such information to customers along the relevant value chains can help create market demand for ULGCS. Since it is a novel raw material, and any product created will be new to customers, marketing activities will be necessary to introduce users to the idea, benefits, safety, and efficacy of cottonseed products.

In addition, Cotton Incorporated must communicate the value and existence of end-markets to farmers. Depending on the existing regional level of knowledge and enthusiasm, farmers may or may not have to be convinced to grow ULGCS. Since seed companies that license the ULGCS technology will likely charge a higher technology fee for seeds containing the trait, Cotton Incorporated must effectively convey the availability of the higher-value end-markets for ULGCS seeds. This will allow farmers to accurately compare the value of the end-markets with the higher cost of seed.

Lastly, Cotton Incorporated can pursue consumer awareness campaigns that are more general and far reaching than the specific ULGCS market applications. The majority of consumers are still not aware that cottonseed is now edible, or was ever a missed opportunity in the past. Much in the same way that Cotton Incorporated generates awareness for the use of cotton fiber, now they should undertake similar campaigns for the uses of cottonseed. A sample fact sheet about ULGCS can be found in **Exhibit VIII** of the Appendix.

***Aquaculture***

Aquaculture producers have a demonstrated need for ULGCS: access to cheaper, less risky yet equally-performing fish feed. Cotton Incorporated can undertake marketing activities that communicate to producers how ULGCS feed can satisfy that need. This could be done in partnership with any company with an advanced market commitment for ULGCS feed, since such a company will likely have robust marketing, business development, and sales departments. Since they have a guaranteed contract for ULGCS, they will be interested in actively pursuing potential customers.

***Human Food Applications***

Cotton Incorporated creates various formats of advertising and digital content to raise consumer awareness and desire for cotton fiber products. As stated on the company website, "Cotton Incorporated creates ads that appeal to consumers emotions and spans generations" all under the trademarked statement that cotton is "The Fabric of Our Lives"[97]. The efficacy and impact of these consumer-facing campaigns could be replicated for ULGCS.

Cotton Incorporated should create advertisements and digital content that showcases the many uses of ULGCS in human food products. This will help generate consumer demand, which may in turn spike food company interest in using cottonseed in their products. Consumers will not begin to ask for cottonseed products, nor may they even trust or understand such products, until some degree of awareness and excitement is created. Cotton Incorporated is well situated, and has the adequate experience, to create the necessary marketing content.

[97] Cotton Incorporated. (n.d.) *The Fabric of Our Lives* [Video File]. Retrieved from https://www.cottoninc.com/consumer-marketing/advertising-digital-content/

## 5. Explore international markets and regulations

While the launch of ULGCS should be focused in the United States where deregulation of the product is well underway, it would be prudent for Cotton Incorporated to continue to track the market potential for ULGCS in both India and China, the top two cotton producing countries. In 2016, nearly twice as much cotton was produced in India than in the United States at 11,400 metric tons versus 5,910 metric tons. China is not far behind India at 9,330 metric tons.

***China***

China is a promising market for ULGCS not only because of its high cotton production but also because of the countries' demand for both pork and aquaculture feed. Given that China produces more than twice as much pork than any other country, and the fact that soy is already being used as a protein supplement in feed for pigs, Cotton Incorporated should look for opportunities to substitute some of the soy-based feed with cottonseed feed.[98] China is also the world's top farmed fish producer. The percentage of global fish supplies sourced from aquaculture will increase in coming years, but the cost of feed remains a barrier to the growth of the sub-sector.[99] There may be an opportunity to present cottonseed as an affordable input to aid the growth of China's aquaculture sector. Once ULGCS is proven to be a nutritional feed input for both pork and aquaculture and it is produced in larger quantities, there may be a profitable market for the seed in China. As such, Cotton Incorporated should begin thinking what the process for deregulation in China might look like.

*Regulatory Trend & Regulation Authorities:* China has a historically slow and unpredictable process of approving GMO crops. However, in July 2017, China approved the first GMO crop imports from United States. In June 2018, the CPC Central Committee and the State Council approved *the Special Administrative Measures (Negative List)* for the Access of Foreign Investment (2018). The *Negative List* includes the transitional periods for access restrictions to be canceled or relaxed in certain fields, at the expiry of which such restrictions shall be canceled or relaxed as scheduled. So far, the allowed crops are limited to the crops that are used for animal feed or further processing. Thus, this paper recommends that Cotton Incorporated and its partners (1) export ULGCS seeds for animal feed, and/or (2) export ULGCS seeds used as raw materials for processing.

In China, the Ministry of Agriculture (MOA) is responsible for the GMO regulation, and the Ministry of Commerce (MOC) makes the decisions on specific imported and exported GMOs. Compared with the domestic GMOs developed in China, the imported GMOs are subject to a separate and more stringent regulation, mainly based on Regulations on Administration of Agricultural Genetically Modified Organisms Safety. See **Exhibit VII** for more details regarding application requirements for those seeking deregulation.

[98] United States Department of Agriculture, Foreign Agricultural Service, Office of Global Analysis. (2019). *Livestock and Poultry: World Markets and Trade.* Washington, DC. Retrieved from apps.fas.usda.gov/psdonline/circulars/livestock_poultry.pdf

[99] FAO. (2018). The State of World Fisheries and Aquaculture 2018 - Meeting the sustainable development goals. Rome. Retrieved from www.fao.org/state-of-fisheries-aquaculture

***India***

While China is second to India in cotton production, India is second to China is fish production. India is expected to domestically produce nearly two thirds of its fish supply by 2030.[100] This growing market may be an outlet for cottonseed meal. A second potential end use for cottonseed in China is as a protein supplement for humans. India bears a quarter of the world hunger burden with nearly 195 million undernourished people. It has one of the highest child undernutrition rates, with 80% of the population being protein deficient. If produced in mass, cottonseed could be used for food fortifications as a protein supplement. As ULGCS production ramps up, it is advisable to begin looking at the process for deregulation in India.

*Regulatory Trend & Regulation Authorities:* The Food Safety and Standard Authority of India (FSSAI) has initiated work on framing regulations on Genetically Modified (GM) Food. FSSAI has not allowed any import of GM products on paper, but has failed to curb illegal sales. Bt cotton is the only GM crop permitted for production in India. This is likely due to the fact that cotton is not currently a food crop. In contrast, edible crops brinjal, mustard and potato are still awaiting field trial and seed production approval. Therefore, even though India is a large cotton producing country, it is not an ideal market for ULGCS cottonseed products to expand.

[100]G Seetharaman. (September 9, 2018). Fish Farms to Produce Nearly Two Thirds of India's Fish Supply by 2030. Retrieved from: https://economictimes.indiatimes.com/news/economy/agriculture/fish-farms-to-produce-nearly-two-thirds-of-indias-fish-supply-by-2030/articleshow/65734974.cms

## Immediate Next Steps

Making ULGCS a reality will require a coordinated, cross-value chain effort. Four immediate action items for Cotton Incorporated can be recommended based on this analysis:

**1. Fund an Agricultural Economist**
Priority number one is to fund an agricultural economist to seek greater understanding of how ULGCS will impact the cottonseed market, quantify economic impacts to farmers and seed companies, and evaluate potential long term ULGCS supply growth patterns.

**2. Hire a Business Development Associate**
Cotton Incorporated should hire a business development associate to exclusively focus on customer acquisition and raising money for the ULGCS venture. Even if the start-up business model we propose is not fully realized, a full-time staff member is still necessary to further understand the market barriers and opportunities we have identified, and to act as the direct liaison between Cotton Incorporated and any interested parties.

**3. Implement a Marketing and Communications Plan**
Cotton Incorporated should begin implementing a plan to drive awareness and build demand for ULGCS based on the marketing and communications strategy summarized in this document.

**4. Begin Fund Raising and Partner Outreach**
Moving forward, Cotton Incorporated will need to secure funding and to carry out the recommendations above. Funding for studies may be sought from government agencies such as NOAA and USDA, as highlighted in **Exhibit V** of the Appendix. Additional grant funding to support further market and nutritional studies as well as marketing efforts could be sought from foundations with missions having to do with aquatic conservation, global health and nutrition, and land or forest preservation.

**While barriers exist, we believe ULGCS offers a robust market opportunity for both cotton farmers and the aquaculture, pet food, and human food markets. We recommend Cotton Incorporated continue to move forward in bringing the seed technology to market as soon as possible.**

## Appendix

Exhibit I: Cotton Production and Supply Chain
Exhibit II: Life Cycle Assessment Data
Exhibit III: Sample Operations Plan for a Stand-Alone Company
Exhibit IV: Sample Marketing and Communications Plan
Exhibit V: Table of Potential Funders and Collaborators
Exhibit VI: Samples Questions for Economic Study
Exhibit VII: China Deregulation Application Requirements
Exhibit VIII: Sample Marketing Materials

## Exhibit I: Cotton Production and Supply Chain

Cotton produces two main products: the fiber and the seed. During the harvest, a stripper or picker is used to remove the seed cotton from the plant, which contains both the fiber and the seed. The seed cotton is then brought to a gin, which is a facility that separates the two products. The ginning process removes the fiber from the seed cotton and passes the seed off as a secondary product. The fiber then goes through additional processes to reach the textile market. From here, we will focus on the process the seed goes through. Once collected, the seed has two fates: oilseed or feed. For oilseed, a ginning facility will send the cottonseed to an oil mill. The oil mill presses the seed for cottonseed oil, a popular cooking oil. This process leaves behind the rough hull and protein-rich flesh. This product, cottonseed meal, is then used as an animal feed. If the seed has not been processed, it can be sold to livestock operations. Since the toxic gossypol remains in all cotton passing through the supply chain today, it can only be used in ruminant animals in small quantities. Ruminant animals can eat cottonseed with the hull intake, which acts as roughage. However, this can be removed earlier in the process if desired.

The chain of custody varies widely between countries. Developing countries often will operate through a decentralized system, where there are many smallholder farms who operate through large enterprises to process and sell their product. In the United States, farming operations are much larger, and may not need to operate through an aggregator. If an aggregator is not used, a farmer will sell the seed cotton directly to the ginner.

In the US, the relationship between the farmer and ginner is quite symbiotic—the ginner needs a consistent supply of cotton to efficiently run the mill, while the farmer must have a reliable relationship with the gin in order to process the harvest into a saleable product. Once the ginning facility receives the harvested cotton (containing both fiber and seed), it will be processed and sold it to a textile mill, oil mill or directly to a livestock operation for feed. In the case that the ginning season is particularly profitable, the ginner may return a portion of profit to the farmer, called a seed rebate.[101] These offer an incentive for farmers to stay loyal to a particular gin. Seed rebates can range in value, but the presence of a higher value end product, such as that which ULGCS can offer, has the potential to increase the value of seed rebates. The scope of our project examines the value chain of the seed as it passes through an oil mill or to a feed operation. We will not examine the chain of custody of the fiber.

[101] Personal communication, 20 February 2019

## Exhibit II: Life Cycle Assessment

Growing ULGCS will not change the environmental impacts generated per acre of cotton. However, as ULGCS if sold to higher-value end uses, the proportion of impacts allocated between the fiber and seed shifts. We conducted a life cycle assessment for both cottonseed and cotton fiber in the OpenLCA program using the EcoInvent database, and the TRACI impact assessment framework. Impacts were generated per kg of cottonseed and per kg of cotton fiber, then converted into per-acre impacts based on the most up to date cotton farming yield values. This results in total impacts per acre of planted cotton, which can then be allocated between seed and fiber depending on the economic value of each product. If ULGCS can achieve a higher market price, and therefore generate more economic impact given the same inputs and environmental impacts, a greater share of those impacts should be allocated to the seed. In other words, the impact "pie" is not getting larger, but merely sliced differently between cottonseed and fiber.

Our LCA analysis contained three scenarios: a baseline with current market prices for cottonseed and fiber, Scenario 1 where the price of cottonseed doubles, and Scenario 2 where cottonseed price rises to half of the current fishmeal price which is somewhat unlikely given how significant that increase would be. Graphs depicting the allocated impact between the two co-products can be found below.

The scenarios were chosen based on comparable prices for commodities used in end-markets ULGCS hopes to access. Soybean commodity market price[102] is currently twice that of cottonseed ($0.15 vs. $0.07 on a per pound basis), while current fishmeal[103] prices are nearly ten times raw cottonseed ($0.68 vs $0.07 per pound). For end-market use, ULGCS can hope to achieve price equity with soybean inputs to pet food, hence the selection of double the current price for Scenario 1. For Scenario 2, there is limited potential for ULGCS to achieve the same price as fishmeal, since it cannot achieve a direct one-to-one replacement in aquaculture feed. However, given its applicability and attractiveness to fish farmers due to a lower input price point, charging half as much for the raw input is reasonable for this initial analysis.

As expected, the greater the price of cottonseed, the greater its share of the environmental impacts associated with cotton production becomes. However, there is a positive environmental message in that greater economic value is being created with ULGCS for no change in the resource intensity, volume of inputs or negative outputs associated with cotton production. Cotton fiber remains a much higher value crop than cottonseed, and any LCA split up based on value will always allocate greater impact to the fiber. However, as the difference in value between the two products becomes less extreme.

Tales summarizing the economic value of the seed and fiber under each scenario, as well as graphic depiction of LCA results for the greenhouse gas environmental impact category, are found below.

[102] Markets Insider Cotton Price Commodity. (April 2019). Retrieved from https://markets.businessinsider.com/commodities/cotton-price

[103] Fishmeal Monthly Price - US Dollars per Metric Ton. (April 2019). Retrieved from https://www.indexmundi.com/commodities/?commodity=fish-meal&months=120

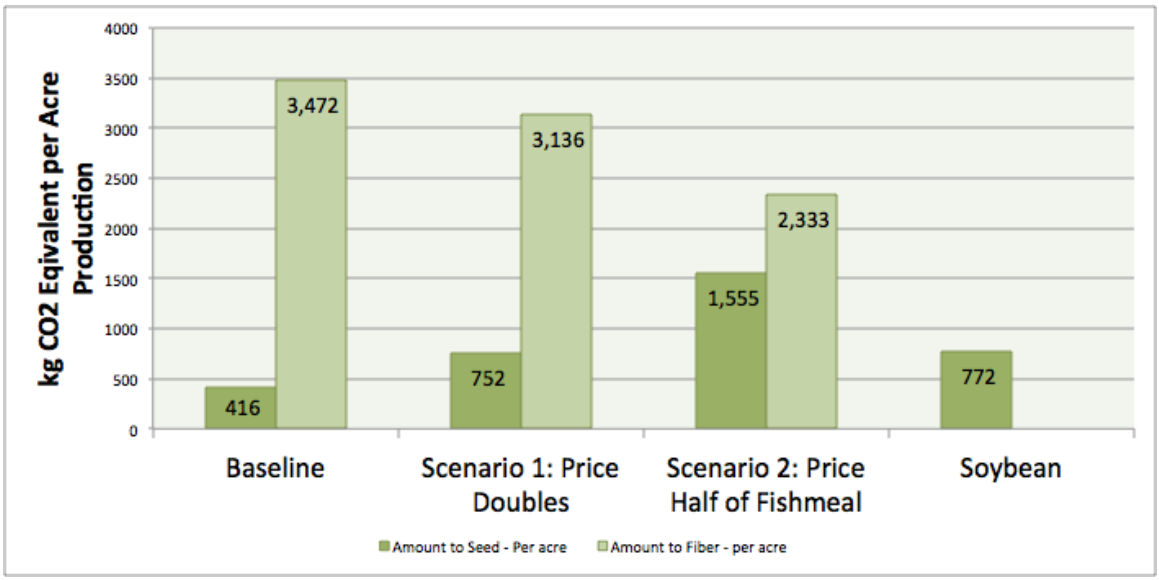
***Allocation Scenarios***

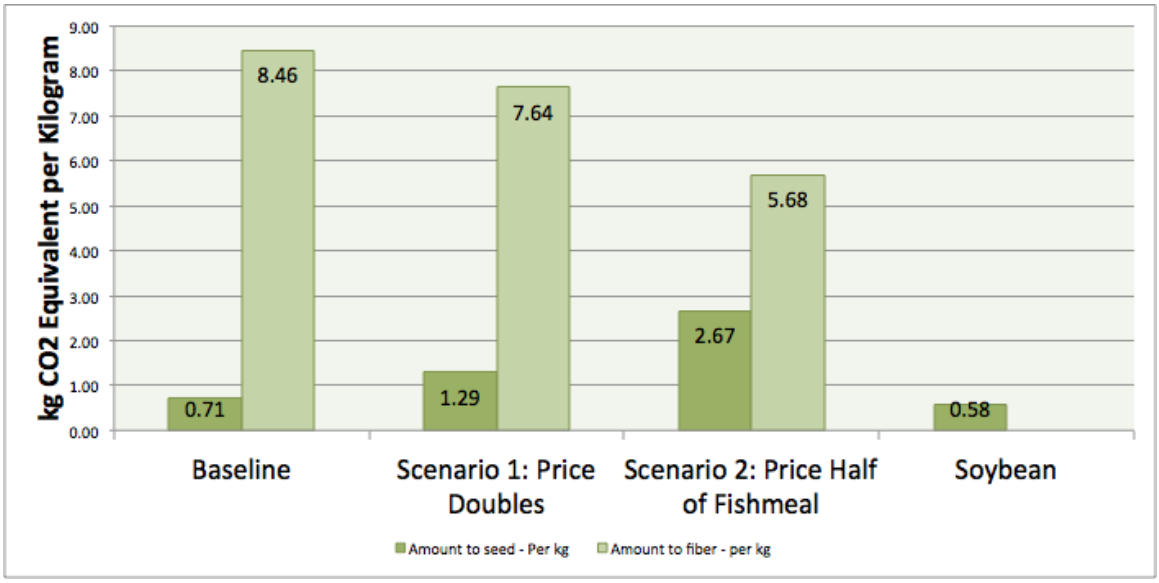
| Baseline Scenario: Current Market Prices | | | |
|---|---|---|---|
| | Production value, $/acre | Price, $/lb | % Value |
| Cotton Fiber | $651.60 | $0.720 | 89% |
| Cottonseed | $78.10 | $0.061 | 11% |
| Total | $729.70 | $0.78 | 100% |

| Scenario 1: Doubling Cottonseed Price | | | |
|---|---|---|---|
| | Production value, $/acre | Price, $/lb | % Value |
| Cotton Fiber | $651.60 | $0.72 | 81% |
| Cottonseed | $156.21 | $0.12 | 19% |
| Total | $807.81 | $0.84 | 100% |

| Scenario 2: 50% of Fishmeal Price | | | |
|---|---|---|---|
| | Production value, $/acre | Price, $/lb | % Value |
| Cotton Fiber | $651.60 | $0.72 | 60% |
| Cottonseed | $434.16 | $0.34 | 40% |
| Total | $1,085.76 | $1.06 | 100% |

***Allocated CO2-equivalent emissions***




***Land Use Impacts***

The introduction of ULGCS and its meal into the market has the potential to offset other feedstocks, such as soybean and corn. On a macro scale, the introduction of ULGCS would minimally impact the acres of other common commodities planted. The potential decreased demand of soy as a feedstock would likely be offset by an increased demanded in another market segment. Thus, we cannot state for certainty that ULGCS would contribute to an overall increase in agricultural sustainability. On a micro or enterprise level scale, however, ULGCS offers markets the opportunity to select a more nutritionally efficient feedstock and a means towards operating in a more sustainable manner. Rising awareness of enterprise level sustainability can have broad reaching impacts in regard to responsible agriculture and healthy food systems.

## Exhibit III: Sample Operations Plan for a Standalone Company

**Model:** A standalone company (DuoCotton) will obtain the exclusive license from Cotton Incorporated in exchange for equity in the company, i.e. 5%. After obtaining the IP, DuoCotton will begin the international deregulation process with an initial focus on Mexico. Simultaneous to deregulation, DuoCotton will continue to field test the product and back cross the event into conventional varieties. DuoCotton will be ready for market within 5 years, at which point the company will begin to gain profit from seed sales of ULGCS cottonseed in conventional varieties. Once deregulation is complete in key countries (Mexico, India, China), DuoCotton will approach the large seed companies to license the event and generate a yearly profit.

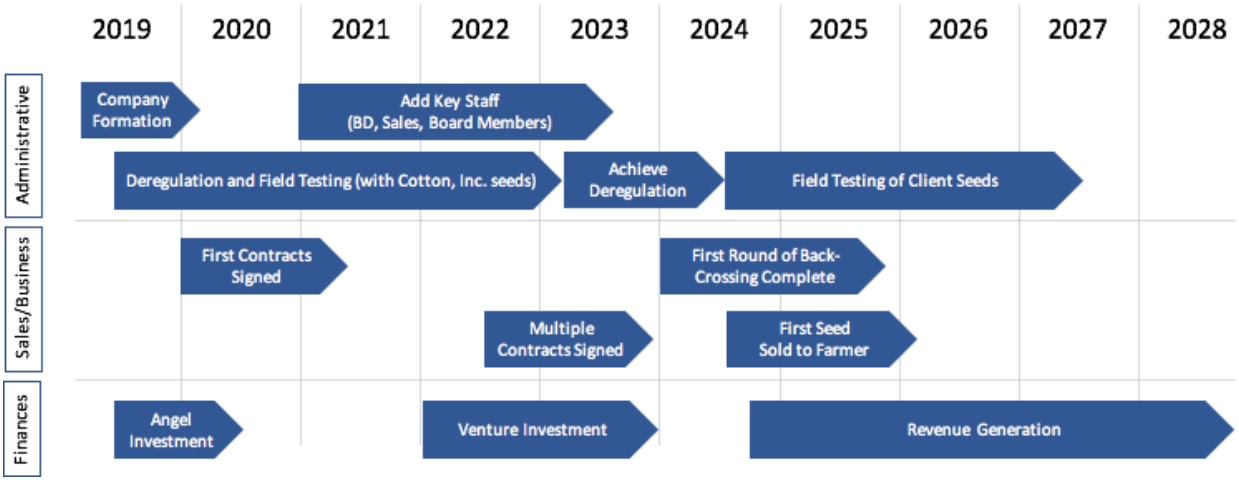
**Development & Manufacturing:** DuoCotton will pursue business development activities to gain customers for the ULGCS trait. These include large, dominant firms such as Bayer Crop Science, Dow-Dupont, and Syngenta or smaller companies with less commonly-grown cotton varieties. Working with a smaller company and group of entrepreneuring farmers early on, with whom DuoCotton can conduct further field studies, proof of concept, and end-market testing could be beneficial to future success. Such information can drive further business development with larger seed companies, leading to wide adoption of the ULGCS trait over time.

Manufacturing begins with the lengthy back-crossing process, by which the ULGCS trait is added to existing varieties of cotton. This requires laboratory work using RNA interference to block the expression of the gossypol trait, multiple generations of plant breeding to produce stable varieties that do not produce gossypol, and final production planting to produce seeds for sale. This must be done in partnership with a seed company in order to maintain other proprietary traits farmers depend on. DuoCotton will not require any private facilities to conduct such back-crossing, since the trait is licensed for production to customers. Thus, manufacturing needs will cease after back-crossing is complete. However, DuoCotton will maintain existing facilities to ensure continuous improvement activities can be undertaken when necessary.

**Key Expenses:**

| Expense | Cost | Year of Cost Incurred |
|---|---|---|
| Salaries | $953,720 | 2019; ongoing henceforth |
| R&D | $8,250 | 2019; ongoing henceforth |
| Deregulation | $525,334 | 2021; ongoing henceforth |
| Sales & Marketing | $40,100 | 2019; ongoing henceforth |

**Timeline (note: dates reflect target time ranges):**



# Summation of Intellectual Property Requirements

As a business designed around an innovative formulation of cottonseed, control of the idea's intellectual property (IP) is essential to establish market dominance and long-term financial viability. Below, we assess what is required or necessary for DuoCotton across the four key IP components: patents, trademarks, copyright, and trade secrets.

**Patents:**
Currently, Texas A&M University owns a design patent for a specific method of significantly reducing the level of Gossypol in cottonseeds. This method is done by expressing with the seed a heterologous nucleic acid construct encoding a 6-cadinene synthase gene trigger sequence. The details of this patent are below:

*Name:* Rathore, Keerti S.; Sunilkumar, Ganesan; and Campbell, LeAnne M. "Cotton Plant with Seed-Specific Reduction in Gossypol." *Texas A&M University*. Patent No. 7,999,148 B2.
*Issued:* Filed February 16, 2007. Issued August 16, 2011.
*Applications*: 60/773,893

Despite being owned by Texas A&M University, Cotton Incorporated currently controls the sole sub-licensor rights to this patent technology. As part of our business model, DuoCotton will gain this sole-licensing right through an equity distribution to Cotton Incorporated, giving us full control over this intellectual property.

DuoCotton's business model of exclusive control over the licensing of the trait will serve as sufficient intellectual property protection. Because of this, we do not expect that any additional patents will be required.

**Trademarks:**
DuoCotton expects to license out the seed formulation to a variety of retail seed manufacturers under the brand name DuoCotton. While we do not expect to "brand" the proprietary seed, given its many potential applications once in the marketplace, a trademark application of the company name "DuoCotton" is required through the federal Patent & Trademark Office. Additionally, we expect to file a federal trademark on the company logo affixed to the top of this document through the same process.

**Copyright:**
Overall, we do not expect that any copyright protection will be required for this business. However, if any marketing taglines or unique works describing the benefits of ultra-low gossypol cottonseed (such as its dual purpose) are created, copyright applications can be filed through the United States Copyright Office.

**Trade Secrets:**
Licensing of a design patent that explains the precise scientific method behind ultra-low gossypol cottonseed eliminates the concept of trade secrets for DuoCotton's business model. However, the exclusive licensing relationship with Texas A&M University and Cotton Incorporated's expert teams provides DuoCotton access to key information and any potential developments that would lead to future trade secrets. Because of this, any agreements or contracts with these teams that can secure the exclusivity of the relationship should be explored.

# Summation of Key Agreements Required for Operations

Note: agreements organized by relevant stakeholder group

**Employees:**

For all current and future employees of DuoCotton, an employment contract must be signed, in which the following will be agreed upon:

- Annual salary and potential bonus, based on values provided in financial model.
- Non-compete agreement should the employee leave the company, stating that they may not legally enter a directly competitive field upon vacancy at DuoCotton.
- Common stock option agreement, stating the percentage of total shares allocated upon employment, length of employment needed to retain equity (suggested 2 years), and details on equity will be paid out contingent upon a profitable exit scenario.
- Non-disclosure agreement signed during first interaction, in which employee (or candidate) may not discuss any valuable details of the DuoCotton outside of the workplace, including IP, technology, customers, partnerships, company finances, or anything else that could affect DuoCotton's business operations.

**Wholesale Seed Manufacturers:**

Licensing the ULGCS formulation to seed manufacturers is the revenue-generating portion of the business model, and as such a licensing contract must be signed. Our intent is to generate revenues at the point of sale between farmers and seed manufacturers, with no cash transfers before that point.

When cottonseed is sold to farmers from manufacturers, bags of seed have costs broken out by components, with different technology fees attached for various traits within the product, such as drought resistance, pest prevention, etc. The ULGCS formulation will have its own technology fee, which will be the focus of our revenue stream. The details of this contract are described briefly below, with a draft of this agreement presented at the end of this document.

- Contracted seed manufacturers will receive the ULGCS formulation from DuoCotton at no cost for independent backcrossing with their own product.
- Once backcrossed seeds are produced (3-5 years, typically), manufacturer can sell product to farmers under any agreements they prefer.
- Within sale price of bags of seed, manufacturer includes a line item for the ULGCS technology fee.
    - Based on our calculations using existing technology fees and standard number of acres served by one bag, we estimate this fee to be roughly $400 per bag.
- As a licensing fee, DuoCotton will take 10% of this ULGCS technology fee as payment.
- Manufacturers may not discuss or share any information about the ULGCS with non-contracted parties.

**Investors:**
DuoCotton will need to meet with multiple potential investors, as well as potentially sign deals. Two different agreements are necessary in order to facilitate this process.

- A two-way NDA must be generated for any conversations with potential investors. This will assure that all proprietary information will be kept between the two parties, and that any discussions of finances or potential investment are not shared publicly
- If an investment is agreed upon, a contract is necessary to outline the following components:
    - Company valuation, total investment, and percentage of equity purchased
    - Potential dividends, liquidation preferences
    - Board status

**Texas A&M University:**
As the owner and original developer of the ULGCS trait patent, Texas A&M University requires compensation as part of our business model. DuoCotton will allocate 2% of revenues to Texas A&M University as a fee for using their intellectual property. DuoCotton will not be required to deliver payment to the university until real revenues begin to accrue. In other words, no investment dollars must be provided to Texas A&M University.

**Cotton Incorporated:**
Cotton Incorporated currently controls Texas A&M University's ULGCS patent as a sole sub-licensor, giving them exclusive access to the trait and formulation. However, Cotton Incorporated is not pursuing any action with this license, and DuoCotton will seek to incorporate Cotton Incorporated into our ownership pool in exchange for sole sub-licensor status. Under the terms of our agreement, Cotton Incorporated will receive a 2.13% equity share in the company in exchange for their sole sub-licensor status.

**Consultants/Contractors:**
DuoCotton may leverage outside consultants or contractors as a result of normal business operations. As a result, DuoCotton must prepare a standard contract all consultants must sign before beginning work. In addition to stating the total compensation and length of partnership in the agreement, it will also include a one-way NDA that prevents signees from sharing any information discussed about the company, while letting DuoCotton use and share information gained in whatever way is necessary.

# Ultra-Low Gossypol Cottonseed Formulation Manufacturing Contract

This licensing agreement, entered into contract on this date, (ENTER DATE), entitles (INSERT MANUFACTURER) to license DuoCotton's proprietary ultra-low gossypol cottonseed (ULGCS) formulation technology for commercial use.

The following information details the nature of this agreement, and how (INSERT MANUFACTURER) and DuoCotton shall be legally bound:

**I. LICENSING AGREEMENT**

Upon signature of this contract, (INSERT MANUFACTURER) will gain access to DuoCotton's ultra-low gossypol cottonseed trait, including all proprietary information included within the formal utility patent accompanying the technology, of which DuoCotton retains sole sub-licensor status.

(INSERT MANUFACTURER) will have entitlement to formulate and back-cross cottonseed product using this technology. DuoCotton will not dictate how the technology is used or directed, only that seeds be back-crossed with an intended commercial use.

(INSERT MANUFACTURER) is forbidden from sharing any details of the ULGCS technology with actors outside of the company, including potential customers. Additionally, all (INSERT MANUFACTURER) employees that will work with, or have access to, details of the ULGCS technology must sign one-way NDA agreements, stating they will not share details of the formulation with any other individuals.

**II. FINANCIAL AGREEMENT**

Under the terms of this contract, (INSERT MANUFACTURER) will not owe compensation to DuoCotton until cottonseed is sold to farmers for production.

As a compensation mechanism, (INSERT MANUFACTURER) agrees that for all bags of ULGCS sold, 10% of the ULGCS trait technology fee affixed to the sale price will go directly to DuoCotton. (INSERT MANUFACTURER) is required to keep this fee as an individual line-item in seed-bag sales, and to report to DuoCotton any price changes and justifications for said action.

**III. SIGNED AGREEMENT**

I, (INSERT NAME), as a legally recognized representative of (INSERT MANUFACTURER), agree to license the propriety ULGCS technology from DuoCotton under the terms described above.

Signed: _____ Date: _____

Witness: _____ _____

## Exhibit IV: Sample Marketing and Communications Plan

### Goals and Objectives

The primary goal of this marketing and communications plan is to successfully bring DuoCotton (the spin-off company formulated by Cotton Incorporated) to industry and return value to cotton farmers. The corresponding marketing goals are:

- Increase awareness among and gain acceptance from targeted audiences.
- Position DuoCotton as a less expensive but higher nutritious alternative to current protein.

### Target Audience

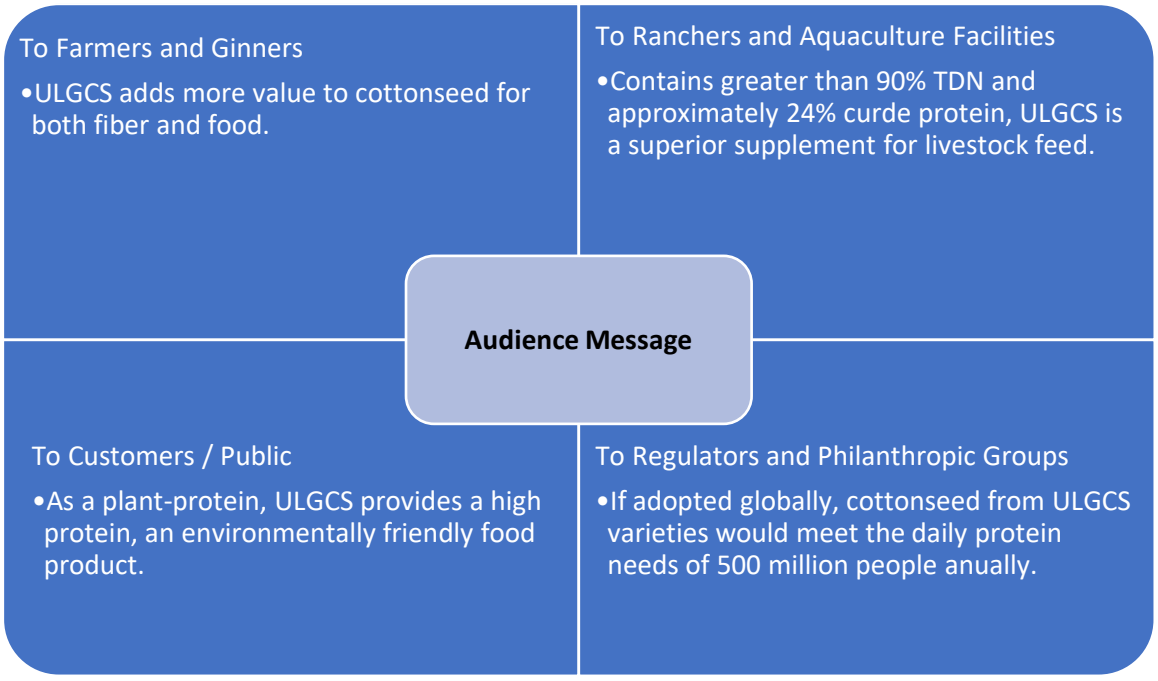
DuoCotton's target audiences includes two distinct groups. Upstream, there are top seed companies as buyers of seed traits and farmers as growers of seed. Farmers would sell their cotton to ginners at a higher price, because the crop's second output – cottonseed – would have additional value due to the minimize gossypol. Ginners, ranchers and aquaculture facilities, and food product companies are considered downstream audiences. Ginners would benefit the most from DuoCotton, because they make money from either added value of their products or reduced costs of processing. Instead of selling the cottonseed at to just oil mills or dairy farmers, ginners would sell DuoCotton to a broad array of feed companies and aquaculture facilities as animal feed or to human food companies as food ingredients. The food products using cottonseed as an ingredient will offers protein sources to vegans or consumers of all dietary choices. Therefore, DuoCotton could directly or indirectly deliver value to the following markets: (1) animal feed industry (including pet food), (2) meat substitute product, and (3) human nutrition market.

The seed company acts as a key role in DuoCotton's value chain, but it is difficult to engage them in. Unlike putting weed- or insect-resistance into seed which give producers direct benefit, the market for DuoCotton has to be established downstream before there's value upstream.

### Key Messages

| Value Proposition |
| --- |
| • By removing gossypol, DuoCotton is safe for consumption by a wider variety of animals and even humans. Cotton therefore have an optimal sub-products for animal and human consumption due to its high value protein. Unlike current fish meal which cost more than twice as expensive than cotton seed meal per pound of protein, DuoCotton would become an economic ingredients for animal feeds. |

**Audience Specific Messaging**



[104]

**Future Market Size / Potential**

India, China, and United States are the top 3 cotton producing countries in 2017/2018.[105] Due to regulatory limitations, Cotton Incorporated is focusing on the U.S. market which produces 6,725 thousand tons of cottonseed in 2017.[106] Currently, cottonseed is divided into two main uses: cattle feed and cottonseed oil. By removing gossypol, cottonseed will deliver its value to farmers.

The global aquaculture feed market will be worth US$122.6 billion by 2019, an astronomical increase from US$57.7 billion in 2012. This growth will be primarily driven by an increased demand for fish, especially in the Asian market. Cottonseed meal has the potential to replace costly and unsustainable fishmeal in farm-raised fish diets due to its higher protein and fat content. Currently, fishmeal costs $0.681 per pound, which translates to $1.05 per pound of protein in 61% protein meal. At its current price of $0.127 per pound and 47.6% protein, cottonseed meal is more than 4 times cheaper per pound of meal, and nearly 3 times cheaper per pound of protein, compared to fishmeal. The price differential between fishmeal and cottonseed meal presents an exciting market opportunity; even a modest increase in the price of cottonseed could translate to large increases in profit for cotton farmers, and significant cost reductions for fish feed producers.

The farm animal feed industry in the United States is currently valued at US$33.4 billion and is projected to grow to US$34.5 billion by 2022. DuoCotton and its various products could replace corn and soybeans

[104] Kansas State University Agricultural Experiment Station and Cooperative Extension Service. (May 2002). *Composition and Feeding Value of Cottonseed Feed Products for Beef Cattle*. Retrieved from: https://www.bookstore.ksre.ksu.edu/pubs/mf2538.pdf

[105] US Department of Agriculture. (n.d.). Cotton production by country worldwide in 2017/2018 (in 1,000 metric tons). In *Statista - The Statistics Portal*. Retrieved April 24, 2019, Retrieved from https://www.statista.com/statistics/263055/cotton-production-worldwide-by-top-countries/.

[106] USDA. (April 2019). Cotton: World Market and Trade. Retrieved from: chrome-extension://ikhdkkncnoglghljlkmcimlnlhkeamad/pdf-viewer/web/viewer.html?file=https%3A%2F%2Fapps.fas.usda.gov%2Fpsdonline%2Fcirculars%2Fcotton.pdf

in animal feed. Different farm animals require different macronutrient ratios, which is why animal feed companies must purchase a variety of input materials to mix into different types of feed. Cottonseed is rich in both protein and oil while cottonseed meal has comparable levels of protein to soybean meal at a 10% lower price. In aquaculture feed market, fishmeal is more than twice as expensive than cottonseed meal per pound of protein.

The total market revenue of meat substitutes are $3.7 billion worldwide and $644.1 million in North America. With the growing share of young people identifying themselves as vegetarians, the plant protein market is promising. Currently, wheat and soy proteins are the primary meat replacement source. Due to the higher protein value, DuoCotton is expected to seize large market share due to its higher protein value. Finally, the global sports nutrition market reached $28.4 billion in 2016 and is expected to be $45.3 billion in 2022. As for U.S., its market size is $4.7 billion in 2015 and is expected to climb to $7.5 billion in 2020.

**Competition**

There is little direct technology competition for DuoCotton, because Cotton Incorporated holds the exclusive licensing rights to the gossypol gene-silencing technology. However, competitions from other substitutes of animal feed ingredients are stiff.

**Strategy and Tactics**

**Company Spokesperson:** Cotton Incorporated should identify an employee as the main spokesperson that will represent the company at networking events to maintain consistency in influencer relationships. This spokesperson should be equipped with necessary information and be prepared for inquires.

**White Papers:** Write white papers outlining the added value of DuoCotton compared with normal cottonseed and illustrating that other characteristics of DuoCotton are as same as normal cottonseed including yield, cotton quality, and pesticide usage. It will be used to supplement a product launch at the bottom of the sales funnel.

**Customer Outreach:** Continue to outreach target customers in both upstream and downstream of value chain in order to gauge their needs before DuoCotton coming to market. Introduce and educate public via mass media.

**Industry Expert Outreach:** Reach out to industry experts and Associates such as American Farm Bureau Federation and American Poultry Association. The ways of outreaching industry expert include (1) seeking out presentation opportunities at agriculture or food industry events and (2) setting one-on-one meetings with representatives from seed companies and food companies.

**Trade Shows**: Seek out presentation opportunities at seed or agriculture industry, GM crops industry, and animal breeding industry to reach prospective clients, network potential collaborators, and raise public awareness. A list of upcoming trade shows are shown below:

**Relevant Trade Shows:**

| **Seed / Agriculture Industry Trade Show** | | |
|---|---|---|
| **Name** | **Time** | **Location** |
| Vegetable and Flower Seed Conference & Expo | February | Orlando, USA |
| China International Seed Trade Exhibition | March | Shanghai, China |
| Kisan Fair | December | Pimpri-Chinchwad, India |
| International Conference on Agricultural and Biological Science | December | Bangkok , Thailand |
| **Animal Breeding Industry Trade Show** | | |
| **Name** | **Time** | **Location** |
| International Production & Processing Expo | February | Atlanta, USA |
| IPE/IPPE International Poultry Expo | February | Georgia, USA |
| World Dairy Expo<br>International Trade Show for the Dairy Farmer | October | Shanghai, China |
| **Seed / Agriculture Industry Trade Show** | | |
| **Name** | **Time** | **Location** |
| Food & Nutrition Congress | December | Duibai, UAE |
| 13th International Conference on Agriculture and Plant Science | January | Osaka, Japan |
| 12th Food Chemistry & Food Microbiology Conference | February | Abu, Dhabi, UAE |
| Aquaculture & Fisheries Conference | February | Osaka, Japan |

## Exhibit V: Table of Potential Funders and Collaborators

| Organization | Sector | Funding Areas | Contact / Link |
|---|---|---|---|
| **Development Finance Institutions (DFIs)** | | | |
| **International Finance Corporation (IFC)** | | A member of the Roundtable for Responsible Soy, a group that has placed a moratorium on soy production in parts of South America. | https://www.ifc.org/wps/wcm/connect/corp_ext_content/ifc_external_corporate_site/home |
| **National Oceanic and Atmospheric Administration (NOAA)** | Sustainable Fisheries | NOAA has an Office of Aquaculture as fisheries is one of NOAA's 8 focus areas. The government agency tracks 474 fish stocks. Its relevant programs include:<br>● **Alternative Feeds Initiative:** Develop alternative feeds for aquaculture to reduce the amount of fishmeal and fish oil in aquaculture feeds without taking away from health benefits. Cottonseed is not on the initiatives list of potential alternative ingredients[107] The initiative is looking to commercialize alternative feed to reduce dependence on marine fish resources by feed manufacturers and seafood farmers globally. Partnering with USDA.<br>● **Sea Grant Marine Aquaculture Grant Program (National Marine Aquaculture Initiative):** Supports alternative feeds research and nutrition projects for a variety of fish species.<br>● **Northwest Fisheries Science Center:** Group of nutritionist and industry representatives that led research that resulted in the FDA approval for taurine in 2017, headed by Dr. Ron Johnson. | Michael Rust, Science Advisor; Dr. Ron Johnson, Aquaculture Program Manager<br><br>https://www.fisheries.noaa.gov/noaa-usda-alternative-feeds-initiative<br><br>https://www.fisheries.noaa.gov/national/aquaculture/aquaculture-funding-opportunities-and-grants<br><br>https://www.nwfsc.noaa.gov/ |

[107] NOAA Fisheries. (April 6th, 2018). Feeds for Aquaculture. Retrieved from: https://www.fisheries.noaa.gov/insight/feeds-aquaculture#what-are-potential-alternatives-to-feeding-fish-to-fish?

| Organization | Sector | Funding Areas | Contact / Link |
|---|---|---|---|
| **US Department of Agriculture** | Sustainable Fisheries | Has several programs relevant to aquaculture and food security:<br><br>**Agricultural Research Service**<br>● **Alternative Feeds Initiative:** Develop alternative feeds for aquaculture to reduce the amount of fishmeal and fish oil in aquaculture feeds without taking away from health benefits. Cottonseed is not on the initiatives list of potential alternative ingredients[108] The initiative is looking to commercialize alternative feed to reduce dependence on marine fish resources by feed manufacturers and seafood farmers globally. Partnering with NOAA.<br><br>**National Institute of Food and Agriculture**<br>● **Aquaculture Research Program:** Supports the growth of an environmentally and economically sustainable aquaculture industry by addressing industry constraints with science-based information and innovations.<br>● **Specialty Crop Research Initiative (SCRI):** Funds projects to research plant breeding and genetics to improve crops, their productivity, and their profitability. This includes projects related to crop policy and marketing. The initiative also promotes new technologies and methods to address potential food safety hazards in the production and processing of specialty crops.<br>● **Small Business Innovation Research Program - Phase I:** Funds projects that prove the scientific or technical feasibility of novel approaches to agriculture manufacturing.<br>● **Food Security Challenge Area:** Funds projects related to breeding and phenomics of food crops. | Gene W. Kim (Aquaculture Research Program); Thomas (Tom) Bewick (Speciality Crop Research Institute; Scott Dockum (Specialty Crop Initiative); Dr. Ed Kaleikau (Food Security Challenge Area). |

[108] NOAA Fisheries. (April 6th, 2018). Feeds for Aquaculture. Retrieved from: https://www.fisheries.noaa.gov/insight/feeds-aquaculture#what-are-potential-alternatives-to-feeding-fish-to-fish?

| Organization | Sector | Funding Areas | Contact / Link |
|---|---|---|---|
| **US Fish & Wildlife Service** | Sustainable Fisheries | Operates seven Fish Technology centers which develop science-based approaches to the conservation and management of aquatic resources. A facility in Bozeman, MT collaborates with the USDA in a program focused specifically on developing “plant-based fish feeds to reduce reliance on ocean forage fish for fish feed protein” . | https://www.fws.gov/mountain-prairie/fisheries/ |
| **Research Institutes / Research NGOs** | | | |
| **Conservation International** | Deforestation | A member of the Roundtable for Responsible Soy, a group that has placed a moratorium on soy production in parts of South America. | http://www.responsiblesoy.org/about-rtrs/members/?nombre=DuPont&busca=busca&pais&categoria&lang=en |
| **Consultative Group on International Agricultural Research (CGIAR)** | Food security | A global partnership of funders and research centers that focuses on improving food security, nutrition, and responsible management of natural resources. | https://www.cgiar.org/ |
| **Frank Mars** | Sustainable Fisheries | A biotech center that works in the aquaculture space. | Barbara@conservationxlabs.org |
| **Hubbs-SeaWorld Institute** | Sustainable Fisheries | Researches Sustainable Seafood (Aquaculture). One of its core research areas is Nutrition: “Minimizing the Use of Fishmeal and Fish Oil in Diets for Carnivorous Marine Finfish”. President and CEO Don Kent said, “there is potential to reach zero percent” wild capture diet. | Don Kent, President and CEO |

| Organization | Sector | Funding Areas | Contact / Link |
|---|---|---|---|
| **Universities** | | | |
| **University of California Santa Barbara** | Sustainable Fisheries | Conducts aquaculture-related studies through the Sustainable Fisheries Group (SFG) as part of the Universities' Environmental Market Solutions Lab. | http://sfg.msi.ucsb.edu/research/sustainable-aquaculture |
| **University of Maine** | | Conducts research to develop the aquaculture sector through its Aquaculture Research Center. | https://umaine.edu/aquaculture/about-ari/facilities/aquaculture-research-center-arc/ |
| **Borlaug Center @ Texas A&M** | | A research center that focuses on food and plant science and safety, agricultural engineering, and economics and policy. | https://borlaug.tamu.edu/ |
| **Foundations** | | | |
| **Aga Khan Foundation** | Food Security | Relevant focus areas include agriculture and food security; early childhood development; and health and nutrition. Work is focused in India. | https://www.akdn.org/our-agencies/aga-khan-foundation |
| **Bill & Melinda Gates Foundation** | Food Security | Works to reduce hunger and poverty among farming families in Sub-Saharan Africa and South Asia by improving agricultural productivity in a sustainable manner. Has committed more than $2 billion to agricultural development efforts, primarily in Sub-Saharan Africa and South Asia. | https://www.gatesfoundation.org/search#q/k=food%20security |
| **Global Alliance for the Future of Food** | Food Security | A member group of philanthropic funders that has two relevant impact areas: i) Agroecology and ii) Health & Well-being. The Alliance supports a project housed by United Nations Environmental Program (UNEP) that looks at the environmental, health, social, and cultural externalities involved in food production. | https://futureoffood.org/ |

| Organization | Sector | Funding Areas | Contact / Link |
|---|---|---|---|
| **Rising Tide Conservation** | Sustainable Fisheries | An organization dedicated to developing and promoting aquaculture of marine ornamental fish species to reduce the impacts of wild fish collection on fish populations and the coral reefs where they live. Rising Tide supports research by Hubbs-SeaWorld Institute. | https://www.risingtideconservation.org/ |
| **Impact Investors** | | | |
| **Encourage Capital** | Sustainable Fisheries | Investment firm that makes investments related to sustainable fisheries. | http://encouragecapital.cco/solutions-strategies/sustainable-seafood/ |
| **Corporate Entities** | | | |
| **ADM** | | A member of the Roundtable for Responsible Soy, a group that has placed a moratorium on soy production in parts of South America. Also a corporate partner for World Food Program efforts to prevent famine in East Africa. | https://www.adm.com/adm-worldwide/brazil/sustainability/round-table-on-responsible-soy |
| **Bunge** | | A member of the Roundtable for Responsible Soy, a group that has placed a moratorium on soy production in parts of South America. Alos a partner for World Food Program efforts to prevent famine in East Africa. Its corporate responsibility efforts have a food security component. | https://www.wfpusa.org/organizations/bunge/ |
| **Dupont** | | A member of the Roundtable for Responsible Soy, a group that has placed a moratorium on soy production in parts of South America. | https://www.dupont.com/content/dam/assets/corporate-functions/our-approach/sustainability/commitments/product-stewardship-regulator/articles/documents/DuPont%20GRI_Report_2018i.pdf |

## Exhibit VI: Sample Questions for an Agricultural Economist

Our MP research team has been working with Cotton Incorporated to find answers to the following research questions:

What is the market value for ULGCS?
What is the business outlook for ULGCS?
How will the adoption of ULGCS impact food markets?
How would introducing ULGCS change the value of cottonseed?
What might the environmental impacts of a market for ULGCS be?

Providing answers to these research objectives could be greatly aided by econometric modeling. More specifically, modeling to show the impacts of introducing ULGCS to markets as related to i) price; ii) nutrition tradeoffs; iii) market share and value allocation; iv) land use; and v) feasibility with or without subsidy could be helpful for developers of ULGCS going forward. Research questions under each of these themes are detailed below.

### i. Price

*ULGCS*

- What price can farmers initially expect for ULGCS?
  - What price can farmers expect for ULGCS if end-market demand for ULGCS changes?
  - How will the price change as ULGCS supply increases?

*Animal feed*

- How might changes in the price of cottonseed affect feed costs of:
  - Cattle farmers
  - Fish farmers
- What will happen if prices in other complimentary markets change?
  - Soy
  - Fishmeal

*Cottonseed Oil*

- How will ULGCS impact the prices of cottonseed oil given the expected decrease in processing effort?

### ii. Nutrition savings / tradeoffs

- How does the price of a ULGCS protein additive adjusted for lysine savings compare to other protein supplements used in the market for pet food?
  - Soy
  - Pea

### iii. Market share / Value allocation

- How will the market share change between ULGCS, soy, and fishmeal for:
  - Aquaculture
  - Pet food
  - Other markets?
- How will the value generated by the introduction of ULGCS be allocated among seed companies, farmers, oil mills, and product manufacturers?
- How might production volume of cotton change in light of movement away from fossil fuels and petroleum based synthetic fibers?

### iv. Land use

- Will the availability of ULGCS cottonseed impact the total amount of land under cotton cultivation, or simply replace other varieties of cottonseed on the currently cultivated land?
- How will the market for soy respond in terms of land use if cottonseed replaces soy in animal feeds?

### v. Subsidies

- How much support will growers need from Cotton Incorporated to get the seed in to the market (i.e. in terms of seed cost)?

## Exhibit VII: China Deregulation Application Requirements

*Application Requirements for Deregulation in China*

For GM plant seeds used for breeding fish, livestock and poultry, any export companies and GMO used as raw materials for processing, the exporting company shall apply to the competent agricultural administrative department of the State Council. The exporting company should meet the following conditions (*Action 32 & 33*):

- The exporting country or region has permitted the usage for the same purpose and the putting into market thereof;
- The exporting country or region has, through scientific experiment, proved that they are harmless to human beings, animals and plants, microorganisms and ecological environment;
- The technical inspection body of agricultural genetically modified organisms has confirmed, upon inspection, that there is no danger to human beings, animals, plants, microorganisms and ecological environment; (only for GMO used as raw materials for processing)
- Having adopted appropriate safety administration and precautionary measures.

*Approval to Import of Agricultural GMO by Overseas Developers*

Application Procedures:[109]

- Acceptance of application documents. The required materials includes:
    - Application for Safety Assessment of Agricultural GMOs
    - Safety level of the agricultural GMO and basis for determination of the safety level
    - Marketing approval certificate issued by the exporting country/region
    - Documents on safety in the exporting country/region
    - Test Report produced by the institution for technical testing of agricultural GMOs entrusted by MOA
- Examination.
- Issue of approval document on entry of GMO materials.

Time Limit and Charge:

The application deadlines are March 1st, July 1st, and November 1st. The competent agricultural administrative department of the State Council and the exit-entry inspection and quarantine department of the State shall make a decision of approval or disapproval and notify the applicant of the result within 270 days from the date of receipt of the application (*Action 36*). The charge is 5000 yuan per application (Fagaijiage [2007] No. 3704).

[109] Ministry of Agriculture and Affairs of the People's Republic of China. (May 3rd, 2013). Approval to Fisrt-Time Import of Agricultural Genetically Modified Organisms by Overseas Developers. Retrieved from: http://english.agri.gov.cn/governmentaffairs/al/201301/t20130115_8174.htm

*Approval to Import Agricultural GMO by Overseas Traders*[110]

Application Procedures:

- Acceptance of application documents. The required materials includes:
  - Registration Form for Safety of Import Agricultural GMOs (used as raw materials for processing);
  - Agricultural GMO Safety Certificate (Import) for developers from outside the Chinese mainland issued by MOA (photocopy);
  - Description on safety control measures during the import process.
- Expert examination
- Reply

Time Limit and Charge:

The promised time limit is no more than 5 workdays after acceptance of application documents for safety assessment and no more than 20 workdays after safety assessment for a reply.

The charge is 3000 yuan per application (Fagaijiage [2007] No. 3704).

[110] Ministry of Agriculture and Affairs of the People's Republic of China. (April 27th, 2013). Approval to Import of Agricultural Genetically Modified Organisms By Overseas Traders. Retrieved from: http://english.agri.gov.cn/governmentaffairs/al/201301/t20130115_8175.htm

## Exhibit VIII: Sample Marketing Materials

**Ultra-low gossypol cottonseed (ULGCS)** is a US Department of Agriculture (USDA) approved variety of cottonseed genetically engineered to be safe to eat. RNA interference (RNAi) technology is utilized to silence the expression of the naturally occurring toxin gossypol in cottonseed while maintaining gossypol in the stem and leaves of cotton plants to protect them from pests.

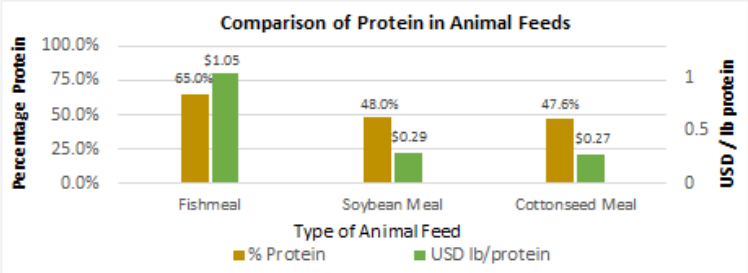
**Cotton Incorporated**, a cotton industry group funded by The Cotton Board, holds the exclusive rights to license the gossypol gene-silencing technology. Cotton Incorporated aims to build an industry that supports environmental, social and economic needs of cotton growers, manufacturers and producers. The ULGCS technology was developed in partnership with Texas A&M researchers.

### ADVANTAGES OF ULTRA-LOW GOSSYPOL COTTONSEED

- **Non-toxic and digestible by animals** – Prior to the removal of the toxin gossypol, only ruminant animals such as cattle were able to digest cottonseed. With ultra-low levels of gossypol, cottonseed is safe for consumption by a wider variety of animals including fish, cats, dogs, and even humans.
- **Cost-competitive protein input** – Cottonseed is approximately 24% crude protein and can be processed to any concentration. Cottonseed meal is competitive in terms of grams of protein per dollar, making it a promising input for aquaculture, pet feed, or human snack and dairy alternatives.
- **Sound technology** – RNAi technology has been widely used in the medical world since the 1990s. It is well understood by the biotechnology community and the Food and Drug Administration.

### NUTRITIONAL BENENFITS

If adopted globally, ULGCS varieties would produce **9.125 trillion grams of protein annually**, enough to meet the daily protein needs of 500 million people. Cottonseed meal has comparable levels of protein to soybean meal at a 10% lower price. It has a higher protein content than most other seeds.

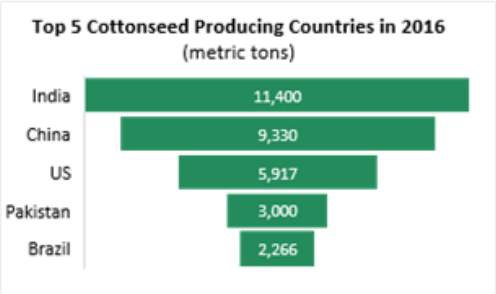



### FIELD TESTED & USDA DEREGULATED

The new ultra-low gossypol seed was deregulated by the USDA in October 2018. The approval process involved the submission of 8 field studies. Deregulation by the Food and Drug Administration is pending.

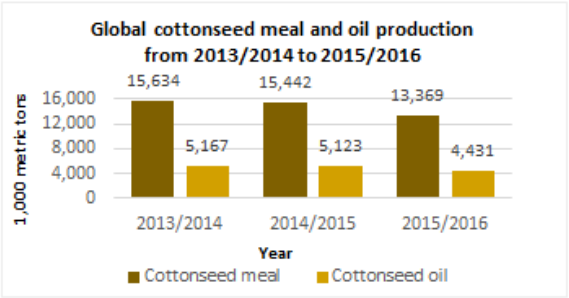
### A GLOBAL COTTONSEED MARKET

There are opportunities to use ULGCS cotton as feed for animals and humans worldwide. Market production in the US is steady.




Cottonseed is currently divided into two main uses:

- In the US, more than 60% goes toward cattle feed.
- In 2017, 2 million tons went toward US cottonseed oil.

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